E-LEARNING

E-learning

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Preface

ELearning is a vast and complex research topic that poses many challenges in every aspect: educational and pedagogical strategies and techniques and the tools for achieving them; usability, accessibility and user interface design; knowledge sharing and collaborative environments; technologies, architectures, and protocols; user activity monitoring, assessment and evaluation; experiences, case studies and more.

This book's authors come from all over the world; their ideas, studies, findings and experiences are a valuable contribution to enriching our knowledge in the field of eLearning.

The book consists of 18 chapters divided into three sections. The first chapters cover architectures and environments for eLearning, the second part of the book presents research on user interaction and technologies for building usable eLearning environments, which are the basis for realizing educational and pedagogical aims, and the last part illustrates applications, laboratories, and experiences.

Marina Buzzi

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E-learning for the new generations, a Web 2.0 approach

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1. Introduction

E-learning has come a long way from being just a book-like content. Today, with the technological advances and the availability of higher bandwidth, E-learning became richer with multimedia content, more interactive and personalized. E-learning systems (also referred to as Learning Management Systems) and Intelligent Tutoring Systems (Brooks et al. 2006) are widely used to provide distant learning, and to complement the traditional classroom learning. Learning Management Systems have become very complex and include many utilities and tools, such as communication tools (chat, forum, email, etc.) to support electronic communication between tutors and learners, and among learners themselves, productivity tools (bookmarks, calendar, synchronization functionalities, etc.) to help learners be more productive, learner involvement tools (group work support, portfolio tools, etc.) to help the learners better interact with one another and course delivery tools (automated testing and scoring, course management, etc.) to help tutors with the delivery of course materials. Recently, E-learning has been going through new transformations into what is referred to as E-learning 2.0, with reference to Web 2.0 (Schauer 2005). The drive behind this change is the shift in education from being tutor-centered to becoming more learner-centered (Mccombs & Vakili 2005) along with the support of Web 2.0 technologies. In tutor-centered education, the tutor is the active participant in the educational process and learners are considered as passive receptacles of knowledge, whereas in learner-centered education, the learners have access to various sources of knowledge and the tutor places more emphasis on what learners can contribute to the educational encounter. Similarly, Web 2.0 does not refer to an update or any technical specifications, but rather to changes in the ways software developers and end-users perceive and use the web. In the context of Web 2.0 web users are not just recipients of information, but actively participate in the creation of such information. The abundant Web 2.0 web pages and applications that can be used in the context of learning are starting to change the way tutors and learner perceive E-learning. Specifically, websites such as academia.edu, a social networking site for academics, promote networking between tutors and learners. Tutors have easy access to their peers, to collaborate and share knowledge, and learners can easily contact experts, and other learners for collaborative work and help. Additionally, many existing web pages and tools, such as Footnote.com, VoiceThread.com or Diigo.com, can help learners during the learning process. The combination of these tools, whether formal or informal, is referred to as a

Personal Learning Environment (PLE) (van Harmelen 2006). The appeal of PLE for learners relies in the fact that they can choose the tools that best suit their preferences, whereas, the shortcoming of this is the lack of control of the tutor has on the educational validity and quality of the tools and information learners are accessing. On the other hand, Learning Management Systems provide a controlled learning environment, but lack the flexibility of PLEs. We argue that the best way is to combine both LMS and PLE into a single learning environment in order to take advantage of the control of LMS and flexibility of PLE, and we present SHAring REsources and Knowledge (SHAREK) (Hage & Aimeur 2008), which provides a framework to combine a PLE within an LMS.
This chapter is organized as follows: Section 2 introduces Web 2.0, and details its three pillars: SOA (Service Oriented Architecture), RIA (Rich Internet Application) and Social Web. Section 3 illustrates E-learning 2.0 by defining learner centered education, and highlighting several Web 2.0 applications and technologies used for E-learning. Section 4 details the differences between Learning Management Systems (LMS) and Personal Learning Environment (PLE), and presents SHAREK. Section 5 concludes the chapter detailing the trends and challenges for combining LMS and PLE.

2. Web 2.0

Although the term Web 2.0 suggests a new version of the World Wide Web, it does not refer to an update or any technical specifications, but rather to changes in the ways software developers and end-users perceive and use the web. Indeed, the term Web 2.0 refers to a perceived second generation of web-based communities and hosted services (such as blogs, Wikis, etc.) which aim to facilitate creativity, and to promote collaboration and sharing between users. Table 1 formulates a sense of what is Web 2.0 by example:

Web 1.0	Web 2.0
Britannica Online	Wikipedia
Personal websites	Blogging
Publishing	Participation
Directories (taxonomy)	Tagging ("folksonomy")
Content Management Systems	Wikis

Table 1. Web 1.0 vs. Web 2.0 (O'Reilly 2005)

For instance, Britannica Online (http://www.britannica.com/) is the online version of the renowned Encyclopedia Britannica. The content of an encyclopedia is usually authored and validated by well established scholars, and the access to that content costs a certain amount of money, whether by buying the book collection, or an online membership. On the other hand, Wikipedia.com is a free multilingual encyclopedia, authored by the public at large. Wikipedia has 10 million articles written collaboratively by volunteers around the world (Wikipedia 2009). Almost all of its articles can be edited by anyone who can access the Wikipedia website.
In short, the following point summarizes the difference between Web 1.0 and Web 2.0: publishing vs. participation. Specifically, in Web 1.0 (publishing) the content is controlled by the publisher, and the users are just the recipient of the information. Whereas in Web 2.0 (participation) the users are no longer passive recipients of information, but are active

participants in the creation of such information, participating in Wikis, tagging, rating, sharing, and/or referring websites. A recently published report (Lenhart et al. 2007) indicates that 64% of online teenagers in the US, ages 12 to 17, engage in at least one type of content creation. Moreover, both YouTube and Wikipedia are listed among the top 10 most visited sites by Alexa (Alexa 2008). Both sites rely heavily on user input.
There are three pillars to Web 2.0: the Social Web, Service Oriented Architecture (SOA) and Rich Internet Application (RIA).

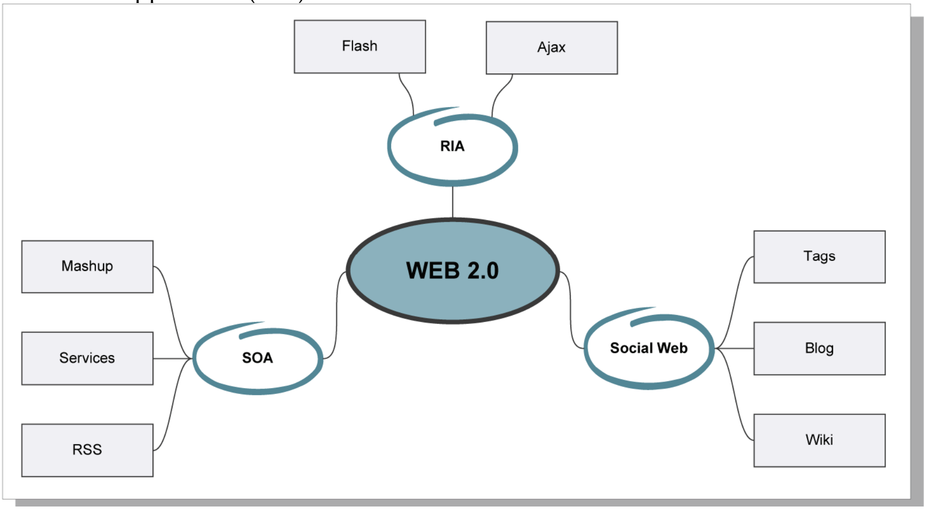

Fig. 1. The three pillars of Web 2.0 (Webilus 2008)

2.1 Social Web

The Social Web refers to the "social interactions" between the users of the web, and the resulting virtual "social groups". It allows users to share their writings, videos, photos, and more with their friends, family, colleagues, or the public at large. For instance, the Social Web includes simple publishing through a blog or a wiki. As such, in the case of the blog the owner of the blog and his faithful readers can become a social circle where the readers can comment on the blog posts, or each other's comments. Similarly, with the Wiki, the users who regularly visit, contribute to, or maintain the Wiki become a virtual social community centered on the Wiki.
Another aspect of the Social Web is the Social Networking Sites (SNS), where users can create a public or semi-private profile in order to stay in contact with other users of the site, referred to as Friends. Specifically, SNS such as MySpace.com or Facebook.com enable users to crate a profile page, add other users to their friends list, share photos, and other multimedia content. Other specialized SNS focus on certain aspects of social networking, such as LinkedIn.com which provides an environment for professional networking, and provides specific functionalities such as to recommend someone for a position or a job. Similarly, Academia.edu provides a social networking environment for academics, where researchers can connect and offers particular functionalities, such as to share research paper or to help locate other users with similar research interests.
The main drive behind the Social Web is collaboration and the harnessing of collective

intelligence. Common features that exist in the Social Web, such as tagging, rating, comments and recommendation, exploit and share the knowledge and experiences of the users. As an example, we will consider social bookmarking sites, such as delicious.com or StumbleUpon.com. Such sites enable users to bookmark their favourite web sites. Moreover, users can share their favourite web sites with other users, or a community of friends. Additionally, users can add tags, comments, even rate these websites (such as thumbs up or thumbs down in StumbleUpon). Furthermore, users can search for web sites using the tags, or even receive recommendations based on their profile - StumbleUpon provides Collaborative Filtering (Burke 2002) recommendations based on the ratings of the users.

2.2 Rich Internet Application

Rich Internet applications (RIAs) are web applications that provide functionalities and interactions similar to desktop applications. Typically, RIAs are delivered through browser add-ons or directly through the webpage using for instance Ajax or Macromedia Flash. Consider the following application, Coolprieview (http://www.coolpreviews.com), to illustrate how RIA is delivered through a browser add-on. Coolpreview is designed to help users while browsing the web. Specifically, Coolpreview offers the users with the possibility to preview the page attached to with a link, without ever leaving the current page. For instance, consider the case of a user interested in information about the German Shepherd dog. After performing the search in Google, usually the user has one of three options: first, following each link returned by Google, then using the browser's back button to return to the search result page; second, opening each link in a new browser window, and third opening each link in a new tab. In contrast, Coolpreview opens for the user a virtual preview window, which displays the target website (Figure 2 in the middle). Additionally, Coolpreview offers several functionalities, including the possibility to display the next link on the page (or in this case the next web site), add the page to a temporary bookmark stack (Figure 2 on the right hand side), open the page in a new tab or even email the link. Hence, the user can visit several additional websites and perform various actions on them, without even leaving the initial page.

On the other hand, there is a multitude of web pages that illustrate the use of RIA, including web-based virtual computers, such as G.ho.st (http:// g.ho.st/). Such environments provide a virtual computer environment, accessible online using any browser, which provides the functionalities and tools or a regular computer, including disk space (5 Gbytes in the case of G.oh.st), a media player, and even an office suite to create, and store documents spreadsheets and presentations.

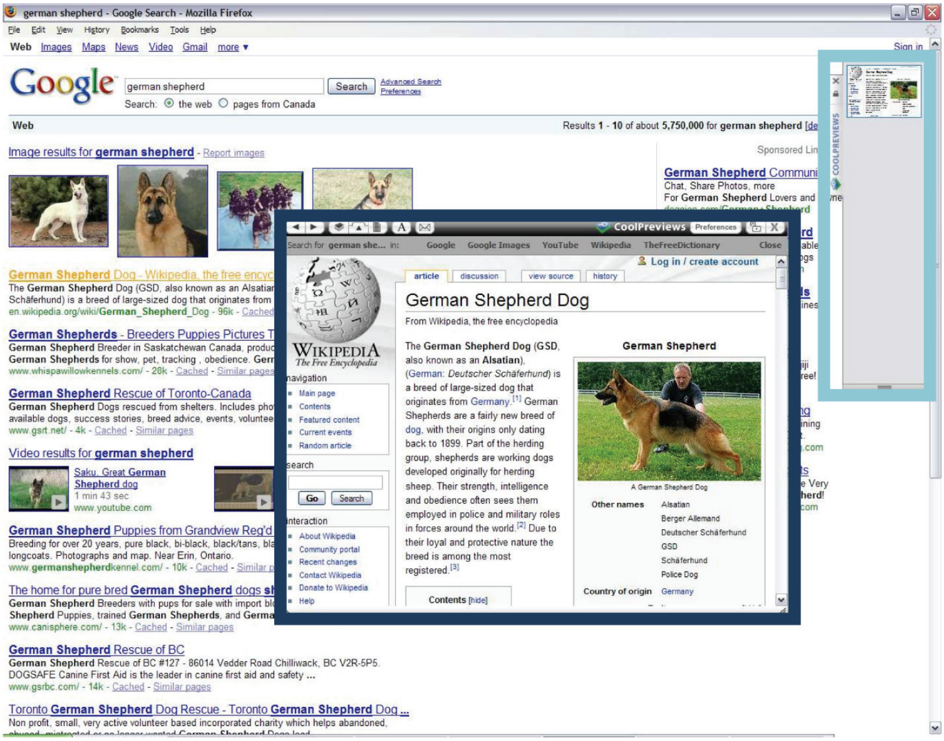

Fig. 2. Coolpreview

2.3 Service Oriented Architecture

Service Oriented Architecture (SOA) is an architectural style where the main goal is to relax the dependencies between various components and to achieve loose coupling. Specifically, a service is a task performed by the service provider to achieve a desired end result for a service consumer. Consequently, a service-oriented architecture is a collection of services (service providers and consumers), where these services communicate with each other. Such communication could be just simple data passing or it could involve two or more services coordinating to perform a certain activity. Note that the service provider can also be a service consumer. SOA usually employs a find-bind-execute paradigm as illustrated in Figure 3. The service provider registers in the directory, providing a detailed description of the service provided. The service consumer queries the directory to find a suitable service provider. When found, the service consumer sends a request to the service provider, who in turn sends the response to the service consumer. Some of the main advantages of using SOA are:

Reusability: In an SOA, a requesting application only needs to know the public interface of a desired service. Hence, the functions of an application are generally easier to access as a service in an SOA than in some other architecture. Consequently, integrating applications and systems as well as reusing their different components can be much simpler.

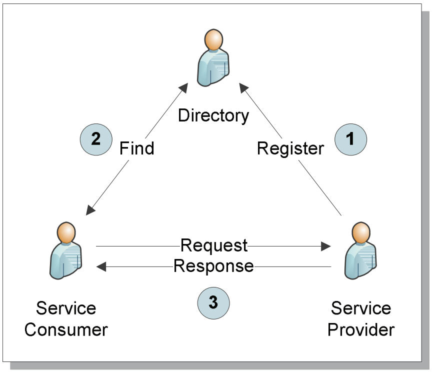

Fig. 3. Simple SOA - adapted from (Booth et al. 2004)

Interoperability: the interaction between loosely-coupled services implies widespread interoperability. In other words, within a SOA, the desired objective is for service consumers and service providers to communicate and understand each regardless of the platform they are on. This objective can be met by having a standard way of communication between services, a way that is consistent across various platforms, systems, and languages. **Scalability:** since services in a SOA are loosely coupled, the applications that exploit these services tend to scale easily, or at least easier than applications in a more tightly-coupled environment. This is due in large to the fact that there are few dependencies between the requesting application and the services it uses.

Flexibility: loosely-coupled services are typically more flexible than tightly-coupled applications. In a tightly-coupled architecture, the different components are usually strongly bound to each other, typically sharing semantics and libraries, and often sharing their state. This makes it difficult to evolve the application to keep up with changing requirements. The loosely-coupled and asynchronous nature of services in a SOA allows applications to be more flexible, and to easily evolve in order to adapt to changing requirements. The most common approach used to achieve the interactions between various services are the web services-based SOAs. A web service is a service that communicates with clients using a set of XML-based standard protocols and technologies, such as WSDL (Web Services Description Language), SOAP (Simple Object Access Protocol), and UDDI (Universal Description, Discovery, and Integration). The universality of the aforementioned protocols and technologies has made web services the most predominant approach to implementing a SOA. In short, **WSDL** (Web Services Description Language) an XML format used for describing a Web Services interface forms the basis of web services.

SOAP (Simple Object Access Protocol) is an XML-based protocol that enables applications to exchange messages and information over the internet. A SOAP message consists first of an Envelope that identifies the XML document as a SOAP message. The SOAP envelope contains an optional Header which provides information on authentication, encoding of data, or how the recipient should process the message. Moreover, the envelope includes the Body which contains the actual message or information.

UDDI (Universal Description, Discovery, and Integration) is a directory storing information about web services. In short, UDDI provides the definition of a set of services and supports the description and discovery of Web Services providers, the Web Services they make available, and the technical interfaces used to access those services. The idea is to locate organizations and the services they offer, much like using a phone book. Figure 4 highlights the SOA architecture presented in Figure 3 based on web services. Note that all the messages are exchanged using SOAP.

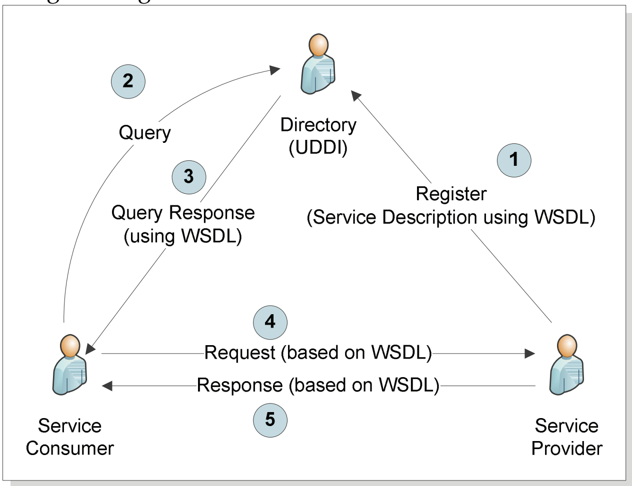

Fig. 4. Web service scenario

The flexibility and interoperability of SOA and web services has lead to a new type of web applications called Mashup. Specifically, a mashup describes a Web application that combines multiple services and/or data sources into one single application. Consider the following examples to illustrate a mashup. Woozor.com combines Google maps with information from weather.com in order to provide an interactive map wich displays weather forecast from around the world. Another example is Netzwelt.de, a German online magazine which combines free and legal promo MP3s along with Upcoming.org tour dates, Amazon CD reviews, YouTube videos and Akuma MP3 download store to provide exhaustive information for music fans.

3. E-learning 2.0

Now that Web 2.0 is clearly defined, let us define what E-learning 2.0 is all about. Similarly to Web 2.0, E-learning 2.0 does not refer to a new class of LMS (Learning Management Systems) or a new educational technology. Rather it is a natural consequence of changes in how tutors and learners perceive learning in general. Indeed, in recent years, education has been shifting from being *tutor-centered,* to being *learner-centered.* In tutor-centered education (Figure 5), the tutor is the active participant in the educational process and learners are

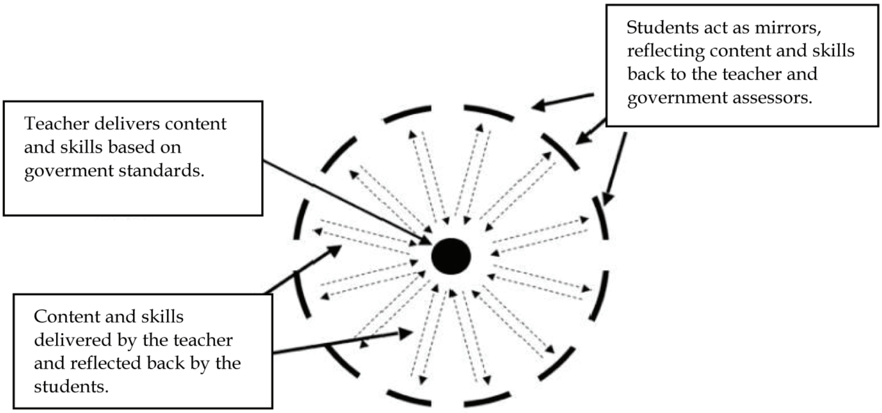

Fig. 5. Tutor-centered education (Webilus 2008)

On the other hand, in learner-centered education (Figure 6), the learners have access to a variety of knowledge sources and the tutor places more emphasis on what learners can contribute to the educational encounter. It is important to note that E-learning 2.0 is not a consequence of Web 2.0. Indeed, both share the same basic concept where the user/learner is not only a spectator and a simple consumer of information, but rather an active participant in the creation of such information. As such, one can view Web 2.0 tools and technologies as a natural recourse to achieve learner-centered education.

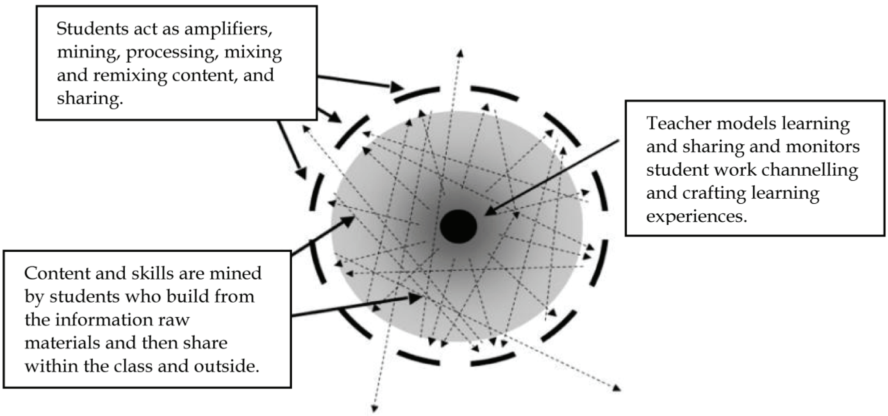

Fig. 6. Learner-centered education (Webilus 2008)

3.1 Web 2.0 and E-learning

This section provides some examples of "Web 2.0" tools and websites designed for and/or used in learning. For instance, a webcast consists of distributing media content over the using streaming media technology. A webcast may be distributed live or on demand. In essence, webcasting is "broadcasting" over the internet. A simple example of webcasting is a

TV station that simultaneously streams over the internet the show being broadcasted on TV. On the other hand, a podcast is a series of media content made available via syndication, such as RSS. Dedicated software applications, known as podcatchers automatically identify and retrieve new available media files. In order to clearly understand the difference between a webcast and a podcast, consider the following example: you like to watch a TV show called "example show". If the show is aired once a week at a certain time, than you need to be home, in front of your TV at that specific day and time to watch the show. The only way to see an episode more than once is on reruns. This illustrates a live webcast. On the other hand, if that same show is available on demand TV, then you can watch the available episodes at your convenience. Nonetheless, you still need to be home in front of your TV. This is similar to an on demand webcast. Now, imagine the TV station has a delivery boy called "podcatcher" who will faithfully deliver to your house, every time a new episode of your show is ready, a DVD with that episode on it. In this case, you can watch any released episode at your convenience, whether on your home TV, or on a portable DVD player on the train on your way to work. This case illustrates the podcast.

The utility of webcasts and podcast in E-learning is very clear: tutors can either webcast their lectures live to students, or the lectures could be made available on demand or through a podcast. Note that a lecture can consist of various media, such as audio only, a slide presentation with audio, a recording of the tutor, etc.

Currently, webcasting and podcasting are being used in several universities worldwide (Shim et al. 2007). It is important to note that webcasting and podcasting are not just used by virtual universities, but also as a complement to lectures in traditional classrooms, for instance, Berkely makes publicly available webcasts of several courses (available at http://webcast.berkeley.edu), consisting of either an audio recording of the tutor's lecture, a video recording of the tutor giving his lecture, or a slide presentation of the lecture with the explanations of the tutor.

Alternatively, wikis are websites that generally allow visitors at large to modify their content. Nonetheless, wikis generally can support authentication, such that certain members can modify only certain pages. This feature is important since it enable the use of wikis in group work assignments. Wikis offer the possibility of central access for all the users or limited user groups, which makes it an ideal choice for running projects, drafting documentations and other group work. As such, wikis are used to promote team work and collaboration between students (Raitman et al. 2005). Alternatively, wikis can also be employed by tutors to collaborate on creating learning content. For instance, wikiversity.org offers tutors the chance to collaborate and create freely available learning resources, where currently, on the English site of wikiversity, there are more than 10,000 pages available, covering various topics.

Similarly, SuTree.com and eduSLIDE.net offer both learners and tutors access to a variety of learning resources. Specifically, SuTree.com offers a variety of how-to videos, raging from learning how to whistle, to following a complete course watching MIT lectures. eduSLIDE allows tutors to create lessons (presentations) and group them into courses, making these courses available for learners.

Additionally, many existing "web 2.0" pages and tools can help learners during the learning process. For instance, Footnote.com allows students to access primary source documents and photos, and to easily create and post online history reports. Moreover, VoiceThread.com can be used by both tutors (to create lessons) and learners (for homework purposes) to upload pictures and create an audio narrative to go along with them. VisualThesaurus.com offers, as its name indicates, a visual thesaurus. Specifically the lookup word is presented in the center of the graph, and edges connect the lookup word with its synonyms. A color code is used on the edge connecting the word to its synonyms to indicate whether the synonym is a noun, verb, adjective or an adverb. Moreover, the edge connecting the lookup word with its antonym is presented differently. Wayfaring.com is a mashup that uses Google maps to list podcasts and webcasts from about 68 universities worldwide. wePapers.com allows users to share academic papers, raging from research papers, tutorials, lectures, to tests and exams. Moreover, users can comment, and even ask questions to the community about these papers. Another useful browser add-on is Diigo (http://www.diigo.com/). Diigo provides learners with the ability to highlight specific parts of webpages, add sticky notes and comments (private or public) to the highlighted sections or the whole page, and learners can share the highlights and notes with their Diigo social network.

4. Combining LMSs and PLEs

The proliferation of tools and websites such as listed earlier has led to the concept of Personal Learning Environment (PLE). PLE is a combination of tools and processes, whether formal or informal, which learners use to gather information, reflect on it and work with it. The appeal of PLE for learners relies in the fact that they can choose the tools that best suit their preferences. An interesting representation I came once across compares a Learning Management System (LMS) and a Personal Learning Environment (PLE) using the following analogy: an LMS is similar to a Swiss army knife containing a set of tools, some of which you might never used. On the other hand, a PLE is like having a box containing the tools you use, but most importantly tools that you chose and prefer. Indeed, although it might be more practical to fit a large set of tools into your pocket (Swiss army knife analogy), having only the specialized tools that you are comfortable with does have it advantages.

Many PLE advocates portray an LMS as being inflexible and used to control the learning and the learner, whereas a PLE is portrayed as easy to use, personalized, and liberated. In short, LMS is equivalent to controlling how you learn, whereas PLE corresponds to giving you control over how you learn. Although controlled and passive learning reduces self reliance and causes loss of curiosity and creativity, an uncontrolled education would create a shortage of certified labour and would introduce unqualified people into the labour pool. Ideally, a middle point between the flexibility of PLEs and the rigidity of LMSs would capitalize on the advantages of both worlds, while circumventing their weaknesses. Indeed, the driving concept behind learner centered education is to promote freedom and flexibility in learning, while maintaining some control (refer back to Figure 6). Specifically, this is where E-learning stands today (Figure 7). The Tutor delivers the learning content to the learner through the LMS. On the other hand, the learner has access to the controlled environment provided by the LMS as well as a PLE containing the set of his favourite tools and resources, which are external to the LMS. As such, the leaner can freely perform the learning activity, relying on the content and tools provided through the LMS, and on external uncontrolled resources through the PLE. In addition, the learner has access to both his personal social network (outside the LMS), and a peer network through the LMS. Note that some peers can also be part of the learner's external social network. In such a scenario, the tutor controls the curriculum (which courses and topics the learner must complete), and he can validate the learner's knowledge through assessments. On the other hand, the learner has the freedom to choose how to complete the learning activities: whether by solely using the content and tools provided through the LMS, by relying completely on his PLE, or a combination of both. In the last case, the LMS can be actually viewed simply as another component of the PLE.

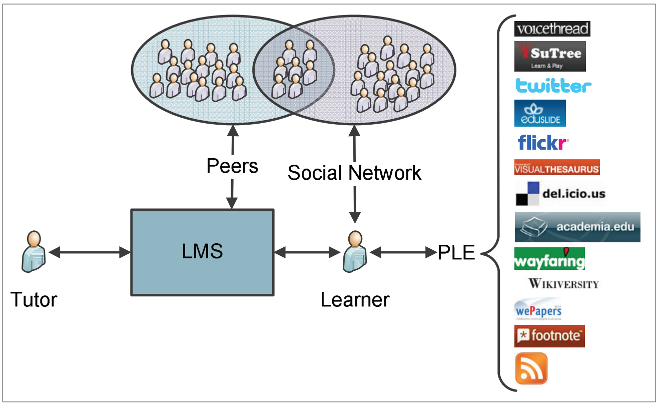

Fig. 7. Using LMS and PLE for education

4.1 SHAREK: combining LMS and PLE

Although this approach does bring together the advantages of LMS and PLE, it still presents some drawbacks, specifically to the learner. First, since there is no formal way to know what external resources the learner is accessing, the tutor cannot validate the content accessed and used by the learner. Hence, the learner may unwillingly access invalid content, which will induce him in error. Consequently the learner will be penalized during the assessment of his knowledge, which may cause conflicts with the tutor. Second, due to the large variety of resources and tools that could be part of a PLE, the discovery of new tools, as well as determining the most suitable tool (depending on the current needs) becomes a daunting task. In (Hage & Aimeur 2008), we propose an approach that addresses both drawbacks mentioned earlier. The proposed approach is inspired by social bookmarking, and consists of adding support for a PLE within the LMS (Fig. 8).

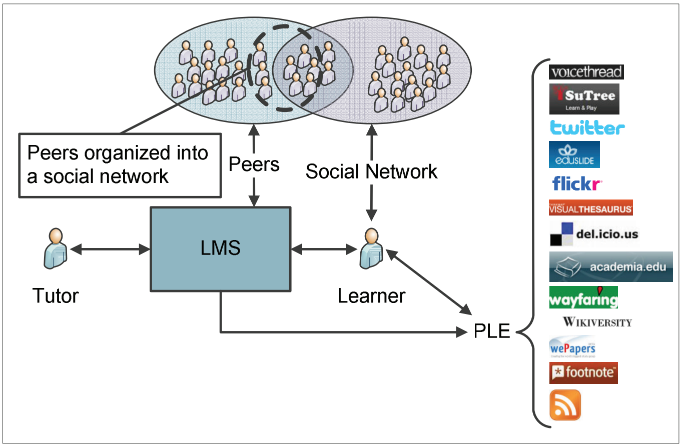

Fig. 8. Combining LMS and PLE

Specifically, learners can add learning resources into the LMS and could attach them either to a course, or a lecture within a course. As such, learners can access the PLE components by linking to them from within the course or lecture. For instance, a learner who relies on VisualThesaurus.com for an English course would add it as a resource to the course. Consequently, whenever the learner accesses this course, he can directly link to VisualThesaurus.com without having to search for it through a large set of bookmarks. Such an approach has many advantages. **First,** it enables learners to organize their PLE components with respect to the courses they are used in. **Second,** since these components are organized within the LMS, it enables the tutor to supervise, to some extent, the use of these components. Specifically, although the tutor cannot control or supervise the activities performed within the PLE, he can still know what components the learners are using in their PLEs. Hence, the tutor can take some actions accordingly: for instance, if he realizes that some learners are using Wikipedia for instance, he can make sure to advise them not to take that information for granted, since the content of wikis might be, in some cases, unreliable or biased. In short, the tutor can discourage and/or caution when questionable components are used in a PLE, and he can encourage and/or promote valid components. **Third,** this setup provides an ideal setting for the discovery of new components, whether for the learners or the tutor. Indeed, one can easily exploit this setup to allow learners to share their knowledge of learning resources. Specifically, in SHAREK (Hage & Aimeur 2008) we propose the following process for sharing and discovery, highlighted in Figure 9. First, learners can add resources to SHAREK, where a resource could be an uploaded file (document, presentation, java applet, etc.) stored within the system for future access, or a link to an external webpage. Moreover, when a learner finds a useful resource, within SHAREK, which was contributed by another learner, he can add that resource to his favourites. Additionally, learners have the possibility to share a resource with their peers and/or friends. In this context, sharing a resource is similar to recommending the resource to peers and/or friends. Furthermore, RSS feeds are employed to facilitate the discovery of new resources. Specifically, RSS is a family of Web feed formats used to publish frequently updated content. Hence, each learner has his own feed, which is automatically updated to inform him of an add resource, favourite, or share events. In order not to be overwhelmed with updates, a learner can choose, for each of his friends and classmates, one or more event feeds to subscribe to.

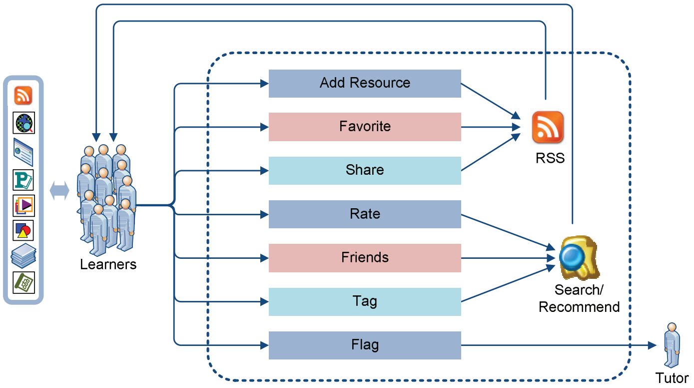

Fig. 9. SHAREK process

On the other hand, learners can rate the resources within SHAREK. A rating is a score (on a scale of 1 to 5) a learner gives to a resource. Within SHAREK, learners provide resources with an overall rating, as well as ratings with regards to its relevance to the course or lesson, its utility, and its clarity and ease of use. Such granularity (compared to using just an overall rating) is useful to evaluate the relevance, utility, and clarity of a resource. For instance, consider a resource that is very useful and easy to use, but was attached to an irrelevant course. When using only an overall rating, learners might give it a low rating because it is irrelevant to the course. Hence a learner who never used this resource would be inclined to consider it as a bad resource due to the low rating. With the granular ratings used within SHAREK, learners will have a better idea why the source was rated in such a manner. Additionally, this granularity in the ratings increases the accuracy of Collaborative Based recommendation techniques (Adomavicius & Kwon 2007).
Moreover, learners can attach tags to the resource. Tags are keywords or terms associated with the resource to describe its content. Tags could be assigned by the contributor when adding the resource, or later on by other learners. Such a collaborative tagging approach, also known as folksonomy, has its strengths, and perhaps the most important is that it directly reflects the vocabulary of users. Indeed, a folksonomy, with its uncontrolled nature (in contrast to a Taxonomy), can adapt quickly to user vocabulary changes and needs. Learners can also flag a resource as being Inaccessible (resource cannot be accessed, broken link, unavailable file, etc.), Unrelated (Resource content is unrelated to lesson), Redundant (resource already exist) or Plagiarized (contributor asserts himself as the author of a resource created by someone else). When a resource is flagged, the flag will reflect within the system to advise learners accessing the resource, and a notification is automatically sent to the tutor to take the appropriate actions.
Additionally, learners can add selected peers and classmates to their list of friends. These friends are used in several contexts, including when specifying the RSS feeds the learner wants to subscribe to (as explained earlier), or when searching for new resources within

SHAREK. Indeed, in addition to the RSS feed, SHAREK offers two other approaches to discover resources. The first approach is based on a CF (Collaborative Filtering) recommendation system. In short, a CF recommender system accumulates user ratings of items, identifies users with common ratings, and offers recommendations based on inter-user comparison. Note that within SHAREK, we take advantage of the multiple criteria ratings of resources and use a multi-criteria collaborative filtering approach (Naak et al. 2009). Moreover, currently SHAREK performs the recommendation either at course level, or lecture level, where, in each case, only the resources attached at that level are considered. On the other hand, a content based search tool provides learner with another alternative to search for and find resources within SHAREK. Specifically, learners can search for resources by specifying one or more of the following criteria: language, rating, tags, date added, format, by the educational type, relation type, or even within their friends' favourite resources. These criteria are a part of the resources' information gathered and stored within SHAREK, and are inspired from, and based on the IEEE LOM (Learning Object Metadata) (IEEE Learning Technology Standards Committee 2002) standard. The data collected is divided into six categories.

The **General** category contains information such as the resource identifier, a unique id assigned by the system, the title, language and a short description of the resource, which are provided by the contributor at the time of adding the resource. Moreover, the general category contains the Tags associated to the resource, the learners' Ratings as well as the flags.

The **Educational** category contains information such as the type of the resource, whether the resource is a lecture, an exercise, a tool to help with the course, etc. Moreover, the educational category contains the Related To, and Relation Type information. The first describes which part of the course, or which lesson the resource is related to, and the second describes the relationship of the resource to the lesson or course: for instance, the resource could be a Java applet that illustrates the theory presented to the learner.

The **Technical** category contains information related as to what are the technical requirements to access the resource (such as plug-in or specific software), the format of the resource (a document, a java applet, a web site, etc.), the resource size (if applicable) and its location. It is important to note the content of location varies depending on the format of the resource. Indeed, if the resource is an uploaded file, then the location indicates where this file is stored. On the other hand, if the resource is located online (for example a website), the location, in this case, will contain the URL address.

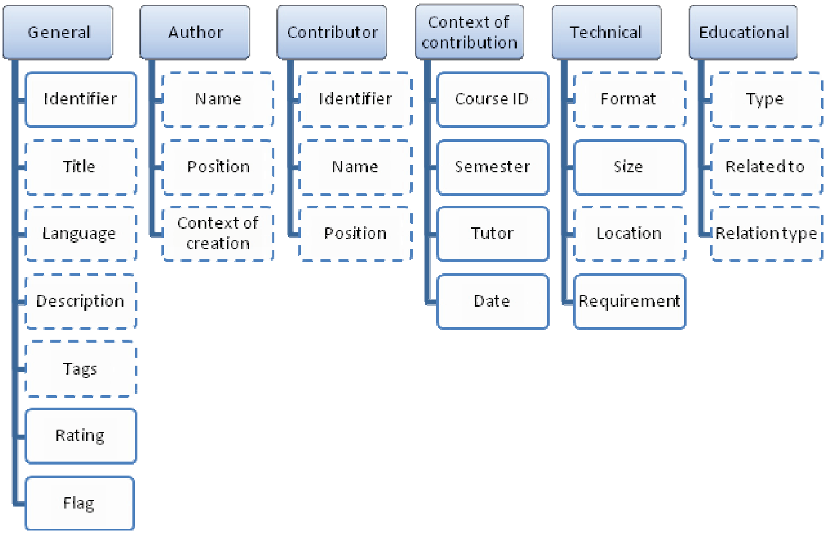

Fig. 10. Resource Metadata

The Contributor category contains the information to identify the learner who contributed, or added the resource. The contributor' unique identifier, as well as his full name and position are stored here. The position indicates the title of the contributor, whether he is a student, a teaching assistant or even a tutor.
The Context of Contribution category holds information about the context in which the resource was added, including the course id, the semester, the tutor and the date the resource was contributed. Such information is important and relates to context in which the resource was created.
Although the contributor could be the author of the resource, there are many situations when he is not. Thus, the Author category contains information about the actual author of the resource such as his name and position (student, tutor, etc.) and the context of creation of the resource (why the resource was created).
SHAREK was implemented and tested into a prototype platform that simulates an LMS, where learners follow a data structure course. 93 graduate and undergraduate students, from the computer science department at the University of Montreal, participated at testing the prototype. The participants highly rated the functionalities provided by SHAREK, and most reported that such an environment would encourage them to further share their knowledge.

5. Challenges and future trends

The change in education from tutor-centered to learner centered, along with the advent of Web 2.0 technologies is reshaping E-learning. Moreover, the proliferation of learning tools and the learners' appeal for PLE, created a competition between LMS and PLEs. Indeed, LMSs are constantly modified and upgraded to include such functionalities that are regularly used by learners and tutors as part of their PLE. Nonetheless, it is quite impossible for the LMS to conclusively win the race for many reasons. Indeed, if a LMS is to provide the large variety of utilities and tools used by learners, it will become very large and bulky, not to mention the high cost of development and maintenance. Moreover, the components of the PLE are usually specialized and dedicated for a certain task, thus outperforming the LMS at that specific task. Alternatively, a PLE cannot provide the stability and control required for proper learning. As such, the best and optimal approach is actually to combine the PLE within the LMS, thus successfully taking advantage of the stability and control of the LMS, while capitalizing on the flexibility of the PLE.

The approach proposed with SHAREK provides a framework to achieve this combination. The approach has many advantages, such allowing learners to share and discover new PLE components easily. Moreover, since these components are not physically part of the LMS, adding or removing them is a fairly simple task.

Nonetheless, this approach does have its limitations: since the PLE components are present outside the LMS, moving back and forth between the LMS and the PLE components might become, in many cases, tiresome. However, embedding the access to the PLE components from within the LMS (using for example approaches similar to CoolPreview) would resolve the issue. Other concerns include authentication and privacy. Indeed, many components and websites used within a PLE necessitate users to have an account and require authentication to give access to their services. It is clear that managing the multiple identities, which might grow quickly, is not a simple task. Additionally, existing research corroborates the need for learner privacy (Aimeur et al. 2007), yet having the learner's personal information duplicated within the PLE components presents some serious privacy concerns. For instance, having some of the learners information (demographic data, email, etc.) stored over the various PLE components increases the risk of unwanted access to such information. Nonetheless, mechanisms, such as OpenID (http:// openid.net) could be used to support the use of just one ID. Hence, including support within the LMS, and the PLE components for such mechanisms will limit the dissemination of learner's personal identification data over several platforms, while reducing and eliminating the need to manage several profiles. Nonetheless, other information could be still stored within the PLE components, which creates concerns with regards to the confidentiality, integrity and availability of such data. Indeed, many Web 2.0 applications, used as part of the PLE, are actually designed for sharing information purposes, consequently increasing the risk of unwarranted access to that information. Although we do advocate information sharing, there are cases where this access and sharing is not desirable and unwanted, for instance information about an ongoing homework or a project. Moreover, since the service might be temporarily unavailable or permanently shutdown, the learners' information might not be accessible or permanently lost.

Another approach to address these limitations would be to rely on the SOA (Service Oriented Architecture) paradigm, where the PLE components act as service providers and the LMS acts as the service consumer. In such a scenario, the learner does not need to leave the LMS in order to access the PLE components, instead, the LMS will request the service for the learner and provide the learner with the answer. Moreover, the learners' information could be stored within the LMS and only the necessary information is communicated to the service provider. For instance, consider Moodle (http: / / moodle.org), a popular open source LMS. The standard package deploys Moodle with the basic required components regularly used within an LMS. Additionally, for further enhancements and personalization,

Moodle offers a vast collection of plugins and modules. Although most of these components are self contained, many rely on existing services and APIs: for example, one module exploits the Google API to offer text translations from within Moodle. Another module enables tutors to import learning objects from DOOR repositories into Moodle. Specifically, DOOR (Digital Open Object Repository) is an Open Source software used to create learning objects repositories. On the other hand, another module can be added to provide web services support in Moodle. In details, it enables Moodle applications to use web services in order to provide and/or consume services.
Yet, this approach has its limitations. For instance, the modules mentioned earlier are typically added by Moodle's system administrator, and not the learners. As such, whenever a learner needs access to a new module, a request must go through to the system administrator, which could become complicated for the learner as well as the system administrator, specifically within large educational institutions. Moreover, using web services to access external components might not suffice in many cases. Indeed, the LMS, or the service consumer, must have the proper support to properly consume the provided service, which might be complicated specifically in cases involving multimedia content. For instance, consider using web services to retrieve information from VisualThesaurus.com (introduced earlier in Section 3.1). In this case, the service provider, VisualThesaurus will reply sending the synonyms, antonyms and their respective types (whether it is a noun, verb, adjective or an adverb) in a textual XML format. As such, in order to properly consume the service, the LMS must be able to reconstitute the visual representation of the lookup word, and its relation to the synonyms and antonyms. Hence, in many cases the LMS will require implementing a new module, using an API (if it exists) in order to properly take advantage of the PLE components.
In summary, the first approach, proposed within SHAREK, provides more flexibility when it comes to adding or removing PLE components into the LMS, but is limited with regards to the confidentiality, integrity and availability of the learner's information stored within the PLE components. The second approach remedies this limitation, but is not flexible when it comes to adding or removing PLE components. In fact, in many cases it requires implementing new modules or plugins to be integrated within the LMS. Hence, we believe that the first approach, even though it represents some risks to the learners' information, remains more flexible, suitable and sustainable than the second approach.

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2

Developing and Implementing a Multi-Agent System for Collaborative E-learning

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1. Introduction

Computer-Supported Collaborative Learning (CSCL) systems have naturally evolved over the past decades as a consequence of the availability of high speed networking and the Internet. The conventional educational methodology has been influenced and different new learning methodologies have evolved accordingly. An excellent example is e-learning which has become one of the most popular teaching methods in recent years. One of its modes is the blended learning where learners can view teaching materials asynchronously from a teaching website and collaborate with their peers, while providing for necessary face-to-face explanation, discussion, and physical operation in the classroom.

Teaching Assistants (TAs) play an essential role in the learning process when the ratio of the number of students to that of the instructors is large due to the difficulty of direct contact between an instructor and his students in a given course. This is noticeable in education environments in youth societies and developing countries like Egypt. Although computer systems are used to solve many problems of handling large volumes of data as in database and data-mining systems, the usage of computer systems to solve the above problem is carried out considering one course and/or one instructor.

Parallel to the evolution of e-learning methodologies, the intelligent agent paradigm has generated such a remarkable interest in many application domains over the last two decades. It is growing to be a continuously evolving and expanding area. This chapter considers the results from developing a Multi-Agent System (MAS) in the field of e-learning education with the help of collaborative learning (learning from peers). The dynamism in e-learning can be made more powerful with the help of intelligent agents. Intelligent agents – the so called e-assistants or helper programs - can reside inside a computer and make the learning in e-learning occur dynamically to suit the need of the user. They can track the user's likes and dislikes in different areas, the level of knowledge and the learning style and accordingly recommend the best matching helpers for collaboration.

This chapter outlines the development and the implementation processes of a Multi-Agent System for Collaborative E-learning (MASCE). It considers mainly the innovation part of the system that is the Teaching Assistant Agent. This chapter deliberates one of the roles of the Teaching Assistant Agent which is the matching and the clustering of the students to find,

for example, the best helper colleague for a student (Mahdi & Attia, 2008 a, b). Collaboration between students (peers) is one of the main tasks of any serious e-learning system.
However, this is not the only task of MASCE which is designed to be used to assist the teaching and learning processes. This system considers the blended learning environment as a supplement to the face-to-face lecture where students can use the system in the lab or from home after attending the traditional lecture in the faculty. The goal is to incorporate the intelligence of the multi-agent system in a way that enables it to actively and intelligently support the educational processes, where multiple agents can interact to exchange information so that students may collaborate on how best to gain knowledge.

2. E-Learning

Over the past decade, speed in the transmission of knowledge is no longer the way it used to be. Due to this change, conventional educational methodology has also followed this trend and has gone through a huge transformation. An excellent example is e-learning which has achieved and broken through the restrictions of time and space. In recent years it has become one of the most popular teaching methods (Yang, 2000).
Digital learning, or e-learning, is defined by the American Society of Training and eDucation (ASTD) as: "E-learning is the application of digital media by the learner in the learning process, where digital media includes the Internet, corporate networks, computers, satellite broadcasts, audio tapes, videos, interactive television, and CD-ROMs, etc. The scope of e-learning applications includes online learning, computerized learning, virtual classrooms, and digital cooperation." While the ASTD definition emphasizes digital tools, the inflexible use of digital tools can by no means affect the sweeping reform of educational methods. For example, the Computer Aided Learning (CAL) used in the 1960's concentrated only on the use of computers in learning. Course content and learning activities were not significantly different from those of the age of pencil and paper. After the Internet emerged in 1995, online learning – which is also known as web-based learning (WBL) – used database and server technology to ensure that data transmission, access, and response were highly interactive and extensible. As a result, research in e-learning must include the establishment of a teaching and learning platform, development of teaching material content, and design of learning activities (Chen & Chiu, 2005).
Online e-learning uses three kinds of transmission models: asynchronous, synchronous, and blended. The two former models overcome the spatial limitations of conventional classroom learning, while the blended model proposes improvements to overcome some of the disadvantages of the first two models. Asynchronous teaching models employ a transmission method that can be divided into two parts: "Teaching content" is transmitted via a webpage or CDROM, while "teaching interaction" is transmitted via e-mail or discussion area. The synchronous model employs "virtual classroom" hardware and software, and uses the Internet to conduct videoconferencing and chat room activities to transmit "teaching content" and "teaching interaction." The aim of this model is to achieve teaching as synchronous as in a real classroom. If we compare the two models, we can see that the former offers the advantages of in-depth learning at any time or place, but has the disadvantages of inconvenient communication and lack of real-time response capability. Although the latter enables real-time interaction and a sense of participation, it has the disadvantages of time limitations, high cost, and need for high-technology supporting

equipment. As a result, in order to cut costs while offering good interactivity, most recent e-learning systems adopt the highly feasible blended model. In a typical blended model, learners can read teaching materials asynchronously from a teaching website, while providing for necessary face-to-face explanation, discussion, and physical operation in the classroom (Rosen, 2009).

2.1 E-Learning 2.0

The term e-learning 2.0 is used to refer to new ways of thinking about e-learning inspired by the emergence of Web 2.0. From an e-learning 2.0 perspective, conventional e-learning systems were based on instructional packets that were delivered to students using Internet technologies. The role of the student consisted in learning from the readings and preparing assignments. Assignments were evaluated by the teacher. In contrast, the new e-learning places increased emphasis on social learning and use of social software such as blogs, wikis, podcasts and virtual worlds such as Second Life (Rosen, 2009).

E-learning 2.0 is built around ***collaboration***. E-learning 2.0 assumes that knowledge is socially constructed. Learning takes place through conversations about content and grounded interaction about problems and actions. Advocates of social learning claim that one of the best ways to learn something is to teach it to others.

E-learning in general must not be considered as an electronic variant of classical education. That is indeed the problem. Not only the conditions of the educational offer are totally different, but also the cognitive and social behavior of humans require a completely dedicated analysis that most of the times has no precedents and thus requires a research attitude. This is the challenge of e-learning. E-learning is therefore NOT an application of technologies to human learning, in the sense that assuming to know what to apply (the technologies) and how (the pedagogy) one gathers things together and the result will be a success (people learn). On the contrary, each profound effort risks being unique in the sense that it requires specific technologies and specific pedagogical principles to be developed and applied in a trial and error fashion (Cerri, 2002).

The major obstacles for e-Learning are bound to the innovation for individuals and institutions of the asynchronous distance interactions among humans and electronic resources (documents, but also programs). However, the available technical tools are quite sophisticated and developed in many respects. Investigating the recent Intelligent Tutoring Systems or AI in Education Conferences one may notice the progress. Perhaps one can enhance the image by putting research efforts in the integration, or in the dialogue management, that is yet poor in real situations. However, it is believed that the bottleneck is more to be found on the human motivation for engaging in e-Learning practices. By "human" we include any role: learners, teachers, managers, experts, as well as combinations, i.e.: societies (classes, groups of teachers, etc.). One of the reasons for a lack of motivation in learners is the difficulty for certification of their learning when it has occurred at a distance. Another is the relative lack of friendliness of systems. The list of problems continues, yet human motivation is fundamental in order for technologies to be successfully introduced in human social practices (Cerri, 2002). Some solutions for these problems will be discussed later just after we have a background of agents.

3. Agents and Multi-Agent Systems

Over the last two decades, a major Computer Science research topic has been the development of tools and techniques to model, understand, and implement systems in which interaction is the main issue.

Agents, Software Agents or Intelligent Agents are intelligent in the sense that they are adaptive, independent, and possess reasoning capability. They can plan and execute tasks in cooperation with other agents in order to satisfy their goals. A Multi-Agent System (MAS) is defined as a loosely coupled network of problem solvers that work together to solve problems that are beyond the individual capabilities or knowledge of each problem solver (Agent). The increasing interest in MAS research is due to significant advantages inherent in such systems, including their ability to solve problems that may be too large for a centralized single agent, provide enhanced speed and reliability, and tolerate uncertain data and knowledge. Some of the key research issues related to problem-solving activities of agents in a multi-agent system MAS are in the areas of coordination, negotiation, and communication. With advances in Web technologies, collaborative applications are now server based and the user interface is typically a Web browser. Thus, a collaborative application can be a Web-based solution that runs on a local server that allows people communicate and work together, share information and documents, and talk in real-time over the Internet. Recently, much research has been conducted in distributed artificial intelligence and collaborative applications. Several interesting methodologies and systems have been developed in areas such as distributed multi-agent systems for decision support, Web search and information retrieval, information systems modeling, and supply chain management. In particular, intelligent agents and multi-agent systems, and a variety of applications have been built in various domains (Sugumaran, 2009).

''Agent'' has different meanings and definitions in different domains and communities. Agent refers to a computer-simulated character, which presents users with human-like properties, such as domain competence, emotions, and other personal characteristics. The characteristics can be expressed or displayed in text, graph, icons, voice, animation, multimedia, or virtual reality.

An agent is a computer system that is capable of *independent* action on behalf of its user or owner (determining what needs to be done to accomplish design objectives, rather than constantly being ordered). A multi-agent system is one that consists of a number of agents, which *interact* with one-another. In the most general case, agents will be acting on behalf of users with different goals and motivations. To successfully interact, they will require the ability to *cooperate*, *coordinate*, and *negotiate* with each other, just as people do (Wooldridge, 2002). The field of Multi-Agent Systems is influenced and inspired by many other fields such as Economics, Philosophy, Game Theory, Logic, Ecology, and Social Sciences.

We build agents in order to carry out *tasks* for us. The task must be *specified* by us. But we want to tell agents what to do *without* telling them how to do it. The *agent function* maps percept sequence to actions: $f: P^* \rightarrow A$. The *agent function* will internally be represented by the *agent program*. The agent program runs on the agent *architecture* to produce f (Wooldridge, 2002).

As part of their study of agent systems, researchers began to develop terminology for agents. Some of these terms are explained as follows (Mendez, 1999):

- **Agent Architectures** analyze agents as independent reactive/proactive entities. Agent architectures conceptualize agents as being made of perception, action, and reasoning components. The perception component feeds the reasoning component, which governs the agents' actions, including what to perceive next.

- **Agent System Architectures** analyze agents as interacting service provider/consumer entities. System architectures facilitate agent operations and interactions under environmental constraints, and allow them to take advantage of available services and facilities.
- **Agent Frameworks** are programming tools for constructing agents. Examples of these are Voyager, Aglets, JADE, and Odyssey.
- **Agent Infrastructures** provide the conventions that agents follow to communicate and to understand each other, thereby enabling knowledge sharing. Agent Infrastructures deal with the following aspects:
  - **Ontologies**: allow agents to agree about the meaning of concepts.
  - **Communication Protocols**: describe languages for agent communication.
  - **Communication Infrastructures**: specify channels for agent communication.
  - **Interaction Protocols**: describe conventions for agent interactions.

Using Mobile Agent in E- learning

Comparing the three distributed paradigms (client-server, code on demand, mobile agent), it can be seen that mobile agent provides greater flexibility. Furthermore, mobile agent possesses the following advantages (Quah et al., 2002):

1. Mobile agent moves computation code to data rather than data to computation, the repetitive request response handshaking is eliminated, by creating an agent to handle the transaction and sending it from client to server, the intermediate results and information passing are reduced, hence the network bandwidth consumption is reduced and the efficiency is improved.
2. The agents do not require a continuous connection between machines. The client can send off an agent into the network when the network connection is healthy, then it can go offline. The network connection needs to be reestablished later only when the result was returned by agents from remote host. Hence it provides a more reliable performance with intermitted or unreliable network connection.
3. The agent operates asynchronously and autonomously, and the user doesn't need to monitor the agent as it roams in the Internet. This saves users' time, reduces communication costs, and supports a decentralized network structure.
4. With adaptive learning and automation added to agents, the agent can be tooled with AI for information retrieval and filtering.

The main problem with mobile agent is security, which still presents a prospective area of research. In an agent system with low level of security, the mobile agent may harm the host or the host may harm the mobile agent. With the above characteristics, the software language to construct mobile agent system should be object oriented, platform independent, with communication capability, and implemented with code security. At present, the languages being used for mobile agent include Java, Telescript, Tcl and IBM Aglets with Java (Quah et al., 2002).

3.1 Multi-Agent Systems

Various definitions from different disciplines have been proposed for the term multi-agent system (MAS). As seen from DAI (Distributed Artificial Intelligence), a multi-agent system is a loosely coupled network of problem-solver entities that work together to find answers to problems that are beyond the individual capabilities or knowledge of each entity. More recently, the term multi-agent system has been given a more general meaning, and it is now used for all types of systems composed of multiple autonomous components (agents) showing the following properties (Sugumaran, 2009):

- Each agent has incomplete capabilities to solve a problem
- There is no global system control
- Data is decentralized
- Computation is asynchronous

One of the most important current factors promoting MAS development is the increasing popularity of the Internet, which provides the basis for an open environment where agents interact with each other to reach their individual or shared goals. To interact in such an environment, agents need to overcome two problems: they must be able to locate each other (since agents might appear, disappear, or move at any time); and they must be able to interact.

Multi-agent systems are composed of two or more intelligent agents. An agent has detectors, effecters and a decision-making mechanism. Using these mechanisms, a multi-agent-based simulation reproduces some phenomena inside online communities, including decision-making process of an agent, local interactions among agents and the system dynamics generated by local interactions, allowing us to observe and understand them (Yamada et al., 2004).

One of the most interesting research topics is the organizational architecture styles of multi-agent system (Kolp et al., 2006) where human organizations is used as a metaphor to suggest a set of generic styles for agent systems. Several architectural styles have been used in the development of multi-agent systems. (Shehory, 1998) describes four such organizations:

- Hierarchical multi-agent systems
- Flat multi-agent systems
- Subsumption multi-agent system
- Modular multi-agent system

3.2 Traditional Multi-Agent System Applications

Multi agent-based simulations have previously been used to analyze social systems, such as public goods problem, traffic simulation, supply chain management and Open Source Software (OSS) development. Public goods problem used the simulation based on Game Theory to explain why we need to provide the public goods. This simulation used an agent that has a simple payoff matrix given by system designers as a consumer.

Traffic simulations were used to analyze how a roadway or a parking space affects traffic flows. This simulation used an agent that has some simple rules given by system designers as a car. These rules were made from the empirical rules of designers, for example, *stop at a red light* and *reduce speed when the distance between two cars is narrow*.

Supply chain management used multi-agent-based simulations to optimize the supply chain network. Supply chain management is a new management technique to minimize total costs that are composed of inventory costs, distribution costs, and so on. This simulation used an agent as an element of a supply chain network, such as manufactures, distributors and customers (Yamada et al., 2004).

The analysis of OSS (Open Source Software) communities used multi-agent-based simulations to understand the phenomena inside of OSS communities. This simulation used an agent as an open source software developer. The agent selected an action from some rules, which were: *creation of a project*, *participation of a project*, *abandonment of a project* and *continuance of the current collaborations*, based on simple utility function given by system designers (Yamada et al., 2004).

4. Design Issues of the Educational Agent

(Bernard and Sandberg, 1993) proposed that a student in a learning environment should be placed within the framework of surrounding entities that assist the student's access to learning resources, learning by various means, and participating in different learning activities. This idea has been extended to a situation in which educational agents are presented in a social learning environment. In this environment, a student has access to many learning resources, which can be classified into three categories: *content, community, and computational support.* The *content* includes the student's learning materials, such as books, libraries, museums, and databases. The student can participate in *communities* and communicate knowledge with fellow students, teachers, volunteers, and parents. Additionally, the student is empowered by *computational support*, such as calculators, note-pads, and different kinds of computer software.

Accordingly, an educational agent is a kind of computational support, which enriches the social context in a social learning environment either by providing virtual participants to enhance the member multiplicity of communities or by supporting facilities to promote communication among real participants.

The positive influence of research on educational agents lies in its ability to reinforce the social learning environment. The research issues can be divided into *design issues* and *implementation issues*. Design issues are concerned with two main elements of defining a particular social learning model— the structure of the model and the protocols of learning activities. Structure relates to the members of the learning environment, including the numbers, roles, and characteristics of the educational agents. The protocol is a set of rules that governs the learning activity, including communication among participants.

The existing social learning model or theory, which is successful for real participants, is usually adopted in designing educational agents. A widely applied theory is Vygotsky's hypothesis, which regards cognitive development as the gradual internalization and personalization of what was originally a social activity (Vygotsky, 1978). Vygotsky also proposed a hypothetical distance, ''*zone of proximal development*'', between development through solving problems independently and potential development through solving problems under adult guidance or in collaboration with more capable peers. Other social learning theories have been recently explored and applied to educational agents, such as *responsibility sharing*, *socially distributed cognition*, *reflection and articulation*, *reciprocal tutoring*, and *learning by teaching* (Chou et al. 2003).

Through different communication media, face-to-face communication among real participants and communication between a student and an educational agent (computer software) have different benefits and constraints. Face-to-face communication is easy to produce, has a high bandwidth and is highly interactive, but cannot be reproduced, distributed, or modified. Meanwhile, the educational agent, as a kind of computer software, is easily reproduced, distributed, and modified, but is difficultly produced. It allows computer interaction, and variable bandwidth of communication. Thus, educational agents and real participants provide a student with alternative social contexts to promote learning.

Various combinations of educational agents and real participants enhance a social learning environment (Chan, 1995). Furthermore, an educational agent can not only directly enforce its perspectives on the student, but also stimulate learning and collaboration among real participants (Chou et al. 2003).
Educational agents with controllable characteristics facilitate particular learning models or learning environments. For example, Aimeur and Frasson proposed a strategy of learning by disturbing, in which an educational agent intentionally gives misleading advice at times (Aimeur & Frasson, 1996; Aimeur et al., 1997). If the system detects that the student's self-confidence is high, the agent provides a mistaken suggestion and waits for the student to explain his or her decision or provide a correct solution. Otherwise, the agent provides correct suggestions to reinforce the student's beliefs.
The strategy "strengthens the attention of the student, increases the perception of details and provides the means for arguing and memorizing" (Aimeur & Frasson, 1996). Chang and his colleagues proposed a learning environment in which a student is surrounded by four kinds of companions—collaborator, peer tutor, troublemaker, and tutee (Chang et al., 1999). These companions have different levels of knowledge, adjusted according to the knowledge of the student. Thus, during learning, the knowledge levels of these companions are adapted to fit the student's expectations of the companion and to support the planned pedagogical strategy (Chou et al. 2003).
Several investigators have suggested the multiple "agents" implementation approach to deal with the complicated tasks and various perspectives of educational agents. Unlike the agents discussed previously in this section, these "agents" are pieces of software, which autonomously deal with some tasks, interact with other software "agents", and hide inside the system. The approach divides the task of implementing educational agents into several subtasks and handles these subtasks by employing several software ''agents''. For example, the mechanism for building a student model can be implemented by constructing spy "agents" and task "agents". The spy "agents" observe and identify the student's actions; the task ''agents'' analyze the action and construct the model (Chou et al. 2003).

5. Research Status

Multi-agent methodology has recently appeared as an alternative to conceive distributed learning applications as a consequence of the evolution of multi-agent technology itself. The main reason of this is that the multi-agent methodology deals well with applications where vital issues, such as: distance, cooperation among different entities and integration of different components of software, are found (Biswas, 2001).
An empirical study done in (Thaiupathump, 1999) to evaluate the effectiveness of intelligent agents in online instruction has shown that agents can improve completion rates of e-learning courses, learner satisfaction and motivation.
Systems designed to aid human learners are usually divided into two categories (Sklar and Richards, 2006):

- *Training*, which generally refers to adult learning of job-related skills, often but not solely in military settings; and
- *Education*, which generally refers to child and adult learning in academic settings, including schools, colleges and universities.

While the terms “education” and “training” may indicate different areas within the field of human learning, from the point of view of computer systems development, they have a lot in common.

There are three main types of agents embedded in human learning environments. The first are *pedagogical agents*, personalized assistants that interact directly with a learner and explicitly guide him through the domain. Pedagogical agents are involved in the teaching component and user interface. Typically they consult the user model in order to understand the student and provide feedback that encourages the learner within his suitable “zone of proximal development”.

The second type of agents are *peer learning agents*, the explicit use of agents as interactive partners in the learning process itself. These agents are built into the user interface and, as with pedagogical agents, have knowledge of the user. While these agents may have teaching capabilities, they are typically less engineered for guiding learning explicitly than pedagogical agents.

The third type of agents is *demonstrating agents*, where the agents themselves are interactive mediums for learning; for example, interactive agent-based simulations or educational robotics. These agents represent the domain knowledge and are removed from the other components of the learning system. An open area for future work is the development of systems which combine this third type of agent with one or both of the others (Sklar & Richards, 2006).

Several projects implement learning systems based on multi-agents architectures. For the sake of brevity, it is not possible to present an extended review about the application of agents in the area. Some of them work on a generic platform of agents but usually the focus is given to a specific agent type. Interesting results have been achieved by pedagogical agents regarding the student motivation and companion agents acting sometimes as mediators of the learning process. Finally, tutor agents are usually related to student modeling and educational decision taking.

6. MASCE

The complete Multi-Agent System for Collaborative E-learning (MASCE) system provides functionalities essential in the educational process, such as real-time, as well as offline data and information gathering, analysis and distribution, embedded feedback, assessment, and collaboration.

The first phase of this complete system considers mainly the development of the basic functionality of the Student and Instructor Agents. It focuses on the building of the complete functionality of the Assistant Agent. The analysis and design phase of MASCE is done using Beliefs, Desires, Intentions-Agent Based Software Development (BDI-ASPD). We find desires first from the system requirements and then find their intentions and corresponding beliefs. This idea comes from the natural approach we usually do in the real world. An agent’s *beliefs* are a set of data describing the state of the environment. They are the knowledge that *intentions* use to fulfill their goals (*desires*).

The proposed MASCE system considers two types of users; namely students and instructors. Each of these users has a corresponding agent. These are Student Agent and Instructor Agent. Each student is equipped with a Student Agent, which helps the learning process of the student. It manages the student's personal profile and also tracks the student

actions during learning process and updates his profile accordingly. On the other hand, the Instructor Agent provides teaching materials, assesses the progress and participation of different students through quizzes, and manages the progress of the course.
The innovation in the proposed system is the introduction of the Assistant Agent which is initialized as soon as any of the users starts to use the system. It plays a centric role in the proposed system. Thus, the proposed MASCE consists of these three types of agents; the Student, Instructor, and Assistant Agents.

6.1 Student Agent

Each student has the corresponding Student Manager Agent that helps the learning process of the student. It acquires the student's preferences and profile. During the learning process, as the student enrolls in new courses, a dedicated student agent for each course is created.

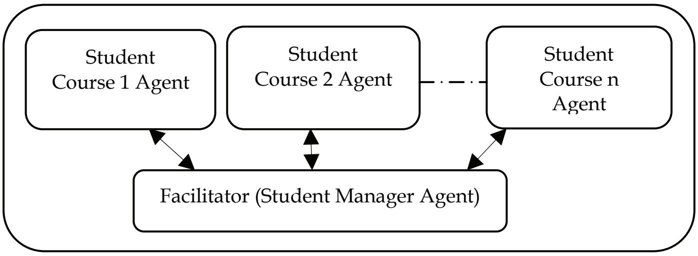

Fig. 1. Student Agent

It tracks the student actions in that course. Accordingly, the tracking mechanism updates the student's profile and preferences. All the student agents of different courses of the same student are under the control of the Student Manager Agent as shown in Figure 1.

6.2 Instructor Agent

The Instructor Manager Agent or simply the Instructor Agent assists the teaching process while interacting with the instructor. It is assigned for each instructor. For each course that is taught by the instructor a dedicated instructor agent is created. It provides teaching materials when requested by Assistant Agent for distributing to students' agents, assesses the progress and participation of different students through quizzes, and manages the progress of the course. All the instructor agents of different courses of the same instructor are under the control of the Instructor Manager Agent as shown in Figure 2.

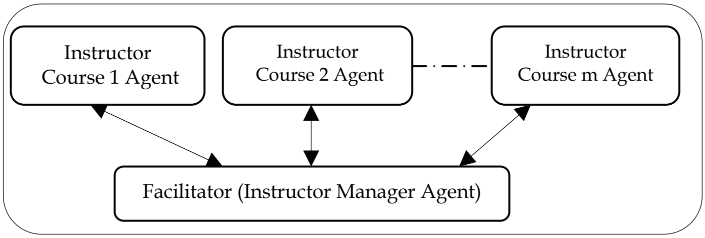

Fig. 2. Instructor Agent

6.3 Assistant Agent

The innovation in the proposed system is the introduction of the Assistant Agent shown in Figure 3 which is initialized as soon as any of the users starts to use the system. The Assistant Manager Agent or simply the Assistant Agent plays a centric role in the proposed system. For each course, a dedicated Assistant Course Agent is created. It has a collaboration mechanism which will be used for “match-making” and “community-building” to help increase collaboration between peers in a certain course. It also gives hints to the instructor of the course to help in the teaching process such as statistics of the results of quizzes and summaries of students’ profiles to help in the final grading. It acts a mediator (facilitator) between Student Agents and Instructor Agent of a specific course. After receiving the preferences (goals) of the instructor and the students, it will run autonomously and self-dependently. All the Assistant Agents of different courses are under the control of the Assistant Manager Agent.

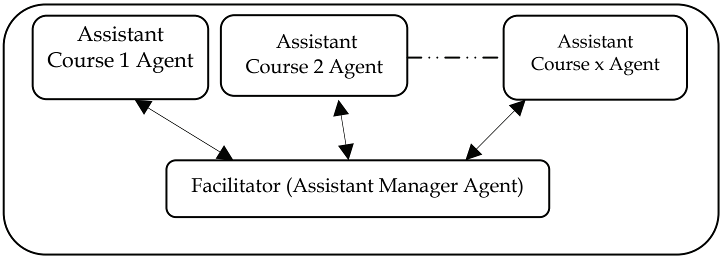

Fig. 3. Assistant Agent

The course material is going to be structured in a hierarchical form where the course is divided into chapters and each chapter is divided into sections which in turn are divided into subsections and so on until we reach the leaves (concepts which cannot be divided any further).

For each of these leaves the following will be provided:

1. Teaching materials
2. Quizzes to test student’s knowledge level
3. Students’ notes (blogs)
4. Discussion Forums
5. Questions asked by students requiring help

The student can review all the teaching materials provided and add notes to his blogs if he wants to. He will take quizzes after each module to test his understanding (knowledge level) in that part so as to update his profile. If the student asks a question in a particular section, the Assistant Agent (Match Maker) will try to find the best potential helper for this question who is currently available online, willing and able to provide help. The Assistant Agent uses the students' models in this match making process.

7. Parameters for Modeling

Two classes of parameters are considered for modeling students; namely static and dynamic parameters. Static parameters are collected from the student himself through a questionnaire given to the student when he first uses the system including:

1. Help willingness
2. Initial availability
3. Preferences such as cognitive style, maximum numbers of concurrent discussions
4. Initial belief of the student knowledge level through a simple quiz given to the student to classify him as either: novice, beginner, intermediate or advanced
5. Weighted importance of various attributes: such as if he requires help quickly from any available willing helper, or he would rather wait to be matched with the helper with the best knowledge level in the concept he is asking about

The other parameters needed are dynamic; they are updated dynamically as the student interacts with the system and more new information is collected. Old information may be *outdated* or even *wrong*. For example, after each help session between two students, an evaluation form is presented to each of them to evaluate his colleague. These peer evaluations along with the collected information about the student by the tracking system such as rate of his responses, are all used to update the helpfulness parameter. Different Computational Intelligence (CI) techniques can be used for modeling see for example (Hagras et al., 2007).

The Assistant Agent also groups students together according to their similar preferences and complementing abilities into "buddies groups" to solve group projects or assignments. Thus a community of learners may be built up. So in addition to the one-to-one relationships that grow through the use of MASCE, learners can be arranged into groups with similar concerns who support each other on specific issues. This might be a problem solving session with one or more learners assisting each other with similar problems, or it might be a longer term study group where each member contributes to mutual understanding of the subject matter in some way. Interaction at the one-to-one and the group level is designed to bring learners closer together, and contribute to the evolution of a community of learners anxious to support each other in their learning. Thus the second goal of MASCE which is the promotion of collaboration and knowledge sharing can be fulfilled.

Using this principle of the ready, willing and able helper greatly increases the likelihood of benefit among participants: Helpers are willing, and are not receiving help requests for which they have too little time or knowledge; the helpee is more likely to receive the kind of help he/she requires, and will appreciate the positive attitude of the helper. In return, the helpee may be more keen to assist the helper should an occasion arise where he is in a position to do so (students can add others to a 'friends list', indicating to their agent their particular willingness to help that person in the future). Thus the kind of community of learners that is built in MASCE is designed to benefit everybody which is the third goal of MASCE. This is clear in the case of the helpee, who receives personalized assistance when facing a problem. In addition, formulating their questions may help some learners to solve their problem for themselves, thus providing them with an additional learning strategy they can apply in the future. Furthermore, it is not only the helpee who benefit from the interaction; the helper also can improve his own understanding of the topic through peer tutoring (learning by teaching).

8. MASCE System Requirements

The Multi-Agent System for Collaborative E-learning (MASCE) is intended to be used to assist teaching and learning process and also to encourage collaboration learning among peers. This system shall be used in a blended learning environment as a supplement to the face-to-face lecture where students can use the system in the lab or from home after attending the traditional lecture in the faculty. Our objective is to incorporate the intelligence of the multi-agent system in a way that enables it to actively and intelligently support the educational processes, where multiple agents can interact to exchange information so that students may collaborate on how best to gain knowledge.

The system consists of the following:

1. Multi-agent software system consisting of three types of agents: Instructor Agent, Student Agents and Assistant Agent.
2. Two types of users (instructors and students) interacting with each other and interacting with collaboration services provided: forums, wikis, blogs, chat rooms, e-mails and also interacting with databases in the system. Typical web browser will be used to access the system such as Internet Explorer.

The student who shall use the system should have the following characteristics:

1. Accept technology, used software tools (discussion forums, chat rooms, etc) and possible problems associated with it.
2. Be prepared for open, honest and fruitful learning.
3. Accept different cultural backgrounds, different skills and different workloads among his buddies group.
4. Troubleshoot problems, report progress to instructor.
5. Meet deadlines.

The instructor who shall use the system should have the following characteristics:

1. Be familiar and comfortable with the used software tools (discussion forums, chat rooms, etc) and possible problems associated with it.
2. Dedicate some of his/her time to be online so as to interact with the students, answer questions posted by students and correct any misconceptions they may have.
3. Troubleshoot problems reported from students.
4. Design courses in a hierarchal form so as to facilitate retrieval of teaching materials, asking questions and testing understanding level of students through quizzes.
5. Motivate the students to use the system by rewarding them (with extra marks for example) for their positive content postings in order to encourage them to make effort when using the system. They can take turns in reading the postings during the week and summarizing them and making a presentation during the next lecture about the important postings.

9. MASCE System Analysis

The Brief External Use Case treats the System as a black box, and shows how the entities outside of the system interact with the system. The reason they are called *external* Use Cases is that they can show how external entities in the environment interact with the system and how the external entities *use* the system to get something done.

Usually, Goals can be extracted from *what* the system is trying to achieve and generally remain constantly throughout the entire analysis and design process. They can be decomposed into finer and finer-grained goals. We can find a global goal for a system and a set of intentions to achieve the global goal. We implement these intentions that in turn become the sub-goals of other intentions, and so on and on. That gives us an idea that we can decompose goals from top to bottom, step by step. During the Brief External Use Case process, we identify the services of the system being developed from an external point of view; we do not describe the internal workings, components, or design of the system. Through this task, we determine what services our system should provide. The Brief External Use Case captures *who* (actor) does *what* (interaction) with the system, for what *purpose* (goal), without dealing with the system internals.

The system for which we have written the requirements is a Multi-Agent System for Collaborative E-Learning (MASCE) whose overall goal is to enhance the learning and teaching process and to facilitate collaborative e-learning among peers. This system shall be used in a blended learning environment as a supplement to the face-to-face lecture to help students:

1. Review lecture slides, audio, video and view recorded instructor's notes.
2. Exchange views, have discussions and receive help from best-helper matches.
3. Most importantly collaborate with their peers within buddies group recommended by the agents in the system.

One key component that is missing in today's multi-agent systems in education is to enable the system to utilize and analyze the observed behavior collected from individual agents and subsequently adapt to such behavior. *Our objective is to incorporate the intelligence of the multi-agent system in a way that enables it to actively and intelligently support the educational processes,* where multiple agents can interact to exchange information so that the students may collaborate together on how best to gain knowledge. The Brief external use case for MASCE is given in Table 1.

Enhance the collaborative e-learning process

1. Instructor logs to the system and is given a user name and a password for administering particular course(s).
2. Instructor adds teaching materials (slides, audio, video of lectures and notes) to the system.
3. Student logs to the system and is given a user name and a password for authentication in a specific course.
4. Student is presented with a questionnaire asking about his general information, preferences and learning styles.
5. Student is given a quiz to evaluate his background of the course to be taken.
6. Student can view all available teaching materials: lecture slides, audio and video of the lectures, instructor's notes written on the Tablet PC and wikis.
7. Student can view others' blogs and write his own.
8. Student can write postings on the discussion forums.
9. Whenever the student needs help in a particular section of the course, he can post a question on the discussion forum.

10. The system (MASCE) finds the best potential helper to assist the student in that particular part.
11. After each help session, each of the helper and helpee are provided with an evaluation form to evaluate his peer.
12. The system (MASCE) gathers the students into buddies groups for solving group assignments and projects in that course.
13. Members of the same group are approached frequently and evaluate each other at the end of the assignment or project.
14. The system keeps track of the number of times each item of the teaching materials is viewed by the student.
15. The system keeps track of the materials added by the student to his blogs (notes, papers, etc….).
16. The system keeps track of the number of times the student accepts help requests.
17. The system keeps track of the number of times the student neglects help requests.
18. The system keeps track of the number of the student's postings on discussion forums.
19. The system keeps track of the number of the questions asked by students.
20. This monitoring information is used to update student model.
21. The instructor can log on to the system at predefined times so as to have synchronous interaction with his students in the discussion forums.
22. While instructor is online, he can correct any misconceptions that the students may have.
23. The system sends the questions posted by the students for the instructor to answer them when he is online.
24. The system dispatches instructor's responses to students who asked these questions through private emails.
25. If there are common questions, the answers are posted on the discussion forums for the benefit of all the students.
26. Instructor can also check the progress of the groups formed to solve assignments or do projects together and which have been recommended by the system using clustering and match making algorithms.
27. Instructor posts quizzes on the system after each module to evaluate the understanding of the students.
28. The system collects the students' answers to quizzes, grades them and performs statistics.
29. At the end of the course, the system sends a summary of the student profile and progress during the course for the instructor to help in the final grading.
30. At the end of course, the student is provided with a questionnaire to evaluate his learning experience.

Table 1. External Brief Use Case

The External Brief Use Case of MASCE in Table 1 has the overall goal of enhancing the collaborative e-learning process. After analyzing this main goal, we can divide it into several sub-goals. The headings of the sub-goals which are identified from the above processes are the following:

- Add teaching materials
- Collect initial information about student
- Present teaching materials and collaboration tools to student
- Help a student having a question in a particular part of the course to collaborate with peers
- Group students to solve assignments and perform group projects
- Monitor student behavior
- Assist instructor in interacting with students
- Assist instructor in evaluating students' understanding and in final grading
- Get student evaluation of his learning experience

10. MASCE System Design

From this point, we shift from the analysis to the design phase. During agent-based design, there is an emphasis on defining software agents and how they collaborate to fulfill the requirements. The design phase is the most difficult part in the software engineering. It involves elements of both science and art. In this approach, we will utilize some agent patterns suggested by (Einhorn, 2002). There are three of them: agent identification patterns, agent creational patterns, and agent goal assignment patterns.

The *agent identification pattern* tries to identify common agents in agent software systems, which includes three sub patterns; namely manager agent pattern, service agent pattern, and broker agent pattern. The manager agent pattern suggests creating a manager agent between the interacted internal and external agents. Hence, the main duty of the manager agent is to communicate the external agent with multiple internal agents. Not only it can locate the proper internal agents based on its interaction with the external agent, but also removes the need for the external agent to know detailed information about internal agents. In large software systems analysts can create several manager agents to bridge the external and internal agents. If a system has multiple manager agents, analysts can build a special manager agent, named delegation agent, above these manager agents.

The service agent pattern guides us to create a service agent based on certain kind of service. For instance, analysts could create a database access agent for a database access service. So, other agents can access database through this database access agent. The broker agent pattern suggests if several different agents provide similar services, they can register their services with the broker agent. Then they can communicate with the broker agent when they want to use those services. After the broker agent has the request, it will choose the proper service agent to serve the requester.

The second category pattern is the *agent creational pattern*. It suggests creating an agent while a system needs, such as the long-lived agent. Whenever the system is running, the long-lived agent is needed. It is going to handle the start and shutdown processes for the system.

The third category pattern is the *goal assignment pattern*, which suggests us remain the coupling low between agents when analysts assign goals to agents. An agent, with vastly different goals, can be treated as an overly complex agent. It would be better to decompose it into several smaller agents.

The Internal Use Case concerns interactions among elements inside the system. The reason we call such Use Cases *internal* Use Cases is because they can show how entities interact to the system internally and how the entities *use* each other to get things done. The purpose of this step is to identify the *intentions* (plans). Based on the external use cases, we decompose the scenario of each use case into details. That will help us find *intentions* for the goals and discover more roles that are not easy to be seen from the external point of view. In order to create the brief internal use cases, we read the external use cases and decompose their scenarios while keeping the rest of the parts unchanged. In our research, a role includes a particular goal or set of goals and a set of intentions. It will be mapped to an agent who is responsible for satisfying those goals. An example of the internal Use Case is shown in Table 2 for Add Teaching Materials sub-goal.

Use Case ID	**UC-0101**
Use Case Name	**Add Teaching Materials**
Goal	Add teaching materials to system
Primary Actor	Instructor
Stakeholders	Instructor and students
Pre Conditions	1. Instructor has slides of the lectures together with his notes recorded on a Tablet PC after each lecture 2. Audio and video of lectures are recorded 3. Courses are designed in a hierarchal form to facilitate retrieval of teaching materials
Post Conditions	Teaching materials are available on the system for use by the students.
Main Success Scenario	1. When instructor uses the system for the first time, Login Service is launched. 2. Instructor first determines that he is an instructor, a login form is displayed and then instructor inputs a user name and a password for administering particular course(s). 3. Login service checks if the user name and password matches login rules. 4. The user name and password are stored in the system for authentication later on. 5. Instructor launches Teaching Materials Service which displays an input form. 6. Instructor uses Teaching material Service to add (slides, audio, video of lectures and notes) each in its place in the course hierarchy.
Extensions	3a. User name or password chosen do not match rules 3a.1 Instructor is asked to enter other user name or password 3a.2 Instructor chooses other user name or password until they are accepted

Table 2. Add Teaching Materials Internal Use Case

11. Clustering and Matching

Clustering algorithms can be classified into (Jian et al. 1999):

- Exclusive Clustering
- Overlapping Clustering
- Hierarchical Clustering
- Probabilistic Clustering

In case of *Exclusive Clustering*, data are grouped in an exclusive way, so that if a certain datum belongs to a definite cluster then it could not be included in another cluster. On the contrary the second type, the *Overlapping Clustering*, uses fuzzy sets to cluster data, so that each point may belong to two or more clusters with different degrees of membership. In this case, data will be associated to an appropriate membership value.

On the other hand, a *Hierarchical Clustering* algorithm is based on the union between the two nearest clusters. The beginning condition is realized by setting every datum as a cluster. After a few iterations it reaches the final clusters wanted. Finally, the last kind of clustering, *Probabilistic Clustering* uses a completely probabilistic approach. In MASCE, *Hierarchical Clustering* is used for clustering and matching between students.

11.1 Hierarchical Clustering Algorithms

Given a set of N items to be clustered, and an N*N distance (or similarity) matrix, the basic process of hierarchical clustering as explained in (Johnson, 1967) is this:

- *Step 1:* Start by assigning each item to a cluster, so that if you have N items, you now have N clusters, each containing just one item. Let the distances (similarities) between the clusters the same as the distances (similarities) between the items they contain.
- *Step 2:* Find the closest (most similar) pair of clusters and merge them into a single cluster, so that now you have one cluster less.
- *Step 3:* Compute distances (similarities) between the new cluster and each of the old clusters.
- Repeat steps 2 and 3 until all items are clustered into a single cluster of size N.

Step 3 can be done in different ways, which is what distinguishes *single-linkage* from *complete-linkage* and *average-linkage* clustering. In *single-linkage* clustering (also called the *connectedness* or *minimum* method); we consider the distance between one cluster and another cluster to be equal to the shortest distance from any member of one cluster to any member of the other cluster. If the data consist of similarities, we consider the similarity between one cluster and another cluster to be equal to the greatest similarity from any member of one cluster to any member of the other cluster (Berkhin, 2002).

In *complete-linkage* clustering (also called the *diameter* or *maximum* method), we consider the distance between one cluster and another cluster to be equal to the greatest distance from any member of one cluster to any member of the other cluster. In *average-linkage* clustering, we consider the distance between one cluster and another cluster to be equal to the average distance from any member of one cluster to any member of the other cluster.

11.2 Steps for Clustering

First we get the parameters of students then we get the weights with which we will multiply the parameters to calculate the function on which clustering is based. Then we will get the type of the cluster we will deal with: if the instructor wants to cluster students with the highest calculated function together or if the instructor wants to cluster some high students with some low students or if instructor wants to put maximum number for each cluster. Sometimes the number of students in each group must be equal to the maximum number specified from the instructor, and in other times instructor may not need the maximum number of the students to be in each group.

Needed Parameters

Instructor will specify the parameters we will use to cluster like: if he wants to use the last year degree and how are the responses of each user and numbers of answers in that point and the interesting fields of each user or the rating of question of each student in this point and so on. After getting student parameters, we will normalize these parameters. We will get these parameters from the collected database of each user using queries.

Calculation of Weights

Instructor will also specify the parameters which he/she wants to have the larger weights or smaller weights like if the instructor wants to put large weights on the previous year degree or something else. After getting student names and their parameters and weights, we will then multiply these parameters with their selected weights to get the function which would be clustered.

Available Data

For testing our methodology for matching and finding the proper helper, we used www.ee2008.com as a source for historical data which is a simple forum for students in Electrical Engineering Department of Ain Shams University, Cairo, Egypt. We analyzed 726 posts during 25 days covering: 5 Courses, 20 Chapters and 61 Students.

12. Time-Matching between Students as an Example

Time-Matching between Students can be used as a measure of the availability. The availability will be used as an example of a parameter that is set initially from the user (student) and then will be modified dynamically according to the interaction of the student with the system. Time-matching process is to find a time that suits two or more students. Let's start with studying two students logging time (plotting the results of the most recent posts of the two users). When we plot the same number of posts for two users this means that the areas surrounded with their patterns is the same as shown in Figure 4.

Matching a third student with them is to match the resultant intersection line of the two students with the third student line and so on. This makes the intersection area of the whole students' lines gets smaller and smaller, agreeing with the fact that it gets harder to arrange for an appointment when the number of persons increase.

It is easy to recognize the maxima of intersection from the graph but we need to find an algorithm that finds the maximum of the intersection (or the time period where it is located) numerically. Locate the recent N posts for each user over hours of the day (or giving the recent post higher weights). The period of intersection we get is the best period during which the two students can meet.

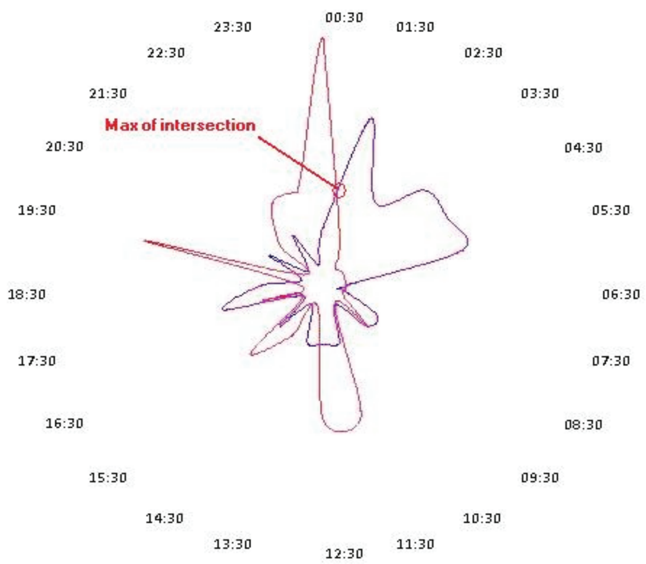

Fig. 4. Time Matching between Two Students

Applying *cross-correlation* calculation over the day will give a value representing how often they can meet all over the day time. This can be very helpful if we are going to make teams out of students as we need to group students who have a higher cross correlation value over the whole day time together. It can also be used to introduce "how often can you meet someone" value, if the student is going to choose one of many other students who can help him.

STUDENT	dony	ehab	eking	eng	esraa	fahum	fatta7	flower
dony	1.75	0.6667	1.0714	0.875	0.6667	0.5	1.4231	1
ehab	0.6667	2.4375	1.4286	0.8125	1.4444	0.3333	1.7628	0.25
eking	1.0714	1.4286	2.0204	1.5	1.381	1.0714	1.2747	0.2857
eng	0.875	0.8125	1.5	3.8125	1.5833	1.25	1.1154	0.25
esraa	0.6667	1.4444	1.381	1.5833	3.3333	0.6667	1.5128	0
fahum	0.5	0.3333	1.0714	1.25	0.6667	1.75	0.0769	0
fatta7	1.4231	1.7628	1.2747	1.1154	1.5128	0.0769	3.3432	1
flower	1	0.25	0.2857	0.25	0	0	1	1

Table 3. Cross Correlation between Students' Logging Times

We can expect that the maximum correlation for a user with another one to occur when the two users log to the system with the same timings manner i.e. calculating correlation between a student and himself gives a maximum correlation which can be shown in Table 3.

Example of finding the best helpee for Chapter 3 in the course "Optimal Control" is shown in Figure 5.

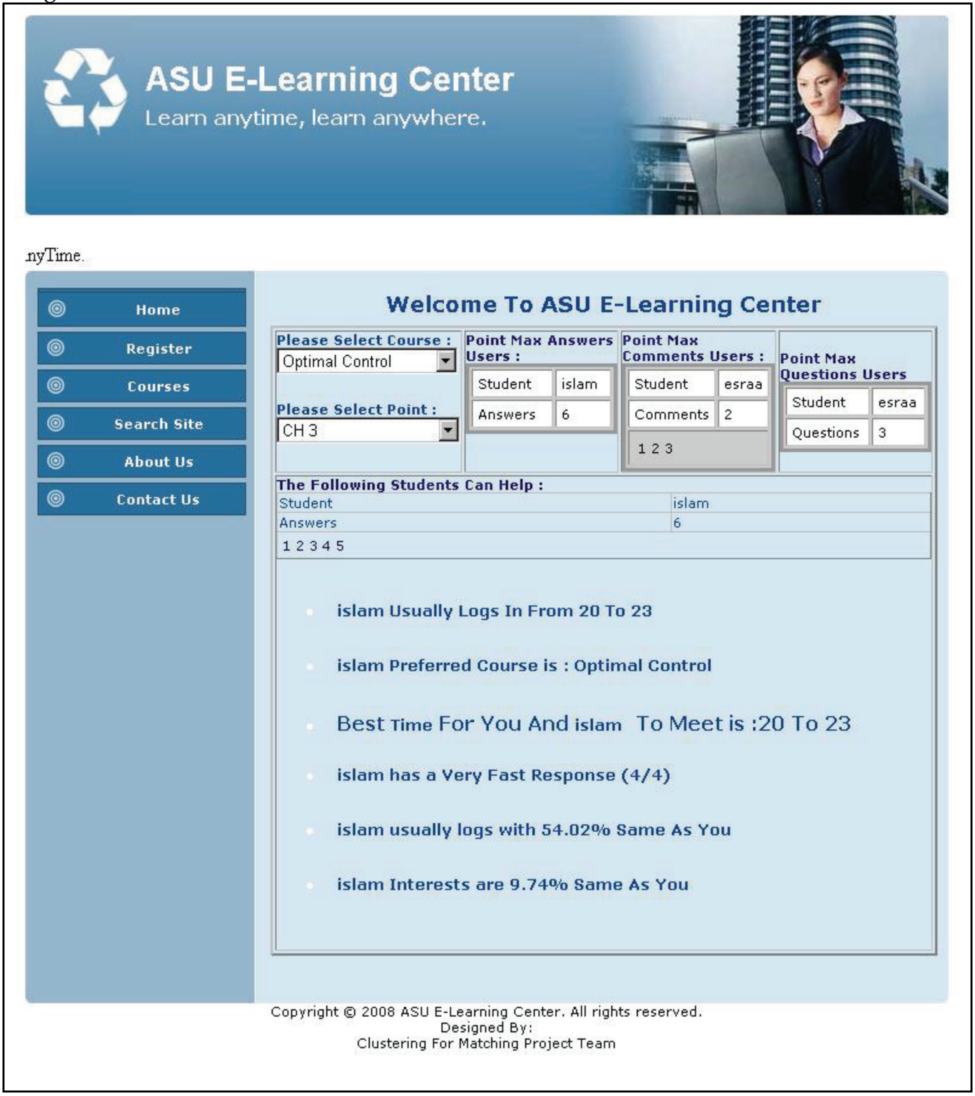

Fig. 5. Student Get Candidate Helpers Page

13. Conclusion

This chapter outlined the development and the implementation processes of a Multi-Agent System for Collaborative E-learning (MASCE). In MASCE, intelligent agents are employed to build a computer-aided collaborative learning and teaching environment. Clustering and match-making algorithms are used to build communities for facilitating learning from peers.

MASCE considers two types of users; namely students and instructors. Each of these users has a corresponding agent. These are Student Agent and Instructor Agent.

The innovation in the proposed system is the introduction of the Teaching Assistant Agent which is initialized as soon as any of the users starts to use the system. It plays a centric role in the proposed system. It can also track the user's likes and dislikes in different areas, his activities and then can nominee a peer for the user to get help.

The agents in MASCE are designed using a modified BDI (Beliefs, Desires and Intentions) architecture. Desires are determined first from the system requirements and then its intention and corresponding belief are found. This idea comes from the natural approach we usually do in the real world. Two kinds of use cases were used during designing of the system. External use cases are used for discovering the functions or services that the system should provide. Internal use cases are used for identifying plans (intentions), goals (desires), and their beliefs from the system services discovered from the external use case.

Hierarchical clustering algorithms are used for matching to find the best candidate helper for a peer according to the parameters collected by the system either from the user himself through a questionnaire or through user interaction with the system. The data used is the questions and answers posted to a simple forum for students in Electrical Engineering Department of Ain Shams University, Cairo, Egypt. 726 posts were analyzed during 25 days.

Due to time limits, the matching and grouping processes are done for the time being using the Teaching Assistant Agent. However, in the future work we want to build separate Student and Instructor Agent to be responsible about performing services in the client machines.

This can be done on two phases. In the first phase all agents will be executed on the server's side. In the next phase, the Student Agent will be located on the student's PC working as a client program. The same also goes for the Instructor Agent which will be located on the instructor's machine and they will communicate with the Assistant Agent residing on the server to provide different services for the users of the system (both students and instructors). Any announcements, updates or answers for questions will appear to the user as a pop up while working on his computer instead of having to log on to the site to check every now and then if someone answered his question for example.

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Distributed E-learning Based on SOA

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1. Introduction

In this chapter, we propose distributed architecture for e-learning presentation and generation based on Service Oriented Architecture (SOA). In first, we present Web based architecture for the distributed e-learning system on SOA. In this architecture, e-learning systems are composed of services such as LMS, Learning Object Service, Learning Content Management Service (LCMS) and so on those are published through Learning Service Providers on the Web. E-learning systems can publish or use these services to share their applications and contents. In our proposed distributed e-learning architecture, we show a complete solution for distributed e-leaning based on multi-layered architecture that each layer has specific purpose to aggregate and present services. In this architecture, service providers, service requesters and service brokers are described. In Following, we will represent some sections about how to generating a course for the e-learning system. According to our experience in using web based e-learning systems, course generation is a time consuming task meanwhile the course is the most important part of the system.

An e-learning system could not be successful without representing high quality courses. Because technology is changing rapidly, time is an important factor in creation a course, especially in areas where knowledge and skills change rapidly, such as in the IT domain, when the course is finally finished and ready to publish, the content of the course is out of date. Therefore, using automatic course generation beside the conventional methods of course authoring could be an inevitable solution. The goal of section 7 (Distributed course generation) section is representing a way to better usage of myriad electronic documents those are freely available in making tutorials and helping researchers in extracting and refining their required information from data centers and World Wide Web.

In some sections of this chapter, we are going to represent the usage of semantic Web, Knowledge Objects and Learning Objects in generating, maintaining and updating the courses.

2. Service Oriented Architecture and Web Service

Service Oriented Architecture (SOA) is an architecture that functions are defined as services and are accessible through their interfaces. This architecture enables rapid creation of

distributed application from distributed services base on their functionality. SOA consists of services. The services of SOA are software entities with discoverable interface to provide certain functionality.
SOA consists of three entities, Service Provider, Service Broker and Service Requester (Figure1).

- Service Provider creates the services and publishes them by registering the implemented services in Service Broker.
- The services are registered in Service Broker based on contract.
- The Service Requester finds the service in Service Broker and binds their applications to the Service Provider.

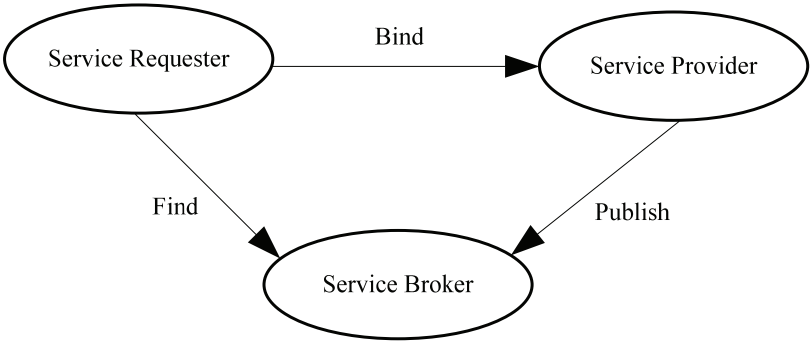

Fig.1. Service Oriented Architecture

Web Services are systematic and extensible framework for applications interaction and comprise of SOAP (Simple Object Access Protocol), WSDL (Web Service Description Language) and UDDI (Universal Description Discovery Integration) that can be accessed via Internet. Web Services architecture is independent of the platform and language, so it is usable among various applications and frameworks. Implementation of Web Services means data and operations structuring inside an XML document that complies with the SOAP specification. SOAP is a protocol specification that defines method of exchange XML encoded data between platforms. It also defines a way to do remote procedure calls (RPCs) using HTTP as the foundation of communication protocol. Web Service is used as a technology to implement SOA (Curbera et al., 2002), (Huhns et al., 2002), (Zheng et al., 2008). Entities of SOA can be implemented through Web Services. For this purpose, Service Provider describes the Web Services function with WSDL document. The description includes data type definitions, operations, input/output, network addresses and so on. Service Broker used UDDI specification to register and locate web services in Service Provider. UDDI is a web service based on XML and SOAP.

3. Architecture of Distributed E-learning based on SOA

As described in the previous section, the SOA is composed of three entities. So, the architecture of distributed e-learning based on SOA has three entities as described below (Figure2) (Bahrami et al. 2007):

3.1 E-Learning Portal

E-Learning Portal acts as service requester of SOA. This center gets the services of e-learning from E-learning Service Centers on the web and interacts with e-learning users to provide e-learning services. Communication of E-learning Portal and E-Learning Service Center is done on the web through SOAP and XML protocol.

3.2 E-Learning Service Center

E-Learning Service Center acts as service provider of SOA. This center provides the services of e-learning for E-Learning Portals. E-Learning Portals search the services on the web to find the required services. So, the E-learning Service Centers should be registers their services in Registration Centers.

3.3 E-Learning Registration Center

E-learning Registration Center acts as service broker of SOA. Services of E-learning Service Centers are registered in this center. This center provides WSDL document to publish and search service description for the UDDI. E-learning Portal finds the service in E-learning Registration Center and binds the service from E-Learning Service Center.

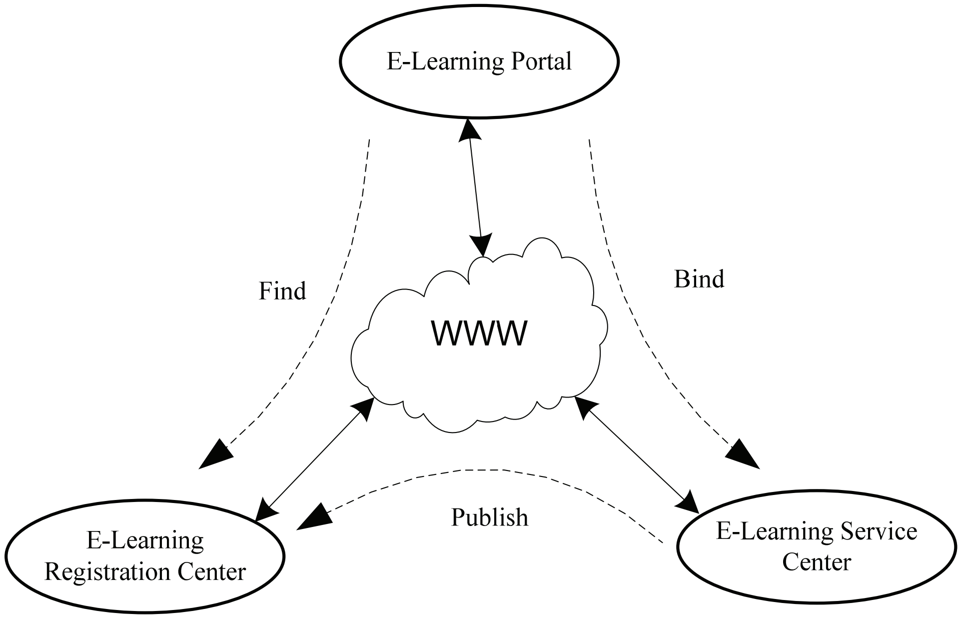

Fig.2. Distributed E-learning based on SOA

4. E-learning Portal as Service Requester

In this section, we propose multi-layer architecture of e-learning portal. The proposed e-learning portal has 3-tier architecture (Bahrami et al. 2007), includes Front-End tier, Middle-Ware tier and Back-End tier (Figure3):

4.1 Front-End Tier

Front-End tier provides customized and personalized web based user interface of the e-learning system. The contents of presented web pages are aggregate from various sources. This tier provides interface of e-learning services. E-learning services have implemented in Middle-Ware tier and include six services, namely, Course Content Design Service, Course Content Offering Service, Course Management Service, Learning Registration Service, User Management Service and Collaboration Service.

Front-End tier communicates with Middle-Ware tier in a web-based environment through web services. For this purpose, this tier initiates SOAP messages and requests information from services of Middle-Ware tier. In the reverse direction, the Front-End tier collects and integrates the SOAP response results obtained from Middle-Ware services and represents to users (Cheng et al., 2006), (Fu et al., 2005).

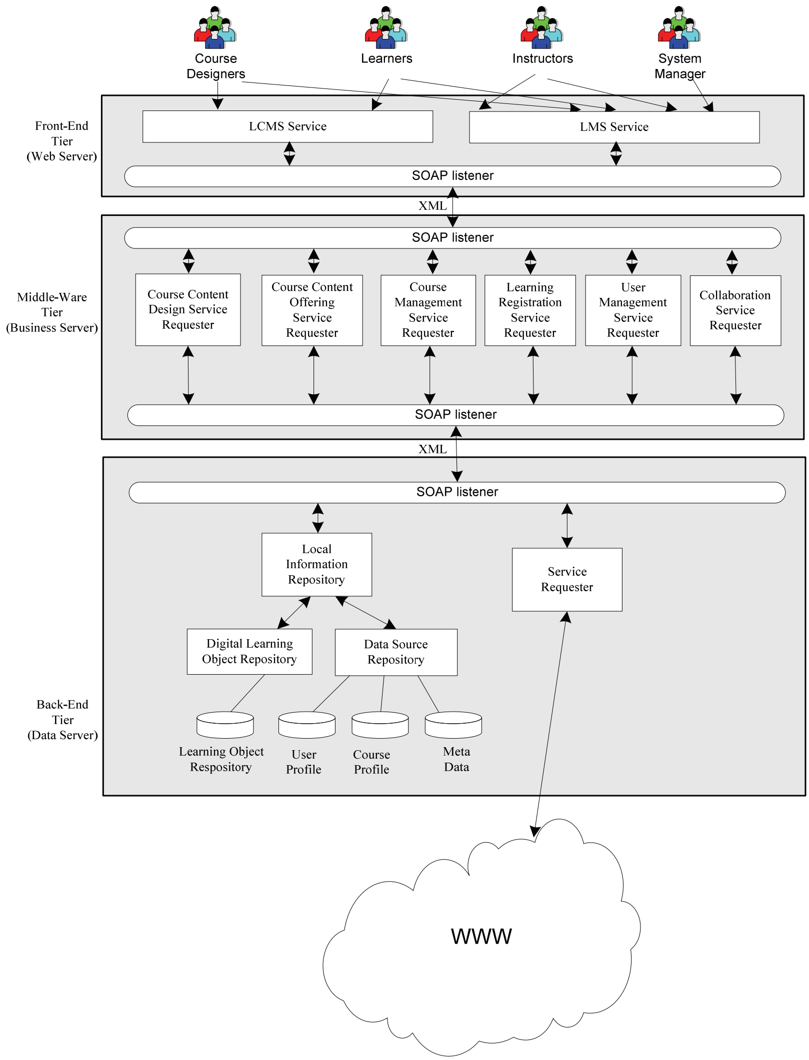

Fig.3. Architecture of E-learning Portal

4.2 Middle-Ware Tier

Middle-Ware tier is the engine of the portal e-learning system and provides logical and control functions of the e-learning system for Front-End tier. For this purpose, this tier searches and provides services of e-learning from e-learning service providers on the web. This tier supports six services, namely, Course Content Design Service, Course Content Offering Service, Course Management Service, Learning Registration Service, User Management Service and Collaboration Service. So, this tier uses a requester module for each service to get the information from services on the web and provide the functionality for Front-End tier. These requester modules are described below:

- Course Content Design Service Requester

This service requester gets the functionality of Course Content Design Service in service providers to provide designing capabilities for content authors and course designers (Vossen et al., 2006).

- Course Content Offering Service Requester

This service requester gets the functionality of Course Content Design Service in service providers to provide the learning contents to learners. Learning contents are composed of learning objects that subsequently are forwarded to the learners and presented at client browser.

- Course Management Service Requester

This service requester gets the functionality of Course Content Design Service in service providers to define new course, remove a course and update course information.

- Learning Registration Service Requester

This service requester gets the functionality of Course Content Design Service in service providers to register the learner information and course information in course registration database.

- User Management Service Requester

This service requester gets the functionality of Course Content Design Service in service providers to define new user, remove a user and update user information. It also provides the user information to the Learning Registration Service.

- Collaboration Service Requester

This service requester gets the functionality of Course Content Design Service in service providers to provide the collaboration tools and environments (e.g. messages, forum, email) to the users to provide loosely connection for users.

In addition, Middle-Ware tier includes Learning Object Aggregation Engine. Learning Object Aggregation Engine provides a global view of distributed learning contents and learning objects on learning content providers. The global view is obtained from the global Metadata schema. This schema shows virtual structure and navigation of course content and learning objects. It also provides the physical storage site of learning objects on learning object repositories. This service aggregates the learning content and learning objects for Course Content Design Service, Course Content Offering Service and Course Management Service (Guiling et al., 2005).

4.3 Back-End Tier

This tier includes Local Information Repository and Service Requester to provide learning content and learning objects to upper tiers. These centers offer digital learning objects and learning contents and related local schema. The schema includes the global information about learning objects and digital learning contents. As mentioned above, web services are used for implementation of learning object repositories to deliver digital learning content to services of e-learning systems (Navaro et al.,2006), (Liao et al., 2004). This tier has composed of Information Repository and Service Requester.

- Local Information Repository

Local Information Repository provides the digital learning object repository and data source (user profile and course profile) to the services and components of the LMS/LCMS subsystems. This subsystem delivers information to LMS/LCMS applications of e-learning systems using web services.

Digital learning object repository includes Meta data repository and learning objects. Meta data repository includes the global information about learning object repositories and digital learning objects and global schema. Meta Data Repository provides a global view of distributed learning contents and learning objects. This schema views virtual structure and navigation of course content and learning objects, but doesn't show the physical storage site of learning objects on learning object repositories. This service aggregates the learning content and learning objects for Course Content Design Service, Course Content Offering Service and Course Management Service of Middle-Wire tier.

Data source repository includes heterogeneous data sources that are not designed with the focus on sharing, such as course profile, user profile and so forth.

- Service Requester

Service Requester includes web sites and other e-learning systems that provide the e-learning services to components of the LMS/LCMS subsystems. As mentioned above, SCORM standard and Web Services are perfectly achievable for implementing the learning object repositories and delivering the digital learning content to LMS/LCMS applications of e-learning systems. These repositories are any learning object repositories on the Web that support SCORM standard (Li et al., 2005), (Madhour et al., 2006), (Frosch et al., 2004), (Shih et al., 2006).

5. E-Learning Service Center as Service Provider

E-Learning Service Center includes web sites and other e-learning systems that provide the various kinds of e-learning services such as Course Content Design Service, Course Content Offering Service, Course Management Service, Learning Registration Service, User Management Service and Collaboration Service to components of the LMS/LCMS subsystems. These services are described below:

- Course Content Design Service

This service provides designing capabilities for content authors and course designers. These capabilities include course structure design, course content and learning object design with SCORM standard (Vossen et al., 2006).

- Course Content Offering Service

This service is responsible to provide the learning contents to learners. Learning contents are composed of learning objects that subsequently are forwarded to the learners and presented at client browser. It also tracks the learner activities and updates the learning status in learner profile during the learning process. Another capability of this service is assessment of learners. This service uses the content of Learning Object Repository to provide learning objects.

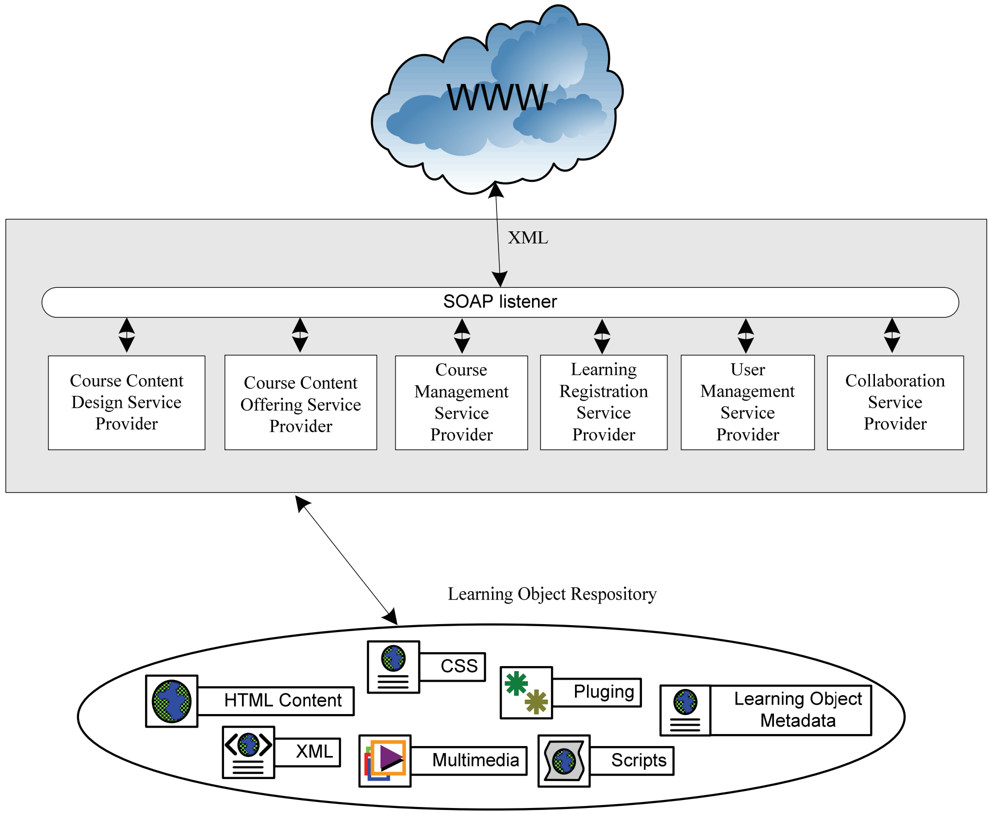

Fig. 4. Architecture of E-Learning Service Center

- Course Management Service

This service provides the capabilities to define new course, remove a course and update course information. It also provides the course information to the Learning Registration Service.

- Learning Registration Service

Once a learner selects a course for learning, the Learning Registration Service registers the learner information and course information in course registration database.

- User Management Service

This service provides the capabilities to define new user, remove a user and update user information. It also provides the user information to the Learning Registration Service.

- Collaboration Service

This service provides the collaboration tools and environments (e.g. messages, forum, email) to the users to provide loosely connection for users.

6. Why distribution?

In regard to the large volumes of data, redundancies and processing power, distribution of Learning Object Repositories is needed in an e-learning system. In the content provider architecture (figure 5), non stop knowledge object generating and updating tasks are running in each of the lowest level nodes. Mediators are also busy with continuous knowledge object enrichment and Learning Objects generation. Without using distributed architecture all of the above heavy I/O and CPU band tasks ought to run in the content provider node that is not economical.

7. Distributed Course Generation

Producing courses on a distributed network is depended on the employed architecture. Our proposed architecture is depicted in figure 5. According to this architecture, we have chosen a tree like distribution over the chosen medium (e.g. Power line networks, wireless networks or other employed media in World Wide Web). At the lowest level, there are some Learning Object providers and at the middle level there is

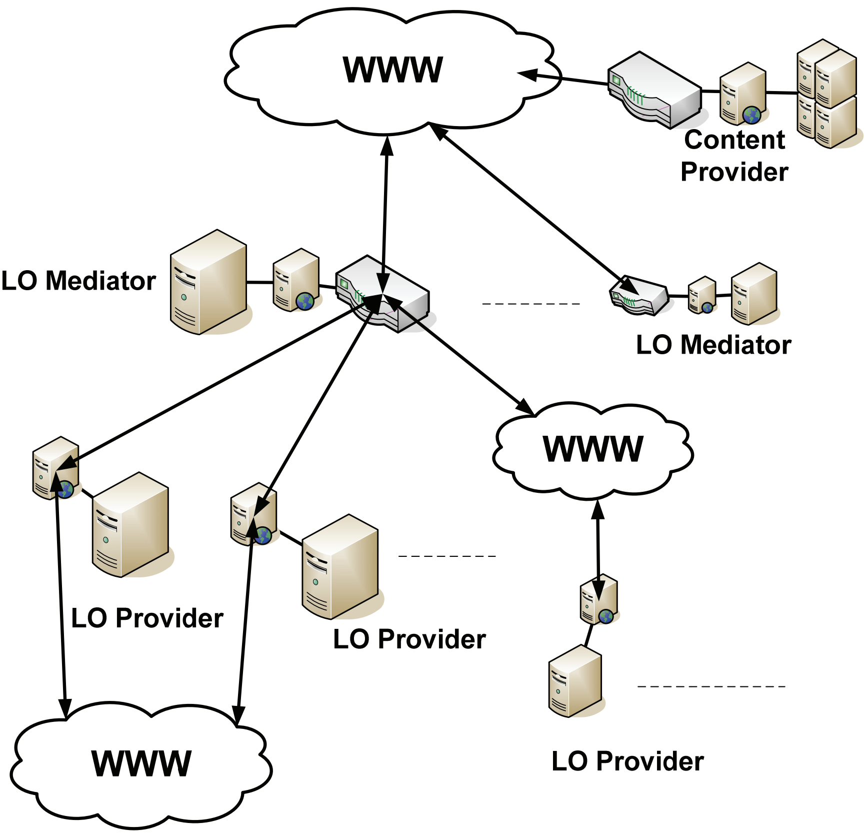

Fig.5. Architecture of the distributed content provider

a Learning object mediator for providing Learning Objects for highest level that is the content provider node. Services those are running at this node provide courses contents for the e-learning system. Each level of the hierarchical architecture has an important role in generation of the courses, but it is the highest node that is working as a Learning Object Repository (LOR) for the system. There is no limitation for us in the number of Learning Object Repositories. In fact, the highest node is a shared space where several Learning Objects are available in there for professionals and learners. The idea of Learning Objects is grounded in the object-oriented concept of computer science. Object Oriented Programming (OOP) has employed for decreasing the cost of maintaining and producing large programs for computer science. The same as OOP, the principle of Learning Objects (LO) is the creation of didactic components that can be reused in variety of different learning contexts. Learning Object is designed for teaching a focused concept and it is relevant to the course content. It must have considerable contribution for the course subject. In fact, it is a fundamental reusable building block composed of all the didactically necessary components to comprise a self-contained instructional unit plus extracted metadata (that is a descriptor for the content and concept of the LO using for indexing). LO composed of multimedia learning materials and assets those are included, but are not limited to, Java applets, animations, tutorials, texts, Web sites, diagrams, audio and video clips, exams, pictures, maps, and assessments combined for the purpose of presenting interchangeable examples, arguments, cases, and practical exercises, which can be guided by teacher or based on a learner self determined need or adaptive, based on learner's talent and quality. In a distributed environment, Learning Objects vary in size, scope, and level of granularity ranging from a small set of instruction to a series of resources combined to provide a more complex learning package but the size of the objects must be tolerable for the distributed node. In other words, the size must be as small as possible for maintaining the response time of the relevant network. Course contents are generating with merging these Learning Objects by the content provider node. Without usage of Learning Objects' metadata, machine/human is not able to distinguish which is which among the large number of Learning Objects those are stored at the system. Learning Objects must be indexed in order to be interpretable for e-learning system and determine how they can be used during the learning process. This is done by an abstraction representation file (Metadata). A Metadata is a collection of attributes about a Learning Object (LO) describing some features such as its type (text, simulation, slide, questionnaire ...), the required educational level (high school, university ...), the language, the interactivity level and so on... Several organizations such as IEEE (IEEE Std 1484.12.1-2002), EDUCOM, IMS Global Learning Consortium, etc. are focusing their attention on the creation of Metadata standards specifying the syntax and the semantics of the attribute declarations. (Sangineto et al. 2007)

8. Multiple Author Course Generation

With current rapid changes in skills and knowledge and the advent of multidisciplinary educations, having more than one author for a course is normal. Moreover, in a multiple author course, learner has a great chance to study and compare variety of different point of views in a united package. For the sake of generating a course with homogenous content, there must be a good cooperation between authors and a unique rule and a coordinator (human or machine) for all of the authors for playing their role in the content generation. The role of coordinator is so important, and it must arrange proper authors for improving the quality of the course. Each author already has a local bank of information that is related to the subject of the course, and he/she needs to develop it before beginning to generate the content. Consequently, the course authoring flow is usually as the following steps:

1. Information aggregation and clustering;
2. Knowledge Object extraction;
3. Knowledge Object aggregation and clustering;
4. Creating and gathering training aid assets for the subject;
5. Merging training aids and knowledge objects to generate enriched knowledge objects;
6. Clustering the enriched knowledge objects and extracting its metadata;
7. Generation of standard learning object and its relevant metadata by merging enriched knowledge objects;
8. Making course and with merging learning objects;
9. Checking the correctness and quality of course by coordinator;

10. Voting for generated course from experienced reviewers and normal learners;
11. Revising the course with cooperation of authors by coordinator;
12. Go to step 1 for maintaining the course and keeping it up-to-date;

If Authors are human, these 12 steps will take long time from them, especially in first 7 steps. There is no specific limitation for information aggregation in step one. It is very hard for human to gather all the available information those are related to the subject. Knowledge extraction is relatively easier for human in comparison with a machine but the inference engine of human is not stable and her/his inference ability is changing from time to time especially when he/she encountered with huge volumes of data. Moreover, before execution of step two, the authors ought to read all the gathered information in step one that is a very time consuming task. Furthermore, authors ought to find relations among huge volumes of data those are needed for Knowledge Object extraction. This latter task is even harder than reading all the gathered information, especially in multi author course generation because in step 3 authors may encounter with large number of conflicted Knowledge Objects. Steps 4, 5, 6 and 7 are more reliable with human authors but expensive and time consuming. Therefore, nowadays, semi-automatic method is the best way for generating courses. Obviously, finding relevant data and merging them intelligently according to the didactic principles are very important in course generation. Next sub sections will try to describe all kinds of merging clearly without complicated mathematical formulas or program codes.

8.1. Conceptual merging of aggregated information

The first step in generating content is aggregation of relevant information. How we could find relevant information for our subject? Normally, we will search over local documents and then over the Internet for finding proper files, assets and documents. Information aggregator could be a Web agent that is running on a machine. It could be a number of human operators too. Nowadays, conceptual search engines are not ubiquitous, but a Web agent could download huge volume of data from World Wide Web, 24 hours per day, and 7 days per week using relevant keyword to the subject of the course content and a search engine. For example, if we search keyword "LOR" for our subject that is e-learning, we will find the following texts for its definition:

Definitions of LOR on the Web:
Lor is a commune in the Aisne department in Picardie in northern France.
Loricrin, also known as LOR, is a human gene.
The ratio of the total light output of the luminary to the output of the lamp(s), under stated conditions.
Learning Object Repository: A shared space where several learning objects are available to professionals and learners.
Letter of Recommendation
Level of Risk, i.e. low, moderate or high

Obviously, the fourth definition is the correct one but without conceptual clustering, the correct answer or relevant information is not detectable by machine. Someone must create a proper metadata that is understandable for a machine then it will be able to distinguish which one of the definitions is in scope of the subject. This will happen via using another level of abstraction that is Ontology. Ontology used to represent Domain Concepts and their relations (A Domain Concept is a concept belonging to the described instructional domain and could be explained by one or more Learning Objects (Sangineto et al. 2007)). The Ontology concept is not limited to this definition. In fact, it is applicable even for a primitive level of information such as a simple text paragraph. In this situation, Ontology could be used for representing the words and their relations. In this situation, the domain concept could be a simple didactic keyword. Thanks to very complicated Natural Language Processing tools those exist now, generation an enriched metadata for a piece of aggregated information (retrieved from local disk or downloaded from Internet) is possible and some programs for conceptual information clustering are under research and development. With the help of such programs, lowest nodes of the architecture those are depicted in figure 5 are able to gather and cluster the information that is relevant to the course subject in the line of making Knowledge Objects. Each Knowledge Object must have an attached metadata. The duty of this metadata is making the concept of Knowledge Object and its hidden pedagogical intention, interpretable for the machine as much as possible. (Zouaq et al. 2007) However, to do that, the node must be able to understand the concept of the course subject. Lots of solutions are representing for this problem. We have to feed the machine with some unique specification and relevant keywords of the subjects and ask it to find all matched information then machine must find the tiny didactic domains inside the gathered information via data mining algorithms and generate the Ontology for them. At the end of the process there must be an Ontology that is representing all didactic domain concepts and their relations. Each of these didactic domains or a set of them could be a Knowledge Object for us. The metadata of these Knowledge Objects will be generated based of the extracted Ontology.

8.2. Merging the aggregated information by reviewers vote.

As you can see in section 8.1 the search result for the definition of "LOR", only an intelligent engine that knows about the concept of e-learning via enriched metadata of the course could filter the useless information and refine information those are relevant to the subject. Obviously, a human that is familiar with the subject of the course (e.g. Course author or one of the course authors) could do the above duty at a glance. When the machine has found so many different correct parallel definitions from different resources for a specific concept, it is the human who can find which of the retrieved definitions is more complete so in this case merging by reviewers could be a good solution. In this method author could see the parallel definitions of a concept in a package and in front of each definition, there is the score of that definition that is generated by the vote of experienced reviewers. Obviously, author could use these voted definitions (those are confirmed by a number of experts in that field) for generating more reliable and confirmed knowledge objects.

8.3. Merging the aggregated information by authors

In this method, the refining and filtering of the gathered information is done by humans. This method is similar to conventional method of course authoring but there is a difference. In this method gathering of information is not done by the author necessarily. The author is just the one who uses the already gathered information for generating knowledge objects. These knowledge objects are based on the author point of view and responsibility. In case that there are multiple authors for the course, there must be a coordinator for auditing over the quality of the knowledge objects.

8.4. hybrid method for merging

In this method, the coordinator is taking advantage from all of the above methods. In other words, merging the human outcomes and machine outcomes will do by coordinator and he/she will use each method in its proper situation for obtaining the best quality in generated knowledge objects. In this method, the same as sections 8.2 and 8.3 the metadata must be generated by human that is the coordinator in this method.

9. Automatic Course Generation

In last section, we represent different ways for generating knowledge objects in a distributed environment. Knowledge Objects and their related metadata are the outcome of the activities those are described in last section. Clustering and aggregation of Knowledge Objects needs the same sequences those are described in last section for aggregating and clustering of information. One of the differences is that in addition to the processes those are described in last section, authors may have to create some multimedia assets and interactive animations or scripts for adding to the Knowledge Objects. Automatic generation of these assets is not easy for a machine and with current technology it is a task for human authors (see section 6). Merging these assets and Knowledge Objects will make enriched Knowledge Objects. This merging operation has to be done by the author and it is the duty of the coordinator in case that there are multiple authors for the course. There must be a metadata for each enriched Knowledge Objects. This metadata could be generated by machine or human but the final quality assurance must be done by the coordinator. The other difference is that there must be an instructional method for representing the course. How we can add this capability to the automatically generated course? In fact, there are some templates for learning theories and human operators could feed these templates to the machine.
Nowadays, some tools take an instructional theory as input (Zouaq et al. 2007) and offer a mapping of the theory's principles with the asset categories (instructional role Ontology). Instructional theory is a discipline that focuses on how to structure material for promoting the education of human beings and formalized as a set of Instructional steps those are expressed in the form of rules combining asset categories and predefined methods. Semantic Web Rule Language (SWRL) is a good tool for the rule formalism. SWRL could enable the hierarchical rules to be used with an Ontology Web Language (OWL) knowledge base. SWRL rules can then exploit OWL classes, instances and properties in their body and head. OWL is a knowledge representation language for authoring ontologies and is built on top of RDF (Resource Description Framework designed as a metadata model) and designed for being interpreted by machine not human that is using XML syntax. OWL is for modeling data and better than RDF for representing metadata.

9.1. Learning object generation from knowledge objects

The outcomes of the section 5 are enriched Knowledge Objects with their relevant metadata those are defined with OWL. In this section machine will try to make standard Learning

Objects (based on SCORM) from the already produced Knowledge Objects. The same as human author during writing a text book, machine needs some relevant notes, proper scientific background about the subject of the course and an instructional method for representing the course. Knowledge Objects (enriched or not) could play the role of the notes for machine. The extracted Ontology has the same role for machine as the scientific background has for human author and the instructional method must be defined for a machine based on advanced reliable learning theories as templates. Using these three, the machine could generate Learning Objects and their relevant metadata by ordering and merging proper enriched Knowledge Objects in a package. These packages must not have large volumes because the intrinsic limitations of the distributed environments in transferring data. As a rule of thumb, Learning Objects are not longer than 30 minutes. Obviously, the content of Learning Objects is depending on the instructional policy and templates those have feed to the content provider engine by the coordinator or author.

9.2. Course generation using conceptual LO aggregation

Using the enriched metadata of Learning Objects those are made from Knowledge Objects' metadata, the engine will try to merge the Learning Objects for making a concept. The merging process is guided by the instructional policy and templates those are feed by the coordinator to the content provider engine. For example, in the case that machine has provided Learning Objects those it takes 100 hours from learners to watch them, there may be a defined policy for the conceptual engine to select just 24 hours of Learning Objects those are enough for covering the course and in the case that 24 hours are not enough for covering all aspects of the subject, there may be an instructional rule to divide the course to some parts. These rules could be implemented using SWRL over OWL knowledge bases. How the tool could find that which set of the chosen Learning Objects from Learning Objects knowledge base has the proper coverage for the course?

The answer is inside the Ontology. The extracted Ontology that is described in section 8.1 is familiar with all the domain concepts those are relevant to the subject. Therefore, a set of Learning Objects has enough coverage for the course subject if all the relevant domain concepts have been described in the metadata of its related Learning Objects. The generated course must be equipped with metadata too. This metadata will help the e-learning engine to represent better service to learners, better coverage check and is very useful for updating processes.

9.3. Automatic creation of new courses

When the engine will receive a subject, it will try to make a course based on it by data mining over the aggregated information. The sequence of automatic course generation is similar to section 8.1 but the difference is that in this situation, we do not have any background science about the subject of the course and the only thing that we know is the exact and correct name of the subject. In fact, we need to an intelligent fuzzy method inside the content provider engine to find a set of keywords those are really relevant to the subject of the course. Afterwards these keywords will feed to the retriever Web agent and gathering of the related information will begin according to the sequences those are described later. In this kind of course generation human is just a policy maker and feed the instructional theory templates to the engine. Afterwards, he/she will check the generated course and doing some editing on it for maintaining the homogeneity with other courses. This kind of course generation is very useful for those researchers who are entering to a completely new field of science. Without this engine, they must spend too much for gathering the primary information while machine could do that for them when they are asleep.

9.4. Keeping generated course up to date

Keeping the generated course up with current technology is more important than generation of the course. There are lots of feedbacks from learners and lots of advancements in the area of the course. Therefore, updating the courses is a need. In regard to large number of courses in an e-learning system (for example, more than 1400 courses in Payame Noor University www.pnu.ac.ir), keeping them up-to-date with using human authors is very expensive. When course updating routine is scheduled, it will search over the Web and local free to use documents for finding new relevant domain concepts. These domain concepts will add to the set of the subject relevant domain concepts and then the Ontology must be updated based on newly added domain concepts. Afterwards, all the intelligent sequences will run again and new Learning Objects will be produced. The newly produced Learning Objects must be used to regenerating the courses. In this regeneration, the feedbacks of the learners for each Learning Object could be a useful guide and those Learning Objects, which have more negative feedbacks could be replacing by new ones. Obviously, the metadata of the course and its Ontology must also regenerate. The update sequences could run repeatedly or run by E-learning system administrator based on the owner of the system policy and the distributed network traffic limitations.

10. State of the Art

E-learning systems have been achieved to great advancements but still there are so many problems in the line of developing a course. Managers' demands for generating high quality courses at very short time are increasing day by day especially because the rapid change in the technology and the advent of new branches of science and technology. Therefore, non stop research on new aspect of course development is a need.

10.1. Making multimedia presentation from aggregated knowledge

With a complete library of characters, background and other animation primitives, making an intelligent game engine equipped with physics rules that can convert a text to animation is possible. Text to animation tools has been appeared in some patents and Chatbots (Alice Chabot) but they are at the very first steps. In fact, converting a text to animation is very similar to translation of the Chinese to English.

With using papers those are published in this field we could generate a super compiler for translating a text to a primitive flash based animation. The soul of idea is simple. The parser of the compiler must find the relation between words and generating the Ontology of the text. Afterwards the compiler must map each important actor in the text to one of the elements in its library. For example, a unique character in the animation library could be assigned to each subject in the sentence and there must be a good movement or state in the animation library for each verb in the sentences. Obviously, generating such a compiler is not so easy but the result is fantastic. With such a compiler, we could make an animation from a scenario at a very short time and it is a real advancement in generating high quality multimedia courses.

10.2. Conceptual merging of ready made pictures and movies

There are lots of free to use ready made relevant assets those are gathered by the retriever Web agents from local documents and Web or by human operators. In some cases analyzing these assets and making proper metadata for them could be a good task for machine. For example, there are tools for decompiling flash files those are able to convert flash files to lots of reusable objects, characters and primitive animations. Using the library that is generated by these tools could be very helpful in saving the time of course animator or the author. Moreover, with assigning proper metadata to each multimedia asset, the part of engine that described in section 5 could merge these assets and make a covered course from them if we already have a proper library of the multimedia assets.

10.3. making interactive intelligent humanoid interface for course presentation

An interactive intelligent human user interface is a good choice for course presenter. The idea that is behind Chatbots like Alice and Ellen could be very useful for this user interface. These Chatbots could represent the course by reading it and acting according to the text. Some deaf people could read from the lips of the Chatbot and the presence of a good looking Chatbot could prevent the learner to be bored during long hours of sitting behind the computer. Another application of these Chatbots is interviewing with learners to find their level of knowledge and guiding them to the courses at proper level according to the learner capabilities and interests.

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Regionally Distributed Architecture for Dynamic e-Learning Environment (RDADeLE)

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Abstract: Grids are increasingly being used in applications, one of which is e-learning. As most of business and academic institutions (universities) and training centres around the world have adopted this technology in order to create, deliver and manage their learning materials through the web, the subject has become the focus of investigate. Still, collaboration between these institutions and centres is limited. Existing technologies such as grid, web services and agents are promising better results. In this paper we support building our architecture Regionally Distributed Architecture for Dynamic e-Learning Environment (RDADeLE) by combining those technologies via Java Agent DEvelopment Framework (JADE). By describing these agents in details, we prove that agents can be implemented to work well to extend the autonomy and interoperability for learning objects as data grid.

Keywords: Data grid, Regional grid, Multi-Agent System (MAS), JADE, E-learning, Intelligent, Autonomous, Distributed data grid, Learning Objects (LO), Search.

1. Introduction

E-learning has been increasingly used by both academic institutions and businesses for learning and training activities. Various types of e-learning platforms and tools have been introduced in many different education institutions and private training centres. Many technologies include web services (Rodrìguez, Anido-Rifon, & Iglesias, 2003), grid computing and data grid technology (Yang & Ho, 2005) and agent technology (Sousa, Silva, Teixeira, & Filho, 2006) have been integrated into e-learning environments to enhance the architecture.

Web services have emerged as a paradigm of distributed computing, and have been proposed as an intermediary framework for the integration of standard compliant e-learning platforms in order to eventually embrace advantage of the benefits offered by their technology (Rodriguez et al., 2003).

Data grid technology is another supporting technology for e-learning services in order to make learning materials such as Learning Objects (LO) sharable by learners in different sites (Yang & Ho, 2005). In data grid, replication services can be used to enhance the performance in reliability, scalability and fault tolerance (Chervenak et al., n.d.) (Guy, Kunszt, Laure, Stockinger, & Stockinger, Edinburgh, Scotland, July 2002.).

Agents can provide both useful abstraction at data grid environment and very dynamic and robust services. Using the agents' essential powers is strongly recommended in grid environments.

MAG (Mobile Agents Technology for Grid Computing Environments) is developed by Federal University of Maranh˜ao, Brazil. The aim of the project is developing free software infrastructure based on mobile agents technology that allows the resolution of computationally intensive problems in computer grids. MagCat extends MAG to handle applications that manipulates huge amount of data. Although the multi-agent system MagCat has its search agent (known as SearchAgent) which is responsible for performing queries in distributed metadata repositories, this agent does not analyse the result of its search (Sousa et al., 2006).

These technologies have not been adopted cooperatively and collaboratively to support e-learning services. Agent and data grid architectures seem different from each other. As a matter of fact, we can learn from one in order to improve the other (Thompson, 2004). E-learning services are composed of many components which are part of distributed systems. These components and the system as a whole are designed to be cooperative. Grid and agent communities are pursuing the development of such distributed systems (Foster, Jennings, & Kesselman, 2004). In our architecture, we intend to support e-learning services using these technologies.

The organisation of the paper is as follows. First, in section II we present a background which includes grid computing and agent and information management. In section III we present an overview of our architecture Regionally Distributed Architecture for Dynamic e-Learning Environment (RDADeLE). This includes descriptions of architecture components and regional grid structure. In section IV, we introduce agents' specifications. This includes MAS-based e-learning, agent architecture, and agents formalisation. In section V, we introduce the implementation which includes the platform, registries and multi-agent systems, and case study. Finally, in section VI we conclude the paper and future work.

2. Background

The following is background about the technologies mentioned in the previous section in order to present an introduction and definitions. Those technologies are adopted to be embedded in our model to produce a dynamic e-learning environment. Those technologies include grid computing, agent and its role in data management, and finally learning objects.

A. Grid Computing

Grid computing provides an environment where a widely distributed scientific and academic community shares its resources across different administrative and organisational domains. The purpose of grid computing is to solve large-scale computing and data-intensive applications and collaborate in a wide variety of disciplines. Grid computing, therefore, enables the creation of a virtual environment which facilitates physical resources across different administrative domains in order to be beneficial; these resources are then abstracted into computing or storage units that can be transparently accessed and shared by large numbers of remote users.

Data grid is concerned with massive datasets and remotely separated storage units organised in a virtual environment. As a result of the increase of learning materials (Learning objects) and the need for huge masses of information to be archived and shared among academic institutions and training centres, data grids become an indispensable technology in learning fields. E-learning platforms and systems have been adopted, developed and published. These platforms and systems are based on client-server, peer-to-peer and web service architectures (Pankratius & Vossen, 2003).

Based on some papers written in grid fields, there are few extant data grid topologies which have been implemented as case studies or prototypes.

One of these topologies is the tree type (Lamehamedi, Shentu, Szymanski, & Deelman, 2003). The European Organisation for Nuclear Research (CERN) has adopted tree topology in its data grid. The CERN project is implemented as a tree topology consisting of three levels; the root (called Tier 0), intermediate (called Tier 1), and user (called Tier 2) levels (Nuclear Research (CERN), 2006). Another architecture which produced a platform using a Sharable Content Object (SCO) repository is based on data grid technology. This platform integrates the technology of data grids and Shareable Courseware Reference Model (SCORM) (Yang & Ho, 2005). Although this architecture uses Globus Toolkit middleware to accomplish learning processes it, does not exploit agent technology in its architecture.

There are two known Data Grid Management System (DGMS) middleware responsible for controlling and managing data grid within the grid environment. The _rst middleware is Storage Resource Broker (SRB). San Diego Supercomputer Center (SDSC) develops this middleware which supports shared collections that can be distributed across multiple organisations and heterogeneous storage systems (Center, 2005). The second middleware is OGSA-DAI (Open Grid Services Architecture-Data Access and Integration). OGSA-DAI is a middleware product that allows data resources, such as relational or XML databases, to be accessed via web services (Team, 2007).

B. Agent and Information Management

Agents have many different definitions, one of which is that they are any entities that perceive their environment through sensors and act on that environment based on their own reasoning capability. Examples include human, robotic and software agents (Russell & Norvig, 1995). Agent technology has been exploited heavily on the web through applications in many fields including industry, business, education and training. One of the most famous agent applications is video games, which have become a large part of many people's lives. Applying agent technology in video games has many aspects. One of the obvious benefits of video games is the elimination of risk to human life involved in any real-world application. They also make an excellent testbed for techniques in artificial intelligence (Laird & Lent, 2000).

Information management has an important role in any enterprise system. The Internet and World Wide Web (WWW) refer to massive distributed datasets. If we want these datasets and data to be beneficial, we have to organise them in such way that they can be managed. One of the most well-known methods of managing information is by using agent technology. In the context of information management, the types of agents depend on their purposes and functions. There are three types of agent (Stathis, Bruijn, & Macedo, 2002). The first type is a personal service agent whose purpose is to model the interactions of community members with personal devices, the second type is a location service agent whose purpose is to models the interactions of community members with shared devices placed in specific community locations, and the third type is a memory service agent which models how the information content is stored and disseminated to people or locations. Agent technology has been exploited in e-learning environments for many reasons, especially for integration with other technologies to build more robust, scalable and e_cient systems. Many e-learning architectures have been proposed using integration between agent technologies and web services (Hussain, 27-28 Aug. 2005). Although this architecture integrates agent and web services technologies, it does not exploit data grid technology.

C. *Agent-based Grid*

There are many projects which have been built based on grid, web service, and agent technologies. Those projects were built according to the user and organisation needs. At the same time those projects were produced based on different approaches and techniques. Yet there are some issues not resolved in those projects and at the same time the aim of using agents technology in our model is different from them. These differences will be detailed in the next chapter. The projects include ChinaGrid and ESESGrid (Engineering Structure Experiment and Simulation Grid).

ChinaGrid (Hai Jin and Li Qi, 2005) project is based on Open Grid System Architecture (OGSA) ChinaGrid is designed as four levels architecture. The levels are physical resources level, common support platform level, application support platform level, and applications level. The first level is physical resources level which takes care of all kinds of physical resources, such as computational resources, storage resources. The second level is common support platform level, which its kernel component is ChinaGrid Support Platform (CGSP). It provides the virtualization for the physical resources level and expands from the core of Globus Toolkits. The third level is application support platform level, which provides the common Problem Solving Environment (PSE) to support the different requirements in various research domains. Application professionals and developers use this level to deploy grid-enabled applications. Finally, the fourth level is applications level, which is the general user interfaces for applications over ChinaGrid, so all requests to ChinaGrid are sent through this level. This level is designed for application users and researchers who need know their application specific knowledge.

ESESGrid (Wang Li, Wang Cong, Long Hao, and Di Rui-Hua, 2008) is designed to share resources for engineering structure researchers in and collaborative work environment. ESESGrid data acquisition system is based on open, common standards and compatible with the relevant norms of WSRF and WS-Notification to build distributed heterogeneous and dynamic resource management in engineering structure research. The structure is composed of four layers. There are local site, agent layer, grid core service layer, and client side. The first layer local site gets real-time experiment data from the experiment centre. The second layer is agent layer, which all agents are responsible for the real-time experimental data management and access. The third layer is grid core service layer. It supports the integration and share of heterogeneous resources. The forth layer is client side which is a means for administrators and common users to use the system.

3. RDADeLE

RDADeLE architecture was designed to achieve and fulfil objectives and aims designed for agent-based e-learning environment needs. These aims include:

1- Dynamic e-learning environment. This aim is achieved by using active components, agents here, which are responsible for most activities in the environment.
2- More coherent e-learning environment by using multi-agent system technology. Agents within multi-agent system have infrastructure specifying communication and interaction protocols. These protocols support the coherence in RDADeLE.
3- Scalable environment: the number of students, members of learning centres, grid services, and other RDADeLE components are increasing. This why scalable environment is required in order to accommodate all components (agents in our architecture).
4- Interoperable environment: environments in general and e-learning environments in particular are not using the same standards to communicate. Interoperability in e-learning environments plays a big role in communication between components in the same environment or between different environments.

RDADeLE is our architecture, which is different from other and above architectures mentioned in the previous section in many ways. The following is the main difference:

1- RDADeLE is divided into a number of regional grids in which each region has its own components as shown in Figure 3 (AlZahrani, Ayesh, & Zedan, 2008). These regional grids have been adopted in RDADeLE for many reasons. It is recommended that massive number of data (data grid) divided into smaller number of segments in order to reduce problems or congestions may occur. Another reason is that such a divided regional grid gives members of each regional grid flexible way to customise the regional grid according to the characteristics of members and environment. Yet another reason is that for any reason if a single regional grid is disconnected from the RDADeLE that will not affect other regional grid in particular and the whole system in general.
2- The multi-agent system is embedded in the RDADeLE. Mulit-agent system has many features which strengthen of RDADeLE. These features include coherence, interoperability, and scalability.
3- There are three layers in RDADeLE: learner (user) interface layer, agents' layer, grid service layer. The first layer is the learner interface which is considered as a means for entities outside RDADeLE to communicate to it. The second layer is the agent layer which is the core part of the RDADeLE. There are three types of agent in this layer administrative agent (AA), regional agent (RA), and sensor agent (SA). More details will be provided later in this chapter. Finally the third layer is the grid layer which is data grid management system. This layer is responsible for connecting between learning objects (LOs) repositories in the same regional grid.

A. Architectural Components

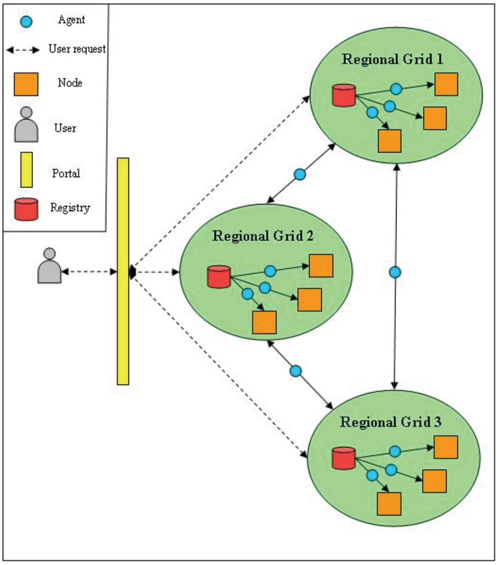

Fig. 3. RDADeLE Overview

Figure 3 shows an overview of our architecture (RDADeLE) which consists of agents providing the internal structure. These agents are triggered when the state of e-learning environment is changed and when a request is initiated by a user. The user in our architecture refers to an end user or a requester representative. Dotted lines show the request path which travels to regional grids in order to search for LOs. The path also shows the results returned to the user. The portal is a thin client which provides a user interface. The portal is a means to enable the user to send a request and receive a response to and from the system. Using data grid and thin client (portal) enables learners, employees and the general public to search for and collect information about (LOs), learning units (LUs), courses and degree plans from nodes all over e-learning environment. The solid lines show the interaction between system components within each regional grid and between grids themselves. On the one hand, the role of agents within each regional grid is both to help users to search and retrieve LOs and update each regional registry. On the other hand, agents traveling between regional grids are responsible for controlling the data passing between them according to assigned constrains which are part of the regional grids' properties.

The square shapes represent nodes. Nodes represent the locations of servers which provide grid services. Grid services include providing educational materials (i.e. Learning Objects LOs). Each regional grid has one or more server which represents one or more academic institution or training centre.

B. Regional Grid Structure

Regional grids each represent one or more educational institutions and training centres. What concerns us is the grid services provided by these sites. Grid services in our architecture will make repositories of LOs and their metadata available to requesters. Each repository represents an institution or training centre as shown in Figure 4.

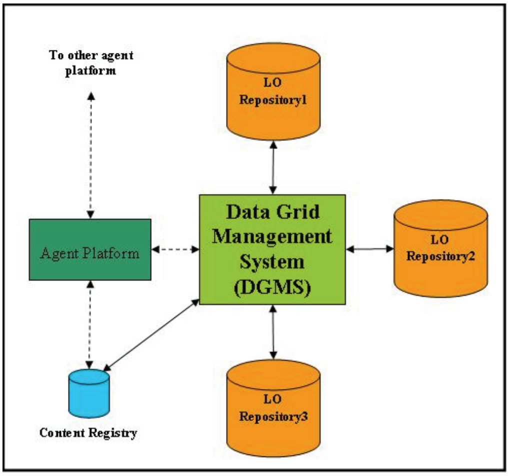

Fig. 4. Architecture of Regional Grid Node of RDADeLE

Reasons for using grid computing in our architecture (particularly data grid) include the following. Data grid provides an optimal organised platform for massive and remote separated storage units (LOs) in a virtual environment. These LOs are needed to be archived and shared among academic institutions and training centres.

Our purpose in distributing the registries in our architecture is based on an approach which will be explained in this section. There are two approaches which could be adopted in our architecture. The first is to create a central global registry. The content of this global registry is the contents of all registries in each regional grid. Users can discover all LOs in all regional grids via the global registry. At the same time, registries in each regional grid are used to discover only that grid's LOs. Users can access global and regional registries to discover LOs. The second approach is based on assigning one regional registry for each regional grid. In this approach there is no central registry with which to discover LOs. Instead, regional registries are used to discover regional LOs. If any regional grid has been disconnected from the global grid other active regional grids will not be affected. In RDADeLE, members (users) of academic institutions or training centres represent the active entities, while the regional grids support the infrastructure:

- A member may dynamically connect (join) and disconnect (leave) from RDADeLE.
- Regional grid is supposed always to be connected to RDADeLE.
- Each regional grid has one registry which publishes all LOs of institutions connected to it.
- A registry of a particular regional grid is updated according to the number of LOs repositories which connect or disconnect from the regional grid.

- Each regional grid has its own constraints which are considered part of its properties. Information is passing between regional grids according to these constrains.

Reasons for dividing our architecture into regional grids (regional segments) include the following. Such a division helps produce a sound structure. This gives the designer a flexible approach of constraint-based segments. The other reason is that regional grids could include one or more countries which have common cultural or demographic properties. This will ease the way for any institution or training centre to connect to the regional grid with the similar properties. Yet another reason that dividing our architecture provides a exible constraint setting for particular regional grids, which is useful in utilising each regional grid in particular and the whole global grid in general.

4. Agents' Specification

We intend to create dynamic e-learning environment which depends on data grid and multi-agent technologies. In our architecture, services are distributed since each regional data grid has its own registry. However, requests from portal could be massive which affects services to be a bottleneck. Using distributed agents in this context will help in resolving part of this problem. Agents in our architecture have been designed to be intelligent and autonomous. In order to make agents autonomous and have flexible behaviours, they have to be reactive and social. Reactivity means that agents can perceive their environment, and respond in a timely fashion. Agents perceive the learning environment through the requesters (learners or students) and service providers (institutions). On the other hand, social means that agents are capable of interacting and communicating with other agents and humans. Agents in our architecture from social context satisfy these features in interaction with requesters and in communication with each other. In this section we will present some details of three titles: MAS-based E-learning, Agent Architecture, and Agents Formalisation.

A. MAS-based E-learning

The primary concern of the MAS-based e-learning environment is the interaction of agents themselves and their relationships with their environment. These relationships are created in order to introduce dynamic e-learning environments. Controlling and organising agents' behaviours are another feature in producing a dynamic e-learning environment. The multi-agent platform in Figure 5 (Lee, 2006) plays a major role in relationships between regional grids themselves and between components within each regional grid. The main role of multi-agent systems in regional grids is to build a dynamic, intelligent and collaborative environment.

The multi-agent structure used here is hierarchical (i.e. layered). This approach is ideal for solving large-scale, complex problems. Hierarchical structures have been adopted and studied in many fields of research including scientific computing and business processing. The basic idea of hierarchical structure is that a complex system can be divided into subsystems; the overall behaviour of the system is figured out by its subsystems which perform sub-functions (Simon, 1960). Hierarchical layered MAS has three layers, the upper, middle and bottom levels, as shown in Figure5.

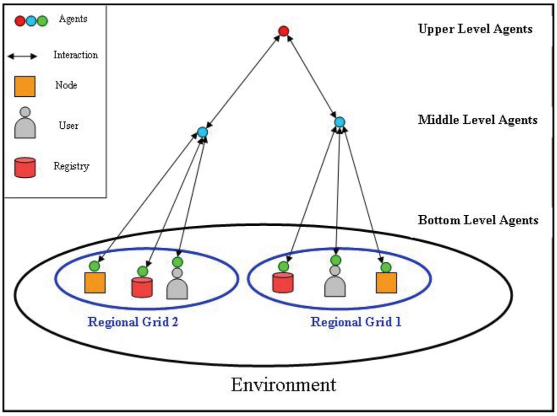

Fig. 5. Hierarchical Agent Organisation of MAS-based E-learning

Agents need to get behavioural instructions, whether from their higher level agents in the hierarchical structure or from other environment components (e.g. learners), and get support from agents in lower-level agents to perform their tasks. In our model, RDADeLE corresponds to the upper level agents (administrative agents). These agents are responsible for controlling and managing other agents at lower levels, who in turn are responsible for regional grids communicating with each other. Regional grids correspond to middle level agents, which are responsible for supporting activities within regional grids. Regional grid components correspond to bottom level agents which are considered to be sensors of the environment. The following table presents Agents Category:

TABLE 1
AGENT CATAGORY

Agent Name	Agent Category	Agent Level
Sensor	Sensor	Bottom Level
Regional	Regional	Middle Level
Administrative	Administrative	Top Level

B. Agent Architecture

Agent architecture is essentially a map of the internals of an agent. Agent architecture includes agent data structure, the operations that may be performed on these data structures, and control flow between these data structures. There are many agents' architectures which have been adopted in many applications. These architectures include Logic-Based architecture, Reactive architecture, Belief-Desire-Intention architecture (BDI), Layered architecture, and Deliberative architecture. Subsumption architecture is arguably the best-known reactive agent architecture in which agent decision making is achieved through the interaction of a number of behaviours. Most of the agents in the e-learning environment are subsumption agents. This type of agents is behaviour-based architecture which decomposes complicated intelligent behaviours into many simple behaviours, which in turn organised into layers (Weiss, 1999).

There are two models of agents which could be compared. The first one is that there is only one type of layered architecture which substitutes to do different functions. This type of agent is suitable for homogenous systems. The other type of agent is behaviour-based agents. In our architecture, we intend to adopt behaviour-based agents which are capable of achieve intelligent behaviour. This type of agent suitable for heterogeneous systems.

C. Agents Formalisation

Based on what we have mentioned, there are three types of agents. The first one is the administrative agents, the second one is the regional agents, and the third one is the sensors agents.

The administrative agents are described as a tuple as follows:

$$AA = < cr, e, a, c > \tag{1}$$

where:

- cr is a control request.
- e is an entity.
- a is an action.
- c is a constraint (policy).

Administrative agent: This kind of agent works as an information service for the system. It collects and preserves information about the system which includes registered regional grids, registered sensors (learners or users). Also it is responsible for authentication and registering of regional grids. This information helps in searching for grid services (learning objects). The agent is described as <cr, e, a> where cr: is control request, e: entity, and a: action. The control request (cr) includes creating and terminating other agents (regional agents and sensor agents). The entity (e) is either regional agents or sensor agents. Actions (a) which are performed include authentication services, registering and deregistering regional grids, creating grid model.

The second type is the regional agents which again can be described as a tuple as follows:

$$RA = < Rg, l, s, a > \tag{2}$$

where:

- Rg is a regional grid.
- l is a learning object.
- s is a service.
- a is an action.

Regional agent: This agent type works on behalf of regional grid. Grid services through this agent are presented to help learners to search for desired learning objects. According the constraints the desired learning objects are delivered the learners. The agent is described as <rg, l, s, a, c> where rg: is regional grid, l: learning objects, s: service (grid), a: action, and c: is constraint. The regional grid (rg) is a unique name and the learning object is the description of the desired learning object. The service (s) here is a special agent represents a grid service which is published in regional registry (yellow pages) to be discovered in order to retrieve desired learning object (l). Some actions are performed by this type of agent with cooperation with other agents. Those actions include searching for desired learning objects, updating regional grid data by authorised staff, and applying constraints to deliver learning objects.

The third type is the sensors agents which can also be described as a tuple as follows:

$$SA = < e, r, st, p > \tag{3}$$

where:

- e is an entity.
- r is a request.
- st is a state.
- p is a perception.

Sensor agent: This agent works on behalf of learners (users). The agent is described as <e, r, st, p> where e: is entity which is here a learner, r: is request from learner which include searching for learning objects. st: is state of learner which include some properties like unique name, number, institution belongs to, and regional grid belongs to. p: is perception.

In our model, the highest level agents are responsible for monitoring the environment. This means that the primary role of these agents is controlling both the behaviours of a whole environment and the data passing between regional grids according to assigned constrains. The middle level agents are intermediate ones which are responsible for controlling the behaviour of a regional zone that includes a number of low-level agents.
In a regional grid, possible requests can be represented as a set

$$R = \{r0, r1, r2, \ldots\} \tag{4}$$

For each user request, there exists constraints which forms a set of constrains:

$$C = \{c0, c1, c2, \ldots\} \tag{5}$$

Once the agent perceives the request, it executes an action. Agent capabilities can be represented by a set of actions:

$$A = \{a0, a1, a2, \ldots\} \tag{6}$$

This process of agent action generation can be represented as a function:

$$\text{action} : R \times C \rightarrow A \text{ (or an = action (rn, cn))} \tag{7}$$

5. Implementation

The implementation is performed under the JADE platform to produce required agents. These agents collaborate with each other and collaborate with data grid which is considered as the infrastructure of the RDADeLE.

A. The Platform

JADE is the middleware developed by TILAB[1] for the development of distributed multi-agent applications. Both the intelligence, the initiative, the information, the resources and the control can be fully distributed on mobile terminals as well as on computers in the fixed network (Bellifemine, Caire, Poggi, & Rimassa, 2003). This middleware has some features within its platform. These features include heterogeneous entities communication, security, and Interoperability with other agents. JADE is an ideal platform to implement our model in order to present concepts and objectives of our research. In (Chmiel, Gawinecki, Kaczmarek, Szymczak, & Paprzycki, 2005), authors have proven some features of JADE platform. These features include efficiency, effective, and scalability. The features are limited by standard limitations of Java programming language and other factors which include processor speed, amount of available memory and speed of network connection. Experiments with thousands of agents and thousands of ACL messages had been implemented effectively. Hence, these features of JADE platform are needed in our model in order to present concepts and objectives of our research, and we see this platform is suitable to implement part of our model.

B. Registries and Multi-Agent Systems

As we have mentioned before in this paper, we have adopted the second approach of registries distribution. This approach is based on assigning one regional registry for each regional grid. In this approach there is no central registry with which to discover learning objects (LOs). Instead, regional registries are used to discover regional LOs. In this approach, all regional registries should be connected to each other in order to discover all LOs across the global grid. Agents in MAS update these registries and help to communicate between registries. However, this approach provides information service in order to handle the search process more efficient. This means that the search process will search for required information only in the registries which have it. This is accomplished by using information service the Administrative agent provides in the system. A broker middleware is responsible for connection between regional registries and universal Description, Discovery and Integration (UDDI) in order.

C. Implementation Scenarios

The implementation is limited to the role of agents in our architecture. As we mentioned earlier, the following includes three types of agents and their roles in the implementation:

1. Sensor (user): This agent represents a learner or a user who sends a query. The query includes LOs, universities or institution connected to the global grid, and a degree (major).

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[1] Telecom Italia Lab is the R&D branch of the Telecom Italia Group and is responsible for promoting technological innovation by scouting new technologies, carrying out and assessing feasibility studies, and developing prototypes and emulators of new services and products.Telecom Italia has conceived and developed JADE, and originated the Open Source Community in February 2000.

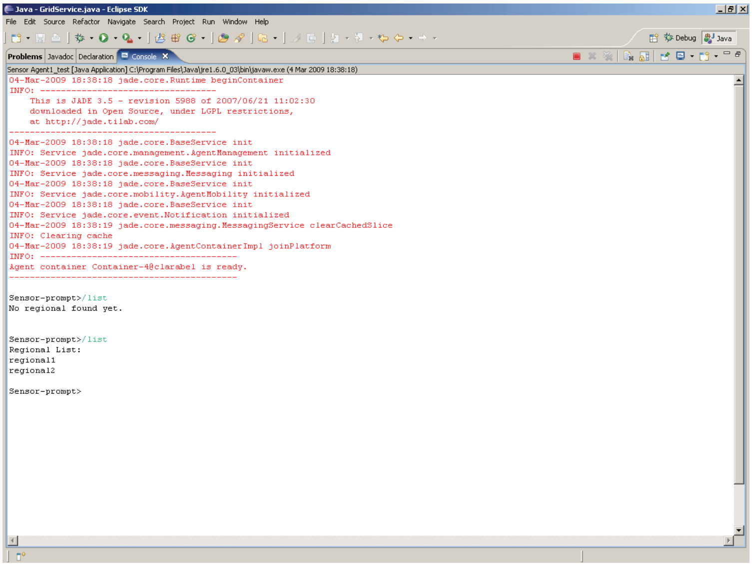

Fig. 6. Screen shot of Sensor agent.

2. Regional: This agent represents a regional grid. The role of this type of agents is to connect LOs registry of a particular regional grid to the global grid in order to make it available to be queried. Regional grids need to be registered using Administrative to be authenticated and connected to the global grid.

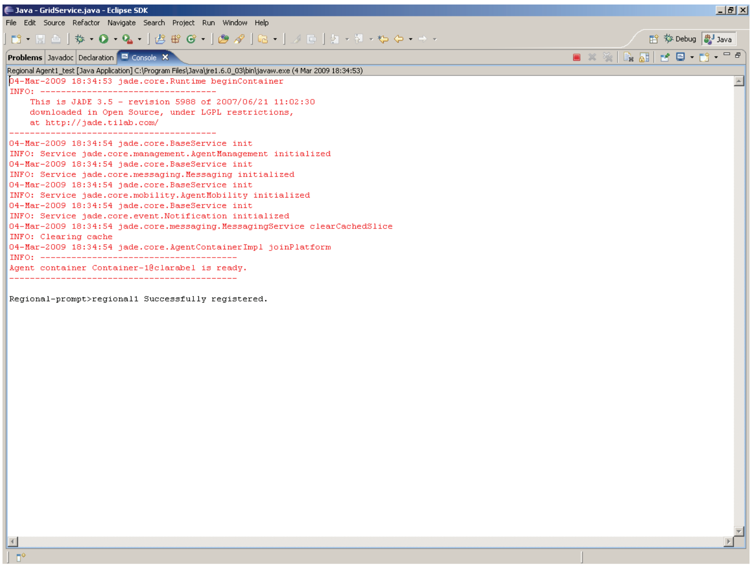

Fig. 7. Screen shot of regional agent.

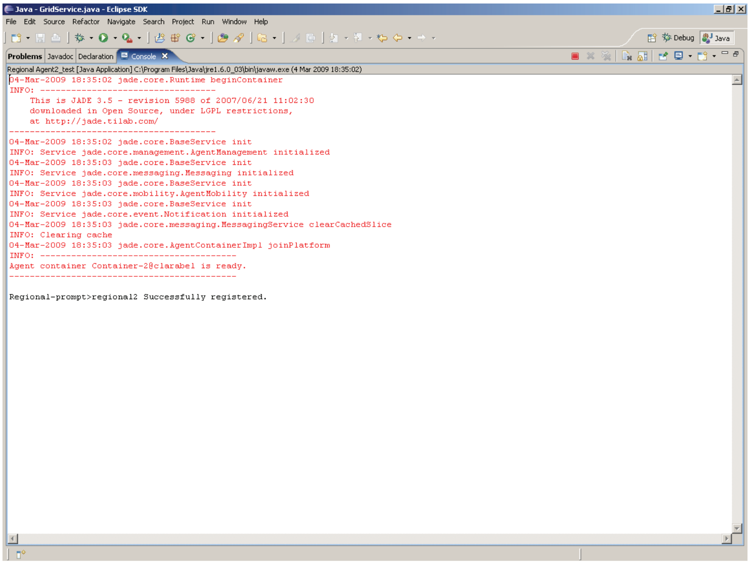

Fig. 8. Screen shot of another regional agent.

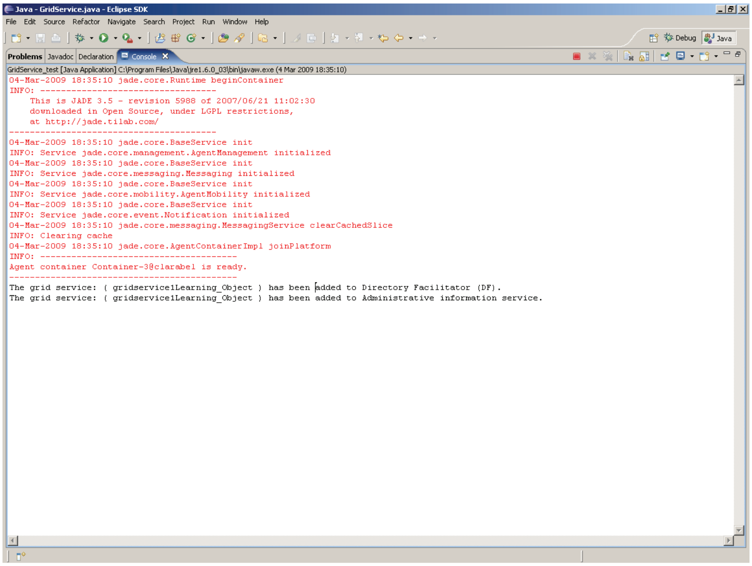

Fig. 9. Screen shot of registration of grid service.

3. Administrative: This type of agent has two roles. The first one is to supply authentication and authorisation services for different regional grids to be connected to the global grid. The second role is to function as an information service for the whole global grid to ease the search process and make it more efficient.

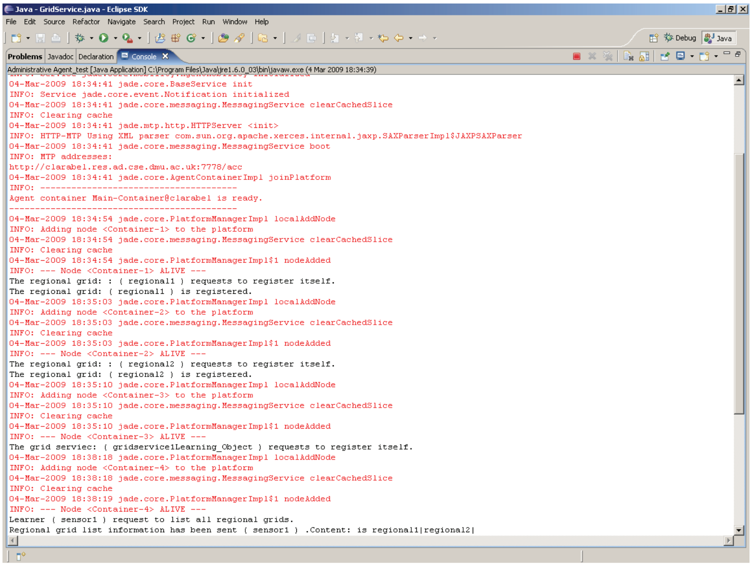

Fig. 10. Screen shot of Administrative agent.

The cooperation of the developed multi-agent system begins when Administrative agent has been initiated. First, a regional agent is initiated to be authenticated and authorised using initiated Administrative agent in order to connect regional grid to the global grid. This means that a particular regional grid has been connected to the global grid which implies that registry of that regional grid has been connected to the whole system in order to be available for learners to be queried. The agent Administrative is responsible for registering and authentication of regional grids. It the same time, Administrative agent plays as information service which includes information about all connected regional grids all over global grid. Second, a learner agent is initiated to represent a learner. The learner should be authenticated by authentication and authorisation agent in order to access to (LOs) via OGSA. At this time, learner may search for LO, connected institutions, and degree. On the other hand, authorised persons (staff) should be authenticated by Administrative agent in order to update and amend regional and institution registries. According to a learner request and the portal, a query could be:

- About LOs, institutions, and degree.
- Request a LO.

In the first case, a Sensor agent send a query about a LO. The search process will be initiated to search for the required LO. The required LO is determined by a field and subject from learner. The search process looks for all LO and their locations from all registries of connected regional grid and bring back search result to the learner. The same process will occur if the query about institutions. But process will be different if the query is about degree. In this case the Administrative agent will play as information service for the whole grid. This agent will help the learner to find different years courses in all connected regional grids. The agent will ease the search by providing the learner regional grids (institutions) that have required courses. After that the learner will connect to these regional grids (registries) to obtain information about degree courses. The second case (Request a LO) will be in the future work. In this case, learner requests the desired LO in order to access related materials. This could be available via Learning Management System (LMS). Policies of a particular regional grid are applied on components of that regional grid for both cases (e.g. LOs, learners, institutions).

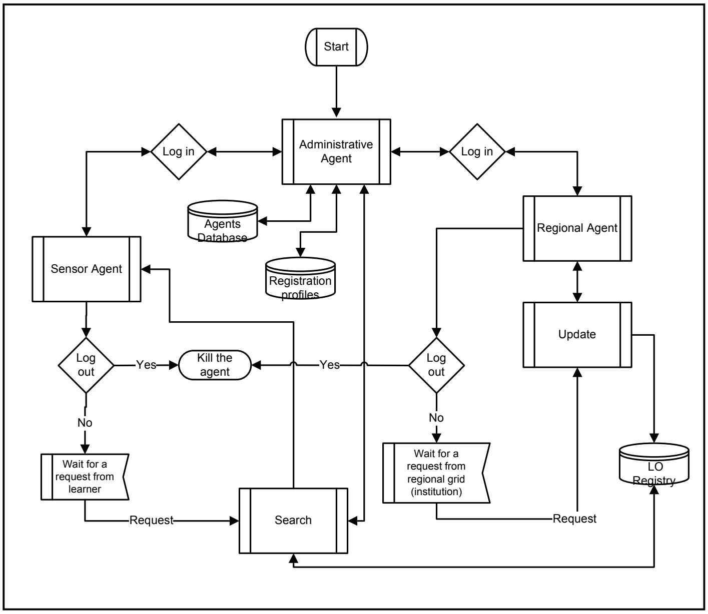

Fig. 11. illustrates the chart of processes of agents in our model.

6. Conclusion and Future Work

In this paper we have presented the role of multi-agent system in Regionally Distributed Architecture for Dynamic e-Learning Environment (RDADeLE). This paper, mainly describes in details the role of agents in regional data grids; the agent role is based on multi-agent systems using JADE to guarantee autonomy, interoperability, and reliability in the whole system. We began the paper by highlighting two factors: grid computing and agent technology. Secondly, we presented an overview of our architecture Regionally Distributed Architecture for Dynamic e-Learning Environment (RDADeLE), its components, and regional grid structure. Then, we presented agents' specifications. Finally, we introduced the implementation. Implementation performance was analysed, and some practical applications and further experiments remain to be performed in the future. The next steps of our project are incorporating OGSA-DI in order to produce grid services, ameliorating the performance of the whole project in general and refining search result in particular, developing an ontology agent to ameliorate the heterogeneity of regional grid, and developing appropriate policies for regional grids.

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5

Dynamic analysis of activity of e-learning system users

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1. Introduction

One of the key problems that should be taken into consideration when constructing, developing and evaluating a computer system is the identification of the dynamical characteristics of the interaction between a computer system and its users. The user's activities modify different properties of the computer system. The analysis of the changes in time of such properties can be useful for understanding the dynamics of interaction between users and computer systems.

The Learning Management System (LMS) records activity of many users: students, teachers and administration workers. Each student using the LMS can be treated as dynamical system whose activity is caused by LMS, but system activity results from activity of teachers and university administration. Each of the mentioned users can be treated as dynamical system as well. It means that e-learning system is a virtual place where thousands of dynamical systems (users) communicate each others. These communication leads to changes of users' activities.

The users (human) behavior is nonlinear (Sulis et al., 1995), therefore we can say that LMS is a virtual platform of interaction of nonlinear dynamical systems (Ignatowska et al., 2005; Ignatowska et al., 2008; Mosdorf et al., 2006).

The trajectories of nonlinear dynamical system in the phase space form objects called strange attractors of the structure resembling the fractal (Schuster, 1993; Ott, 1993). The analysis of strange attractor gives us information about the properties of dynamical system such as system complexity and its stability. The application of Takens theorem (Schuster, 1993) - in connection with possibilities of modern measuring and computing techniques - enables an analysis of dynamics of non linear processes by analysis of single time series. In nonlinear analysis the reconstruction of attractor in certain embedding dimension has been carried out using the stroboscope coordination. In this method subsequent co-ordinates of attractor points have been calculated basing on the subsequent samples, between which the distance is equal to time delay τ. The time delay is a multiplication of time between the samples. In the nonlinear analysis the following time series is analyzed.

$$\{ x_n \} = \{ x(t), x(t+\tau), \ldots, x(t+n\cdot\tau) \} \tag{1}$$

where x is a measure quantity

In case of LMS system the number of logs of each user is a one of the measure of his activity, therefore in the chapter the dynamics of changes in time of logs to LMS have been analyzed. The identification of behavior of nonlinear dynamic systems must be done step by step. The process of analysis cannot be automated and subsequent steps of analysis require the detailed interpretation of calculation results (Awrejcewicz et al., 2003). The following phases of analysis have been presented in the chapter:

- The frequency analysis (Fourier and wavelet analysis),
- Long range dependence analysis,
- Attractor reconstruction,
- Recurrence plot analysis,
- Calculation of attractor dimension and larger Lyapunov exponent.

Because e-learning system focus activities of many users therefore the problem of synchronization of users and system can be analyzed (Mosdorf et al., 2007). In e-learning system the synchronization between students and teachers can be treated as a measure of effectiveness of education process. The synchronization analysis allows us to better understand the correlation between activities of different groups of e-learning system users. The third part of the chapter will contain the analysis of synchronization between e-learning system users.

2. The nonlinear analysis of e-learning system users

2.1 Data collection and preliminary statistical analysis

The university LMS is used by different groups of users like:

- students,
- teachers,
- administrative workers,
- users who search for information about the university.

For the evaluation of the activity of e-learning system we need to know the dynamic characteristic of different kinds of system users' behaviours. We would like to answer the question which methods are useful to identify the behaviours of different groups of users.

In academic year 2002/2003 the Internet LMS was applied in University of Finance and Management in Bialystok in order to support the management of university administration and the learning process. The system is integrated with the university website and consists of such modules like: E-student, Candidate, Teacher and Dean's Office (Daniewicz et al., 2005a; Daniewicz et al., 2005b). Teachers use their module to input syllabuses, marks, reports and materials for students. The E-students module is integrated with Moodle e-learning platform. At present the LMS system contains registered accounts of about 6 500 students, 480 teachers and 30 administrative users. There are also about 1500 syllabuses in the system.

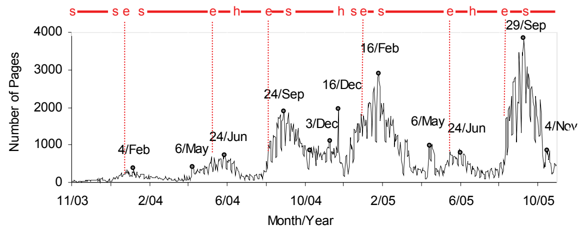
In the chapter the analysis of three data sets has been presented.

- The first set is the time series of number of requests of LMS system per day.
- The second one is the time series of number of requests of LMS system per every two hours.
- The third one is the time series of number of requests of Moodle e-learning platform per hour.

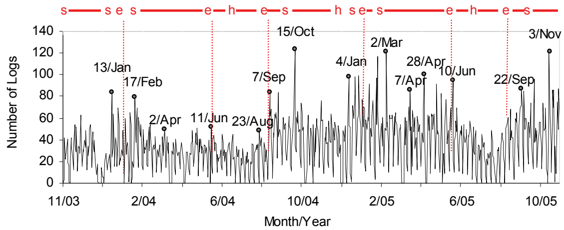
Preliminary statistical analysis allows us to find out the similarity between the analyzed system and the stochastic system as well as the correlation between the samples. Usually the analysis starts from the calculation of the basic statistical coefficients and comparing the obtained characteristics with standard distribution (Gajek et al., 2000; Awrejcewicz et al., 2003).

2.1.1 Set number one

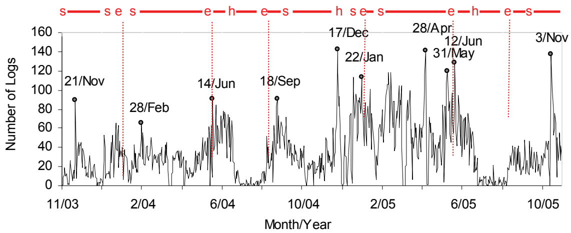
The analyzed data comes from two sources: logs into the Recto system (the system database) and logs into the web server, which were processed by the program Analog 5.91beta1 (Ignatowska et al., 2005). In Figure1 the logs time series have been presented.



a)



b)



c)

Fig. 1. The logs into: www pages, administration module and teacher module of Recto system: a) logs into the web server; processed by the program Analog 5.91beta1 (Mosdorf et al., 2006), b) logs of the university administration into the Recto system (database), c) logs of teachers into the Recto system (database), e – exams, h – holidays, s – semester

2.1.2 Set number two

The second set of data is the time series of number of requests of LMS system per every two hours. In Figure 2 the time series of LMS system logs in two hours long sampling interval, normalized to (0;1) range have been presented. Data has been collected in two intervals (Ignatowska et al., 2008):

– Learning time (7 January 2005 – 13 March 2005) – number of samples: 792,
– Holiday (1 July 2005 – 1 September 2005) – number of samples: 756.

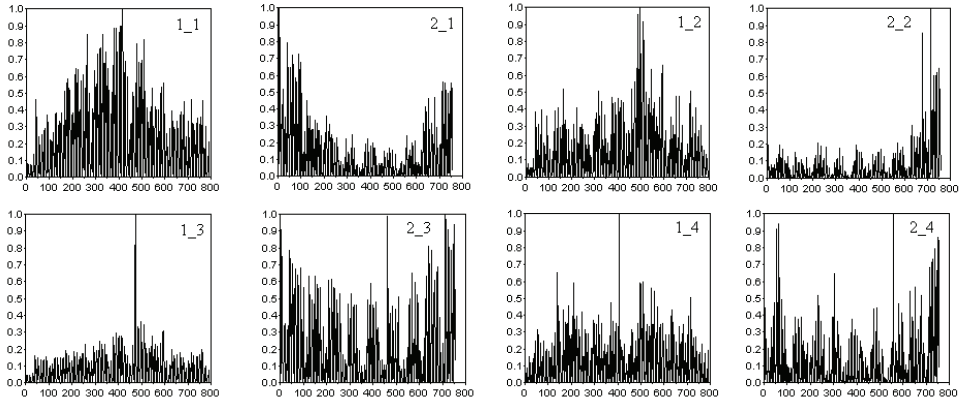


Fig.2. The changes of the number of requests of LMS system www site in two hours long sampling interval normalized to (0;1) period. 1_1. The logs into LMS system in the learning time. 2_1. The logs into LMS system during holidays. 1_2. The logs into Internet university information board in the learning time. 2_2. The logs into Internet university information board during holidays. 1_3. The logs into main university web site in the learning time. 2_3. The logs into main university web site during holidays. 1_4. The logs into download system in the learning time. 2_4. The logs into download system during holidays. (Ignatowska et al., 2008).

2.1.3 Set number three

The E-students module of LMS is integrated with Moodle e-learning platform. The Moodle e-learning platform was implemented in academic year 2008/2009, is used as a virtual learning environment for 10 e-learning courses, attended by approx. 250 students of the university. There are 16 academic teachers who are course designers responsible for the learning process. The courses provided via Moodle platform were designed to be interactive, with virtual support of the learning process by the teachers via forums, chats etc. All of the courses contain not only the learning content (i. e. reading material, films, presentations etc.) but also tests (quizzes), group work environment (such as wiki). Therefore studying via e-learning platform requires regular attendance in the courses, both for the students and teachers.

In Figure 3 the logs into the Moodle platform have been presented. The data from Moodle platform were sampled using 1-hour long interval.

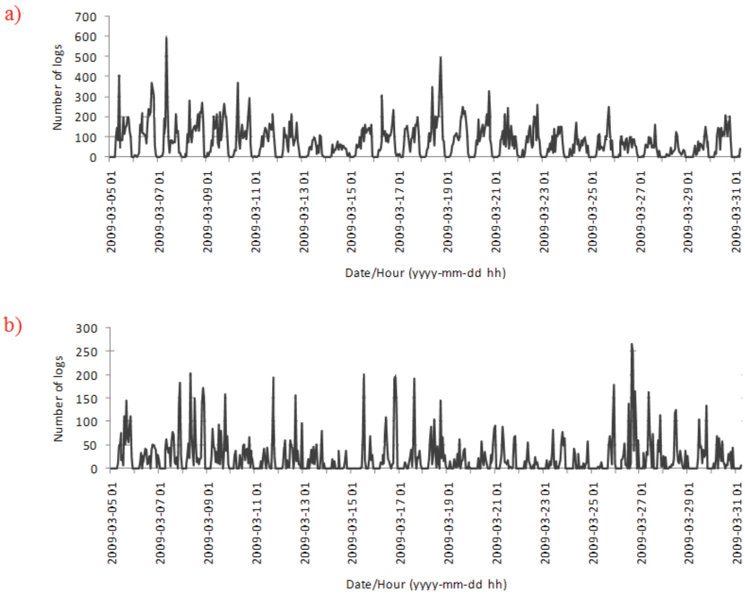


Fig. 3. The activity of Moodle e-learning platform users (1 hour sampling interval): a) logs of students, b) logs of course designers and teachers.

2.2 The frequency analysis

The Fourier transformation allows us to represent time-domain data in the frequency domain. The Fourier power spectrum answers the question which frequencies contain the signal power. The answer has the form of a distribution of power values as a function of frequency. In the frequency domain, this is the square of Fourier transformation magnitude. The power spectrum can be computed for the entire signal at once or for segments of the time signal. For the measurement data in the form of discrete series $\{x_n\}$ the Fourier transformation has a following form: (Gajek et al., 2000)

$$F_k = \sum_{n=0}^{N-1} x_n e^{-j\frac{2\pi}{N}kl} \tag{2}$$

In this case the power spectrum is defined as $|F_k|^2$.

The power spectrums of time series of logs (set number one) are shown in Figure 4. The results of frequency analysis presented in Figure 4 allow us to distinguish limited number of dominant frequencies. Five dominant frequencies have been found out.

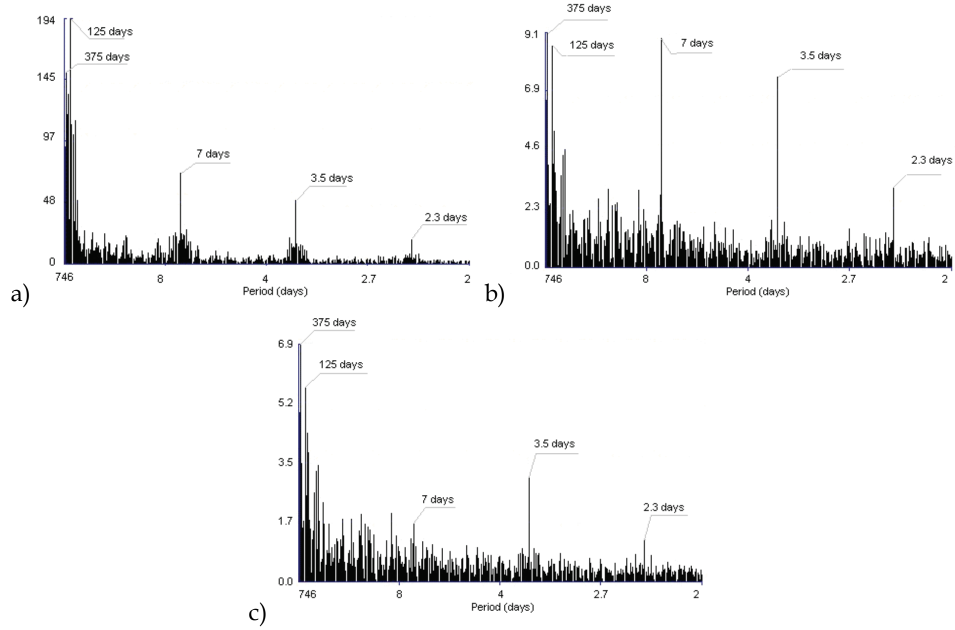


Fig. 4. The power spectrum of LMS system logs time series (set number one): a) logs into the web server, b) logs of the university administration, c) logs of teachers. (Mosdorf et al., 2006).

The example of changes of number of logs into www pages has been shown in Figure 5, where the observed periods changes of the number of visited web pages have been schematically shown.

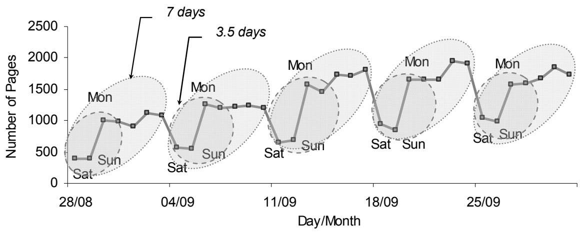


Fig. 5. The examples of periodic changes of daily www logs (Recto system) (Mosdorf et al., 2006).

In all data series we can identify two dominant low frequencies connected with time periods equal to 375 and 125 days. It seems that these changes are connected with yearly and semestrally activity of system users. The rest of identified dominate frequencies with time periods equal to 7, 3.5, 2.3 days appear in analyzed data series with different intensity. These frequencies can be clearly identified in the data series describing the activity of university administration (Figure 4b). The 7 days cycle seems to correspond with the weekly cycle of administration work, but remain 3.5 and 2.3 days cycles are connected with changing of logs

numbers within the weeks. The examples of such changes are shown in Figure 5 where the decrease of number of logs within subsequent weekend can be observed. The changes characterized by time periods equal to 7, 3.5 and 2.3 days are clearly visible also within logs into the www pages (Figure 4a), whereas the 7 days cycle disappears in teachers' logs data series. That can be driven by the fact that university teachers don't work as regular as administration. A lot of them have lectures on Sunday, Saturday, every fortnight or once a month. The teachers like to cumulate their hours and come to have some time to carry out their research, prepare themselves to lectures and so on.
In Figure 6 the Fourier power spectrum of data from set number three has been presented.

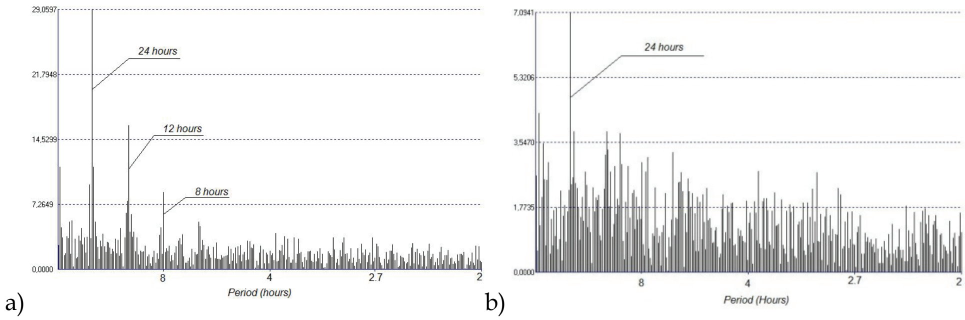


Fig. 6. Fourier power spectrum for Moodle e-learning system users' activity time series:
a) logs of students, b) logs of teachers

The analysis of activity of the users (1-hour sampling interval) allows us to identify the dominant frequencies that stand for 24, 12 and 8 hours long cycles. The existence of observed cycles can be described by the normal daily routine of users. Teachers usually visit platform at least once a day at their own specified time – to check or update the courses. Students, who have more activities to fulfill usually visit platform more than once a day.

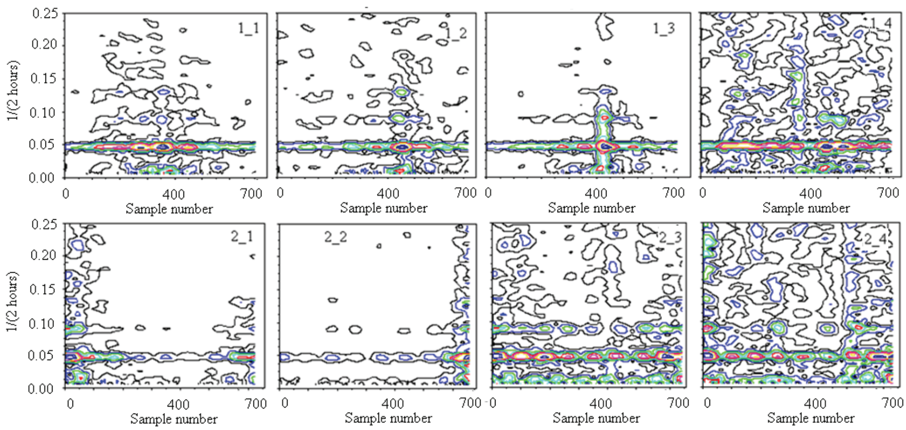


Fig. 7. The spectrograms of the number of requests of LMS system www site in two hours long sampling interval. The ordering of the pictures is described in Figure2. (Ignatowska et al., 2008).

In Figure 7 the spectrograms of the number of requests of LMS system www site in two hours long sampling interval time series (set number two) have been presented.
As we can see the bands equal for 24, 12 and 8 hours long changes can be identified. The results obtained in the analysis allows us to conclude that all of the times series being investigated have various characteristics: the way the frequencies appear and disappear is different for each dataset. In case of the logs to LMS system during the semester there are many different frequencies visible, but during the holiday period only the dominant cycle of 24 hours can be observed. The similar result can be seen when looking on the frequency of the university web information board. In other words it can be concluded that during the summer vacations period the users log into Recto system, as well as read the information from the University information board in 24 hours long cycle, whereas during the teaching term the cycles of 8 and 12 hours become important. In case of the main university web-site the summer vacation period seems to be more noisy than the teaching period, where the cycles of 24, 12 and 8 hours are clearly visible. The data obtained from the files download module of the LMS system seem to have the same complicated structure both for the teaching and vacation period.
The Fourier power spectrum do not allow us to identify the frequencies changes in time. This problem can be analyzed using the windowed Fourier transformation but this is an inaccurate method for localizing time–frequency. The wavelet analysis is free from this inaccuracy, it is a tool for analyzing the localized variations of power spectrum within the time series x_n, with equal time spacing δt.
The continuous wavelet transformation of a discrete sequence x_n is defined as the convolution of x_n with a scaled wavelet Ψ (Białosiewicz, 2000; Torrence et al., 1998a; Torrence et al., 1998b):

$$W(t,s) = \sum_{t'=0}^{N-1} x_{t'} \Psi * \left[\frac{(t'-t)\delta t}{s} \right] \tag{3}$$

where (*) indicates the complex conjugate.

Because the wavelet function $\Psi_o(\eta)$ is in general complex, the wavelet transformation $W(t,s)$ is also complex. The wavelet power spectrum is defined as: $|W(t,s)|^2$. During the analysis the Morlet wavelet has been used as the based wavelet. The Morlet wavelet has a form (Białosiewicz, 2000; Torrence et al., 1998a; Torrence et al., 1998b):

$$\Psi_o(\eta) = \pi^{-1/4} e^{i\omega_o\eta} e^{-\eta^2/2} \tag{4}$$

where: ω_o - nondimensional frequency, in the paper it is equal to 6.

In Eq. 3 the parameter s assigns the frequency whereas the parameter t identifies the time around which the assigned frequencies are investigated. The wavelet power spectrum is presented in the form of three dimensional map, where the horizontal axis shows the values of parameter t, while the vertical axis shows the values of parameter s (frequency). The values of wavelet power spectrum $|W(t,s)|^2$ are presented as an altitude. The wavelet

power spectrum allows us to observe the changes in time of each frequency power (Białosiewicz, 2000; Torrence et al., 1998a).
The wavelet power spectrum of LMS system logs time series is shown in Figure 8. The wavelet analysis allows us to identify the time periods in which we can observe the changes of log numbers with frequency identified in Fourier analysis. The 7 days cycle of changes of number of university administration logs (Figure 8b) is present in the whole analyzed time. The 3.5 days cycle appears in the whole first year but can be identified only in separated periods in second year. It happens close to terms of exams. The wavelet analysis of the teachers' activity (Figure 8c) shows that the appearance of 3.5 days cycle is correlated with the time of exams. Incidentally this cycle appears during the time of semester. The cycle of 7 days is not intensive and appears incidentally which shows the irregular usage of system by teachers. The intensity of appearance of 7 days cycle is similar with the intensity of 14 days cycle, which seems to be connected with the teachers' work during external study. The disappearance of the cycles shorter than 20 days can be observed during the periods of summer students' holidays. In the power spectrum of logs into www pages (Figure 8a) the 7 days cycle is visible too. The intensity of appearance of such cycle increases during the students' examination time and disappears during the summer holiday and during semesters. The increase in intensity of appearance of 7 days cycle is accompanied by the increase in intensity of 3.5 and 2.3 cycles. It seems that this process is connected with administration workers and teachers' activities. Activities of other users cause the disappearance of 3.5 and 2.3 days cycles.

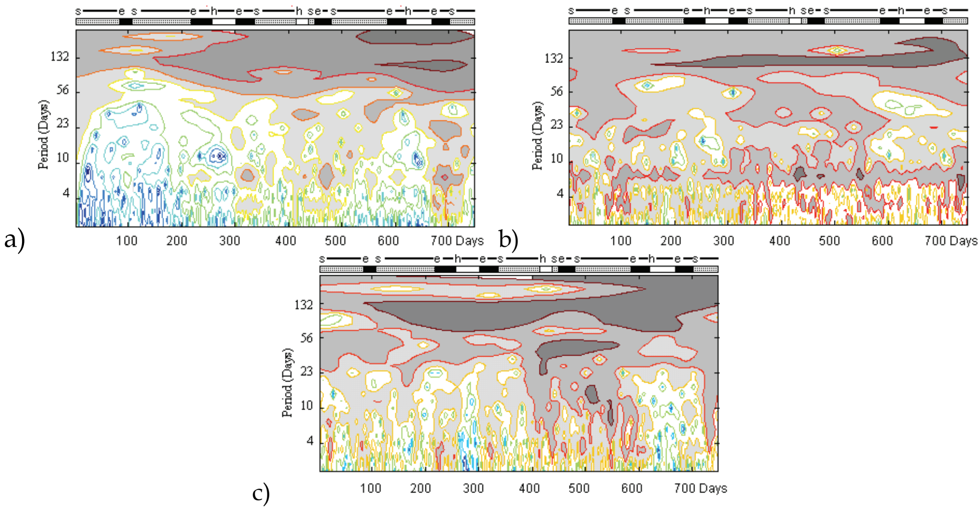


Fig. 8. The wavelet power spectrum of Recto system logs series. a) logs into the web server, b) logs of the university administration, c) logs of teachers, (e – exams, h – holidays, s – semester). The grey area indicates the local maximum (Mosdorf et al., 2006). The calculations have been carried out using computer program published in (Białosiewicz, 2000; Torrence et al., 1998a). (Wavelet software was provided by C. Torrence and G. Compo, and is available at URL: http://paos.colorado.edu/research/wavelets/).

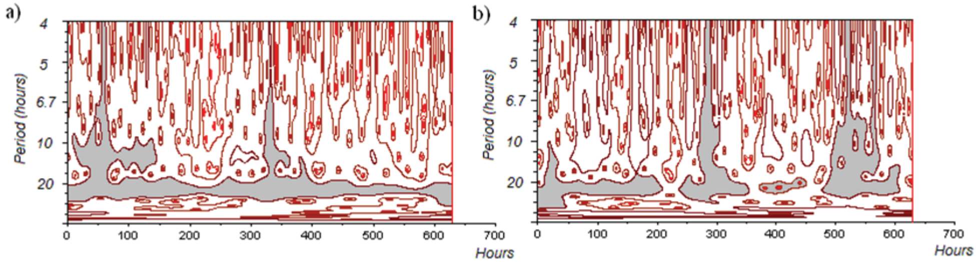


Fig. 9. The wavelet power spectrum of Moodle platform logs series: a) logs of students, b) logs of logs of teachers

The wavelet power spectrum of Moodle platform logs time series (data set number three) is shown in Figure 9. We can conclude that 24-hours long cycle of users activity is present during the analyzed period. When comparing the wavelet power spectrums of both main groups of platform users it can be observed that students seem to work more regularly than the teachers. The 24-hours cycle for the students can be identified in the whole analyzed period, whereas for the teachers it is not as regular (there are some periods where the cycle disappears). The other cycles of shorter length (i. e. 4–12 hours long) can be seen mostly in approx. 300 hours long interval. What is more, when comparing the activity of the students (Figure 9a) to the teachers' logs (Figure 9b) we can see that there is a strict correlation between the appearance of shorter cycles of activities in both groups. The excessive teacher's activity seems to appear at about 24 to 48 hours before the observed higher students' activity. The answer for that phenomena seems to lay in the organizational background of the studies and the e-learning classes schedule as well. Both for students and teachers the excessive activity is observed during (or just before) the weekend classes of extra-mural studies. Such classes are conducted every two weeks, that gives the period of about 300 hours between the accumulation of cycles (see Figure 9a and 9b).

2.3 Long-Range Dependence

A time-series has long-range dependence if it has correlations which persists over all time scales. The long-range dependence is characterized by the parameter *H*. The Hurst parameter in range $(1/2;\ 1)$ indicates the presence of long-range dependence. There are a number of different statistics which can be used to estimate the Hurst parameter. For time series X_t which has a finite mean (weakly-stationary time series) the autocorrelation function is given by (Clegg et al., 2005; Cajueiro et al., 2005)

$$\rho(k) = \frac{E[(X_t - \mu)(X_{t+k} - \mu)]}{\sigma^2} \tag{5}$$

where $E[X_t]$ is the expectation of X_t, μ is the mean and σ^2 is the variance.

From the formal point of view we can say that the time-series X_t is said to be long range dependent if $\sum_{k=-\infty}^{\infty}\rho(k)$ diverges. For estimation of changes in time the function of $\rho(k)$ the following function is used (Clegg et al., 2005; Cajueiro et al., 2005)

$$\rho(k) \approx C_\rho k^{-\alpha} \tag{6}$$

where $C_\rho > 0$ and $a = (0; 1)$, the symbol ~ mean asymptotically equal to. The parameter a is related to the Hurst parameter (Clegg et al., 2005; Cajueiro et al., 2005)

$$H = (2-\alpha)/2 \tag{7}$$

Similar definition can be formulated in frequency domain. The spectral density $f(\lambda)$ of a function with autocorrelation function $\rho(k)$ and variance σ^2 can be defined as

$$f(\lambda) = \frac{\sigma^2}{2\pi}\sum_{k=-\infty}^{k=\infty}\rho(k)e^{ik\lambda} \tag{8}$$

where λ is the frequency, σ^2 is the variance and $i=\sqrt{-1}$.

The spectral density can be estimated by function (Clegg et al., 2005; Cajueiro et al., 2005)

$$f(\lambda) \approx C_f|\lambda|^{-\beta} \text{ as } \lambda \to 0, \tag{9}$$

for some $C_f > 0$ and some real $\beta \in (0; 1)$.
The parameter β is related to the Hurst parameter by (Clegg et al., 2005; Cajueiro et al., 2005)

$$H = (1+\beta)/2 \tag{10}$$

In Figure 10 and the autocorrelation function of the users activity time series (data set number three) obtained from e-learning system is shown. In case of periodic function of users activity (presented function of Moodle students' activity in 1-hour sampling interval, Figure 10a) each sample in the interval of multiplication of τ takes the same (or similar) value. Because of this the local maximum of autocorrelation function seems to appear periodically. In case of not periodic data the increase of τ cause that subsequent values $x_{i+\tau}$ and x_i are not correlated and subsequent elements in the sum (5) will contain the large and small elements. As a result there is a decrease of value of sum (5) in comparison with situation when there are two large elements in the sum. In both cases the $\sum_{k=-\infty}^{k=\infty}\rho(k)$ diverges (Figure 10.). It means that the analyzed data are long range dependent.

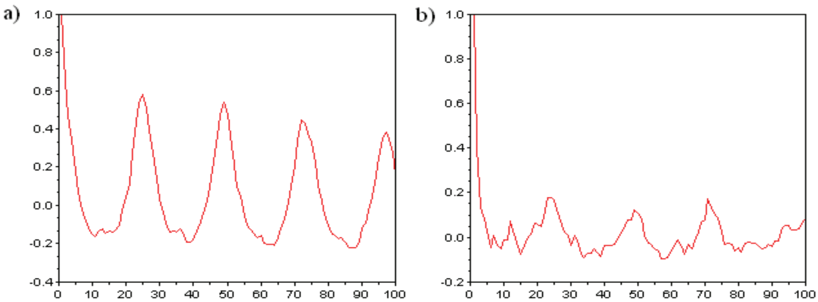


Fig. 10. Autocorrelation function for Moodle e-learning system users' activity: a) logs of students b) logs of teachers

2.3.1 R/S statistic

For the stationary time series $\{x_1, x_2, x_3, \ldots x_\tau\}$ the *R/S* statistic is given by (Cajueiro et al., 2005):

$$\left(\frac{R}{S}\right)_\tau = \frac{1}{s_\tau}\left[\max_{1 \le t \le \tau} \sum_{k=1}^{t} \left(x_k - \bar{x}_\tau\right) - \min_{1 \le t \le \tau} \sum_{k=1}^{t} \left(x_k - \bar{x}_\tau\right)\right] \tag{11}$$

where s_τ is a standard deviation (Cajueiro et al., 2005)

$$s_\tau = \left[\frac{1}{\tau}\sum_{t=1}^{\tau}\left(x_\tau - \bar{x}_\tau\right)^2\right]^{1/2} \tag{12}$$

and $\bar{x}_\tau$ denote the mean value.

Hurst found that the rescaled range *R/S*, for many records in time is very well described by the following empirical relation (Cajueiro et al., 2005)

$$\left(\frac{R}{S}\right)_\tau = \left(\frac{\tau}{2}\right)^H \tag{13}$$

By means of the *R/S* analysis, the Hurst exponent may be evaluated by plotting the data $(R/S)_\tau$ versus τ in a log–log plot and measuring the slope of the straight line. The slope of tangent to 1n(R/S) in the function 1n(N) gives the value of H exponent.

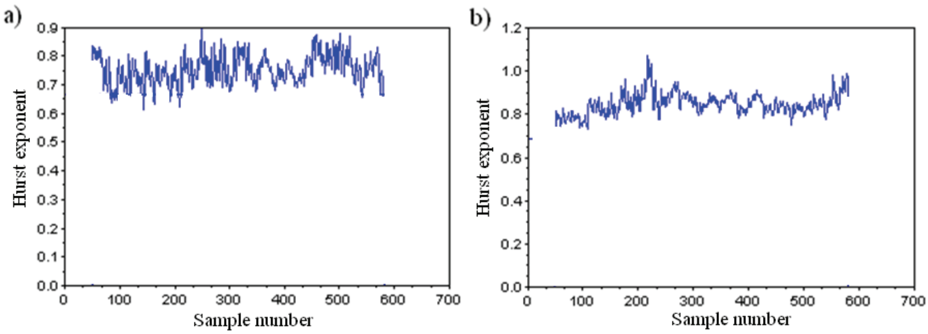


Fig. 11. Hurst exponent estimation for Moodle platform users' activity data using R/S method: a) logs of students, b) logs of teachers

In Figure 11 the estimation of Hurst exponent using R/S method for the data obtained from Moodle platform (data set number three) have been presented. During the analyzed period the change of *H* value can be observed. In most cases the *H* value varies from 0.6 to 0.8 and never takes the value of 0.5. It indicates that the Moodle system users' behaviour is not random. It is rather closer to deterministic chaotic process with long-range memory effects.

2.4 Non linear analysis

2.4.1 Attractor reconstruction

The trajectories of the chaotic system in the phase space do not form any single geometrical object such as circle or torus, but form objects called strange attractors of the structure resembling the one of a fractal (Schuster, 1993). Non linear analysis starts from attractor reconstruction. Reconstruction of attractor in certain embedding dimension has been carried out using the stroboscope coordination. In this method subsequent coordinates of attractor points are calculated basing on the subsequent samples distant of time delay τ. The time delay is multiplication of time between the samples. For the measured data in the form of time series: $\{x_n\} = \{x_1, x_2, ..., x_n\}$ the way of calculation of subsequent coordinates of points of attractor is shown in Figure12.

Embedding dimension (subsequent coordinates)

Point number	1	2	3	4	5	6	
1	x_1	$x_{1+\tau}$	$x_{1+2\tau}$	$x_{1+3\tau}$	$x_{1+4\tau}$	$x_{1+5\tau}$	...
2	x_2	$x_{2+\tau}$	$x_{2+2\tau}$	$x_{2+3\tau}$	$x_{2+4\tau}$	$x_{2+5\tau}$	...
3	x_3	$x_{3+\tau}$	$x_{3+2\tau}$	$x_{3+3\tau}$	$x_{3+4\tau}$	$x_{3+5\tau}$	...
4	x_4	$x_{4+\tau}$	$x_{4+2\tau}$	$x_{4+3\tau}$	$x_{4+4\tau}$	$x_{4+5\tau}$	...
5	x_5	$x_{5+\tau}$	$x_{5+2\tau}$	$x_{5+3\tau}$	$x_{5+4\tau}$	$x_{5+5\tau}$	...
6	x_6	$x_{6+\tau}$	$x_{6+2\tau}$	$x_{6+3\tau}$	$x_{6+4\tau}$	$x_{6+5\tau}$	...
...	...	...	...	...	...	...	...

Fig. 12. Time delay algorithm of calculation of attractor coordinates.

The image of the attractor in n-dimensional space depends upon time-delay τ. When the time-delay is too small, the attractor gets flattened, that makes further analysis of its structure impossible. The selection of time-delay value is of great significance in the analysis of the attractor properties. Therefore the analysis of the experimental data is initiated by determining the time-delay. For that purpose the autocorrelation function is calculated. Autocorrelation function allows identification of correlation between the subsequent samples. In case of chaotic data the value of autocorrelation function rapidly decrease when τ increase. Value of the time-delay τ is determined from the condition $C(\tau)\approx 0.5*C(0)$ (Schuster, 1993).

Attractor reconstruction from data set number two are presented in Figure 13. In Figure 14 the reconstruction of the attractor from www logs series has been presented. In Figure 15 the reconstruction of the attractor from Moodle logs time series has been presented.

The method of calculation of the mutual information can be also used to determine proper delay coordinates for reconstructed attractors. In this case two time series are considered, $X(t)$ and $X(t+\tau)$. As τ is increased, $I(\tau)$ decreases, then usually rises again. τ for which I obtain the first minimum is a proper value of τ.

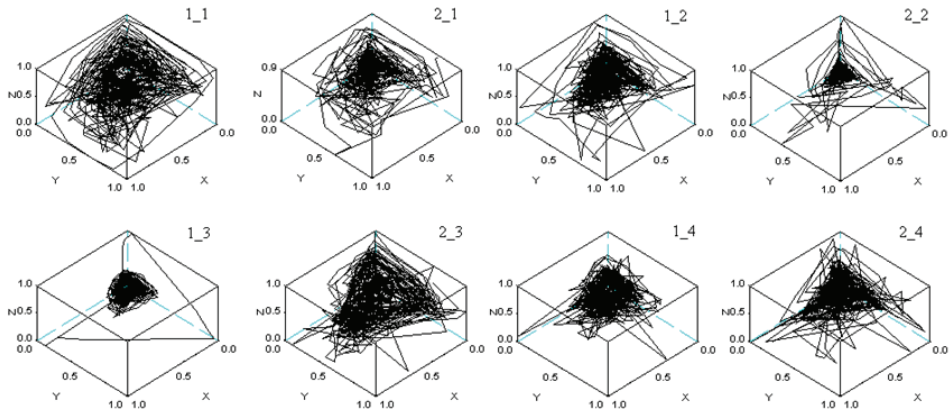


Fig. 13. Attractor reconstruction from data set number two. The ordering of the pictures is described in Figure 2. (Ignatowska et al., 2008)

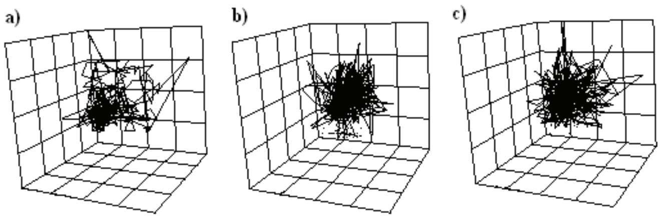


Fig. 14. Attractor reconstruction from time series of data set number one: a) the students, b) the university administration, c) the teachers; for time delay equal to 7 days. (Mosdorf et al., 2007)

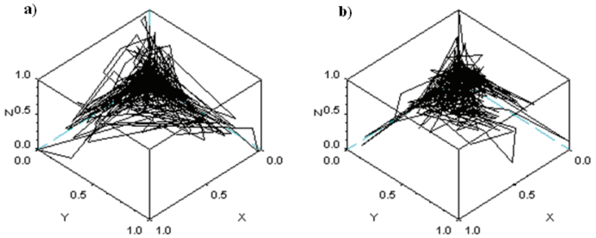


Fig. 15. Attractor reconstruction from data set number three. Moodle platform users' activity. a) logs of teachers, b) logs of students

The mutual information of two discrete random variables X and Y can be defined as (Marwan et al., 2007):

$$I(X,Y) = \sum_{y \in Y} \sum_{x \in X} p(x,y) \log\left(\frac{p(x,y)}{p_1(x) p_2(y)}\right) \quad (14)$$

where $p(x,y)$ is the joint probability distribution function of X and Y, and $p_1(x)$ and $p_2(y)$ are the marginal probability distribution functions of X and Y.
The mutual information is nonnegative, is equal to zero if X and Y are independent random variables.
The examples of mutual information calculated for data from the third data set are presented in Figure 16.

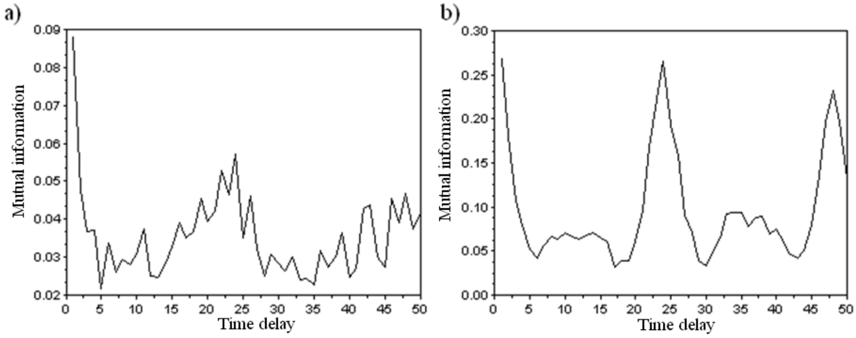


Fig. 16. The mutual information versus time delay for Moodle e-learning system users' activity time series (data set three): a) logs of students, b) logs of teachers

In Figure 17 the mutual information calculated for data from data set has been shown.

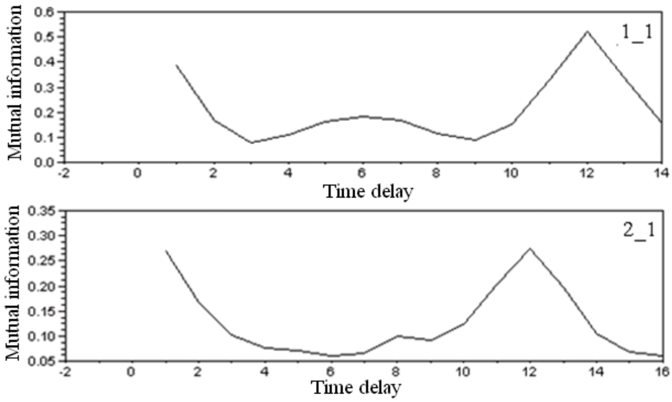


Fig. 17. The mutual information versus time delay for the number of requests of LMS system www site in two hours long sampling interval. The ordering of the pictures is described in Figure2.

The alternative method of time-delay τ calculation is used for determining of Hurst exponent. The slope of tangent to ln(R/S) in the function ln(N) gives the value of H exponent. If N number contains too many measured points the process resembles the random motion (the long-term memory - the memory between succeeding intervals disappears). In this case the slope of a curve changes. For the stochastic signals H=0.5. Border point N^* between area where the $H > 0.5$ and area where $H = 0.5$ corresponds with the boundary of the natural period of a physical system. N^* quantity enables determining of time-delay τ necessary for attractor reconstruction; τ is calculated from the relation: $\tau = N^* / d$.

2.4.2 Largest Lyapunov exponent and correlation dimension

The important characteristic of attractor is the largest Lyapunov exponent. In this case on the attractor immersed in D dimensional space two points have been selected. The distance between these two points $L(t_j)$ is at least one orbiting period. After the passage of some evolution time the distance of the selected points has been calculated again and denoted as $L(t_{j+1})$. The largest Lyapunov exponent has been calculated according to formula (Schuster, 1993; Wolf et al., 1985):

$$\lambda_1 = \frac{1}{t} \sum_{j=1}^{m} \log_2 \frac{L(t_{j+1})}{L(t_j)} \tag{15}$$

where: m - number of point pairs examined, t - time of evolution

The largest Lyapunov exponent allows us to calculate time period ($1/L$) of long time memory in the system in which the process of stability loss occurs. The largest Lyapunov exponent can be determined when such characteristics of attractor as fractal dimension, average orbiting time and time-delay are known. For a long time series, the results of calculation of λ_1 approach stable value, being an estimation of the largest value of Lyapunov

exponent. At least 10^n measuring points and 10^{n-1} orbiting periods are required to determine the largest Lyapunov exponent. The calculation of the largest Lyapunov exponent is possible only if the fractal dimension of the attractor is known. To determine the fractal dimension of the attractor, value of time-delay (the quantity necessary for the reconstruction of the attractor) is required (Wolf et al., 1985).
One of the essential characteristics of fractals is their dimension. For experimental data correlation dimension D_2 based on the Grassberger – Procaccia method is calculated with using the following method (Schuster, 1993; Grassberger et al., 1985; Pawelzik et al., 1987; Parker et al., 1987):

$$D_2 = \lim_{l \to 0} \frac{1}{\ln r} \ln \sum_i p_i^2 \tag{16}$$

where:

$$\sum_i p_i^2 \approx \lim_{N \to \infty} \frac{1}{N^2} \sum_{i,j} \Theta\left(r - \left|\vec{x}_i - \vec{x}_j\right|\right) = C_2(r) \tag{17}$$

$\Theta\ (x)$ Heaviside's step function.

C_2 correlation integral is a measure of probability of finding the two points spacing r. During the calculation neighborhood of all points is examined. This algorithm can be accelerated in this case the neighborhood only the certain randomly selected points has been considered. In this case the correlation integral has a form (Schuster, 1993; Parker et al., 1987):

$$C_2(r) = \lim_{N \to \infty} \frac{1}{N_{ref}} \sum_{j=1}^{N_{ref}} \frac{1}{N} \sum_{i=1}^{N} \Theta\left(r - \left|\vec{x}_i - \vec{x}_j\right|\right) \tag{18}$$

Such defined correlation integral fulfill the following formula (Schuster, 1993):

$$C_2(r) \approx r^{D_2} \tag{19}$$

where: D_2 correlation integral.

Equation 19 can be explained as follows: probability of finding the points of attractor in cubic contains the whole attractor is equal 1 and probability of finding the points of attractor in cubic of size r in D_2 dimension space is proportional to cubic volume.
Using the log function to both size of Equation 19 we can obtain:

$$\log[C(r)] \approx \log\left(r^{D_2}\right) = D_2 \log(r) \tag{20}$$

Than slope of regression line thought linear part of curve $\log[C(r)]$ against $\log(r)$ define the value of correlation dimension of D_2. Correlation dimension is lower border of Hausdorff dimension (Schuster, 1993; Pawelzik et al., 1987).

In Table 1 the results of calculations of correlation dimension and the largest Lyapunov exponent for data set number two have been presented. Obtained results show that visiting the main University internet site during the holidays is more complex phenomenon than visiting it during the period of learning time. The result is consistent with the one obtained from the frequency analysis. The schemas of using downloading file system seem to be the same during holidays and during the time of learning.

The logs into:	Correlation dimension		Largest Lyapunov exponent [1/(2 hours)]	
	Learning time	Holiday	Learning time	Holiday
LMS system	3	2.7	0.15	0.12
Internet university information board	3.2	2.8	0.13	0.08
Main university web site	2.59	33	0.09	0.13
Download system	3.76	3.59	0.14	0.16

Table 1. Correlation dimension and the largest Lyapunov exponent for data from data set number two (Mosdorf et al., 2007)

2.4.3 Example of nonlinear analysis

For identification of dynamic properties of different group of LMS users the nonlinear methods of data analysis have been used. The data presented in Figure 1 have been analysed.

The identification of nature (deterministic chaos, periodic or stochastic) of analyzed data can be estimated with using the Hurst exponent. For the signals of stochastic character H=0.5. The border point N^* between area, where the H>0.5 and area, where H=0.5 corresponds with the boundary of the natural period of analyzed system.

For experimental data correlation dimension D_2 based on the Grassberger – Procaccia method (Fermat et al., 1999) and largest Lyapunov exponent based on the Wolf (Schuster, 1993) algorithm can be calculated. Correlation dimension is the measure of number of degree of freedom of the system but the largest Lyapunov exponent (L) identifies the nature of data. A positive value of largest Lyapunov exponent indicates that in the considered system the deterministic chaos appears. The time of stability loss in the system can be estimated by value of $1/L$.

In the Table 2 the results of non-linear analysis have been presented. The identification of correlation between the time series of e-learning server requests can be calculated with using the correlation coefficient (C). When $|C|$ is close to 1, the analyzed time series are correlated. When the large and low values in both series appear at the same time, then C>0; but when large values in first series meet low values in other series, then C<0. When C is close to zero, then the time series are not correlated.

	Pages	Teachers	Administration	Unit
Time of autocorrelation disappearance	35	47	31	days
Hurst Exponent	0.93	0.812	0.839	
Border point N^*	140	130	130	days
Correlation Dimension	2.25	5.25	5.5	
Largest Lyapunov Exponent	0.105	0.0685	0.0698	1 bit/days
Time of stability loss	9.5	14.6	14.3	days

Table 2. Results of nonlinear analysis (Mosdorf et al., 2006)

Results of calculation (presented in the Table 2) of time periods, in which the autocorrelation disappears, show that the shortest period appears in time series of administration logs and is equal to 31 days. This value corresponds with monthly cycle of Dean Office working time. We can observe the similar length of time period of autocorrelation disappearance in the time series of www logs. In this case the time period is equal to 35 days. The largest time period appears in time series of teachers' logs and is equal to 47 days. The obtained values of Hurst exponent and largest Lyapunov exponent show that all analyzed series have the character of deterministic chaos. The largest value of Hurst exponent has been obtained for time series of www logs. The natural periods of all analyzed series obtained from R/S analysis are similar to semester.

The correlation dimension obtained for attractors reconstructed from analyzed time series shows that the attractors reconstructed from administration workers and teachers' logs have the most complex structure. In case of www logs the obtained correlation dimension equal to 2.25 suggests that changes of number of www logs can be modelled by low dimensional model.

The analyses of largest Lyapunov exponent allow us to estimate the time interval in which the system remains stable. In the result of analyses we may conclude that changes of www logs are the most unstable process. In this case the number of www logs can be predicted within one week. In case of administration workers and teachers' logs the number of logs can be predicted within two weeks.

2.5 Recurrence plot

Recurrence plot (RP) visualize the recurrence of states x_i in a phase space. The RP enables us to investigate the recurrence of state in m-dimensional phase. The recurrence of a state at time i at a different time j is marked within black dots in the plot, where both axes are time axes. From the formal point of view the RP can be expressed as (Marwan et al., 2007):

$$R_{i,j} = \Theta\left(\varepsilon_i - \left\| x_i - x_j \right\|\right), x \in \Re^m, i, j - 1 \ldots N \tag{21}$$

where N is the number of considered states x_i, ε_i is a threshold distance, $||\cdot||$ a norm and $\Theta(\cdot)$ the Heaviside function.

Homogeneous RPs are typical of stationary systems in which relaxation times are short in comparison with the time of system investigation. Oscillating systems have RPs with diagonal oriented, periodic recurrent structures. For quasi-periodic systems, the distances between the diagonal lines are different. The drift is caused by systems with slowly varying parameters which cause changes of brightens the RP's upper-left and lower-right corners. Abrupt changes in the dynamics as well as extreme events cause white areas or bands in the RP.

Single, isolated recurrence points can occur if states are rare, if they do not persist for any time or if they fluctuate heavily. However, they are not a unique sign of chance or noise (for example in maps). A diagonal line occurs when a segment of the trajectory runs parallel to another segment. The distance between trajectories is less than ε. The length of this diagonal line is determined by the duration of this phenomenon. A vertical (horizontal) line indicates a time in which a state does not change or changes very slowly.

In Figure 18 the recurrence plots for data from data set number two have been presented.

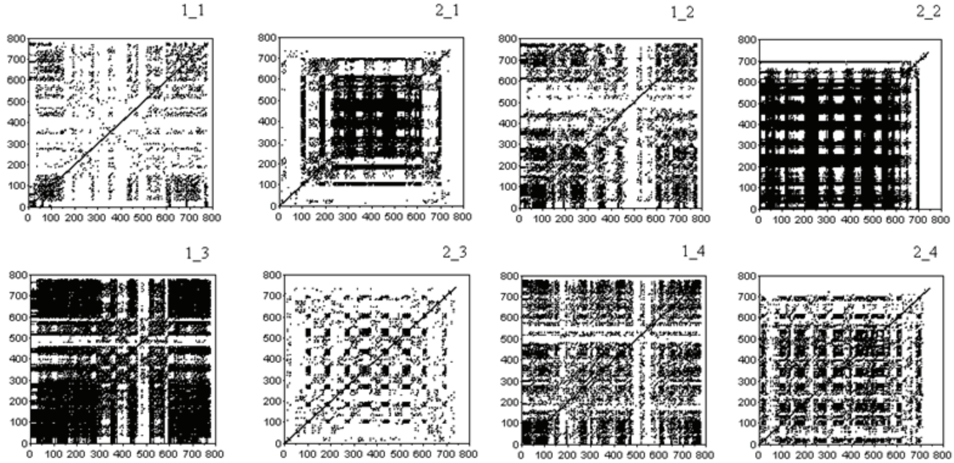


Fig. 18. The recurrence plots for data from data set number two. The ordering of the pictures is described in Figure 2. (Ignatowska et al., 2008)

The obtained results show that visiting the main University internet site during the holidays is more complex phenomenon than visiting it during the period of learning time. The visiting of module E-student (LMS) and Internet university information board is more complex during the learning time in comparison with holiday. The schemas of using downloading file system seem to be the same during holidays and during the time of learning.

In Figure 19 the recurrence plots for data from data set number three have been presented.

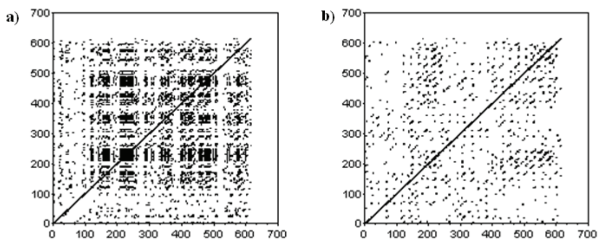


Fig. 19. The recurrence plots for data from data set number three. Moodle platform users' activity: a) logs of teachers, b) logs of students

The results obtained for data set number three show that using the university's Moodle platform by the teachers is more complex phenomenon than the students' activity. What is more, the teachers' behaviour seem to be similar to the main university's web-site users logging schema (Figure 19 a vs. Figure 18 2_3) during the learning time.

3. On frequency synchronization of e-learning web system users

3.1 Introduction

The dynamics of changes in time of logs to: administration module, teacher module and student module has been analyzed. The correlation, Fourier and wavelet analyses have been used to identification of the data nature. Basing on the wavelet analysis it has been proposed the new criterion of evaluation of frequency synchronization. The modified wavelet power spectrum has been used to identify the frequency synchronization of user groups of e-learning system.

The changes in time of daily logs of: administration workers, teachers and students have been analyzed. The data analyzed in the chapter have been presented in Figure 1. It has been observed that the number of students logs significantly increases during the exam sessions and decreases during classes and holidays. The activity of teachers and university administration significantly decreases only during holidays.

The correlation coefficient between time series under consideration has been calculated according to the following formula (Gajek et al., 2000):

$$C_{M,S} = \frac{Cov\left(x_{i,M}, x_{i,S}\right)}{\sigma_{x_{i,M}} \sigma_{x_{i,S}}} \tag{22}$$

where $x_{i,M}$, $x_{i,S}$ are the time changes of number of logs; $\sigma_{x_{i,M}}$, $\sigma_{x_{i,S}}$ are the standard deviations of time series $x_{i,M}$ and $x_{i,S}$, i is a sample number.

When $|C_i|$ is close to 1, time series $x_{i,M}$, $x_{i,S}$ are correlated. When the large values in both series appear at the same time, then $C_i > 0$; but when large values in first series meet low values in other series, then $C_i < 0$. When C_i is close to zero, then the time series $x_{i,M}$, $x_{i,S}$ are not correlated.

Because the value of correlation coefficient is low therefore we can conclude that data analyzed in the paper is low correlated. It means that more sophisticated methods are necessary to identify the relations between the time series under consideration.

The correlation values between considered time series have been presented in Table 3.

C_i	Students	Administration	Teachers
Students	-	0.20	0.34
Administration	0.20	-	0.31
Teachers	0.34	0.31	-

Table 3. The correlation coefficient between: students, university administration and teachers time series. (Mosdorf et al., 2007)

The power spectrum of time series of logs is shown in Figure 4. The results of frequency analysis presented in Figure 4 allow us to distinguish the limited number of dominant frequencies. The identified dominant frequencies are 3.5 and 7 days for students and administration workers and 3.5 and 30 days for teachers. We can state that in all data series one dominant frequency corresponds to data period equal to 3,5 days. The wavelet power spectrums of logs time series are shown in Figure 8.

3.2 General concept of frequency synchronization analysis

The LMS system records activity of many users: students, teachers and administration workers. Each student using the LMS system can be treated as dynamical system whose activity is caused by LMS system, but system activity results from activity of teachers and university administration. Each of the mentioned users can be treated as dynamical system as well. It means that e-learning system is a virtual place where thousands of dynamical systems (users) communicate each others. These communication leads to changes of users' activities therefore we can say that system users interact each others. Number of logs of each user is a measure of his activity. The analysis of logs of user groups (students, teachers and administration) shows that changes of daily numbers of logs of user groups can be treated as a result of deterministic chaos phenomena (Mosdorf et al., 2007; Ignatowska et al., 2005; Mosdorf et al., 2006). In Figure 14 it has been shown the attractor reconstruction from time series of logs of the students, logs of the university administration and logs of teachers. The obtained results presented in Figure 14 confirm that time series under consideration are created by deterministic chaos phenomena. Therefore we can say that LMS system is a virtual platform of interaction of three chaotic dynamical systems.
In the chaos synchronization the trajectories of synchronized systems become similar in spite of synchronized systems being different. In the process of synchronization two different chaotic systems interact. In the theory of synchronization one of them is called master and the other one – slave. The measure of synchronization is a synchronization error defined by (Fermat et al., 1999; Li-Qun Chen, 2004):

$$x_i = x_{i,M} - x_{i,S} \tag{23}$$

where $x_{i,M}$ describes the time changes of master system and $x_{i,S}$ describes time changes of slave system.

In the paper (Li-Qun Chen, 2004) the following types of synchronization have been defined: complete synchronization, partial synchronization, practical synchronization, exact synchronization, almost synchronization. Two chaotic systems are *exactly synchronized* if the synchronization error exponentially reaches the zero. This implies that at a finite time $x_{i,M} = x_{i,S}$. Two chaotic systems are *practically synchronized* if the synchronization error is close to zero. This implies that for all time $t >= t^*$ the trajectories of the slave system are close to the master trajectories, i.e., $x_{i,M} \approx x_{i,S}$. It is said that two chaotic systems are *completely synchronized* if and only if all states of both master and slave systems are practically or exactly synchronized. Two chaotic systems are *partially synchronized* if, at least, one of the states of the synchronization error system is either practically or exactly synchronized and only if, at least, one of the states of the synchronization error system is neither practically nor exactly synchronized. Two chaotic systems are *almost synchronized* if and only if the both master and slave systems display oscillations with the same phase and different amplitude (Li-Qun Chen, 2004).
One of types of synchronization of chaotic system is the frequency synchronization (Fermat et al., 1999). It has been originally defined for periodic behavior of a dynamical system. Recently, the frequency synchronization between two chaotic systems has been discussed.

The key issue to extend frequency synchronization to chaotic systems is to calculate the frequency of a chaotic system (Fermat et al., 1999).
The wavelet power spectrum allows us to observe changes in time of all frequencies. Therefore we can use the wavelet power spectrum to identify the time correlation between frequencies. For that purpose the following coefficient has been proposed:

$$C_f(s) = \frac{Cov\left[\left|W^M(t,s)\right|^2, \left|W^S(t,s)\right|^2\right]}{\sigma_{\left|W^M\right|^2}\sigma_{\left|W^S\right|^2}} \tag{24}$$

where $|W^M(t,s)|^2$ and $|W^S(t,s)|^2$ are time series of wavelet power for the given value of parameter s for master and slave systems; $\sigma_{\left|W^M\right|^2}$, $\sigma_{\left|W^S\right|^2}$ are the standard deviations of time changes of wavelet power spectrum for the given value of parameter s for master and slave systems.

The coefficient C_f, is a measure of frequency synchronization in interacting systems. When C_f is close to 1, then the considered frequency appears in both time series in the same moment of time. When C_f is close to -1, then the considered frequency appears in one time series and disappears in other time series at the same moment. In Figure 20 it has been shown the C_f changes against time periods.
The wavelet power spectrum shows the changes in time of the dominant frequencies. The dynamical systems interaction occurs only on selected frequencies identified by frequency correlation coefficient (24). To indicate the frequencies that are important for synchronization, each wavelet power spectrum has been multiplied by coefficient $C_f(s)$. Finally we obtain the modified wavelet power spectrum in the following form:

$$\left|W_M(t,s)\right|^2 = C_f(s) \cdot \left|W(t,s)\right|^2 \tag{25}$$

The modified wavelet power spectrum of students' logs as the results of multiplication of it by students-teachers frequency correlation C_f has been shown in Figure 21a. It identifies the frequency and the time periods when the correlation between students and teachers appears.

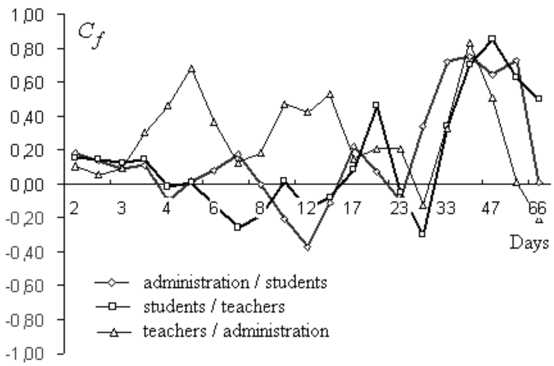


Fig. 20. The coefficient of frequency correlation of time changes of wavelet power spectrum for three user groups

The positive correlation appears for 20 days time period. The negative value of frequency correlation for 12 and 7 days time periods appears in the same time periods – close the exam sessions. Such negative correlation is caused by the fact that in exam sessions the regularity of weekly work disappears for stationary students and in the same time part-time students lost the regularity of 2 weeks work. In other words we can say that students use the system more often near exam sessions and teachers use the system more often near the end of the month.

In Figure 21b the modified wavelet spectrum of administration logs multiplied by administration-students frequency correlation C_f has been shown. Figure 21b has been prepared for selected frequencies of administration activities and it identifies periods when the correlation between administration and students can be observed. The positive correlation appears for time periods of 7 and 12 days. The correlation of 7 days is high, it appears in the time of classes during semesters and exam sessions. This correlation disappears in holidays. The correlation of 12 days appears in the longer periods during classes and it appears before and during exam session in September. The negative correlation between frequency of logins of students and administration has not been observed. The frequency of 7 days is strongly connected with administration activity. The other two groups of system users under consideration do not work in such systematic way.

In Figure 21c the administration logs wavelet spectrum multiplied by administration-teachers C_f has been shown. Figure 21c identifies time periods when the correlation (of 5-7 and 14 days) between administration and teachers appears. The maximum value of correlation of 14 days has been reached in the middle of classes during the semesters and at the end of holidays. The correlation of 7 days has the lowest value during holidays. The minimum value has been observed during summer holidays, which is connected with disappearance of teachers' activity during this time.

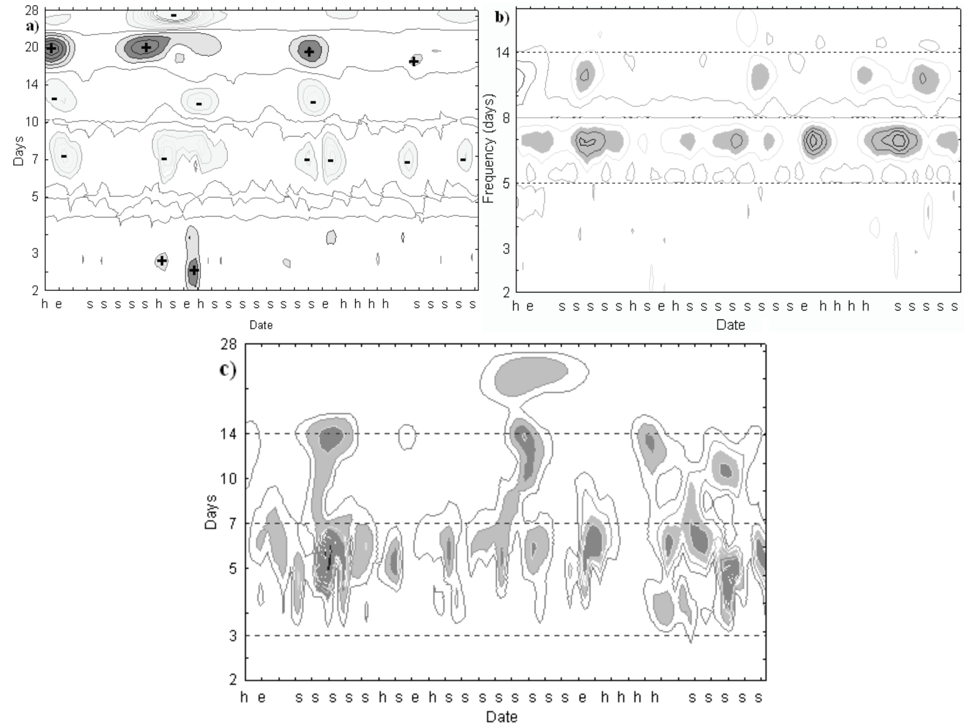


Fig. 21. Modified wavelet spectrum. a) students' logs wavelet spectrum multiplied by students-teachers C_f b) administration' logs wavelet spectrum multiplied by administration-students C_f c) administration logs wavelet spectrum multiplied by administration-teachers C_f .

4. Conclusion

The Learning Management System (LMS) records activity of many users. The behaviours of students, teachers and administration workers usually are nonlinear. Finally the e-learning system is a virtual place where nonlinear users communicate each others. These communication leads to changes of users' activities and LMS properties. Therefore we can say that LMS with all users is a large nonlinear dynamical system. The analysis of dynamical properties of e-learning system can be helpful during the construction and development of Learning Management System and its evaluation. Using the nonlinear methods can be also helpful in detection of anomalies in e-learning system.

In the chapter some selected data from e-learning system have been analyzed:

- the time series of number of requests of LMS system per day;
- the time series of number of requests of LMS system per every two hours;
- the time series of number of requests of Moodle e-learning platform per hour.

Due to finding of many nonstationary behaviours of e-learning systems the obtained results have a preliminary character.

The results of analysis presented in the chapter show that:

- The obtained values of Hurst exponent and largest Lyapunov exponent prove that all analyzed series have the character of deterministic chaos.
- The attractor reconstruction technique confirms that time series under consideration are created by deterministic chaos phenomena.
- The Fourier analysis allows us to identify the dominant frequencies of the system.
- It has been found out that wavelet analysis can be useful method for identification of the e-learning activity.
- We came to conclusion that e-learning process generates the sophisticated chaotic attractor from changes of number of logs to the web server.
- The modified wavelet power spectrum analysis allows us to identify the changes in time of correlations between different user groups.

Analyses carried out in the chapter have shown that non-linear methods are useful in analysing e-learning system dynamics. The modified wavelet power spectrum analysis proposed in the chapter 3 allows us to better understand, in comparison with using the classical wavelet power spectrum, the correlation between different groups of web system users. This kind of analyses identifies changes in time of correlations between different user groups.

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6

An Approach in Personalisation and Privacy in E-Learning Systems

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1. Introduction

The development of user-adaptive or personalised systems has had a great impact on recent developments of application areas such as: information filtering, recommendation systems for products and services, e-commerce, help systems, support systems for on-line collaboration, accomplishment of routine tasks, interface agents, and so on. The approaches of user-adaptation or personalised systems are particularly promising to supply the demands of teachers and to adapt to students in the e-learning context.

This chapter presents an approach to personalisation in e-learning. Applied in the context of a Learning Management System (LMS), the aim is to make a LMS more flexible, adaptable, and extensive to a broad and diverse group of users. An adaptive mechanism dynamically provides didactic contents and learning activities that match the pedagogical goals with the student's preferences and skills.

To accomplish this, the concept of a Personalised Learning Policy (PLP) is introduced. This policy allows instructional designers to configure the system. It is based on the student's profile, which considers both the observation of the student/system interaction, and the aspects that the teacher judges relevant to be observed. These aspects are implemented in the system through a data structure named Orientation Layer. The Orientation Layer is a data model that represents the student's preferences and skills. As a result, the LMS is endowed with a level of configurability and the system adaptive behaviour is consistent with the system users (i.e. teachers and students).

It is important to note that in order to enable the personalisation according to the approach presented in this chapter a LMS should be compliant with the Sharable Content Object Reference Model (SCORM) (ADL, 2009) and have a Run-Time Environment (RTE) that can provide information about learning events in real time.

The remainder of the chapter is organized as follows. Section 2 overviews the student profile. Section 3 describes the PLP. Section 4 illustrates the application of the concepts of a PLP. Section 5 presents a discussion about Privacy versus Personalisation. Section 6 reports on related work. Finally, section 7 presents the conclusions and directions for further work.

2. Student Profile

Individuals present distinct ways of learning, different backgrounds, and diverse preferences. By composing these characteristics, aspects of the student learning process and knowledge construction process can be inferred by a computational system and registered in a profile. In this work, a Learner Profile (LPROF) aims to represent a set of characteristics associated to a student.

Although a number of algorithms and models aim to handle (aspects of) this issue, each of them tackle one or other aspect that is related to modelling the user, such as:

- How to deal with the uncertainty of an approximate profile,
- How to estimate a user profile with a significant number of observations,
- What is a significant number of observations,
- What is a significant observation, and
- How to adapt an algorithm to changes in the users' characteristics along a time period.

The representation of LPROF is a value expressed by a set of characteristics that takes into account aspects of the student's behaviour observed by the system after an event (or a programmed sequence of interaction events) between the student and the system. This set of characteristics has distinct variable values during a time period:

$characteristic_{1,m1}=\{c_{11}, c_{12}, ..., c_{1m1}\}$,
$characteristic_{2,m2}=\{c_{21}, c_{22},..., c_{2m2}\}$,
...
$characteristic =\{c_{n1}, c_{n2}, ..., c_{nm}\}$,where m, n vary from 1 to N

LPROF is represented as a commutative Modoid:
$(A, S, \varepsilon, \|)$,
where A is the set of observable behaviour characteristics of an individual in a e-learning system. Examples of these are student's learning motivation, autonomy, media preference, pedagogical preference, and so on.
S is the set of all possible A characteristics sequences,
$\varepsilon \in S$, is the empty sequence,
$\| : S \times S \rightarrow S$ (1)

The binary operation in (1) establishes the student static profile, represented by the concatenation of the behaviour characteristics that compose the LPROF and satisfy the following:
$f: N \rightarrow S$
is the dynamic profile, that can vary along the time with the following properties:
$\forall\ \sigma \in S : \varepsilon \| \sigma = \sigma \| \varepsilon = \sigma$,
$\forall\ \alpha, \beta, \gamma \in S : (\alpha \| \beta) \| \gamma = \alpha \| (\beta \| \gamma)$,
$f(0) = \varepsilon$, in instant $t = 0$.
Along a time frame, the student interaction events take place and, according to these events, new characteristics can be added to the student's LPROF:
$f(t+1) = f(t)$, maintain the profile value (i.e. non relevant event),
$f(t+1) = f(t) \| ci$, concatenate a new characteristic in the profile (i.e. relevant event),
$f(t+1) = \varepsilon$, restart the profile estimate, (i.e. event determines a profile update).

In order to estimate a LPROF, didactic contents and learning activities must be planned in a way to enable programming strategic checkpoints in the sequence of learning activities and student's choices, which are translated into interaction events to be observed.

3. Personalised Learning Policy

Adaptive systems (Kobsa, 1996, Kobsa, 2001) include a user model that represents student's knowledge, objectives, interests, and other characteristics that enables a system to differentiate among its users. The system gathers information, models users, and uses this information to provide adaptation. This enables the system to interact with several users, in the same context, but in different ways. The sources of information on which the adaptation is based might range from a user's interaction to a direct request for information.

An important aspect of Information Systems and Adaptive Systems is that their development process is a very onerous activity and, depending on its complexity, a lot of time is required and great costs are involved. In this sense, it is desirable that Adaptive Systems present, as much as possible, a degree of configurability, making them extensible, capable of being applied in distinct contexts, and adaptable to new demands. In spite of the difficulties in implementation issues, and considering that not all aspects of a system can be configurable, those that can be implemented and configured should provide for freedom and versatility in the system's use.

System configuration can be associated to adaptation techniques since both of them aim to provide for specific needs of users, adapting some of system functionalities to these needs and yet maintaining the system's organization unchangeable. Particularly in e-learning systems, the possibility of configuring the criteria for observing student's interactions and procedures to be executed in response to these introduces a degree of freedom, as the configuration determines which conditions will trigger system adaptation. Thus, teachers and instructional designers can emphasize different aspects of didactic contents and learning activities and focus on different student's characteristics, cognitive aspects, and pedagogical approaches, among others.

The PLP is implemented by a configurable set of rules and procedures that define the adaptation of didactic contents and learning activities in an e-learning environment. This novel concept implies more degrees of freedom in the personalisation process, and the adaptation is made in an open and flexible way (i.e. not using a rigid set of adaptive criteria).

The rules defined in a PLP establish conditions associated to events that can take place during a given learning experience. Such events can be related to an observable characteristic of a student that belongs to his/her LPROF. Thus, from the observation and interpretation of the student's interactions, the system estimates the LPROF at a given moment and associates it to the pre-defined conditions. The policy also defines the procedures that should be executed to adapt the system's actions. A condition included in a policy might refer to the student's current interaction (i.e. interaction event) and/or previous interactions registered by the system.

It is worth noticing that not all student's interactions are relevant to the LPROF's estimation. When configuring the PLP, it is necessary to define relevant interactions and to which state in navigation model these are associated.

3.1. System Organization

Traditional e-learning systems (i.e. that do not personalise or adapt) are organised as in Figure 1. The exchange of information and/or data between the system components are carried out as described below (numbers correspond to arrows labels in Figure 1)

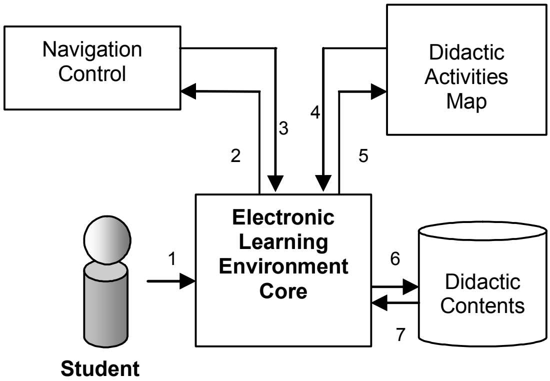

Fig. 1. E-learning system typical architecture

1. student performs action,
2. requests the student's status in the navigation map,
3. returns student's navigation status,
4. requests the next didactic content or learning activity according to student's status,
5. returns the indication of next didactic content or learning activity,
6. requests the didactic content or learning activity ,
7. returns the didactic content or learning activity ,
8. presents the didactic content or learning activity.

Aiming to personalise the interaction in e-learning systems, there are two important interaction events that should be observed: (1) those that request a new didactic content or learning activity and (2) those that are relevant to estimate the LPROF. In this case, the management of learning activities demands information related to such events, for instance, information provided by the RTE defined by the SCORM standard (Dolog & Nejdl, 2003).

In other words, it is important to enable the e-learning system to handle students' interaction and also to provide information about this interaction. This makes possible to analyse and react to the information as defined in the PLP. Three types of events can take place in this context. The first type of event (Type 1) triggers the LPROF updating. The interaction event(s) and the PLP navigation rules are the input for the updating process. The second type of event (Type 2) triggers the adaptation process, which determines the next didactic content or learning activity to be presented to the student according to his/her LPROF. There might also be irrelevant events (Type 3) that do not change LPROF and therefore there is no need for adaptation.

Three types of rules should be defined and configured in a PLP:

- Navigation rules: define which student's actions are relevant to be observed and stored by the system to compose and estimate the LPROF;
- Adaptation rules: define the system next action, e.g., the didactic content and/or learning activities that will be presented next;
- LPROF's estimation rules: define the conditions to initialise and/or update a profile. An example of a rule is: "If a student presents characteristic X associated with 40% of his/her significant interactions then his/her LPROF equals A". As not all interactions are important and significant to initialise and/or update a LPROF, the number of observations is not static and thus this variable should also be defined in the PLP.

All interaction events are observed by the system. However, the events considered relevant to initialise and/or update a LPROF or to present new didactic contents and learning activity are defined in the policy. A PLP can be planned for a specific set of didactic contents and learning activities according to the pedagogical strategies. Therefore, the organization and conceptual model allows configuring, at the same time, different policies applied to different students and using the same didactic contents and learning activities.

The representation of a PLP takes into account: Interaction, Status, Condition, Action, and the LPROF.

Interaction represents a student's interaction action at a certain moment, e.g. clicking on a checkbox for making a choice, entering a URL on a browser, and so on.

Status represents the student's state in the navigation model. Any interaction carried out by a student is associated to a state in the student's navigation model. Every time the student makes an action that is associated to a relevant event, it causes a transition in the navigation model. Depending on the event, the system executes an action according to what is defined the policy.

Condition relates to what is verified by the system and that determines a LPROF update and/or presentation of a new didactic content or learning activity.

A configurable structure named "Orientation Layer" determines the selection of the criteria used in the adaptation process. Each layer represents an aspect to be observed, i.e. a dimension of observation according to what is deemed as relevant. The Orientation Layers constitute a data model, which is configurable and reusable. The configuration feature of the Orientation Layer structure facilitates the introduction of a new approach or direction for the student observation. This is an important characteristic as it facilitates the adoption of the system by professionals from different knowledge areas. In many situations we observe that different teachers and instructional designers can adopt diverse pedagogical strategies. For instance, at the same time a teacher or instructional designer can adopt strategies to stimulate and improve a student unique cognitive characteristic, another teacher or instructional designer might prefer to stimulate an alternative characteristic with the objective of improving a different ability of the same student.

The number of layers, characteristics considered, and options available are defined by the teacher or instructional designer. Table 1 shows an example of a possible configuration of the Orientation Layer structure.

Once the LPROF is initialised or updated according to the observation of the characteristics defined in the Orientation Layers structure, the system is ready to adapt the didactic contents or learning activities by executing rules and actions defined in the PLP. As the system register a student interaction, the LPROF Manager module verifies which characteristic of an orientation layer is associated to a condition in the policy adaptation rules and, depending on this association, estimates (i.e. initialises or updates) the current LPROF. The steps and activities that should be carried out to configure a system according to the approach presented in this chapter are shown in Figure 2.

Screen layout	Presentation format
Texts, Video, Audio, 2D animation 3D animation, etc.	Media format
	Level of knowledge
	Psychological model
	Learning style
	Pedagogical model
	…
	Observation of Multiple Intelligences [Gardner,2003]

Table 1. Example of an Orientation Layer structure

3.2. State Transitions

The actions and associated interaction events in a PLP are represented by a Finite State Machine. A tool interprets the rules defined in a policy and transforms them by translating the policy states and actions into a transition table. The system then is able to interpret and execute the actions.

4. Use scenario

The application of the PLP concept is illustrated with an example of an Orientation Layer with two layers and a set of rules.

The first layer - Learning Orientation - is based on the Learning Orientations model (Martinez & Bunderson, 2000; Martinez, 2002), which takes into account emotions and affective aspects, self-directed and committed learning effort, and learning autonomy. It allows understanding and matching learning orientations, fostering self-motivation, encouraging online relationships, and supporting successful learning and performance. It distinguishes four different learner profiles: Transforming; Performer; Conforming; and Resistant. The second layer - Media - refers to the type of media that the student prefers for presentation of didactic contents and learning activities. These two layers might be applied to a LPROF as exemplified by the rules below:

LPROF = Video_Preference if student chooses a video explanation in more than 33% of relevant interactions.

LPROF = Transforming_Learner if the student prefers case studies in 40% of relevant interactions.

Updating, Navigation, and Adaptation rules are:

Updating: **If** student chooses video in 33% or more of relevant interactions **then** LPROF = Video_Preference.

Navigation: **If** student chooses a case study in a relevant interaction **then** increment the Transforming_Learner counter.

Adaptation: **If** ((LPROF=Video_Preference) and (LPROF=Transforming_Learner)) **then** ((present a video) and (present a case study)).

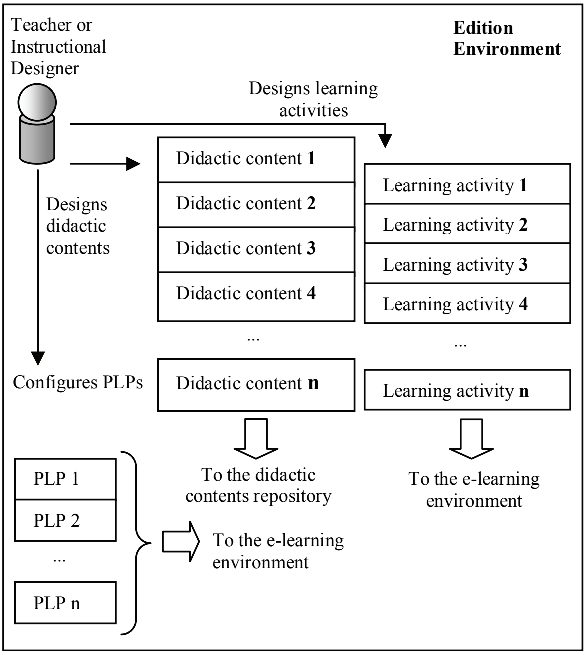

Fig. 2. Edition environment and configuration of an e-learning environment that uses a PLP

5. Privacy versus Personalisation

As Web based Systems are improving in the sense of offering personalised services, users privacy have to be considered and some questions must be answered: are we sure that all users want personalisation and also, are we sure that all users know exactly which are the implications of personalisation? Specially in educational systems developers of personalised systems must be aware that observing a student can have disagreeable and undesirable consequences.

Kobsa (2007) presents a discussion and some considerations about privacy that strive to approximate personalisation techniques to privacy rules. In his research three groups of users, characterized by the privacy characteristic, are presented:

1. privacy fundamentalists: extremely concerned about the possibility of the use of their data, even if privacy mechanisms are present,
2. privacy unconcerned: expresses a mild concern about privacy, and
3. privacy pragmatics: concerned about privacy but much less than privacy fundamentalists (Kobsa, 2007).

Kobsa suggests that in personalised systems developers must communicate the benefits of personalised services to the users not only for a legal reason (privacy laws) but also because

if users know the benefits of these services they probably will be more motivated to collaborate with information and any other action required (Kobsa,2007).
In the model presented in this chapter if one wants to consider the privacy characteristics presented by Kobsa it is not required to reprogram the system software. It is just necessary to introduce these characteristics as a new variable to be observed and considered in the PLP. Considering the set of rules presented in Section 4:

LPROF = Video Preference if student chooses a video explanation in more than 33% of relevant interactions.
LPROF = Transforming Learner if the student prefers case studies in 40% of relevant interactions.

Updating, Navigation, and Adaptation rules are:

Updating: If student defines him/herself as a **privacy fundamentalist** then do not personalise any activity and **LPROF = Does Not Want Personalisation**

If student defines him/herself as a privacy unconcerned then

Updating: **If** student chooses video in **50%** or more of relevant interactions **then** LPROF = Video_Preference.
Navigation: **If** student chooses a case study in a relevant interaction **then** increment the Transforming_Learner counter.
Adaptation: **If** ((LPROF=Video_Preference) and (LPROF=Transforming_Learner)) **then** ((present a video) and (present a case study)).

If student defined himsef/herself as a privacy pragmatics **then**

Updating: **If** student chooses video in **33%** or more of relevant interactions **then** LPROF Video_Preference.
Navigation: **If** student chooses a case study in a relevant interaction **then** increment the Transforming_Learner counter.
Adaptation: **If** ((LPROF=Video_Preference) and (LPROF=Transforming_Learner)) **then** ((present a video) and (present a case study)).

Notice that a different number of observations are programmed to estimate a LPROF according to the privacy student's characteristic.
It is easy to observe that when users want to consider any new variable in the personalisation process presented in this chapter, there is no need to change system's code but only to reprogram PLP´s rules.
In the example presented in Section 4, three new rules were introduce to estimate his/her LPROF. The configuration of new rules can cause some overhead, sometimes compromising system's performance. Even in this case this system present a better option than changing the system's code every time a new characteristic relevant to be to observed is introduced by a user.

6. Related Work

The PLP works like a Security Policy of Information Systems and its security configurable aspects. A Security Policy (Stallings, 2006) is configurable, similarly to the PLP, i.e. by defining a set of rules and procedures that aim to manage information in the system's security activities.
Regarding certain aspects, the Munich Reference Model for Adaptive Hypermedia (Koch & Wirsing, 2002) and the UML state machine based model (Dolog & Nejdl, 2003)share characteristics with the model presented in this chapter.
The Munich Reference Model provides a basis for the development of adaptive hypermedia applications. Its distinctive characteristic is to have a user model and an adaptation model, a dynamic acquisition of the user behaviour, a dynamic rule-based adaptation, and a user behaviour triggered run-time session. The model has a three-layer structure that includes user modelling and adaptation aspects.
Dolog and Nejdl (Dolog & Nejdl, 2003) explain how UML state diagram models for navigation and class diagrams for user modelling can be used for generating adaptive navigation sequences. The UML state machine based model focus on user interaction and user's and system's generated events in navigation.

7. Conclusion and further work

This chapter presented a novel conceptual model for adaptive e-learning systems. This model enables the system to adapt to the student, encouraging knowledge construction, and aiming that the e-learning process be a rich, motivating and significant experience.
The chapter introduced the concept of a PLP in the context of a Learning Management System. The PLP allows one more degree of flexibility in the e-learning system, adding the features of configuration and reusability to the system. The Orientation Layers structure allows that the teacher or instructional designer define and configure in the student profile the aspects that are considered relevant.
In this sense, the model presented provides personalisation and adapts not only to final users, in this case students but also adapts to others users as teachers and instructional designers. Finally some concerns about privacy and how the model treats privacy and personalisation simultaneously without the need of reprogramming system's software are presented.Further work includes evaluating the conceptual model either by proof or experiment and the inclusion of other models to determine students' profiles. In, addition, there are plans to apply some cognitive researches results to create a Layer in the Orientation Layers structure proposing pedagogical strategies that profit from these researches to stimulate and improve student's knowledge construction.

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7

Affective Computing in E-learning

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1. Introduction

Affective Computing is a branch of the study and development of artificial intelligence that deals with the design of systems and devices that can recognize, interpret, and process human emotions. It is an interdisciplinary field spanning computer sciences, psychology, and cognitive science. Realm of this research has been extended to human-machine interface, cognition and text mining.
As a remote learning method, e-learning inevitably lacks the emotional communication between the tutor and the learner. Affective Computing aiming at making computational devices empathic provides a solution to this problem
In this chapter, we try to give an overview of the applications of affective computing in e-learning system and introduce some of the application systems.

2. E-learning and Affective Computing

2.1 Absence of Emotion in E-learning Systems

E-learning provides a convenient and economical mode for education, but separation from tutor and other students may result in a lack of timely and face-to-face communication which is just available in regular education. Students will feel frustrated, and even have emotional resistance towards learning, if learning problems can not be solved, or confusions can not be straightened out over a long period of time.

2.2 Affective Computing

The concept of Affective Computing was originally put forward by Professor Picard from MIT Media Lab in 1995, who, in his later work, defined it as "the computing that relates to, arises from, or deliberately influences emotions" (Picard, 1997). The focus of affective computing is on establishing emotion modes, based on physiological and behavioural signals that are caused by emotion and obtained by various sensors, and on developing a personal computer system, which can apperceive, recognise, and comprehend human emotions to provide intelligent, user-friendly feedbacks for user's emotions. It works well in shortening the emotional distance between machine and user, and creating a harmonious

human-machine environment. Such traits being well employed, Affective Computing, when applied to e-learning, can greatly help recuperate the absence of emotion in e-learning.
The main application of Affective Computing includes emotional perception, emotional comprehension and emotional expression. The purpose of emotion perception is, through various sensors, to obtain stimuli that express user's emotions, and use them for affective computing as pre- information, either in verbal forms (e.g. speeches) or in non-verbal forms (e.g. facial expressions, heartbeats). The method most commonly used is to estimate one's emotion by recognizing his facial expression and detecting his physiological states. Computer can have a basic understanding of the user's emotion state after perceiving, analyzing and recognizing the emotion. The essence of Affective Computing is, through various sensors, to use emotion models to recognize and analyze physiological and facial features, which are caused by emotions, for the sake of understanding human emotions and making suitable reactions. Therefore, the emphasis of this section is how to make suitable reaction to user's emotional change, according to what emotion information has been recognized. Contrary to previous study in which physiological and behavioural features tell the status of emotion, emotion expression is a reverse-process, which focuses on how to extract a given emotion status from physiological and behavioural features.
The growing research and scholarship relating to emotion and e-learning generally indicates the significant part that emotion plays in learning. Models of e-learning systems assisted with Affective Computing methods are being developed. Qualitative and quantitative research has been carried out in a range of e-learning settings to complete the theory and practice of e-learning. Figure 1 shows the application of three main Affective Computing approaches in an e-learning system.

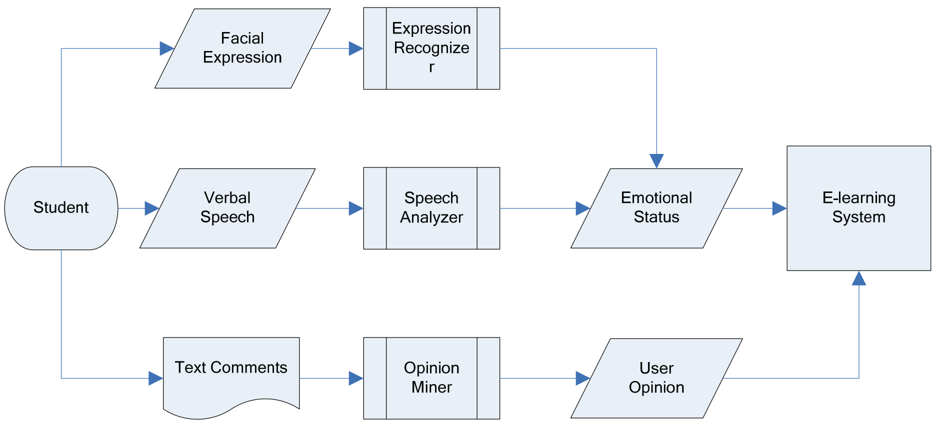

Fig. 1. Application of Affective Computing in e-learning

3. Facial Expression Recognition

3.1 Facial Expression Recognition in e-learning

Traditional e-learning systems are far from perfection. As early as in 1983, it was pointed out by Desmond Keegan (Keegan, 1983), a world- wide famous e-learning education expert, that e-learning differs from conventional education basically in that e-learning separates teachers from students and students from students. Because of the quasi-permanent separation, teachers and students are unable to make face-to-face communication in e-learning as they can do in conventional education, which leads up to the absence of emotion. As a result, modern e-learning takes enough human emotions into account. Despite its complexity, the emotion's state can be reflected in one's facial expressions, which means that in general one's emotional state can be read from his facial expressions. In an e-learning model where disadvantages are overcome of ignoring learners' moods and emotions, learners' state of emotion can be conveyed to teachers, who accordingly take effective actions to ensure that both learners and teachers can achieve the best effect in learning.

3.2 Introduction to Facial Expression Recognition

Facial expression recognition is to extract and analyze distinctive features reflected from people's facial expression. The collected information is classified and understood according to the way how human perceive and think, so that people's mood or emotion can be interpreted, by utilizing emotion knowledge acquired before to teach computers how to associate, think and reason. In a learning system, a harmonious interaction between human and machine can be realized, when computers can acquire learners' emotional state by recognizing their facial expression, helping teachers to know how learners feel and how well they learn, and teachers can accordingly employ suitable teaching approaches for the sake of high efficiency of learning. In e-learning education system, in particular, facial expression recognition can facilitate learners' adjustment of their emotions to coordinate the interaction with computers.

3.3 Facial Expression Recognition Technique

Facial expressions are various and they can be studied from dimensional-quantitative perspective and classification perspective. All human emotions are produced after being combined in a complicated way, based on six facial expressions which are classified by scientists of facial expression as happiness, surprise, fear, sadness, hate and anger. Facial expression recognition gains its improvement in recent years with two significant techniques, detection and location of faces, and extraction and recognition of faces. Compared to the simple technique of detection and location of face, the technique of extraction and recognition of face pictures is complicated, and therefore it is studied more widely and more deeply. To date, there are three methods of facial expression recognition computers can use.

Geometrics-based recognition method: facial expressions are recognized, by mapping and measuring the locational changes of eyes, nose, eyebrow, mouth and etc, and defining the features in terms of size, distance, shape, proportion and etc.

This method calls for a small input of data, but it may cause the loss of important information for the facial expression recognition and classification, as face image is only represented by limited features (Xue Weimin, 2003).

Model-based recognition method:
This method needs a physical model which can anatomically define critical features in face and compare these features to recognize facial expressions. It means that the facial expression recognition is transformed into a flexible matching problem of curved surface.
Recognition method of integrated-face-feature: facial expressions are recognized through mathematical transformation, which are performed for the whole face or for special area of it, with the PCA (Principal Components Analysis) most commonly in use. This recogniton method, based on intergrated face features, is gaining more and more attention, because, for the purpose of expression recogniton, it focuses on saving as much original information as possible, and transforming informaiton of expression shown in the whole face to effectively extract related features from face images.
Below is an introduction to two systems applied for e-learning learning.

3.4 Introduction to an E-learning System Using Facial Expression Recognition

An overview of facial detection: the popular methods employed for facial detection include PCA, neural network, machine learning, information theory, geometric model, Hough transformer and color analysis. Based on the expressive means in computation, there are two main facial detection algorithms: integrated expression algorithm and facial geometric feature algorithm. The integrated expression algorithm is effective in finding faces in images of low quality or in locating small faces in images. While the facial geometric feature algorithm performs well when it recognizes all the sides of faces (Wang & Ma, 2002). In an e-learning system, learners usually face up to a camera which is of low quality so the integrated expression algorithm is chosen in the real e-learning education system.

Facial Expression	Eyebrow's Features	Eye's Features	Mouth's Features
Happy	Eyebrow bent a little	Wrinkles appearing on lower eyelid Crow's-feet expanding to the external corner of eyes.	Corner of mouth rising up, mouth open and the teeth showing up A wrinkle stretching from nose to the corner of mouth
Surprised	Eyebrow raised up Skin beneath eyes stretched	Eyes popped up, upper eyelid rising up Lower eyelid falling down. White of the eye showing up	Lower jaw falling down Mouth open with ease
Neutral	Nothing changed	Eyes open naturally	Mouth closed naturally

Table 1. Primary features of happiness, surprise and neutral facial expression

Learners involved in e-learning often face cameras from a single and fixed angle, so the integration method is commonly used for facial detection computation. This e-learning education system can locate the precise position of the face in pictures with simple background by using light complement, skin color model and inflate techniques. When the system locates the entire face in the picture, recognition technique can help recognize the location of eyes, pupil, mouth and all the other expression information that learners give.

What comes next is to retrieve data of facial expression from original resource of facial expression, which can reflect what the person's emotional state is. Data retrieval of facial expression, based on the model a face represents, falls into two categories: template-based and feature-based (Zhu Aijun, 2004). Given a priority over the model, this system is built up on a transformable template for automatic extraction, which includes four models, part-combination model, eyes model, mouth model and Eyebrows model. Part-combination model, whose design and extraction is, as a matter of fact, an extraction process of subobjectives can locate and combine all the face organs that are called face parts and mainly referred to Eyebrows, eyes and mouth. Fast and reliable, the method depends on both feature location in face detection and accumulated face knowledge to build up a part-combination model and extracts face parts (Jin Hui, 2000). Eye model, mouth model and Eyebrows model all analyze images to obtain geometric images for a demonstration of geometric features, such as curvature, size and related location, so that emotional state can be detected.

Table 1 shows the relation between the mood or emotion and facial expression.

With many mature techniques, MIT Media Laboratory is playing a leading role in the field of affective computing. Though methods they used to employ performed well in facial expression recognition, human interfering was still needed. MIT media lab has recently developed a fully automatic technique of facial recognition (Kapoor, A. et al., 2003), which can be used in e-learning for our purpose.

Figure 2 shows the process of one of the techniques of facial recognition MIT media lab uses.

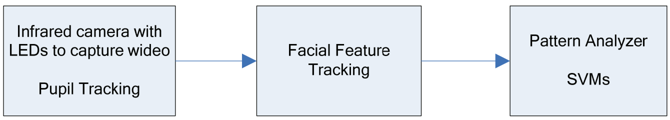

Fig. 2. Overview of the system

The pupil detection system, using the red-eye effect, detects pupils. An infrared camera equipped with infrared LEDs (light emitting diode) is used to highlight and track pupils. The whole unit is placed under the monitor pointing towards the user's face. The system has an infrared sensor coupled with two concentric rings of infrared LEDs to obtain needed information. What MIT does next is to identify what facial expressions these data represent, by using SVM. Even though only face recognition is accomplished, this research result can be applied to e-learning, in that affective problems in e-learning can be conquered if the technique of face recognition is able to precisely interpret people's emotional state. If so, the special separation can be bridged; time can be saved; learning efficiency can be improved.

4. Speech recognition in e-learning

4.1 The application of Speech recognition in e-learning

With the development of information processing technology of computer multimedia since the middle of and late 1990s, more importance is attached to information processing on emotions. In e-learning system, interaction between learners and system is important, as it can enable learners to study in real-life-like settings and intensify their interests, as well as giving timely feedback to the system, which can respond correspondingly, to the extent that learning efficiency can be improved.

As speech is the most important, most effective, most commonly-used and most convenient way for communication, enhancing the speech recognition ability can significantly improve a system's performance. By detecting how students change their speeches, e-learning can recognize the changes in their moods and then respond properly, so that a more real-life-like simulation effect can be achieved.

4.2 The process of Speech recognition in e-learning

Speeches express emotions in that they contain the parameters which can reflect emotional characteristics. Changes in emotions can be detected, by an observation of the differences that occur in characteristics parameters. The speech emotion recognition in e-learning, mainly taking advantage of the methods of measuring, decomposing, analyzing and composing, intends to identify, understand and compose emotional components, so that a sense of emotion for the computer can be developed.

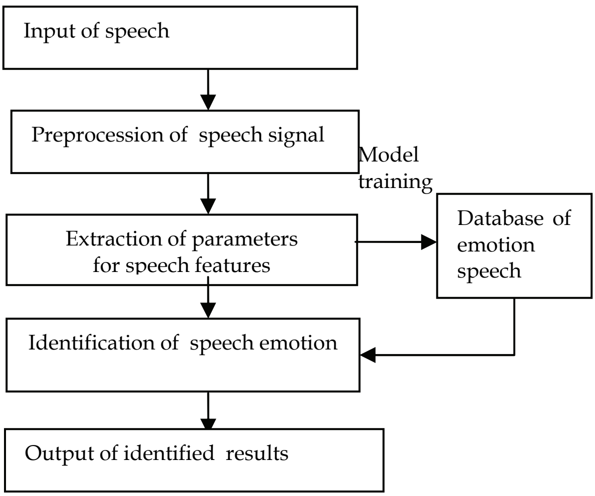

Fig. 3. Flow chart of identifying speech emotion

This research focuses on the recognition of speech emotion, combination of speech emotion, integration with other emotional information and their applications in related fields. As the basis of speech emotion recognition, speech emotion recognition helps to gain a deep understanding of the complicated relationship between the characteristics parameters in speech and the emotions. Speakers, in different states of mood, use different speeds for talking, such as excitement calling for a higher voice than usual. Changes in emotions reflect learners' states of learning, and therefore, based on the speech speed and the duration of the address, the degree of excitement can be measured, which, in return, will instruct the system how to make responses accordingly, an example of which is that the difficulty and intensity of learning can be increased when students are found happy and efficient in learning. Similar to the feature of time, the feature of vibration and various emotions are highly related, with vibration being drastic for happiness, anger and surprise but less noticeable for sadness. The bigger the degree varies, the more the emotion changes. For example, one's pitch can be marked as an upsweep curve when he is happy, but as downward when he is sad. As a result, learners' emotion can be known based on the recognition of different speeches, so that feedbacks can be instantly given and the performance of e-learning system can be improved. In short, e-learning system is able to make adjustments after analyzing learner's learning state concluded from the emotion- expression related parameters.

The computer-aided speech recognition includes establishing speech database, extracting parameters of emotion feature, identifying speech emotion, training model and etc. The process can be illustrated below:

(a) Establishing database of speech emotion

The database of speech emotion, with a large amount of data for analyzing and modelling speech emotion, lays a foundation for model construction and provides speech corpus of training and testing for speech emotion recognition. Whether for identifying or for composing speech emotion, a real, effective and abundant database of speech emotion is needed.

Speech materials can be obtained, on one hand, by recording, for which some professional announcers or good-expressers are invited to read the specified sentences, and on the other hand, by clipping, which takes phonetic fraction from films and television. Comparatively the latter has a higher degree of reality, but it is still far from natural expression, even if it facilitates the sample collection (Douglas-Cowie et al., 2000).

It is a big issue to establish a genuine speech emotion database that enables users to conveniently add, retrieve and use speeches and parameters.

(b) Selecting speech emotion parameters

Speech emotion parameters can be analyzed to manifest emotional states. Nowadays, there are many research findings in the selection of speech emotion parameters, such as fundamental frequency, formant and energy, from which are also deviated some other parameters, including average, maximum, average variance ratio (Pao et al., 2003).

(c) Establishing speech recognition model

Establishing recognition model is the key part of speech emotion recognition and its core is selecting and using classifiers. Many methods of pattern recognition, such as Linear Discriminant Classifier, k-Nearest Neighbourhood, Sport Vector Machine, Gaussian Mixtures and Hidden Markov Model are applied and have obtained good results (Cowie, 2001).

4.3 Difficulty of speech emotion recognition in e-learning

Although speech emotion recognition in e-learning has a promising prospect, there are still some difficulties which prevent it from being used widely.

(a) One of the important applications of speech recognition is for identifying and understanding natural language. The first problem to be solved is to clarify the ambiguous border of basic model, because phonetic is changing when intonation, pitch of sound or words are combined in continuous speeches. An expert system, which can understand the rules of grammar and lexeme, is also needed to be built up.
(b) The changes of voice messages are drastic. Speech recognition varies both for different speakers and even for the same speaker. For example, one's voice is different when he is talking casually from that when he is talking seriously; time also influences the speech recognition, as one's voice message is different at present from that of a month later, even if he is speaking in the same way.
(c) Voice is ambiguous. Different voices sometimes sound similar, so how to classify them is a huge challenge.
(d) It is difficult to identify speech in too much noise. Speech data are all collected in an almost- ideal condition, but when being applied in real circumstances, they may cause tough problems, obviously due to the noise. This is one reason why it sometimes happens that speech emotion fails to be identified.
(e) Speech emotion recognition, as an interdisciplinary study, involves computer science, psychoacoustics, psychology, cognitive science, and signal and information processing. Distinguished from traditional information processing and with the help of machine, it intends to identify and understand the surface information of speech signal rather than to perceive the sensibility of speech signal. Part of emotional information and manual handling, it represents an advancement of traditional signal and information.
Despite a series of developments that have been made in speech emotion recognition, many problems are worth researching on its application to a real e-learning system.

5. Opinion mining in e-learning

5.1 Opinion Mining

Opinion Mining is a new and important research discipline, aiming to automatically acquire useful opinioned information and knowledge from subjective texts. It is mainly characterized by text processing of allegations and comments, which express opinions, feelings, and attitudes of individuals, groups, or organizations. Opposed to subjective text, subjective texts are expressed in natural languages, describing what individuls think of things, people and events (in group or organization). Generally found in journals (readers' comment) and on internet (BBS), this type of text, which contains opinioned sentences, either appreciatory or derogatory, is called opinion-expressing texts.
As defined by Kim and Hovy, opinion consists of four elements, namely, topic, holder, claim and sentiment, among which there is a coorelation, that is, opinion holder makes a claim of sentiment over a topic (Kim & Hovy, 2004). Opinion mining is a synthesized discipline, related to text mining, information retrieval, machine learning, natural language processing, statistics, ontology, corpus of applied linguistics, visuable technology, and etc.

5.2 Opinion mining in e-learning: Opportunities and Challenges

Opinion mining technology offers new opportunities for e-learning. Unlike other technologies, it can reflect holders' long-term and reasonable needs, when the processed information is processed more maturely by intellect and sense. The application of opinion

mining in e-learning is important, because emotions expressed by written words are more mature, specific and reasonable than those reflected by facial expression and voice. It is signigicant that the teaching effect of e-learning and improvement on the system can be achieved, if subjective opinion-expressing information relating to e-learing can be obtained from text.
Students can know how others think in two ways. In the e-learning system, through email, weblog, instant message, students can exchange information,experience, and feelings with teachers and other students.
Teachers in e-learning must be aware of students' opinions as a whole before they can give instructions in diverse ways according to particular individuals. Teachers can use more advanced materials when one has positive emotion about a topic.
To e-learning providing organizations, opinion mining provides a new wayto evaluate effectiveness and efficiency in all aspects of e-learning. In Learing Forum, students can freely write down their feelings and opinions. By analyzing emotions, opinion mining can give a general and instructive comment on what is evaluated. For the purpose of teaching effect and teaching schedule, organizations can make good use of the timely feedback to direct, control and remedy the e-learning process and learning activities.
To understand, in a reliable way, the process of how students feel, will defintely bring about a better learning effect. But it's also a huge challenge to mine valuable information from learning-related text, as information is always exchanged over broad topics and in free styles. First, text mining falls into the category of data mining, but different from the regualr data ming, which mines in formated database, it is carried out on a loose structure and, sometimes, on a weak semantic link. Second, information is exchanged in a free style of text, and fewer formated rules are obeyed. Oral language often used, there are no fixed vocabularies for opinion expression, and therefore, analysis is hard to make.

5.3 Opinion Mining Procedures

The process of e-learning is to automatically identify those factors in the natural language text and define the relationship in between. Generally speaking, the sub-tasks of this process include topic extraction, subjective recognition, and sentiment analysis.
The aim of subjective recognition is to delete those objective statements, that is, to retain the texts concerned with expressions within a certain scope of topic and holder. The size of subjective recognition should match that of e-learning. For example, in 'Joan owns a clear mind and a good attitude', if the whole sentence is recognized as a unit, 'mind' and 'attitude' share the same sentimental polarity. While in the sentence 'The difficulty level of the exam is ok, but some questions are too narrow', 'difficulty level' and 'questions' share different sentimental polarity, so we cannot come to a right comment if we analyze the sentence as a whole unit.
The purpose of topic extraction is to identify and evaluate those terms related to the topic. To find out useful information in the texts, the theme of the information must be obtained, that is, the target of evaluation. The themes related to e-learning can be divided into four aspects: student, teacher, teaching content, and media. It is very important to deploy exact ontology concepts in certain areas for the themes to be evaluated completely and correctly. Such a capsulization of coments on the concept can offer the most complete information to those concerned.
To perform sentiment analysis is to determine the subjective attitude of the opinion holders,

with the research mainly focused on the appreciatory and derogatory degrees of 3 levels: word-level, sentence-level, and text-level. In terms of the degree, words serve as the basis; sentences specifically express; texts are the combination of commenter, the topic and the degree. When students evaluate a subject, evaluations for its aspects can be seen in the text, such as the courseware's structure, technique, interaction, understandability, information volume, etc. The degree on the subject can be available when several key contents on the subject are defined and the degree of the subject and content is calculated the same way as the degree of words is measured.

5.4 Applying Opinion Mining in e-learning: a

Subjective Recognition was the focus of the 2006 Blog Track at TREC (Iadh et al., 2006). To tell whether a given sentence is subjective or not, (Hatzivassiloglou & Wiebe, 2000) the effects of adjective orientation and grade on sentence subjectivity are examined. Wilson addresses the problem of determining clause-level opinion strength (Popescu & Etzioni, 2005); researchers deploy classical machine learning methods when subjective recognition is formulated as classification problem (Nigam & Hurst, 2004) (Yu & Hatzivassiloglou, 2003) . Minimum Cuts in Graphs are used to find subjective parts of a document, which can be successfully used in sentence-level and document-level analysis. To analyze subjective in small grade, researches have done in a more specific range to come up with close relations between topics and claims. For example, Turney defines the grade to analyze adjective- and adverb-having noun phrases (Turney, 2002).

In topic extraction, two strategies are taken. The first follows the properties of noun phrases, such as, Yi tested likelihood to determine a topic according to the composition and position characteristics of noun phrases. But this method has difficulties in covering most subjective terms. The second follows the co-occurrence phenomenon of candidate topics in context. Hu and Liu[10] recognize frequent and infrequent topic terms according to the co-occurrence phenomenon. Similarly, Popescu and Etzioni acquire candidate topic terms by Point-wise Mutual Information.

Sentiment Analysis system often starts from the word level. As little is used as "excellent" for appreciation and "poor" for derogation, the sentiment polarity is just captured from a large corpus library, like on Internet. Baroni and Vegnaduzzo use Point-wise Mutual Information to recognize the sentiment polarity of adjective words (Baroni et al., 2004). The orientation of the pronoun between two adjectives is exploited using graph algorithms (Hatzivassiloglou & McKeown, 1997). Some researchers use Naive Bayes, Max Entropy, and SVM to do classification experiments(Pang et al., 2002). The features, including unigram, bi-gram, adjectives POS and position, are examined, improving the accuracy rate up to 86.4%, with the additional help of a subjective classification pre-processor to filter objective sentences.

In Dalian Univ. of Technology(DUT), comments and remarks related to e-learning are collectively published in the Bulletin Board System, providing language data for opinion mining. The test corpus consists of 213 review articles in the learning domain of the university DLUT's BBS (3,617 sentences). Their first step is to represent an opinion as a tuple < Subject, Content, Term>. 'Subject' means which subject the opinion observes on, for example, 'Computer science' and 'Law'. 'Content' means which aspect of the subject the opinion comments on, for example: 'teacher' and 'course-ware'. 'Term' means which sentiment terms the user uses in the opinion. To identify the subject corresponding to a given value expression, two simple heuristics are used. First, if there is any subject expressions preceding the given value expressions, the one nearest to the value is selected. Second, in other cases the first one of those following the value expression is chosen. To simplify the sentiment polarity determination, a maximum distance is defined between the sentiment term and its degree adverb. If the distance between a sentiment term and a degree adverb is smaller than the maximum, the degree adverb is considered as the sentiment term's modifier adverb, and the product of the intensity of the sentiment term and the intensity of the adverb as the strength of the opinion. In a word, this example empirically examines opinion mining in Chinese e-learning documents.

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Empathic Multiple Tutoring Agents for Multiple Learner Interface

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ABSTRACT

This paper describes a Multiple User Interface with Multiple Tutoring Software Agents using eye movement information to facilitate empathy-relevant reasoning and behavior. Eye movement tracking is used to monitor user's attention and interests, and to personalize the agent behaviors. The system reacts to multiple users' eye information in real-time and the empathic software agents owned by each learner exchange the information. This paper reports on a multiple learner interaction framework designed for using eye-aware agents. Eye Information is used for exchanging information of different learners. Based on these measures, the ESA infers the focus of attention and motivational status of the learner and responds accordingly with affective and instructional behaviors. The online learning process provides an interactive learning process to learners who have similar experience and concerns. In addition to describing the design and implementation of empathic software agents, this paper will report on some preliminary usability test results concerning how users respond to the empathic functions and how users interact with other learners using the character agents..

Keywords

Multiple user interface, interaction, eye tracking, e-learning, character agent, tutoring, tracing, educational interface, eye-aware interfaces

1. Introduction

Learners can lose motivation and concentration easily, especially in a virtual education environment that is not tailored to their needs, and where they may be little contact with live human teachers. As Palloff and Pratt [1] noted "the key to success in our online classes rests not with the content that is being presented but with the method by which the course is being delivered" (p. 152). In traditional educational settings, good teachers recognized learning needs and learning styles and adjusted the selection and presentation of content accordingly.

In online learning there is a need to create more effective interaction between e-learning content and learners. In particular, increasing motivation by stimulating learner's interest is important. A related concern is how to achieve a more natural and friendly environment for learning. We will address this concern by detecting the attention information from the real-time eye tracking data from each learner and modify instructional strategies based on the different learning patterns for each learner.

Eye movements provide an indication of learner interest and focus of attention. They provide useful feedback to character agents attempting to personalize learning interactions. Character agents represent a means of bringing back some of the human functionality of a teacher. With appropriately designed and implemented animated agents, learners may be more motivated, and may find learning more fun. However, amusing animations in themselves may not lead to significant improvement in terms of comprehension or recall. Animated software agents need to have intelligence and knowledge about the learner, in order to personalize and focus the instructional strategy.

Figure 1 shows an ESA as a human-like figure embedded within the content on a Web page. In this paper, we use real time eye gaze interaction data as well as recorded study performance to provide appropriate feedback to character agents, in order to make learning more personalized and efficient. This paper will address the issues of when and how such agents with emotional interactions should be used for the interaction between learners and system.

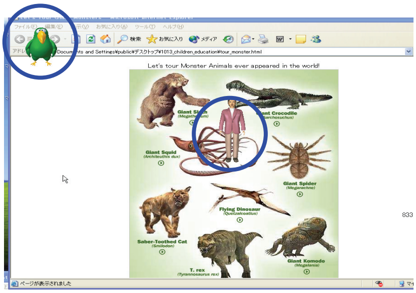

Fig. 1. Interface Appearance

2. Related Work

Educational research, as well as anecdotal observation, indicates that the human qualities and psychological insights of teachers are important components in learning, motivating learning performance, and adapting content presentation in response to user needs. Cooper et al. [2] argue that showing emotions, empathy, and understanding through facial expressions and body language is essential in tutor-learner and learner-learner interaction.

For instance, eye gaze (i.e., teacher looking at pupil) has been shown to significantly enhance information recall performance (Ottenson [3]; Sherwood [4]). Regarding teacher reactions to success and failure affecting children's expectations of success, Graham [5] showed that children who received sympathy from the experimenter after failing at a task, tended to attribute that failure to their lack of ability, while children who received mild anger tended to attribute their failure to lack of effort.

Animated pedagogical agents can promote effective learning in computer-based learning environments. Learning materials incorporating interactive agents engender a higher degree of interest than similar materials that lack animated agents If such techniques were combined with animated agent technologies, it might then be possible to create an agent that can display emotions and attitudes as appropriate to convey empathy and solidarity with the learner, and thus further promote learner motivation. [x]

For the learner's attention information and performance, the ontology base is used to store and communicate learners' data. By using ontology, the knowledge base provides information, both instant and historical, for Empathic tutor virtual class and also the instant communication between agents. Explicit Ontology is easy and flexible to control the character agent.

Several attempts have been made to build learner models that consider emotion and affective state. Klein et al. [6] described an interactive system that responds to the learner's self-reported frustration while playing a computer game. MIT's affective learning companion [7] developed the system for using affective sensing and appropriate relational-agent interactions to support learning and meta-cognitive strategies for perseverance through failure. Ou et al. [8] described a system that took account of the attention of the learner, and the expected time required to perform task, to choose when to interact with learners. In some educational contexts, character agents represent a person. For instance, Fabri et al. [9] described a system for supporting meetings between people in educational virtual environments using quasi face-to-face communication via their character agents. In other cases, the agent is a stand-alone software agent, rather than a persona or image of an actual human. Stone et al. in their COSMO system used a life-like character that teaches how to treat plants [10].

Eye tracking is an important tool for detecting users' attention information and focus on certain content. Applications using eye tracking can be diagnostic or interactive. In diagnostic use, eye movement data provides evidence of the learner's focus of attention over time and can be used to evaluate the usability of interfaces [11] or to guide the decision making of a character agent. For instance, Johnson [12] used eye-tracking to assist character agents during foreign language/culture training. In interactive use of eye tracking for input, a system responds to the observed eye movements, which can thus serve as an input modality [13]. Our approach is to use real-time eye tracking for improving interaction between learners and software character agents.

3. Education Interface by Real-time Eye Tracking

In the past,, Broadly defined, an intelligent tutoring system is educational software containing an artificial intelligence component. The software tracks students' work, tailoring feedback and hints along the way. By collecting information on a particular student's performance, the software can make inferences about strengths and weaknesses, and can suggest additional work

The functions of an ESA can be divided into those involving explicit or implicit outputs from the user, and those involving inputs to the user. In case of outputs from the user, empathy involves functions such as monitoring emotions and interest. In terms of output to the user, empathy involves showing appropriate emotions and providing appropriate feedback concerning the agent’s understanding of the users’ interests and emotions. Real time feedback from eye movement is detected by eye tracking, and the character agents use this information to interact with learners, exhibiting emotional and social behaviors, as well as providing instructions and guidance to learning content. Information about the learner’s past behavior and interests based from their eye tracking data is also available to the agent and supplements the types of feedback and input.

Analyzing eye movements provides information on how learners look at images, principally in terms of where they look and how long they spend looking at different objects. Changes in eye position can also be used to infer head movements. In our system, we use eye gaze information for both real time feedback and non real-time collection of eye-tracking statistics. The interface provides the multiple learner environment. The information of each learner is stored with ontology base and the information is sent to character agents. The character agents shares the information of the learners according to their learning states.(Figure 3)

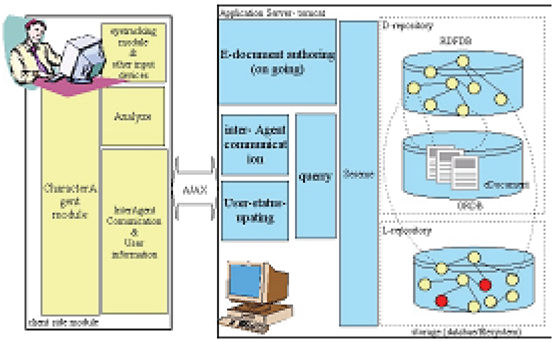

Fig. 3. The system structure

3.1 Real-Time Eye Gaze Interaction

Figure 3 shows how the character agent reacts to feedback about the learner’s status based on eye-tracking information. In this example, the eye tracker collects eye gaze information and the system then infers what the learner is currently attending to. This information is then combined with the learner’s activity records, and an appropriate pre-set strategy is selected. The character agent then provides feedback to the learner, tailoring the instructions and emotions (e.g., facial expressions) to the situation.

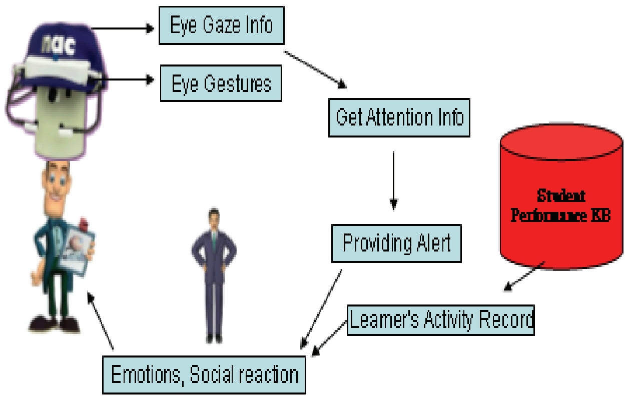

Fig. 3. Real-Time Use of Eye Information in ESA

We also show some examples of the functions using real time eye tracking in the system.

3.1.1 Topic Choosing

Information about where learners are looking can be used to infer interest and the current focus of attention. For instance, in Figure 4 there are three pictures or panels and the red circle indicates that the learner is looking at the middle one. If the learner "gazes" at that panel, which indicated by the eye dwell time being longer than a chosen threshold, then the system will treat it as a selection input and will zoom in and give more details on the associated topic.

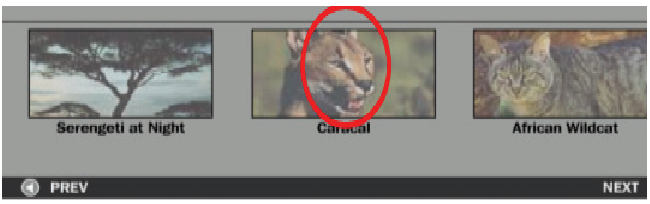

Fig. 4. Topic Choosing Interface

3.1.2 Awareness of learners

Human teachers are able to read body language and understand the psychology of the learner to some extent. E-Learning agents may also benefit from an awareness of user states and the ability to customize and adapt instruction accordingly. For instance, an agent may be "eye-aware", using information about eye movements, pupil dilation, and changes in overall eye position (head movements) to make inferences about the state of the learner. After determining the learner's eye position information and current area of interest or concentration, the agents can move around to highlight the current learning topic, in order to attract or focus the learner's attention. For instance, with eye gaze data, agents react to

Eye information in real time through actions such as moving to the place being looked at or by showing the detailed information content for where learners are looking at, etc.

For the multiple learner communication, the system use each learner' character agent to exchange learners' interests, attention information. Each learner has a character agent to repremation to the other learner (Figure 5). Durisent himself. Besides, each learner's motivation is also linked in the learning process. When another learner has information to share, his agent will come up and pass the inforng the interaction among learners, agents detect learner's status and use multiple data channels to collect learner's information such as mouse movements, keyboard inputs, voice, etc.

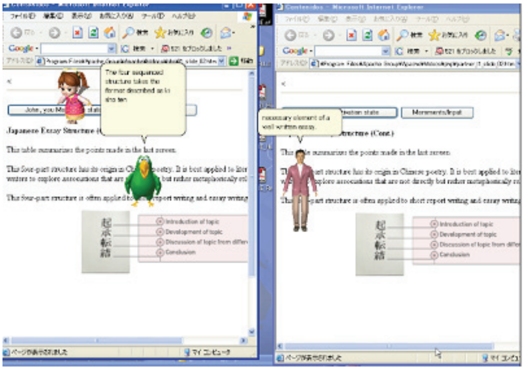

Fig. 5. multiple learner interfa

Also different versions of character agents are used to observe the different roles in the learning process. In the system, the size, voice, speed of the speech, ballon styles, etc. can be changed to meet different situations.

3.1.3 Motivation

The character agent can provide motivation as well as feedback or instruction. For instance, it can remind learners to concentrate on a topic if they keep looking away from the screen.

When learners show interest in the current content the character agents provide positive reactions. However, if a learner shows less interest which is indicated by a smaller amount of pupil dilation in the eyes or less activity in the eye movement, then the interface will inquire if the learner is tired or bored. Boredom or fatigue may also be inferred based on lower overall activity in terms of mouse clicks and key selections. Providing rest time or changing topics are other strategies that character agents can use to deal with situations where the learner appears to be bored or fatigued.

3.2 Eye Input

Eye information is also used as an input method in ESA.

3.2.1 Eye gestures

When learners want to give “yes” or “no” responses, or ask the questions, they can use gestures of eyes/head. If the position of the eyes (head) moves up and down this is taken to indicate a “yes” response, while moving left to right indicates a “no” response. When the head moves in a clockwise rotation, a questioning or uncertain response is inferred. When learners want to select or group the selections, they can use gestures of selection and grouping. By looking at the same place for more than a certain time, the point being gazed at is selected. The group function is used for selecting items of a category. First, the learner selects the Grouping mode and the targeted group, then s/he uses pointing gestures to select the items to put in the target group. This feature of ESA can be used to group learning contents of interest.

3.3 Eye-aware Character Agent

In our system, one or more character agents interact with learners using synthetic speech and visual gestures. The character agents can adjust their behavior in response to learner requests and, in some cases, inferred learner needs. The character agents perform several functions/behaviors including the display of different types of emotion. The agent’s emotional response depends on the learner’s performance. For instance, an agent shows a happy/satisfied emotion if the learner concentrates on the current study topic from their eye gaze information. In contrast, if the learner seems to lose concentration, the agent will show mild anger or alert the learner. The agent also shows empathy when the learner is stuck or gives a wrong answer. In general, the character agent interacts between the educational content and the learner. Other tasks of a character agent include explaining the study material and provide hints when necessary, moving around the screen to get or direct user attention, and to highlight information.

The character agents are “eye-aware” because they use eye movements, pupil dilation, and changes in overall eye position to make inferences about the state of the learner and to guide his behavior. After getting learner’s eye position information and current area of interest or concentration, the agents can move around to highlight the current learning topic, to attract or focus the learner’s attention. For instance, with eye gaze data, agents react to the eye information in real time through actions such as moving to the place being looked at, or by showing the detailed information content for where learners are looking at, etc. ESA can also accommodate multimodal input from the user, including text input, voice input and eye information input, e.g., choosing a hypertext link by gazing at a corresponding point of the screen for longer than a threshold amount of time.

ESA is currently targeted to Biology Online Education (Figure 5) and English Learning contents. The educational content within the system uses multimedia such as figures, flash animations, and video clips.

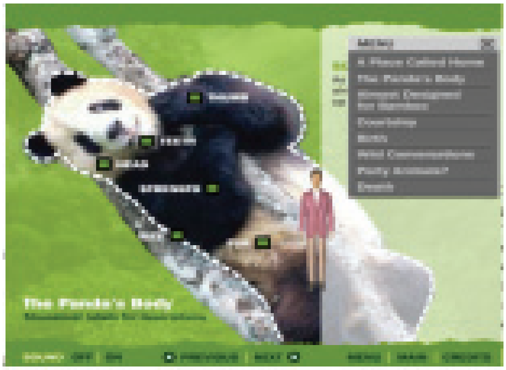

Fig. 5. Biology Content Interface

In our approach, different agents have different roles in the interface. When multiple characters are used they have different roles in the interface and interact with each other. There are primary agent (interaction agent) and secondary agent (student monitoring agent). The primary agent talks with students and explains educational contents to users (Figure 6). The secondary agent provides system-related information with the eye tracking information from learners. It manages the interaction based on if the learner is concentrating on the current topic and looking at the right content, or if the learner appears to be interested or bored by the current topic, etc.

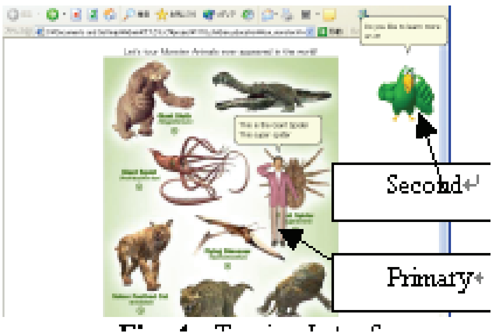

Fig. 6. Topics Interface

4. Implementation

For the character agents in ESA, we used the Microsoft Agent Engine to create the characters and also the emotions, movements and control functions, using the MPML agent control language [14]. Other approaches might also have been used. For instance, Huang, et al. [15] developed a character agent that interacted with people while they were browsing Web pages. Their system was constructed mainly from Java, JavaScript and XML. The eye gaze data is stored and transferred using an XML file. Here the serial Data is transferred to an XML file using the Com port and the information is then sent to the interface using JavaScript. During this process, the eye data is mapped to the screen position.

ESA uses a two-dimensional graphical window to display character agents and education content. The graphical window interface shows the education content, flash animations, movie clips, and agent behaviors. The Eye Marker eye tracking system was used to detect the eye information and the basic data was collected using 2 cameras facing towards the eye (Figure 7). The integration of eye tracking with other sensors in the system is shown in Figure 8. We analyzed the recorded eye tracking data with character agent reacting to Eye Information versus an implementation of the interface that did not provide eye tracking feedback.
Implementation for Database, (Ontology), the real time eye tracking information interaction

For the Server side, Apache tomcat (JSP) is used and Sesame RDF is used for storage and query engine (JAVA) At the client side, we use Microsoft character agent for creating agents' emotions, movements. JavaScript and AJAX are used to build the interactive contents which can get real time information and events from learner side. The knowledge base using Ontology is designed and implemented by protégé[16]. Ontology provides the controlled vocabulary for learning domain

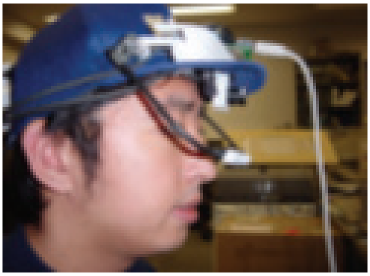

Fig. 7. Eye Tracker in the System

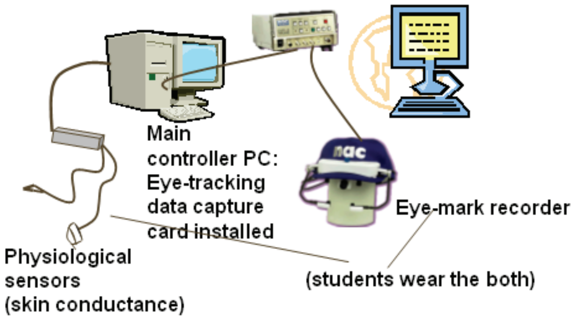

Fig. 8. Experiment Setup

5. Overall Observations

The tutor was often trying to achieve a combination of informational and motivational goals simultaneously. For example, hints and suggestions were sometimes used from getting the learners' attention information about what the learner wants to d. In a usability study of ESA, 20 participant participated using theversion of the multple learners support interface. They learned two series of English lesson. Each learning session lasted about 45 minutes. After the session, the subjects answered questionnaires and commented on the system.

We also investigated the areas where participants looked at, along with their eye traces (Figure 9). The figure shows the areas that people paid attention to. We calculated the number of eye gazes in each area and how the eye trace moved. Of particular interest were eye movement patterns where the learner's eye traces went to the character agent and then back to the learning content. This type of interaction showed that the learners could receive feedback from the character agent and could then return to the current topic without losing track of where they were. Analysis of the data showed that the eye position moves with the focus of the current topic fairly well showing that the learners were concentrating on the content being taught.

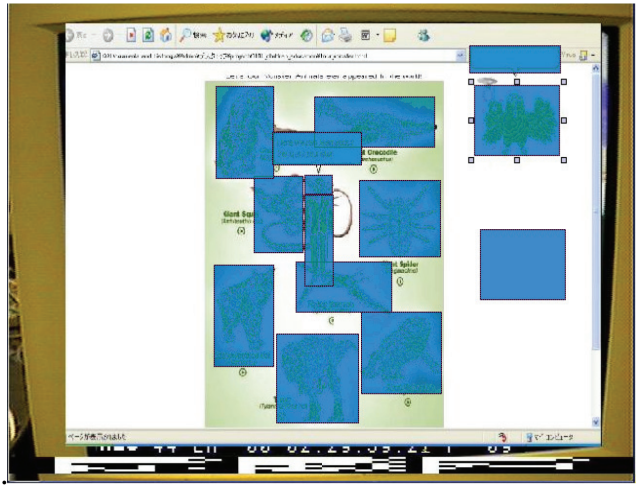

Fig. 9. Eye Traces on Different Areas

We analyzed the questionnaires and comments from the subjects, Participants felt that the interactions among the learners made them more involved in the learning process. They indicated that the information about how others are learning i, made them better able to participate on the learning topic. They also indicated that they found the character agent helpful in learning how to use the interface.

They also felt that the character agent sometimes provided too much information at once. They suggested that multiple agents may be helpful to solve this problem where each agent deals with different types of information and only one agent is speaking/active at any time. Participants in this initial study said that they found the character agents useful and that they listened to the explanation of contents from the agents more carefully than if they had been reading the contents without the supervision and assistance of the character agent.

6. Discussions and Future Work

By using the eye tracking information for the multiple users, learners can get other study partners's learning info, such have the feeling to interact with others. By getting information about learner response (such as eye movement data and bio-signals data), character interfaces such as ESA can interact with the learner more efficiently and provide appropriate feedback. From preliminary assessment of usability, ESA had a beneficial effect on learner motivation and concentration during learning. This result suggests that there may be a larger role for empathic tutor agents to play in acting as guides to learning content. Such agents can provide important aspects of social interaction when the student is independently working with e-learning content. This type of agent-based interaction can then supplement the beneficial social interactions that occur with human teachers, tutors, and fellow students within a learning community.

During the preliminary trials, we found that learners tended to pay attention to the explanation from character agents and found feedback about other learners' performance useful. They felt that they looked at the contents more attentively than without the feedback provided by character agents and this feedback made them more engaged with learning contents.

The current ESA system has some limitations. It is not convenient to carry eye trackers and some noise in the eye tracking data still exists. However, we believe that as eye tracking technology improves, it will become more convenient to use and will provide increasingly precise feedback. Aside from an explicitly educational context, real-time eye gaze interaction can be used in Web navigation. By getting what part of users are more interested in, the system can provide real time feedback to users and help them to get target information more smoothly.

Promising areas for future study include improvements to the collection of eye information and bio-signals, and analysis of video data recorded during online learning sessions to search for correlations between the video and eye tracking data. The use of multiple character agents within empathic tutoring systems represents another interesting direction for this type of research.

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Avatar Augmented Annotation Interface for e-Learning

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Abstract

Creating avatar-augmented presentations that extend gesture and annotation to distance education is laborious and time-consuming. We present Avatar Augmented Annotation (AAA), a project to design and share web based e-Learning materials using an animated avatar and digital inking. Using AAA, the instructor can create a presentation, using free-hand annotations that include high-level teaching behavior without doing any programming. The AAA then generates a script expressed in XML and augments the presentation with an animated avatar following each annotation. We found that AAA provides positive educational effectiveness and usability compared to previous online courseware.

1. Introduction

Today e-Learning, web-based teaching (WBT), and distance learning techniques are common in university classrooms[1],[2],[3]. These approaches enable students to learn in their own spaces and times[2],[3]. However another issue offset this advantage: interactions between students and teachers provide more educational effect[2],[3],[7]. If online teaching systems can't provide any interactions, students become bored with online coursework. Many students who take online coursework print out all web materials as exam period approaches in our experiences.

To address this problem, some interaction techniques are proposed. Many commercial online coursewares provide video and animation clips that have advantages over static web courseware. Several recent systems provide a "cyber teaching assistant" to improve the educational effect of static WBT material. The main advantage of classroom instruction over distance education is that students can easily observe gestures and annotations performed in live instruction. Shindo[2] developed CTA (Cyber Teaching Assistant) for a programming class that includes an animated avatar and scenario markup language. CTA responds to student questions and calls using previously defined scenario files from a database. Ray[3]

makes a course that uses an animated agent to guide students and emphasize specific teaching material. Ray found that students overwhelmingly preferred the animated lecture courses over other online courses they had taken. Mash[4] generates a script to control an MS-Agent avatar[6] without requiring the user to do any programming. In Mash, the user simply chooses gestures, types in the accompanying script, and saves the file.
Surprisingly, avatars may be a better approach than live video[7] – for example, this approach enables an instructor to update a presentation over time, without needing to keep the same suit of clothes in the closet! However, a key limitation of such systems is that the content provider must build avatar movement and interaction into web material manually using a script or other programming language. Creating these avatar-augmented presentations is usually laborious and time consuming. Mash used a parameter box to control the avatar, in which the user enters the physical parameter in the 'X', 'Y' field even though it doesn't require programming. Mash generates script for MS product and mash's format which can't be shared in other system.
Annotation can minimize such effort. Annotation (digital inking) is an important feature of a digital lecture or presentation system[1],[9]. Digital inking can capture the knowledge between student and teacher and easily share and reuse material[1],[9]. Webtour[5] allow to web document designer augmenting the contents with digital ink. Webtour records a user's drawing and supports playback with web media. This scenario is useful and cost effective. But, Webtour can only synchronize annotation itself without any animated agent.
Thus we believe that avatar augmented annotation tool for web-based teaching, can enhance learning effects of distance education and usability. We present the avatar augmented annotation (AAA) interface, which supports a method to design teaching scenarios and augment them using an animated avatar in web based learning materials. The instructor first creates a presentation, and then marks up the presentation using freehand annotations such as underlining, circling, and selects teaching behavior such as introduce, exit which be done by animated avatar. The AAA then generates XML based script to control the avatar movement. Finally AAA augments the presentation with an animated avatar that follows the annotations sequentially, drawing attention to the content that the instructor indicated.

2. Overview of Avatar Augmented Annotation

The overview of AAA interface shown in Figure 1.
As shown in Figure 1, AAA includes an authoring interface to make a scenario with avatar and annotation interface to allow a student to add his or her own knowledge or perspective.
On the authoring interface side, the key components are:

- Annotation recognizer to allow freeform drawing from scenario designer and determine its type.
- Script generator to control avatar movement and create avatar control markup language (XML) that includes high-level teaching behavior.
- Synchronizer to interpret the script and map avatar behavior to low-level avatar movement. Then synchronizer plays avatar lecturing on the HTML/XML document.

On the annotation interface side, the key modules are:

Annotation recognizer to determine marking type such as line, circle, note annotation from the student.
Annotation integrator to store marking as the markup language and print out annotation to the screen.

We describe each interface in detail in the following sections.

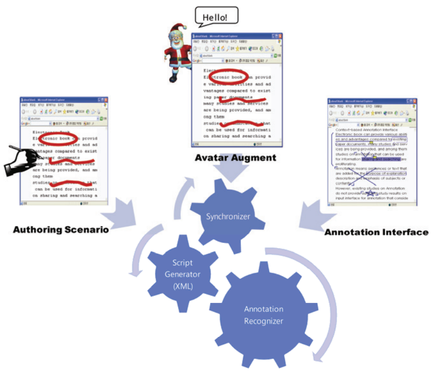


Fig. 1. Overview of AAA interface.

3. Avatar Annotation Markup Language

We define Avatar Annotation Markup Language (AAML) to express annotation and control animated avatar on web document. In AAA, instructor draws freehand annotations and adds comments. Then system creates annotation and avatar motion information represented in XML form. This approach allows users to more easily control the avatar behaviors, compare to previous efforts [2],[3],[8]. Creating scenarios using digital inking in the HTML/XML document requires that graphic information of the markings and context information of the original document be presented in the form of external links [9]. Through external linking, markings are saved independently from the original document and can be shared by multiple users. The overall structure of AAML is shown in Figure 2.
AAML includes 'meta' and 'annotationList' elements. A 'meta' element includes attributes for lecturer, lecture name, date and note. The annotationList element includes each annotation elements (Figure 3). Annotation has 'type', 'behavior', 'context', 'comment' and 'avatar' elements. The type element of an annotation expresses one of nine marking types, for example 'line', 'ellipse', 'highlight' and others. The behavior element describes a high-level motion set for describing avatar behavior in the teaching material.

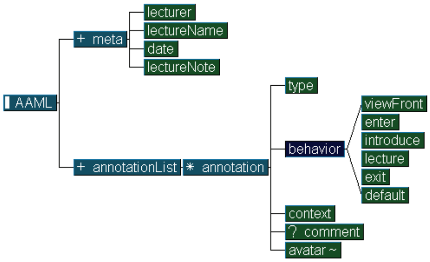


Fig. 2. Overall structure of AAML.

```
<annotationList>

  <annotation>
   <type areaSelect="false">
     <eiilipse color="16744576" page="1"/>
   </type>
   <behavior></viewfront></behavior>
   <context> <nonStructural>pop</nonStructural>
     <structural>
       <startingElement
         offset="138"path="/body[2]/chapter[0
         ]/p[3]/#text[0]"totalOffset="266"/>
      <endingElement
          offset="-43" ath="/body[2]/chapter[0]/p[3
            ]/#text[0]"totalOffset="264"/>
     </structural>
   </context>
   </avatar name="santa">
  </anntation>

</annotationList>
```

Fig. 3. An example of AAML document.

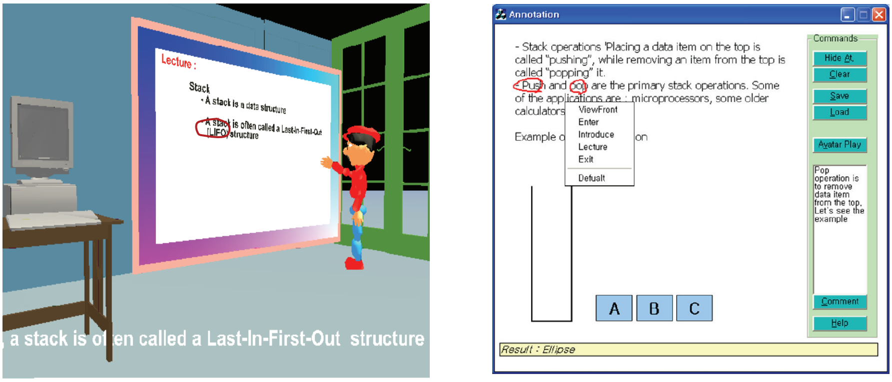
We define 5 kinds of behavior including ‘viewFront’, ‘enter, ‘introduce’, ‘lecture’ and ‘exit’ behavior. If the instructor does not select any behavior, the system selects ‘default’ behavior. Context elements include ‘nonstructural’ and ‘structural’ sub elements. A non-structural context has target (anchor) text. A structural context describes a point and offset within the annotated part such as Xlink and Xpointer.

4. Authoring Interface

In the authoring interface, the instructor first marks on the web content and then selects the teaching behavior of AAML such as introduce, exit, and others. The system generates a teaching scenario with AAML and web contents. The interpreter analyzes scenario information saved as XML and maps high-level motion of teaching behavior to low-level motion of avatar movement. Lastly, the authoring interface augments the animated teaching avatar to follow the annotation.

Figure 4 and shows a scenario for a data-structure course lesson on simple stack operations. Our prototype is based on a Window XP and XML document. This supports 3D-based avatar motion renderer (Figure 4(A)) or 2D-based MS-Agent[6] (Figure 4 (B)) and we will describe each interface in detail next.

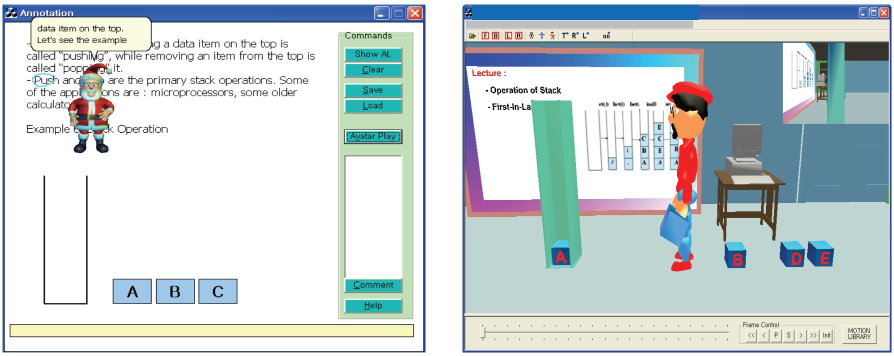
Figure 4 shows a screen shot of marking procedure by the instructor. The instructor draws free-form annotation and selects teaching behavior defined in AAML. In Figure 4 (A), instructor draws annotation on his interesting point. User draws marking on ‘push’ and ‘pop’ context with ‘Viewfront’ behavior selection in Figure 4 (B). He can add a comment that the avatar will pronounce when the avatar presents the lecture on the push and pop concepts.



(A) (B)

Fig. 4. Screen shot of authoring interface.

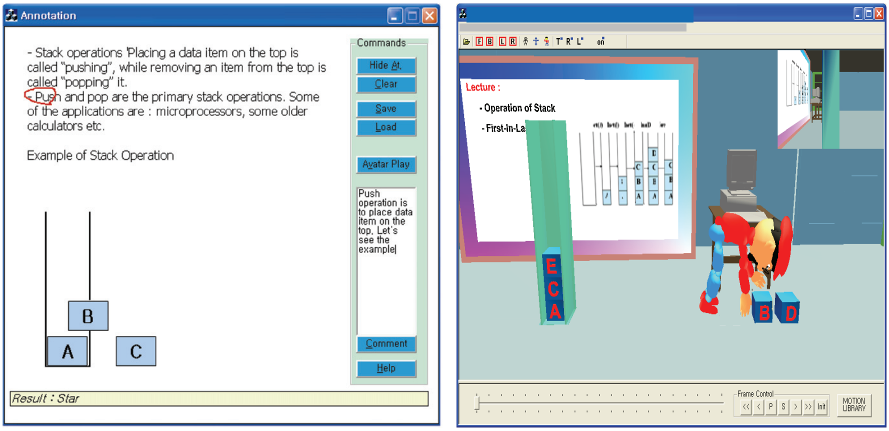
The AAA system generates a scenario script based on AAML after the user pushes the save button. The system recognizes the free-form marking type and analyzes the context behind the marking, which consists of element and physical position.
Figure 5 shows the avatar augmenting procedure after the user pushes the 'avatar play' button. Subsequently the system interprets high-level behavior of AAML and sends it to the avatar motion generator to generate low-level avatar movement. The motion-generator traces the positions of annotation anchors and creates a physical path to each annotation, in order to play back the avatar animation. This approach enables the instructor to design a teaching scenario without having to know a script language or to understand the system architecture in detail.



(A) (B)

Fig. 5. Avatar presents 'push' and 'pop' concept.

AAA supports synchronization between an animated avatar and a multimedia object. In Figure 6 (A), instructor moves each box to show the concept of pushing an element onto the stack. After that, AAA synchronizes the movement between a box and an avatar using internal rules (Figure 6 (B)).



(A) (B)

Fig. 6. An example of synchronization process.

5. Annotation Interface

AAA's Annotation interface is enables students to add questions, comments, critiques, and more using several annotation types. We used a context-based annotation engine[9] which include reorganization and integration modules for the HTML/XML document.

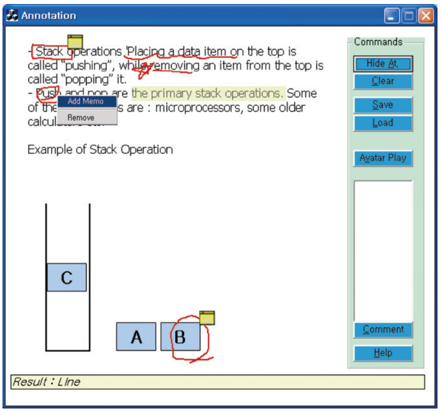


Fig. 7. Annotation Interface in AAA.

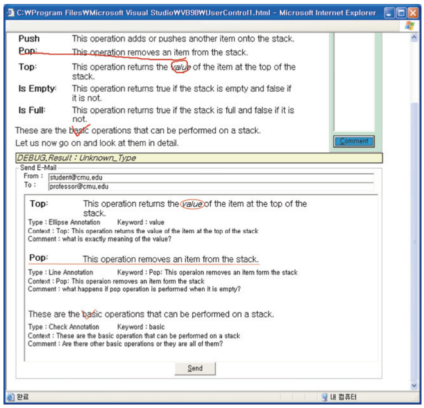


Fig. 8. Interaction techniques between instructor and student in AAA.

Figure 7 shows our annotation interface; students have added line, circle, and note annotations.

AAA provides interaction techniques that enable students to ask questions instructors to reply (Figure 8). To ask questions, students draw marks and type their question in a text input box. The system recognizes the marking type and extracts the context under the marking area to produce an image screen and send it to the instructor along with the question. Hence instructor doesn't need to check the annotation notes on the web site.

6. Summary of Usability Inspection

We conducted a usability inspection on our prototype using heuristic evaluation[11] with five instructors and seven university students. We built a small data-structure lesson using AAA to augment existing university online coursework[10]. We surveyed the instructor and students who had previously taken online data structure courses. The instructors were asked to design scenario. We demonstrated the AAA lecturing to the students and ask to add annotation. After the tests, a survey was done with 5 principles and 6 heuristics which include severity from 1 to 6. For items with severity less than 3, an empirical study was performed through separate survey. In the chapter, only the most important items from test results are summarized.

All five instructors commented that our approach was very interesting and they were satisfied with AAA's easy authoring interface. Four instructors suggested incorporating more real-world teaching behavior into AAA. One instructor pointed out if we would support synchronization functions between annotation and multimedia objects, it would takes too a great deal of time to build on existing material. For this reason, they recommended adding or substituting Flash or Java applets in AAA rather programming the synchronization.

All seven students preferred animated online courses to previous static web courses. Most students were satisfied that they could clearly understand the key point of the page they were shown. However some students disliked the necessity of animated teaching assistant in online courseware. They have to watch the avatar lecturing even though they can grasp the key point quickly. They commented that they would prefer to be able to choose watching the avatar or not.

7. Conclusions and Future Works

We have built an avatar augmented annotation (AAA) interface and investigated its effectiveness and usability. Our authoring interface enables an instructor to create a teaching scenario using digital inking annotation on 2D and 3B based web material. AAA generates a script for avatar lecturing which includes high-level teaching behavior. To do this, we define an avatar annotation markup language and support annotation techniques to lecture material. We found that AAA presents positive educational effectiveness and usability compared with previous static online courseware.

We acknowledge that there are significant technical issues with some of the features and methods as indicated from the user study. Our study applies to e-Learning, IETM (Interactive Electronic Technical Manual), Intelligent Tutoring System, and eBook. In future work we plan to develop a plug-in program to add our lecturing interface on existing web document.

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10

Developing screencasts and video screencasts for e-learning

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1. Introduction: screencasts & video screencasts

In 1995 Udell defined a screencast as a digital movie in which the setting is partly or wholly a computer screen, and in which audio narration describes the on-screen action. (Udell, 1995). Since then, thousands of screencasts have been recorded by internet users and software companies as tutorials, how-tos and demos.
While the popularity of this medium should be a measure of its quality, screencasting has been barely used for e-learning. E-learning products have preferred the usage of slides, or products based on slides, for a variety of reasons. Slides allow a more structured training, are easier to prepare, and maybe the most important reason, teachers are very comfortable in using slides.
So, applications like PowerPoint or Keynote have the feature of "narrated presentations" in which a presenter can record his voice with the pace of slides. This recording can be played later.
A concern in both solutions is that we don't see the image of a teacher. After all, when we go to a standard presentation we see the teacher or the presenter and we think it's important for us to see him and his gestures, not just getting the slides and his voice.
A layout including both a slide channel and a video channel showing the teacher, when delivered on a web page is called a webcast. So, webcasting applications use a slide and presenter layout to accommodate on a webpage of resolution no less than 800x600 both channels of information and a medium bandwidth. We will review some of them later.
Finally we could think on a convergence of the screencast model with the webcast model, then we can get the presenter or teacher y a screen capture of his computer into a web page that can be delivered over a limited bandwidth Internet connection. This setup is what we call a video screencast.
In this chapter we will review first the main characteristics and examples of webcasting products, and then we will present the Polimedia application from the Polytechnic University of Valencia, as an example for a video screencast application. Then we will address how this content can be delivered to mobile devices. After that we will present some tests regarding the quality and the usage of video screencast content and will finish this chapter with the conclusions on the work presented.

2. Content design for webcasting and video screencasting

When producing webcast content, we usually have a screen layout similar to the one that we present on figure 1. We have on the left (or maybe right) side of the webcast application a window of 320x240 in which we have a video of the lecturer and, in 640x480 or 800x600 pixels we have a “slide“ window in which students can follow the slides of the presentation. Using the same layout, an alternative approach is to use the slide window to present screen captures of a software application, typically the teacher’s PC screen.

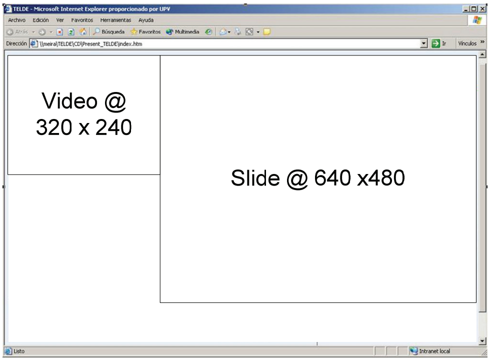

Fig. 1. Usual webcast screen layout

In this layout, the video channel is broadcasted using a standard streaming codec, while the slide channel is sent usually in an asynchronous way, using a standard format, like PNG. Here is important to remark that for the slide channel a lossless codec should be used, because the slide channel has text, and text is a set of thin lines that are smeared by lossy codecs, like JPEG.

A good example of webcast applications is Microsoft Producer, that is a PowerPoint extension written by Microsoft.

PowerPoint slides are the basic source that can be used within a Producer presentation, and the Producer add-on for Microsoft PowerPoint allows users to capture and synchronize audio, video, slides, and images, preview them, and publish them for viewing in Microsoft’s web browser. The output is HTML and Windows media video, with an optional XML description of the HTML files to enable a SCORM compatible learning management system (Dodds & Schawn, 2004). Figure 2 shows an example of a Producer presentation.

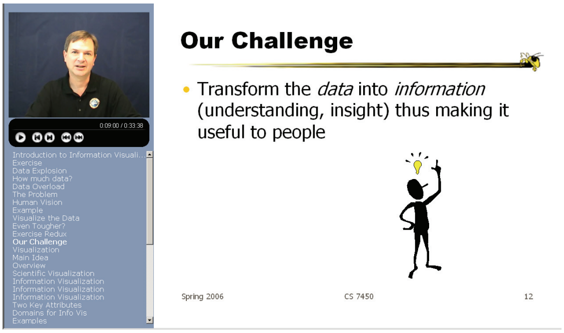

Fig. 2. MS Producer example

There are other similar webcasting products, and we can talk, as a reference, of Adobe connect, D-Lecture from the University of Bremen (Bodendorf et al, 2005) or the MIT webcast application (Huang et al, 2003). These applications work in a similar way as MS Producer having some advantages, mainly in terms of open distribution or open source licenses.

Another layout, which we use in our own video screencast application, called Polimedia, is to use a left slide window of 800x600 pixels in the left side, and a right video window of 320x480 pixels in portrait layout (figure 3). On such layout, lecturer can be fully captured and, by means of video chroma-key technique, he can stand on a more natural way near the slide show. It is also worth mentioning that the slide window is better used as another video stream, but with a lossless codec, giving low frame rate, but high resolution. So we get both smooth video and slide quality on the receiving side.

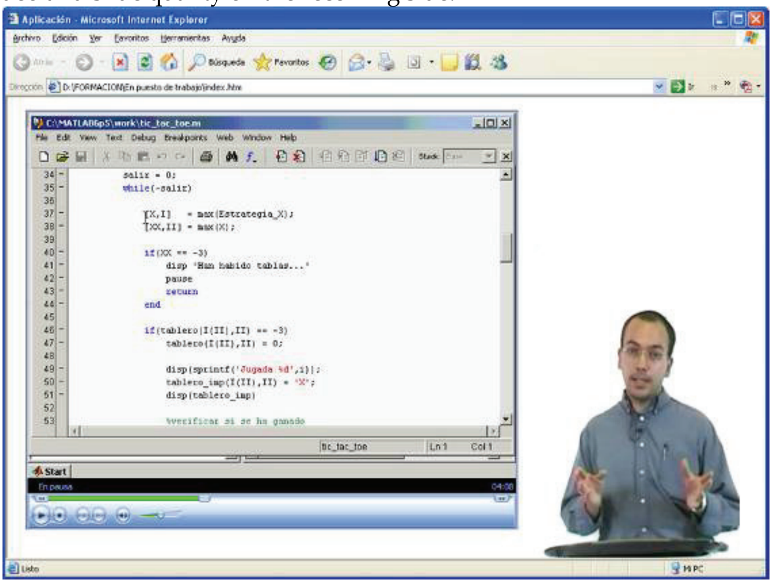

Fig. 3. Polimedia interface

Thus on the final product we have two windows on the PC screen. At the right side there is the teacher's image, captured with a resolution of 320 x 480 pixels and 25 frames per second, and at the left side is the PC's image, captured at a 800x 600 pixels resolution and 5 to 10 frames per second. Both streams are synchronized.
So, the right side is specially designed for slowly moving content, like slides, and computer demos, but also can display live video at a slow frame rate. The use of this slow frame rate allows us to use a lossless video codec, to achieve sharp images of the computer screen or, in the case of using a lossy codec to achieve more compression ratio, use a set of video compression parameters that allow us to maintain such video quality. On the other hand, teacher's video is compressed using a standard lossy codec, which provides us smooth movement and high compression ratio.
From teacher's point of view, recording a Polimedia object is as easy as arrive with a Powerpoint file, a laptop, or even a URL to our recording studio. There are two screens, on at the front of the teacher, and one at the right. In such position he or she will record the lesson and both streams will be recorded. In figure 4 you can see the set up for the studio with a photo of a live recording. Those sources are combined as shown previously to be broadcasted or recorded for future use.
Delivery of content is done through a web page that synchronizes two video streams through MMS streaming or a Flash Streaming Server In fact we don't use any proprietary capability of the Flash Server, so we can use an Open Source Flash Server, like Red5 (reference). The overall bandwidth of a Polimedia recording is of 512 Kbps.

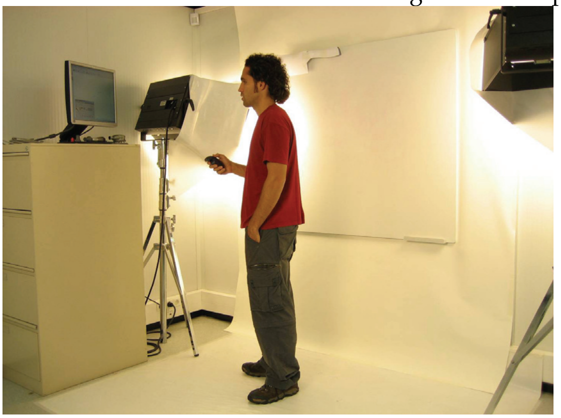

Fig. 4. Live recording on a Polimedia lab

At Polythecnic University of Valencia we use Polimedia jointly with our Sakai e-learning platform, while Polimedia can be used with any other e-learning platform, like Moodle. At today's date, 2814 Polimedia objects have been created by 228 different teachers on 6 dedicated production studios. All of these objects can be accessed through the Sakai e-learning platform of the University, extending its capabilities.
To allow the students to follow the subject we create a syllabus of the course content. This syllabus is stored on the Sakai E-learning server and points to the Polimedia clips, and students are to decide themselves when and how much time they want to allot to syllabus processing. The syllabus is divided into smaller units which can be processed in 10-20 minutes, therefore students' attention is ensured.

Students' work is directed jointly by the structure of the syllabus and navigation opportunities, so they need to be easily manageable and logically structured. The easy processing of the syllabus is ensured by jointly using Polimedia with a varied set of media (animation, video, ands simulation exercises) through any external e-learning platform.
In the case that a course will only use Polimedia resources we recommend to structure the course in modules, and the in lessons, as seen on figure 5. Each lesson will address just one concept.

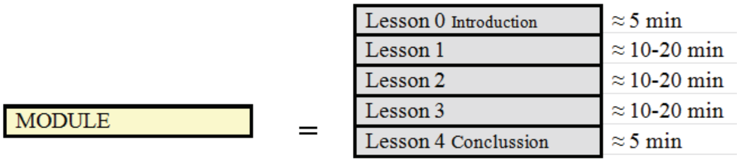

Fig. 5. Structuring a Polimedia course

Before each syllabus module, the students' level of knowledge should be tested by the e-learning platform to decide whether processing the particular syllabus is necessary or not. End of module testing is to show the success of knowledge acquisition. We made testing online through our Sakai platform.

3. Developing video screencast content for mobile devices

Mobile devices place special constraint for webcasts and video screencasts. Usually content for mobile devices has to be developed specifically, because of the limitations in size, processor speed and bandwidth of the receiving devices.
In order to reuse webcast content on mobile devices we have designed and tested an expert system that packs all media content into a video stream than can be viewed, at a 320x240 pixels video resolution (QVGA), and received on most smartphones and PDAs.
We have been unable to find similar systems on the literature. Machniki (Machniki et al, 2002) proposed an expert system to automate video switching on webcasts, and our idea is somewhat similar, but in a different context. Also Mukhopadhyay (Mukhopadhyay et al, 1999) proposed an expert system to segment video webcast content. Our system applies similar ideas specifically for mobile devices.
Our goal is to transform the original content from its initial state to a new state (new structure with new media formats) that takes into account the constraints of limited devices. Unfortunately, such techniques are usually not sufficient to guarantee a correct handling and presentation of the adapted content in particular for limited devices such as smartphones.
So, what we have done to produce quality content from both streams (slide and video) is to merge those streams into a smaller one, but positioning the video stream where there is less overlap with the slide content. As slide content is not static, we will change video stream location and size during the webcast. After this smart merging process we will compress the final stream using a 3gpp or mpeg-4 video codec. This process is depicted on figure 6.

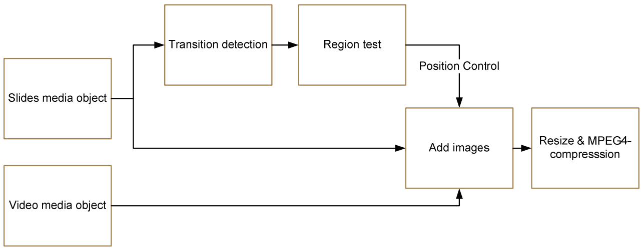

Fig. 6. Processing content

In order to do this process in a computationally feasible way, we have designed an expert system that uses four layout regions controlling the position, size and scaling of video media object into slide media object. Then video object overlapping is computed for each one on each slide transition, and the region with less overlap is selected. If none of them can be used, we will delete video, but not audio, from the slide stream until next transition.
Our layout regions are, as shown on figure 8, on the left with full body, on the left with half body and the same on the right side.

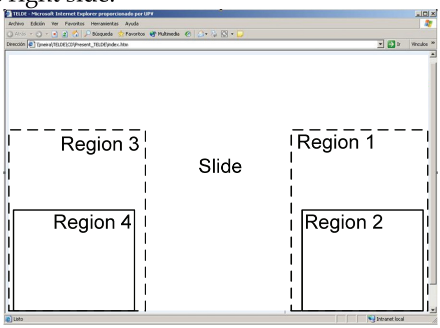

Fig. 7. Video regions.

In order to test our system we have performed two main tasks. First of all we have done an implementation of the system using MATLAB for scene detection and to select the best region between the four possible location and zoom combinations and then we have used Adobe Premiere Editing Decision Lists (EDL) feature to write a script that reformat and compresses all the content. A sample of an EDL for an e-learning content of about four minutes is shown on figure 8.
On that figure we can see thumbnails of the slide channel content and which region has been used for that content. It is necessary to point out that due to some limitations on Adobe Premiere, thumbnails on slide channel are presented at same size while there is a transition at some point in the middle of a thumbnail. For instance, the first transition point between Region1 and Region2 on figure 5 lies at 00:40, and is correctly presented at Region1 and Region2 channels, but it is incorrectly seen at slide channel.

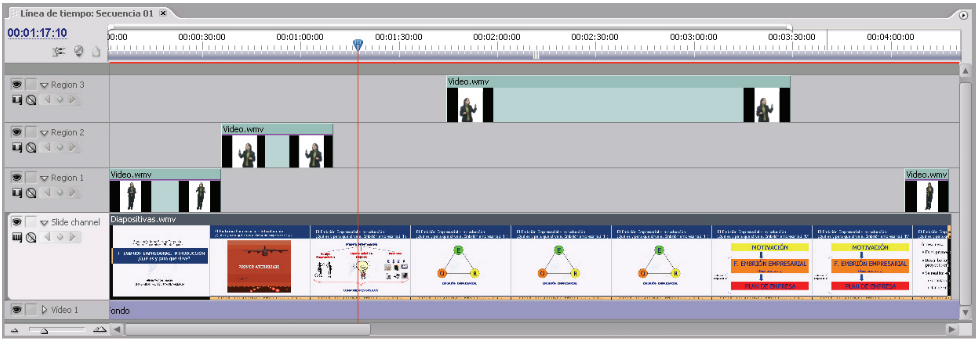

Fig. 8. Editing Decision List

Anyway we also see in this example that right-side regions are more used than left-side ones. This is reasonable because western languages are written left to right. In fact we have only used left-side positions on graphic slides.
It is also true that not all regions are used equally. In Table 1 we summarize our percentages after converting about 10 hours of slide and video content.
After that we have tested the quality of our process by means of a survey in order to find if people can follow properly the e-learning lesson. To achieve this we have compressed some videos to VGA size (640x480 pixels), QVGA size (320x240), for Smartphones and 176x208 pixels, as in most mobile phones. We have used VGA screen size content for reference and we investigate on the requirements for Smartphones and mobile phones. All videos have been encoded at 15 fps.

Region	% use
1	28%
2	42%
3	4%
4	10%
5 (none)	16%

Table 1. Region usage

So, taking as reference some content that users can follow properly at VGA resolution, we have asked our testers about the smallest character size they see comfortably. Results of this survey, shown on figure 9, show that most content can be read well on Smartphones, because people can see content written on a text font of 16 pixels size. On mobile phones we need a text font of at least 20 pixels size. This result means that if we want to develop content for mobile phones we have to design slides carefully and we can't reuse our original content directly.

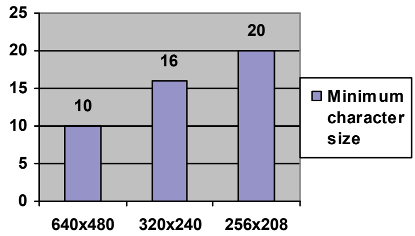

Fig. 9. Minimum character size

So we see that mobile phones can be too small for this kind of application, but Smartphones looks promising. Now, to know about the success of this kind of pervasive e-learning we have shown a 5 minute video sample from a course to a group of students using a Qtek Smartphone (figure 10) and afterwards then we have evaluated their knowledge on the subject with five questions about the subject.

Fig. 10. Receiving the webcast on a Smartphone

The screen of our Smartphone is just 2.8 inches with QVGA screen size and we think that it is a good trial platform for our application because of its small size. As shown on table 2, users follow properly the proposed course and pervasive video e-learning can be considered as a very useful technique.

	Scoring (5 Perfect, 0 Bad)
User 1	3
User 2	5
User 3	5
User 4	4
User 5	4
User 6	5
Average	4,33

Table 2. Average score

4. Effectiveness of video screencasts

We have much data about video screencasts usage at the Polytechnic University of Valencia. We will insight into that data and will obtain metrics and results from it.
In order to get evidence of usefulness for Polimedia we have focused on two indicators, the overall usage of all Polimedia content, and a course taught in two simultaneous instances, one with Polimedia and one with a live teacher.
For the first one, as can be seen in figure 11, Polimedia usage is constantly increasing, especially from the beginning of this academic course. We believe in this indicator as reference from both the student and the teacher side.

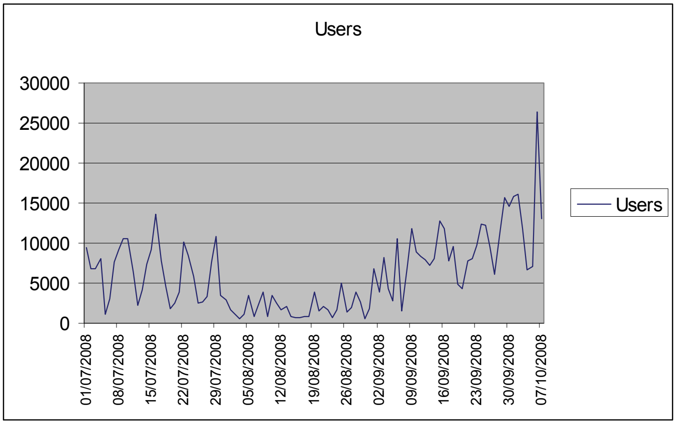

Fig. 11. Polimedia usage

For the second one, we gave a Microsoft Excel course between November and December 2008 to a group of students with the same teacher, syllabus and overall duration (with Polimedia you can replay teacher's explanation as you wish). Results for this experience are very similar in both cases, even having a little preference for Polimedia, as can be seen on Table 3.

	Classical learning	Blended learning with Polimedia
I have reached knowledge objective for this course	90%	90%
Course lenght is appropiate for Course content	85%	90%
Teacher's course can be considered as a good teacher	95%	95%
I wish I would have more presential sessions	N/A	25%
My expectations for this course have been satisfied	80%	85%

Table 3. Efectiveness of video screencasts

5. Conclusion

In this chapter we have presented the techniques of screencasting, webcasting and video screencasting in the field of e-learning. Following that we have had an insight on the video screencasting technique, both for networked PCs and for mobile hone and smartphones. Finally we have evaluated the video screencasting technique with very successful results.

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11

Distance Learning: New Opportunities for the Blind

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1. Introduction

The rapid growth of the Internet has created extraordinary opportunities for distance learning, further enhanced by the diffusion of mobile learning systems. Students especially appreciate the portability and overall ubiquity of electronic content, but they also value legibility, presentation and good design (Wilson et al. 2002). Furthermore, smart searches and other dynamic features (such as tag clouds and semantic data navigation) make content exploration quicker and easier. In this context, quality and enhanced facilities that are unavailable in paper format will fuel the future of electronic learning material.

Chats, blogs, Wikis, collaborative environments, assessment SW, podcasting, games, voting systems and more can be accessed on a laptop, palm device or cell phone—anywhere, anytime. Collaborative and cooperative technologies offer a particular contribution to the learning process. The trend is to create a Virtual Learning Environment (VLE) where students can collaborate and cooperate. Thus, to allow all users to enjoy these services, accessibility and usability principles should be applied when preparing materials and developing the interactive environment. Unfortunately, accessibility and usability have not progressed at the same pace as technology, and special-needs users risk missing out on this great educational opportunity. In particular, visually-impaired students still encounter difficulties when using e-Learning content, both on desktop computers and on mobile devices.

Accessibility and usability are fundamental when designing any user interface, but they are crucial for e-Learning systems, since technological barriers can hinder learning. Technology can support learning if it does not require additional effort on the part of the user. Specifically, the interaction environment should be transparent for users in the sense that it should not interfere with learning, or else the benefits of distance learning risk becoming worthless. When designing electronic learning materials (i.e. Learning Objects) and delivery systems (e.g. Learning Management Systems) it is crucial to identify the needs and requirements of the target community to create a system geared to the individual; based on user profiles, learning objects are delivered according to user ability.

In this chapter we focus on the needs of blind persons who interact via screen reader with voice synthesizer. For effective, efficient and satisfactory design (i.e. usable according to ISO 9241-11), developers must be aware of all the obstacles encountered by users aided by assistive technology and should map accessibility and usability criteria in e-Learning systems from the very earliest stages of the design process.

The chapter is organized as follows. First, the background is introduced: the main problems encountered by blind people when interacting by screen reader, basic accessibility and usability principles, and an overview of studies in this field. Next our discussion focuses on specific guidelines related to e-Learning methodology and systems, also showing two examples of using standard technology for enhancing the experience of the visually impaired. Last, the conclusion discusses future research trends and opportunities.

2. Interacting via Screen Reader: user needs and requirements

A screen reader is an assistive technology used by the visually impaired to interact with a computer or other electronic devices, such as mobile phones. The screen reader interfaces the user with the operating system and the applications. It interprets the user interface (UI) content which is read aloud sequentially by means of a voice synthesizer, or written using a Braille display. However, Braille output is extremely slow and is rarely used (by less than 10% of the blind population, Lee 2004).

Popular screen readers are: JAWS for Windows (http://www.freedomscientific.com/), Windows Bridge (http://www.synthavoice.on.ca/), Windows eyes (http://www.gwmicro.com/) and Hal for Windows (http://www.dolphincomputeraccess.com/). In the following we refer only to JAWS for Windows. Henceforth, we will use the term "screen reader" to indicate a screen reader with voice synthesizer.

Web navigation is still quite difficult for blind persons using a screen reader, as pages are read sequentially one line at a time, starting from the top left-hand corner of the page, losing all layout, style and font information (Goble et al., 2000). In particular, interaction with e-Learning environments is even more difficult due to the complexity of their interfaces, rich in functions and options, and the time it takes to perform even a simple action. More precisely, non-visual perception can lead to many problems:

1. Content serialization. The screen reader reads contents sequentially, as they appear in the HTML code. This process is time-consuming and annoying when part of the interface (e.g. the menu and/or the navigation bar) is repeated on every website page. As a consequence, blind users often have to halt the screen reading at the beginning, and they prefer to navigate by Tab Key, from link to link, or explore the content row by row via arrow keys.
2. Content and structure mixing. The screen reader announces the most important interface elements such as links, images, and window objects as they appear in the code. For the blind user, these elements are important for figuring out the page structure. However, the actual reading process can overload the user, requiring considerable cognitive effort. If the table's content is organized in columns the screen reader (which reads by rows) announces the content of the page out-of-order, and consequently the information is confusing or misleading for the user.
3. Lack of context. When navigating by screen reader the user can access only small portions of text and may lose the overall context of the page; thus it may be necessary to reiterate the reading process.
4. Lack of interface overview. Blind people do not perceive the overall structure of the interface, so they can navigate for a long time without finding the most relevant

content. To resolve this problem it is necessary to structure the HTML code appropriately (for instance using ARIA regions as discussed in the following), add hidden labels, and apply other features to improve navigation.

5. Difficulty understanding UI elements. Links, content, and button labels should be context-independent and self-explanatory.
6. Difficulty working with form control elements. For instance, the order in which the user visits form elements (e.g. via Tab Key) should reflect the logical order in which the user fills out the form. If possible, make the user able to jump to a group of homogenous elements (for instance, using ARIA regions as discussed in the following).
7. Lack of visual perception. For accessing multimedia content such as video streaming or video conferencing, appropriate educational-equivalent textual alternatives should be provided.

Designers of e-Learning systems must consider three crucial factors: usability, accessibility, and educational effectiveness. Consequently, the challenge is to design systems that are accessible to everyone and simple to use while maintaining pedagogical and educational efficacy. In particular, blind students may fruitfully utilize e-Learning systems if educational materials are accessible and learning paths can be tuned to the "rhythm" of the individual student.

When designing for blind users, it is necessary to consider the three main interacting subsystems of the Human Processor Model: the perceptual, motor and cognitive systems (Card et al., 1983). Sightless persons perceive page content aurally and do not interact using a mouse or other pointing device since they only navigate via keyboard. This can make the "reading process" time-consuming, difficult and frustrating, if the content is not designed with special attention to their needs. Analyzing the cognitive part of the interaction is important, since many learning techniques are only relevant for sighted people. Thus, alternative ways to deliver the same content should be provided. Furthermore, a blind person may develop a different mental model of both the interaction and the learning processes, so it is crucial to provide an easy overview of contents.

3. Accessibility and Usability

A Learning Management System is accessible if everyone, including the differently-abled, can access and use all its contents. Designers must be aware of "technical barriers" that a disabled user may encounter when interacting with the system. Specific examples of web barriers for the blind are:

- non-textual content without an equivalent alternative text, for instance video, complex graphs, charts, diagrams with poor or no description (see Fig. 1)
- active elements that do not receive the focus (e.g. dynamically created widgets)
- dynamic applications (Ajax, Asynchronous JavaScript and XML) that change only a portion of the UI and are not announced by screen reader
- graphical alert boxes that are not perceived by screen reader (no alternative text).

Accessible design is not only for the differently-abled but benefits every user. For instance, a person may experience temporary disability due to a medical condition (for instance, after an accident or suffering a medicine's side effects) or may experience reduced perception due to distractions or to performing activities simultaneously (noisy environment, using a cell

phone while driving a car, etc.). Furthermore, as the age of the user population rises, accessibility becomes even more critical.
However, accessibility alone does not guarantee satisfactory use: removing obstacles to access on-line content or services is a prerequisite, but usability completes the design, making a system simple to understand and easy to use. Usability addresses multiple aspects of the interaction including the application domain and user tasks.
Usability principles are extremely important in the educational field where students need to concentrate on the learning process without spending time and effort orienting themselves on the user interface. With an e-Learning system, the same content still has to reach every user. For instance a learning object may be delivered by different media according to student ability, taking great care that textual information (of non-textual content) is educationally equivalent to the original version.
In 1993, five general usability criteria were proposed by Nielsen (Nielsen, 1993):

- Efficiency in carrying out tasks (speed and cognitive effort)
- Errors (few easily recoverable errors)
- User satisfaction
- Memorability of visited items and functions (next time the user accesses the system)
- Learnability, the ability to be proficient quickly, which impacts on performance of novice users.

Compared to interaction with stand-alone applications (with homogenous UIs), the Web poses another difficulty due to interconnections between different sites. In fact, links enable the user to move in one step (mouse click or enter key pressing) from one site to another where the logical organization of the content may be inconsistent, and no guidelines are provided for ensuring inter-application coherence (Scapin et al., 2000).
If taken into account early during the design and development phases, applying accessibility and usability principles requires much less effort than doing so later. However, to be effective, abstract principles need to be expanded into specific guidelines in order to be concretely applied to web sites or systems.
Usability is only one important aspect of a website; also important are content, functions, and popularity. However, usability is crucial in the decision to choose/discard a website: even when the same services are provided, a user will choose one that is most effective, efficient and satisfactory (Nielsen, 2001).
For evaluating accessibility and usability different techniques are commonly used including:

- Automatic/semiautomatic inspection of web content (for instance Markup, CSS and accessibility validators). However, the validator output requires a human control for problems not automatically verifiable.
- Usability inspection (Nielsen, 1994) refers to evaluators (usability experts) analyzing the interface to verify its conformance to a set of principles of usable software design (such as heuristics and cognitive walkthroughs). This approach detects a high percentage of problems and it is easy to implement. However, general principles need to be embedded in the design context. For instance, Squires and Preece (Squires & Preece 1999) embedded usability heuristics proposed by Nielsen in the socio-constructive theory and specified criteria ad hoc for e-Learning .
- Usability testing with users is an efficient method for identifying interface issues. Objective and subjective user tests are possible. Integration of these techniques improves accuracy of results.

Objective usability testing relies on measuring user performance when carrying out a set of tasks. It may be costly since it requires HW/SW for carrying out the test in the lab, collecting and analyzing log files server/client-side and/or recording user actions. An alternative, which considerably reduces the cost, is remote evaluation. The validity of remote testing vs classic laboratory usability testing is a widely discussed topic in literature. Recent studies have shown that during remote testing, users take a bit longer to complete tasks due to the communication overhead, but that results are just as effective as, if not better than, traditional testing in the laboratory (Thompson et al., 2004).

Subjective usability testing measures user satisfaction, for instance by means of questionnaires and interviews.

3.1. Accessibility guidelines

The main objective of the World Wide Web Consortium (W3C, http://www.w3.org/) is to "Bring the Web to its full potential…" while allowing satisfying access to anyone "anytime, anywhere, under any condition, regardless of any disability". Unfortunately accessibility barriers seem to increase over time while websites become more and more complex (Hackett et al. 2004). To counteract this trend two ingredients are necessary:

- accessibility and usability must evolve on the base of the definition and evolution of new protocols, languages and standards
- Web designers must incorporate accessibility and usability into their web systems.

The first point is addressed by the WAI group of the World Wide Web Consortium which define guidelines for web content, authoring tools, and user agent design.

Web Content Accessibility Guidelines (WCAG) version 2.0 are general principles for making Web content more usable to people with disabilities (W3C, WCAG 2.0). The guidelines are grouped into four categories: perception, interaction, comprehension and robustness, as shown in Fig. 1. Unlike the previous version (1.0), criticized by several authors (Sloan et al., 2006), (Leuthold et al., 2008) for addressing only web accessibility, WCAG 2.0 consider the full interaction and navigation paradigm, thus including usability principles for guaranteeing effectiveness, efficiency and user satisfaction to all.

1. **Perceivable**

   1.1 Provide text alternatives for any non-text content so that it can be changed into other forms people need, such as large print, Braille, speech, symbols or simpler language

   1.2 Provide alternatives for time-based media

   1.3 Create content that can be presented in different ways (for example simpler layout) without losing information or structure

   1.4 Make it easier for users to see and hear content including separating foreground from background

2. **Operable**

   2.1 Make all functionalities available from a keyboard.

   2.2 Give users enough time to read and use content.

   2.3 Avoid designing content in a way that may cause seizures.

   2.4 Provide ways to help users navigate, find content, and determine where they are.

3. **Understandable**

3.1 Make text content readable and understandable.
3.2 Make Web pages appear and operate in predictable ways.
3.3 Help users avoid and correct mistakes.
4. **Robust** (consistency, inter-operability)
Maximize compatibility with current and future user agents, including assistive technologies.

Fig. 1. WCAG 2.0 Guidelines - Source W3C

To overcome problems of navigation via screen reader and interaction via keyboard, the Web Accessibility Initiative (WAI) group of the World Wide Web Consortium developed ARIA, the Accessible Rich Internet Applications (WAI-ARIA) Suite (W3C, ARIA), which enhances usability and accessibility for the blind. ARIA makes dynamic content such as AJAX (Asynchronous JavaScript and XML), (X)HTML and related technologies more accessible to the disabled, especially people interacting via screen reader and keyboard (W3C, ARIA).
We do not discuss the WCAG 2.0 Guidelines in detail, as they are available online (W3C, WCAG 2.0). Each guideline is general and can be applied to more than one element. To conform to WCAG 2.0, developers should refer to the "Techniques for WCAG 2.0" document, which contains techniques and failures grouped in general (applicable to any technology) and specific (i.e. Plain Text, (X)HTML, CSS Client/Server-side Scripting, SMIL, ARIA) Techniques.

3.2. Accessible Rich Internet Applications

As discussed in the ARIA best practices document (W3C, ARIA), ARIA offers the following advantages for navigation via screen reader:

- Quicker and easier page navigation. Using standard (X)HTML code, blind users are forced to press the Tab key many times to access active elements (e.g. form elements, links). To simplify interaction and allow easy jumping to main interface regions, developers usually create a link to the main content or use heading levels to structure the page (since the screen reader has a command for showing a table of headings). However, headings have a different purpose and their use to mark sections is not consistent across web sites (W3C, ARIA). Instead, ARIA allows marking sections with standard specifying XHTML landmarks (main, navigation, search, banner, contentinfo, etc.) or defining customized regions, if they do not appropriately reflect the aim of the region (e.g.: <div role="main" title="Chemistry Experiments">).
- using landmarks/regions the user is able to get a page overview (“Ctrl+Ins+;” command in JAWS v.10). This also allows simplifying navigation via keyboard since the user may jump from one region to the next by pressing a key (in JAWS v.10 the “;”).
  Furthermore, the developer using the attribute “flowto” defines the order in which regions should be visited. For example <div role="region" title="Chemistry Lab" flowto="Exercises" >
- reduces user overload, since it is possible to select sections be announced (reducing the amount of unnecessary text announced). Specifically, the use of an (X)HTML element (such as a table) as layout may be silently ignored by the screen reader if it is tagged with the presentation role.

4. Related Work

In recent years e-Learning has become an important research topic. E-Learning is a great opportunity for visually-disabled people, provided that both the interactive environment (created by the LMS) and the learning objects are properly designed and delivered.

Numerous user studies suggest that totally blind people encounter more difficulty than those with other sensorial disabilities (e.g., low vision, motor or hearing impairments) when executing specific tasks (Petrie et al., 2004), (Craven & Brophy 2003), (Ivory et al., 2004). Petrie et al. (Petrie et al., 2004) presented the results of accessibility testing of 100 websites with users who had either visual, motor or perceptual disabilities, showing that websites that are accessible for differently-abled users can also be visually pleasing. Specifically, 100 websites spread out over five sectors were tested with automated verification and user testing, involving 51 differently-abled users, 10 of whom were totally blind. Results showed a mean task success rate of 76% that fell to 53% (the lowest score of all the user categories) when considering only the totally blind. Likewise, regarding user satisfaction, the authors recorded that the blind users encountered more difficulty than other differently-abled users (4.2 on a 1-7 Likert scale, the lowest score of all the user categories). Researchers at Manchester Metropolitan University (Craven & Brophy 2003) highlighted issues of non-visual access by studying a sample of blind and visually-impaired users who performed four information-seeking tasks, including the use of search engines. Visually-impaired users searching the Web for a specific piece of information took an average of 2.5 times longer than sighted users. The efficiency gap was further quantified by Ivory et al. (Ivory et al., 2004); when blind subjects carried out a set of tasks, they took twice as long as sighted users to explore search results and three times as long to explore the corresponding web pages.

An interesting study on improving interaction for the blind was proposed by Leuthold et al. (Leuthold et al., 2008) who defined nine specific guidelines for building "enhanced text user interfaces" (ETI). With a user test involving 39 blind users, authors evaluated efficiency, errors and user satisfaction of a web UI developed according to ETI guidelines with respect to WCAG 1.0-compliant GUIs. Results showed that ETI guidelines enhanced experience for the blind in the search task while a similar result was not found in the navigation task. However, authors did not provide users with a page overview, the main feature for orienting and guiding users in the navigation.

Today developers use two strategies for enhancing interaction via screen reader: (1) inserting a link to skip at the main content and (2) using heading levels to provide an interface overview. Heading levels improve interaction since screen readers have special commands for showing the headings list (f.i. Insert+F6 JAWS command) and moving from one heading to another. Brudvik et al. present an interesting study on how sighted users associate headings with a web page, observing very different results depending on factors such as whether the page has a hierarchic structure, how users identify sections, etc. (Brudvik et al., 2008). Furthermore, authors applied techniques of information retrieval (i.e. training data and a classifier), developing a system for automatically inferring from the context (font, size, color, surrounding text, etc.) whether a phrase "works semantically" (and may function) as a heading, and dynamically adds the heading level using Javascript. The system called HeadingHunter was evaluated using human-labeled headings gathered from the study and showed high precision (0.92 with 1 the max). However today ARIA may perform the same functions (i.e. structuring the interface for a page overview and rapid section navigation) allowing a kind of inter-website coherence, if standard landmarks are applied in different websites (see section 3.2).

Despite numerous accessibility and usability studies, even today various researchers perceive the lack of accurate studies in the e-Learning field (Ardito et al. 2006), (Zaharias 2006), (Kelly et al., 2005). Specifically, Ardito et al. outlines a methodology for the rigorous evaluation of e-Learning applications, but accessibility for special-needs students is not analyzed. Furthermore, Zaharias critically examined the usability of e-Learning applications and proposed a new usability measure: the student's intrinsic motivation to learn. Developing a usability evaluation method based on a questionnaire, he carried out two large empirical studies showing the reliability of this approach (Zaharias 2006). For Sloan et al. the goal of universal accessibility on the Web is inappropriate and instead it is necessary to explore multiple routes to provide equivalent experiences (Sloan et al., 2006). As Kelly et al. argued, rather than demanding that an individual learning resource be universally accessible, it is the learning outcome that needs to be accessible (Kelly et al., 2005). Based on user profiles, metadata and dynamic connection to resources, the user's experience can be customized to match his/her abilities.

De Marsico et al. (De Marsico et al. 2006) defined methodological guidelines involving users with disabilities as well as pedagogical experts in the development process, believing that input of different kinds of know-how would enrich the quality of e-Learning applications and provide a more satisfying learning experience. They also include two examples of building and providing learning objects that are accessible to visually- and hearing-impaired students respectively.

Rodriguez et al. describe a project aimed at improving the e-Learning experience for the visually impaired, based on ethnomethodology and taking into account psychosocial issues, user context and experience (Rodriguez et al., 2006). Next they created different learning object formats suitable for the blind, including DAISY (Digital Accessible Information SYstem). However, although the authors describe the methodology used to improve learning materials, no general guidelines are offered to the reader.

Within the framework of a project aimed at providing an accessible e-Learning platform for disabled and adult learners, Santos et al. (Santos et al. 2007) illustrate a methodology for developing standard-based accessible courses using two-step evaluations. However for the totally blind, more specific UI features are necessary, such as providing a page overview, full control of interface elements and easy and rapid navigation via keyboard.

Furthermore, the rapid evolution of communication technologies has also led to the widespread diffusion of mobile devices (especially cell phones) in developing countries. For this reason mobile learning (m-Learning) promises to help narrow the educational digital divide in rural or economically depressed areas. M-learning denotes the use of learning systems from mobile devices which have reduced resources such as screen, keyboard, and connectivity bandwidth. Debevc et al. (Debevc et al., 2008) provided basic guidelines for designing and structuring accessible m-Learning applications for people with special needs (including the blind), taking into account basic human-computer interaction factors. Arrigo et al. describe a mobile learning environment, AMobiLe, designed for social integration as well as collaborative learning among all students regardless of type of disability. The authors argued that it is necessary to take a broader view of communicative and social needs as well as consider the overall capacities and knowledge of disabled users instead of only focusing on technological barriers and assistive technology (Arrigo et al. 2008). Last, Glavinić and Granić investigated the adaptivity of knowledge representation, interaction style and mobility support within the framework of an e-Learning research project, including usability evaluation methods, techniques and results. The main hypothesis of this work is that intelligent interaction as an adaptation to users' individual characteristics and needs, as experienced through her/his behavior during interaction, can lead to a more efficient, effective and humane ICT-supported education (Glavinić & Granić 2008).

5. Accessibility and Usability of e-Learning systems

The e-Learning system itself as well as the content should be adapted to the users' abilities.

Pedagogically speaking, we should remember that the learning process itself is the main focus of e-Learning-based education methodology. Students should be able to concentrate on content and educational activities. If system components are suited to the user's capabilities, difficulties interacting with the virtual environment can impact on student performance.

An e-Learning environment basically consists of: (I) the integrated system (i.e. the container, which provides the content and interactive activities) and (II) the Learning Object (LO) - the educational content provided through the e-Learning interactive systems.

Consequently, when designing an e-Learning environment two important aspects should be kept in mind:

- Accessibility and usability of the system, i.e. the "container" providing content and activities for the participants should be easy to use
- Accessibility and usability of content, that is the texts, documents and interactive tools used for didactic purposes should be created according to the various users' abilities.

If either of these two aspects is unavailable, interactive distance education methodology is ineffective for people who must interact using assistive technology. This is particularly significant for blind users who interact by screen reader.

5.1 Learning Management Systems

A Learning Management System (or LMS) is a software package that enables the management and delivery of on-line content to learners. Most LMSs are web-based to facilitate "anytime, anyplace, any pace" access to learning content and administration. Typically an LMS provides student registration, access to learning activities, and evaluation and assessment in an on-line environment. Both commercial and free platforms are developed. Open source and Web-based LMS software solutions are growing rapidly in the education and business worlds, offering:

- Quality, thanks to the collaborative effort of many people in designing, developing and maintaining the system
- Use of standards and thus interoperability
- Portability in different platforms.

In addition to managing the administrative functions of on-line learning, Learning Management Systems also provide tools for delivering instructor-led synchronous and asynchronous on-line training (Learning Content Management Systems). An LCMS provides tools for authoring content as well as virtual spaces for learner interaction (such as discussion forums and live chat rooms).

Often, when considering accessibility issues only disabled students are considered, and only LMSs are taken into account. Instead, people with disabilities may also be teachers, who must be able to create and manage the materials used in distance courses. Thus LCMS authoring functionalities should also be accessible to and usable by assistive technologies. In the following we discuss accessibility and usability features referring to both kinds of platforms (LMS and LCMS).

Since the user interface of an e-Learning system is usually based on Web technologies, at first glance it may appear sufficient to apply web accessibility guidelines. Actually, regarding the most widespread e-Learning platforms, some considerations can be made concerning technical aspects:

- Student tracking: provides information about individual use patterns of the participating students. Scorm-based platforms use javascript technologies for tracking activities. Since most e-Learning systems – such as Moodle (http://moodle.org/), aTutor (http://www.atutor.ca/), and so on – are scorm-based (implemented with javascript), the use of ARIA is thus crucial to assure the accessibility of these systems.
- Hidden frames: several e-Learning platforms use hidden frames for storing data to communicate to the Web server. Although according to usability principles frames should not be used, appropriate design suggests using a few hidden frames and positioning them after the frames containing the learning objects. In order to further simplify interaction, it is useful to give appropriate names to all the frames.

5.2 Learning Objects

A Learning Object (LO) may be defined as any entity, digital or non-digital, that can be used for learning, education or training (IEEE/LTSC). A Learning Object can be as small as a paragraph or as large as a complete online course and come in the form of HTML/Text files, simulations, JAVA, Flash, QuickTime movies etc. Depending on the format and complexity of an LO, guidelines and principles should be applied to make them accessible and usable as well.

Apart from technical accessibility, we think that another issue should be considered when developing a Learning Object. Since the main goal of e-Learning methodology is education, a LO should be designed to best exploit the user's abilities. For instance, for a sighted child an image or animation is probably more effective than a descriptive LO whereas for a blind child an audio object is much more effective than a textual one. Thus, the way a Learning Object is designed and structured is very important. In this case it could be made more effective by using different LOs for different users' abilities and skills. Further study is needed to define the best approach for developing accessible and usable LOs.

Moreover, we believe that most difficulties arise from simulation activities. Simulation systems and LOs can present various technical accessibility problems, and a target study in this direction could prove useful.

6. Application domain: Design principles

For blind users to benefit fully from distance education in a collaborative and cooperative manner, e-Learning systems must be made both accessible and usable. Both the interactive environment and the educational materials must be adequately developed, so appropriate guidelines, requirements and suggestions should drive the design phase.

The main objectives of the accessibility and usability principles contextualised for e-Learning are (1) to remove or minimize the potential negative effects deriving from interaction with the UIs through assistive technologies, to avoid compromising the learning process and (2) simplify user interaction.

6.1 Requirements

First of all, the designer should keep in mind how blind users interact with the system: that is, via screen reader and with a keyboard. These interaction modalities mean that various issues should be considered when developing and structuring interfaces and content. Furthermore, in order to move quickly around the page content, a blind person prefers to use the Tab key to jump from one interactive element to another, rather than explore content via arrow keys.

Objective difficulties can be reduced or eliminated by presenting the same content in aural form and providing multiple ways to navigate faster. To guarantee better navigation around the content, the interface and functionalities should be developed so that user interaction is simplified or minimized. Thus, some information could be provided automatically in aural format so that the screen reader is informed about the UI changes. Audio or vocal feedback, as well as the new ARIA suite, could improve perception of some announcements or messages. Particular attention should be paid to multimedia content and interactive activities (e.g. exercises, collaborative work, editing, and so on). Generally speaking, accessibility and usability principles aim to ensure that the content and all didactic tools are also available for students who are obliged to interact via screen reader.

The following principles attempt to be as general as possible, i.e. applicable to both systems and content. However, since Learning Objects can be prepared using several modalities and techniques and can refer to various kinds of materials they may require specific analyses and targeted criteria. Proposed criteria only express general principles; to provide more specific indications, further studies and evaluations should be conducted.

6.2 Basic general principles

In the following, we first discuss the main interaction properties, then we suggest some general principles, taking into account the main features that an e-Learning system should have. However, specific and more detailed criteria can be provided in order to define certain important issues precisely.

6.2.1 Interface Overview

The first problem is that the blind person does not perceive the overall structure of the interface, so they can navigate for a long time without finding the most relevant content. To reduce this gap, the UI (source code) should be structured defining logical sections of the interface so that the screen reader is able to provide this overview. For web-based systems or Learning Objects, defining logical sections and/or areas of the interface can meaningfully increase usability. For instance, by using ARIA regions the UI can be split into several content areas that can be explored quickly. This approach can improve interface structure perception.

Specifically, it is possible to group and structure (by landmarks) sets of homogenous text and elements in order to give the user the idea of the interface immediately, and enable him to jump rapidly from one section to another. Landmark tags, if appropriately applied, are particularly useful since they are captured by screen reader and listed as an index, helping the user to "navigate" the areas of the interface (see section 3.2).

6.2.2 Order of Content Blocks

Main content should be placed at the beginning of the interface in order to facilitate sequential reading. Indeed, the position of the most important content is crucial for a blind user who usually wants to explore the least amount of information necessary. ARIA attributes can affect the order of the content blocks. Navigation of the container may become an obstacle to learning, so it is very important to place the most important element of the interface at the top of the content read by screen reader in order to access relevant content quickly. Instead, the graphical interface must conform to the usual HCI criteria, arranging the content in a more appropriate way for visual elaboration. For instance it is possible to change the order of the <div> block (corresponding to the main content) in the HTML source code, by using "absolute position" in the CSS styles.

6.2.3 Rapid Comprehension of the Most Important Events

When certain basic events occur, such as positive or negative responses, a specific mechanism for immediately informing the user should be applied. In this sense, aural feedback is very useful for blind users since it associates a specific sound with a given situation (e.g. different tones may be associated with the success or failure of an operation) and simplifies interaction with form control elements.

A similar approach should also be used for other important events, such as when specific portions of the page change due to various operations or updates. ARIA specifications can overcome this kind of issue.

The designer may include these features in the e-Learning system interfaces, adding tones in some cases, or implementing appropriate ajax/javascript functions exploiting ARIA functionalities (e.g. role attributes etc.).

Some examples of when aural feedback – i.e. short sounds or brief messages -- could be applied:

- When the interactive form elements (edit field, radio button, or checkbox) receive the focus
- When a lesson module is finished or a new module is started
- When a new user joins a forum or a new message is added.

In other cases, ARIA properties can be more effective than a short sound or message. Here are some examples:

- To immediately inform the user of the success or failure of an operation (for instance the result of a self-assessment)
- To read a new message added to the forum community, the virtual class, the chat room, etc.
- To announce content portions changing due to user interaction (e.g. when expanding items or carrying out certain operations which give out different contents according to the user's choice.

6.2.4 Simple Keyboard Interaction

Interaction with the system via keyboard is simplified if shortcuts and navigation by Tab key are provided in order to jump directly to the most important elements or parts of the interface.

- Access keys must be associated with the most important interface elements or functionalities offering a simple shortcut to the desired point (e.g. skip to the beginning of module, go to course index, move on evaluation assessment, etc.).
- Tab index defines an order for visiting UI elements (e.g. links, objects). In this way, the order of "importance" associated with each element of the interface (i.e. the value of the tab access attribute) "drives" the user's navigation by Tab key. A lower tabindex value indicates greater importance. A tabindex value of -1 enables the element to receive the focus programmatically (e.g. via JavaScript). This is used to enable arrow key navigation to elements (ARIA BP).

6.2.5 Multimedia

Multimedia objects are frequently used in e-Learning systems. Indeed, a multimedia object can deliver visually some useful information for learning and understanding specific concepts. Learning Objects (LOs) are increasingly designed using visual and audio modalities. In addition, other important features could be only provided by a video or audio channel. Also in these cases, specific solutions should be considered to provide accessible alternatives. Several studies have been conducted on these specific topics (Ferretti et al. 2007).

Inability to access multimedia content such as video streaming, video conferencing, and captioning may be partially resolved by providing text equivalents, readable by screen reader. For example, supplementary content in an audio presentation can include the exact text presented as well as the description of relevant graphical content.

However to deal with LO accessibility, some precise experiments should be conducted before their use.

6.2.6 Advanced principles for e-Learning systems

When thinking about e-Learning systems, they are often considered as standard Web applications. Indeed, e-Learning platforms are usually Web-based. Therefore, it would seem correct to refer to accessibility and usability principles for the Web. They are suitable for general purposes and kinds of interaction, but to remove all barriers that could negatively affect the learning, specific and targeted principles are needed. Those principles do not refer only to the user interface, but also to the way content is provided to the user so that he/she can receive it in the most appropriate way. Other examples could be considered for the teachers' and tutors' side. Reports appropriately displayed and arranged can help teachers obtain a great deal of information from their students.

Some suggestions of principles for appropriate LMS for blind students and teachers are:

- **Different alternative and equivalent formats**.
  Providing alternative and equivalent contents that can be downloaded in several formats can be useful in several ways. Although not all content can be provided in audio format, at least the main core should be considered. For instance, the content available in text or

html format could also be provided in audio (mp3) format so that it can be listened to using portable mp3 readers or mobile devices.

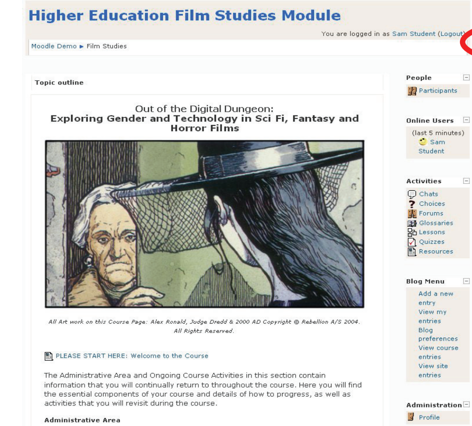
- **Getting portions of contents**.
  It would be useful to be able to select parts of the content so that they can be extracted and read in different ways. For instance, a student could simply store the selected content so that it can be read very quickly at a later date. In practice, this function allows creation of content by assembling a choice of parts. This might prove very useful when studying or reviewing lessons very quickly. On the other hand, the selected content could be converted into different formats in order to obtain them via other tools and modalities. For instance, parts of selected content could be converted into audio / mp3 formats (as mentioned in the previous point) and it could be read using another software program instead of a text editor. This would allow blind users to use the preferred modality when studying or reading important content.
- **Annotating tools**.
  Another important and useful function would be annotating as well as commenting on content using either voice or written text. Other useful functions could be underlining or highlighting functions, which are similar to using a paper-based format. In order to make these functions useful for blind students, they should be arranged not only to be read visually, but an alternative way should also be available. For example, the user might decide to select a sentence or an entire paragraph. Next, when he/she wants to read the underlined or highlighted contents, a function showing or extracting only those parts would be very useful.
- **Customizable services for content delivery**.
  When adding or modifying content in the LMS, a service informing the users on the updates should be available. This kind of service can increase performance in obtaining new content for blind students or teachers. For instance, RSS (Really Simple Syndication) feed could be one way to inform users.
- **Equivalent alternative concepts**.
  Some content is provided in a graphical or schematic way, and using alternative descriptions may not be enough to deliver the same educational concept. In fact, for educational purposes, some concepts are too difficult to describe solely by means of written text. For instance, if three colored circles – containing a lot of information – are used to illustrate the concept of interconnected/intersected contents, a short description like "three intersected colored circles" is not enough to express the same concept. Another example is an exercise whose goal is recognizing an animal. In this case the alternative description with the name of the animal cannot be used, since the goal of the exercise itself involves naming the animal thus defeating the educational purpose. For cases like these an alternative technique is needed. For instance in the latter example a description could be given of the animal's features (such as genre, family, colors, size,…). In other words, different ways can be found to provide the same meaning for blind users.

7. Examples

As a case study, we refer to two application domain examples: LMSs and wikis. The first example was tracked by analyzing a demo course of Moodle (Buzzi et al. 2009a), and the second was derived from a study regarding Wikipedia, the on-line encyclopedia (Buzzi et al. 2009b).

7.1 Interaction via screen reader: a Moodle Demo course

To show the complexity of interaction via screen reader with a Virtual Learning Environment (VLE), we refer to a study on Moodle (Buzzi et al. 2009a), a popular Open Source LMS., which offers a rich VLE (http://www.moodle.org). The system administrator may enable one or more modules between: assignment modules, Blogs, Chat, Course resources (Moodle pages, uploaded files or web links), Databases, Forums, Glossaries, Interaction, Lessons, SCORM packages, Surveys, Quiz module, Wikis and Workshops. This articulate environment may create difficulties in interaction via screen readers.
To provide an example of interaction we chose the Moodle demo course: the "Higher Education Film Studies Module" (Fig. 2, left side).



Heading level 2 Topic outline
Summary: Layout table
table with 3 columns and 18 rows
Heading level 2 Out of the Digital Dungeon: Exploring Gender and Technology in …
list of 15 items
All Art work on this Course Page: Alex...
...
This topic 1
list of 9 items
Heading level 2 Getting Started
...
Heading level 4 Ice Breaker Activity
...
2
list of 15 items
Heading level 2 Genres, Gender … in context
Art work: Alex Ronald, Judge Dredd & 2000 AD Copyright © Rebellion A/S 2004. All Rights Reserved.
...
8
Heading level 2 **Learning Support Space**
...
Heading level 4 **Continued Support for your** ..
…
List end
...
Table end
Heading level 2 **Online Users**
...
Heading level 2 Activities
Link **Chats**
Link **Choices**
...

Fig. 2. Moodle demo Course: UI (left side), content announced by JAWS (right side) – Source http://demo.moodle.org/

Uploading this course, various elements are detected by JAWS: headings, images, layout table, links. In specific, 32 headings are announced, too numerous to be navigated comfortably. By exploring the heading list (Insert+F6 command) we note that most of them refer to the course, but others are related to the e-Learning tools (e.g. chat, blog, and so on), without any clear separation: the main regions: “menu”, “topic outline” and “interacting actions” should be better indicated.
Although headings are used, the page is still too long to be read by keyboard via screen reader, and the use of customized ARIA regions might improve course usability.
To show the Topic outline a table has been used for the layout. Specifically two tables are used, the second nested in the first cell of the first table, but JAWS announces only one table. Although headings are used to split the long content, a table should not be used for the rendering. Moreover, the “summary” attribute of the table is “table layout”, totally useless. A more appropriate summary value could be “table of contents”; in this way, by just pressing the letter “t” JAWS will announce immediately “Table of contents”. If a layout table is used, at least a meaningful summary should be applied.
Furthermore, the page structure is unclear: it is difficult to understand how many modules compose the course, their titles and contents since the module number has not been included within the <Hn> tag so it does not appear in the headings lists. Thus to obtain this information the user must read the page sequentially. Figure 2 (right side) shows the page content as it is interpreted by the JAWS screen reader.
Although the pages appear to be accessible, our initial testing shows some usability issues: difficulty orienting oneself among different information (i.e. headings and links), as well as in handling conceptual information.

7.2. Application domains and specific guidelines: Wikipedia

To provide an example of guidelines for a specific LMS component, we recall results of a previous study that analyzes accessibility and usability of wiki systems for the blind (Buzzi et al. 2009b). Although these guidelines were derived from studying Wikipedia (see Fig. 3), they are general and thus apply to all Wikis.

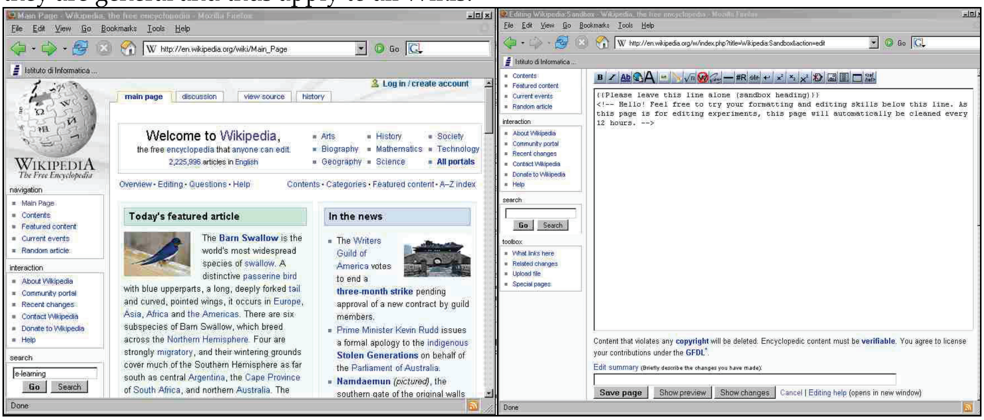


Fig. 3. – The Wikipedia Home (left side) and Editing Pages (right side) – Source http://en.wikipedia.org/

Based on the main difficulties observed when navigating through the search, result and editing functions, we suggest several elements that should be kept in mind when designing a Wiki interface:

- **Make it easy to identify the separate content parts.**

Usually a wiki page is split into several logical sections: navigation bar, header, footer, main content, etc. Each area should be clearly identifiable, both visually and via screen reader, offering a blind user a rapid overview of the main macro topics available on the page (using ARIA landmarks and regions).

- **Make the search box clearly and quickly identifiable.**

The search function is one of the most important features of a portal, so it is essential to find it very easily. Search edit field and buttons should be located at the beginning of the logical flow of the page's main content. Its location early in the content flow should ensure that the screen reader (and thus the user) can identify that important main area almost immediately.
The search box should be easily identifiable and clear labels should be used for edit field and search buttons. Moreover, terminology on the page should be consistent.
Analyzing the Wikipedia Editing page (i.e. selecting Edit this page from the Tab panel) other specific guidelines are:

- **Keep the Editing function simple**.

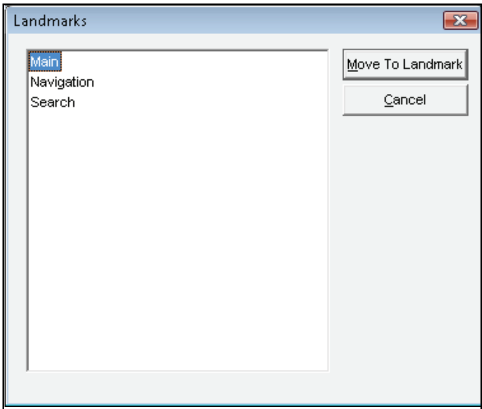
The Editing function is very important in a Wiki system, as in any collaborative environment. Consequently, the Editing commands as well as the Editing page should be easy for anyone to use, independent of the interaction modality used. We offer several suggestions regarding the Editing function:

- Use a separate page for the Editing function.
- Provide a quick way to use formatting functions via keyboard. For instance, if using a graphical toolbar make it accessible via ARIA.
- Provide an alternative textual input that could facilitate formatting for skilled users. To facilitate this modality, two possible suggestions are (1) provide a help page listing all commands with their textual alternative input modalities (2) a very similar HTML syntax could might also facilitate the input process for users who have some experience with HTML.
- Provide a simple way to insert special symbols. In the current version of Wikipedia, to insert a special character a set of over three hundred graphical links is available on the page. Concerning special symbols, two suggestions may be useful:
  - provide a quick and compact way to select a special symbol. Since a great number of links makes interaction via screen reader too difficult, a more effective way should be developed. A list on a separate Web page, or a compact combo-box containing descriptions of all available symbols, are possible solutions.
  - associate a clearer symbol description. Many special chars and symbols are not recognized by the screen reader. A descriptive text would overcome this problem; for instance 'a with circumflex accent' is clearer than the corresponding character (e.g. 'â' is announced by JAWS as 'a').
- Control the edit focus. As in the Editing procedure, the focus is very important and it is necessary to ensure that when interacting with formatting commands or choosing special symbols, the focus goes back to the editing cursor. This feature is fundamental for facilitating the Editing process when using a screen reader -- otherwise, the user

risks losing the Editing position, which makes the composing process difficult or impossible.

As an example of applying the first proposed guideline (make it easy to identify the separate content parts) the XHTML standard landmarks: main, navigation, and search have been included in the Wikipedia editing page source code, as shown in Figure 4 (Buzzi et al. 2009b).

A higher number of regions would facilitate for instance the recognition of important UI parts such as the editing box and the push buttons (save and preview). However, the last JAWS version (v. 10) is unable to detect the 'title' attribute used to customize a region, thus, at the moment, all customized regions are announced by JAWS as 'Region'. This instead of facilitating interaction might make structure unclear and confuse the user. For this reason, at this time we defined only the three XHTML standard landmarks: main, navigation, and search.




```
…
<div role="main" id="main" title="Editing Page"
aria-labelledby="hdr1">
<label title="Editing page"   class="hide">Editing
page</label>
…
<div id="bodyContent">
…
<div role="navigation" id="navigation">
<label title="navigation area"
class="hide">Navigation area</label>
…
<div role="search" id="search" >
<label title="Search Box" class="hide">Search
Box</label>
…
```

Fig. 4. Aria Landmarks of the Modified Wikipedia Editing Page: on the left the landmark lists generated by JAWS, on the right an extract of the HTML code

8. Conclusion

In recent years e-Learning has become increasingly popular, with benefits such as saving time and travel for students and teachers living far from schools or universities, and reduced traffic and environment pollution. Adult education, language teaching, and lifelong learning also profit from the opportunities offered by e-Learning.

Designing e-Learning systems, preparing electronic materials in an appropriate way, and providing content suitable for all end users is a complex task, since three factors must be taken into consideration: usability, accessibility, and educational effectiveness. The challenge is to create a system simple to understand, and quick and easy to use, that delivers effective educational content in multiple formats according to user ability.

E-Learning systems pose new challenges with respect to classic user-centered product design, where the target is a set of homogeneous users. Learner-centered design must fulfil the needs of multiple learner categories with different learning strategies, know-how, experiences, motivation to learn and, not least, user age and ability. If appropriately

designed and implemented, e-Learning systems are more effective and useful than classroom learning (Debevc et al., 2007).
It is important to notice that LMSs can greatly favor the student learning process since the same educational material may be transmitted anywhere, anytime, at any learning rhythm, in a format suited to each individual's ability. On the other hand, since LMSs automatically add a virtual environment to the educational material, if the virtual environment layout is not appropriately designed with a thorough knowledge of accessibility and usability issues, it may induce problems that could spread to the learning objects themselves. This highlights the importance of considering usability issues from the very beginning of LMS development.
Making a virtual learning environment suitable for the abilities and skills of all users offers many challenges. When defining the graphical UI it is fundamental to consider the needs of sighted users, but the needs of blind students should also be kept in mind when writing the UI code. Specifically, the same educational content should be provided through both visual and auditory channels, the design should be optimized for reading via screen reader, the UIs should be easy to use via keyboard and no additional cognitive effort should be required of the blind user.
As technologies evolve new techniques, and standards for assuring quality of the interaction are appearing such as the Accessible Rich Internet Application suite, which enhances usability for the blind in any web-based Virtual Learning Environment. Designers and analysts must be aware of problems of impaired perception, interaction via screen reader, and technological barriers and must know how to apply techniques and standards practically to ensure the quality of the interaction. This requires knowing and sharing best practices that are more accessible than ever today, also thanks to social networks which promote and facilitate human-to-human interaction.
In this chapter we highlighted basic and general accessibility and usability principles for interaction via screen reader when designing e-Learning systems. Future research should focus on analyzing specific Learning Object technologies, showing examples of cases. Another point that deserves special attention is the study of textual-alternative description of multimedia and dynamic contents that are educationally equivalent. This requires a synergic approach involving technical as well as educational experts.
Equal access for all is the basis of our knowledge society. The European Union, with its Communication "Towards an accessible information society" [EU COM, 2008], aims to stimulate Member States to make public websites accessible to and usable by everyone by 2010.

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12

Conception of Lesson Notes as Cartoon for Foreign Language Learning

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1. Introduction

With the development of Internet and new multimedia technologies, e-learning platforms have emerged to improve the quality of the learning activities, by facilitating resource and service access, distance exchange, and collaboration. E-learning platforms are typically web sites that host didactic content and facilitate the implementation of pedagogical strategies (Liu & Wang, 2008). They shared some common functionalities, such as learner self-registration, pedagogical resources and training sequences, on-line assessment, collaborative learning, and training resource management.

However, we assist to a shift from presentation to participation learning. Indeed, learning applications developed in Open Source code tend to be designed as participatory and collaborative e-learning environments. Open source course management systems such as Moodle (Dougiamas, 2004) are highly modularized, allowing teachers and learners to select, edit, or extend learning components most appropriate for their purpose. Moreover, teachers and learners can develop new modules and add them to catalogs of available pedagogical materials, allowing the e-learning platform itself to evolve collaboratively according to the needs and imaginations of the participants. Indeed, current e-learning platforms propose functionalities such as hypermedia, multimedia, forum, blog, wiki, chat, collaborative tools (see (QUIS team, 2004) for a complete analysis).

Nevertheless, to our knowledge, none of the e-learning platforms really directly deal with lesson and summary notes. It seems that learners have to manage by themselves to work and memorize their lessons. Therefore, learners have to resort to classical (non-IT) techniques such as summary notes (paper notes) for the visual people, or reading the lesson several times, either within their head for visual people or out loud for auditory people.

However, we share the vision of (Chickering & Ehrmann, 1996): "*Learning is not a spectator sport. Students do not learn much just sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write reflectively about it, relate it to past experiences, and apply it to their daily lives. They must make what they learn part of themselves.*"

Applied in the e-learning context, we think that e-learning activities must incorporate interactive exercises that are both relevant to the learning objectives and engaging for the

participants. Indeed, the e-learning experience must allow the participants to make choices that have a direct impact on the outcome, to provide an instructive and fun learning session.
In this chapter, we propose a prototype to allow learners to create their own electronic lesson notes from resources present in an e-learning platform, in the context of foreign language learning. In this particular context, it appeared to us that an essential point was to enable the learner to attach sound files to the corresponding text part to allow both learner's channels (vision and audio) to be trained together and linked. Another important point to make the resulting material appealing, therefore the lesson notes are represented as cartoons with audio lecture. This approach thus merges the three possible learning styles, namely the Visual, Audio and Kinesthetic styles. The resulting lesson notes can lately be used for lesson memorization, by simply playing repeatedly the cartoon.
The chapter is organized as follows: Section 2 explains the context of our project, namely the need of learning a foreign language, within the perspective of using learning styles to design the lesson notes. Then, section 3 presents some work related to foreign language learning and cartoons in learning activities. In section 4, we describe the prototype to perform the creation of a lesson cartoon. And in section 5, we present the experiment we conducted to assess the approach, before concluding in section 6.

2. Context

2.1 Learning a foreign language

Usually, French people do not speak foreign language properly, as noticed in a humoristic way in (Altan, 2006): "*For example, it is very common to meet a French person speaking English. Such opportunities can lower anxiety related to the accent*". Indeed, French students usually encounter difficulties to learn foreign languages. They are not used to practice these other languages (except when they have the opportunity to live in a foreign country for a while). Therefore, our school policy is to provide them with different means to apprehend a foreign language, such as classical classrooms and an e-learning platform.
However, this solution appears to be not so efficient, as all the learners do not really improve their foreign language level. We believe that the reason of this inefficiency comes from the fact that learners have to face too much information, with the supplementary documents in the e-learning platform, whereas they already have some difficulties to apprehend all the information within the classroom. In order to provide a useful tool to memorize lessons, we are interested in the way students can learn, which leads us to the Learning Styles.

2.2 Learning Styles

Learning styles are a characteristic and preferred way of learning. Therefore, knowing the learning styles can allow teachers to take into account the conditions under which an individual finds it easiest and most pleasant to learn (Illinois Literacy, 2006). Learning styles are primarily visual, auditory, or kinesthetic (tactile). Visual learners prefer to learn by reading or watching. Auditory learners like to learn by listening. Kinesthetic learners learn by doing, by touching or manipulating objects, or by using their hands.
Although students can learn to adapt themselves to learning styles that are not their preferred ones, most people have difficulties in the first place when they are asked to do something that seems unnatural to them. The most successful teachers are those who can

present material in a variety of ways using a combination of teaching methods to reach the diverse learning styles of their students. The tutoring strategies for each Learning Style, proposed in (Illinois Literacy, 2006), are given in Table 1.

Tutoring Strategies for Visual Learners	Tutoring Strategies for Auditory Learners	Tutoring Strategies for Kinesthetic Learners
1. Use overhead transparencies 2. Use flash cards for key concepts 3. Allow time for student to write down notes 4. Use as many visuals as possible: pictures, diagrams, charts, etc. 5. Use demonstrations whenever possible 6. Write out all key phrases, words, terms, etc. 7. Create outlines for lessons, leaving blanks for student to complete 8. Encourage student to chart out information using maps, diagrams, etc. 9. Have student copy problems and examples 10. Present lesson objective at the beginning of lesson and summary at the end 11. Provide additional worksheets for later practice and reinforcement 12. Write on blackboard when presenting key concepts, etc. 13. Encourage students to keep a notebook/folder of all written work for each lesson/unit	1. Always present material orally 2. Encourage discussion 3. Use a tape recorder to tape session for student review 4. Have student read aloud 5. Ask for oral response to oral questions 6. Ask student to repeat directions, key concepts, etc. 7. Ask student to summarize main points 8. Try to maintain eye contact 9. Encourage student to think out loud 10. Vary the tone and intensity of your voice 11. Plan sessions that are organized in sequential order 12. Give directions orally with only two or three steps at a time 13. Have taped materials available for reference 14. Encourage student to speak answers aloud before writing	1. Have student try out a problem on a chalkboard or lab center 2. Encourage students to make their own flashcards 3. Give demonstrations while allowing student to perform, step by step 4. Plan ways for the student to manipulate the materials 5. Use concrete examples to help the student use the skills gained 6. Involve the student in the planning of the tutoring session 7. Use computer assisted programs, so students can type and move mouse 8. Use association techniques to link new learning with past experiences 9. Allow student to stand, move, etc. during session

Table 1. Tutoring Strategies for the Visual, Auditory and Kinesthetic Learners

In our context of creating summary notes for foreign language learning, we want to propose a prototype that combines these three learning styles, notably thanks to the points:

- 3, 4 and 13 of strategies for visual learners;
- 3 and 13 of strategies for auditory learners;
- 2, 4 and 7 of strategies for kinesthetic learners.

Before presenting our prototype, we present in the following section, some related work to foreign language learning and cartoon in learning activities.

3. Related work

3.1 About Foreign language learning

Various work from different research areas have considered foreign language learning. Indeed, this research theme can be viewed from the linguistic point of view (for instance (Cook, 2001; Johnson, 2001; Klein, 1986; Sharwooed Smith, 1994)), from the psychological point of view (for instance (Gardner & Macintyre, 1992; Sparks, & Ganschow, 2001; Wakamoto, 2000)), from the sociolinguistics point of view (for instance (Loveday, 1982; Preston, 1989; Pride, 1981)), etc. A history of foreign language learning theories well detailed in (Griffiths, 2004) shows that the first methods were based on grammar-translation, then on audio lingual method, followed by other approaches; and lately, most of the current approaches were related to communicative competences.

Concerning foreign language learning using e-learning platforms, from a psycholinguistic point of view, (Doughty & Long, 2001) study the selections among the range of technological options in distance education. They proposed a basis for the creation of optimal psycholinguistic environments for distance foreign language learning, based on ten methodological principles. Among them, we can particularly note: *Promote Learning by Doing, Provide Rich Input, Focus on form.*

From a technical point of view, foreign language learning via e-learning platform has various challenges to overcome. (Hampel & Hauck, 2004) examine the process of development and implementation of online courses in terms of activity design, tutor training, and student support, for language courses using an Internet-based audio-graphics conferencing tool (audiographic web conferencing refers to a technology that enables participants to hold voice communications over the Internet, accompanied with a variety of visual-graphic presentation aids or collaboration tools). (Trajanovic et al., 2007) focus on the problem of the lack of face-to-face communication with peers and the teacher in the case of distance learning system to foreign language teaching, using state-of-the-art tools for synchronous and asynchronous communication. (Volle, 2005) investigates the acquisition of speaking skills in an online distance education course of Spanish learners, based on students' pronunciation production in two types of recorded speaking activities and in two real-time conversations. By analyzing three kinds of data were collected from the conversations - an articulation score, an accuracy score, and a proficiency score, her findings suggest that there were significant gains in scores only in the area of oral proficiency.

Closer to our research theme, (Lo et al., 2000) propose a system to put not only the description of the course content but also the corresponding audio files in order to support a multimedia-teaching environment. (Szedmina & Robert, 2004) present a multimedia application that was created as extra practice material for use outside the English classes. It included multimedia material in the form of pictures, sound files and film material, to enhance the vocabulary of technical English. The application could be used for both practice purposes and self-testing.

3.2 About Cartoons as learning activities

Cartoons, when used in a learning strategy, have several effects, according to the research work of (Clark, 2000): they engage attention; they serve as entertainment; they present information in a non-threatening manner. However, there are some limited references to cartoons in education literature. In science education, they have been used for eliciting the learner's ideas (White & Gunstone, 1992; Hayes et al., 1994), for illustrating scientific ideas (Gonick & Huffman, 1990) and as a stimulus to reflection in science (Lock, 1991).

Cartoons can also be used as stimuli to encourage thinking processes and discussion skills as shown in (Doring, 2002). The author got favorable feedback from students on their use as a teaching strategy. According to her, in being encouraged to be humorous in their approach to concepts and situations, students frequently produce answers that are usually much more interesting and provocative. She notes as well that discussion is richer and students appear more confident, candid and less judgmental and more accepting of other views. Besides, she finds that evidence of the interest emerges from several students' willingness to provide appropriate examples some time after a particular topic has been dealt with.

Besides, (Rule & Auge, 2005) show that students who learned using cartoons achieved higher test scores and provided examples of why they enjoyed learning in this manner. The authors argue that cartoons were an effective pedagogical technique because they created a learning environment in which: students experienced a high degree of motivation to recognize and produce humor; they viewed and analyzed visual images that enhanced memory; they made numerous connections between the new material and prior knowledge through parody and analogy; they identified concepts of which they were unsure and sought clarification from the instructor or text as they attempted to create or improve cartoons; and they engaged in self-motivated practice as they reviewed cartoons for improvement and created their own cartoons.

4. Our prototype

4.1 Existing e-learning platform

The e-learning platform used at the Business High School of Chambery is based on Moodle, an open source e-learning platform aiming at creating communities of learners around pedagogical contents and activities. The e-learning platform is based on a CMS (Content Management System), with supplementary pedagogical and communication functions to create an online e-learning environment, where teachers and learners can interact together, and/or can interact on pedagogical resources.

The particularity of a Moodle platform is to be conceived based on the constructivism paradigm, which postulates that knowledge is constructed in the learner’s mind and not retransmitted statically via books or teachers. From the constructivism point of view, one goal is to create a pedagogical environment allowing learners to construct their knowledge from their experiences and their skills, and not just presenting information and evaluating learners’ knowledge.

We want to add a new tool in the e-learning platform, to allow learners to pick up some parts of their lessons and/or exercises in order to create their own lesson notes, their own files, as a cartoon. We present our prototype in the following sub-sections.

4.2 Design of a lesson cartoon

Our goal is to provide learners with a prototype to create a complete cartoon of a foreign language lesson, associating learning strategies from the three learning styles presented in section 2.2. Indeed, as previously mentioned, visual learners prefer to learn by reading or watching, while auditory learners like to learn by listening, and kinesthetic learners learn by doing, by touching or manipulating objects, or by using their hands. By consequence, our idea is to make students use their tactile sense by manipulating objects – texts, images, sounds – to create their own lesson note, and when they will review their lesson, they will be able to read it with their visual sense, and listen to it with their auditory sense.
The prototype's interface has to be intuitive enough to allow non-IT experts (such as our general learners) to easily handle the system. Indeed, all the actions have to be performed by clicking or dragging the different elements, and by selecting features in the toolbox. The lesson cartoon must be composed of frames that the learner has to fill with images, texts and sounds (cf. Figure 1). As a result, the lesson cartoon can be saved and viewed by any browser later on, for memorization.

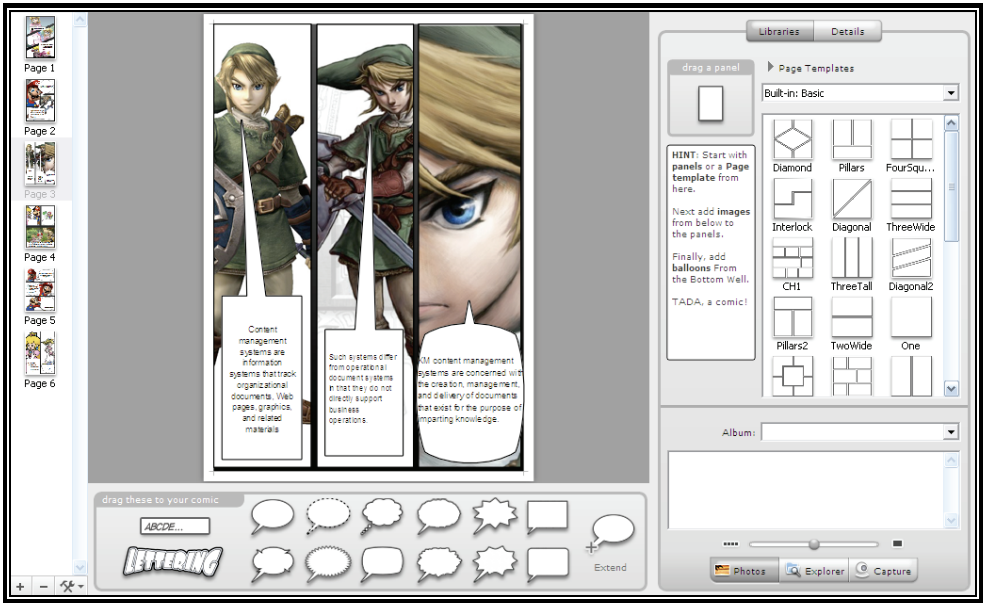

Fig. 1. Example of a learner's lesson cartoon in its visual conception phase, using our prototype with visual functionalities currently based on Comic Life™

Creating the lesson notes will implicitly use the learner's tactile sense; therefore, there are no specific functionalities in the prototype for this sense. We present in the following sub-sections the visual and the sound functionalities for the creation of lesson notes in the prototype.

4.3 Visual functionalities

To create a lesson cartoon, the learner must first add images within frames, in order to create his/her personalized context of the lesson. The learner starts by selecting a page model from a collection of pages where empty frames are arranged in various patterns (see Figure 1).
The learner then selects images that already exist in a collection that may contain varied images representing the overall situations. However, the collection is not large, as the important thing is not details but the general idea of the frame. It may simply consist of a few characters, in different poses and different moods. Further images of objects (scenes, objects of interest, etc.) might be included in the collection to add supplementary information. All of these images can be ordered in categories or can be indexed so that when a learner needs a particular one, s/he just has to perform a search on a keyword, and the results show the corresponding images, from which s/he can pick up his/her preferred one. If ever the learner is not satisfied with the proposed images, s/he always has the possibility to select images from his/her own computer.
Once a frame contains all of the images desired, the learner adds bubbles, legends or annotations into the frame, in which s/he can move parts of the text of a lesson, an exercise, a quiz, etc. Bubbles make the characters speak or think "out loud", while legends give general information about the situation. The annotations are added under a frame to provide any kind of comment such as giving the whole conjugations of a verb or specifying a grammar rule. The learner can then change the font at his/her will (change the size, font, color, use bold or italic style, highlight with colors, etc.).

4.4 Sound functionalities

Besides the visual representation of the lesson cartoon, the prototype allows the learner to add some sound that matches the text, to be played image-by-image, or bubble-by-bubble. The sound file can be created either by using some software that automatically creates sound with an artificial voice from text, or by the teacher who records his/her lecture of the text (the teacher being ideally a native speaker of the foreign language studied). Two cases then appear: either the teacher has recorded the sound files corresponding to the lesson before its happening, or the teacher lets the learners create their own text and when asked, s/he records his/her voice corresponding to the text given. The latter case implies that the teacher first needs to check the correctness of the learners' creation, which can be useful and valuable.

4.5 Discussion

A learner constructs in this way a material, the lesson note, with multiple frames on each page, so that s/he can sort the content of the learning activity to remember and memorize. The lesson note is then completely personalized, and when the learner needs to review it, s/he has the possibility to easily and quite quickly perform multiple passes/lectures through his/her own material (see a final example in Figure 2).
There are several advantages to this approach. First, the learners choose within an image collection the images they want to integrate to their production, namely the lesson cartoon. They can choose the images they like, and modify and arrange them to obtain the results they are looking for. In this sense, they perform a creative activity that should result in a

personalized production. As noticed during the experiment, learners were proud of their creation and liked to share them with the others.

The text already exists in pedagogical resources at the learners' disposal, it just has to be copied and pasted at the desired spot in a frame, and highlighted directly with the formatting toolbox. In this way, the lesson cartoon fills its goal, which is retaining only useful elements, and highlighting the elements according to their level of significance to the learner. And the learners can add sound files to the text to get a sound version of their production. The resulting learner production can be checked, corrected (and even evaluated) by the teacher, to ensure the correctness of the production.

Finally, the learners manipulate different materials to create their own production on a computer, fulfilling part of the strategies for kinesthetic learners. And the combination of text and sound is particularly interesting in the case of a foreign language lesson, since it enables learners to hear a native speaker while reading the text, to match "the visual" and "the sound". The learner then catches information via both perception channels – the visual one and the sound one – which should help him/her match both "perceptions" and better memorize the vocabulary and its pronunciation. This fulfils part of the strategies for visual learners and auditory learners.

However, we can note that some drawbacks may occur. For instance, the creation of a cartoon from the lesson can be time-consuming. Or, the learner might be reluctant to this approach. In such cases, the prototype might not be used.

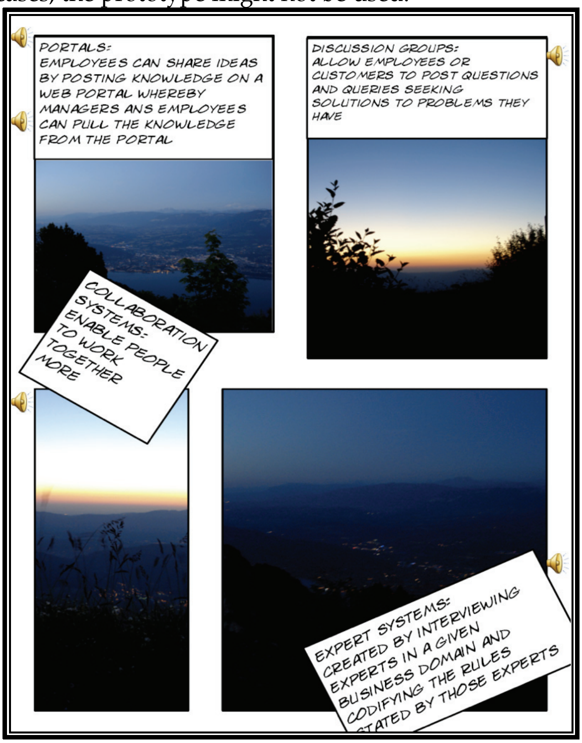

Fig. 2. A page example of a completed lesson cartoon with audio, created by a learner during the experiment

5. Experiment

To assess the level of acceptance of our prototype, an experiment was conducted with a public of 2nd year students at the Business High School of Chambery. It lasted two hours, before the end of an English class. There were thirty-three students in a classroom (two student groups), and during this session, the students had to create their own cartoon lesson by using the prototype. All the necessary resources – documents related to the course, original images, and sound files pre-recorded by their English teacher – were available on the e-learning platform.

5.1 Research Questions

In this study, we want to assess the level of acceptance of our prototype, to check whether it is helpful and valuable for the students to learn a foreign language, or not. Moreover, we want to verify if the students' learning styles may influence their opinions about the prototype. Our research questions thus are:

- (1) Can the present approach motivate students to learn foreign language?
- (2) How do the students perceive the proposed approach based on the combination of the three learning styles?
- (3) Do students' own learning styles influence their opinion about the prototype?
- (4) Does the creation of cartoons as lesson notes influence the students' opinion about the prototype?

To answer these research questions, a combination of quantitative and qualitative research methods was employed for data collection and analysis.

5.2 Methodology

We used the following research procedure divided into three phases. The first phase consisted in performing a test about learning styles. The second phase was the experiment of the prototype itself. The last phase consisted in filling a questionnaire. In order to preserve anonymity, students chose a pseudonym they kept during the complete process.

Phase 1: Test about Learning Styles

The Learning Style Inventory (Illinois Literacy, 2006) was distributed to students to assess their learning style. This inventory helps people to be aware of their own learning style, the way they prefer to learn, to see what their best channel(s) of learning is (are). There are 24 questions with choices, related to the Visual, Auditory and Kinesthetic Learning Styles. Some examples are:

- *Prefer information to be written on the chalkboard, with the use of visual aids and assigned readings* (Visual).
- *Learn to spell better by repeating the words out loud than by writing the word on paper* (Auditory).
- *Enjoy working with tools or making models* (Kinesthetic).

This test took about 20 minutes.

Phase 2: Designing a lesson cartoon

The object of the experiment was presented to students: They had to create a lesson note (summary note) for the English course related to the current lesson. The students

downloaded from the e-learning platform all the resources: course documents, original images, and pre-recorded sound files. Next, a demo of the prototype was performed in front of them. The students then were asked the following question: "What would you put in your lesson note to learn this lesson?". Instead of creating a lesson note on a paper sheet, they were asked to create it using their computer, as a cartoon, where they could add sentences from the course (powerpoint file) and sounds (sentences recorded by an English teacher). In this experiment, they could add all the images they wanted, to make their production more appealing for them.
This experiment phase took about 85 minutes.

Phase 3: Questionnaire
A questionnaire was distributed to students at the end of the experiment, to get their feedback about the approach. The questionnaire was composed of 23 questions: 5 questions about their general impression about the experiment; 7 questions about their perception of this approach to learn; 3 questions about their perception of their resulting production; 2 questions about the motivation for learning using this approach; and a last part to get their general opinion with 2 closed questions and 4 open questions.
This questionnaire took about 15 minutes.

5.3 Data Analysis

We analyze the data collected from the questionnaire and the test about learning styles, to answer our research questions given in subsection 5.1. The learner sample being relatively small, this is only a pilot study to check the possible usefulness of the proposed prototype.

(1) Can the present approach motivate students to learn foreign language?
A first closed question "*Do you find this approach attractive?*" considers the motivation that this approach can bring. The results are presented in Figure 3. Nearly 90% of the students agreed with this, either "normally" (half of the students) or strongly (one third). Only 3% disagreed (one student), and 9% were neutral.

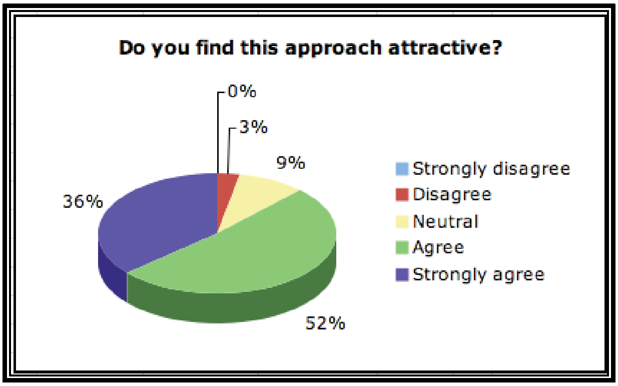

Fig. 3. Results for the attractiveness of the approach

To the open question "*What was disliked?*", few students gave an answer. And the few ones mentioned concern either the start that was slow ("*start too complicate*"), or problems related to the prototype ("*software too slow*", "*bugs*", "*the progress is a little bit long*"), or expectations not fulfilled ("*not very practical to do copy-and-paste*", "*search images*", "*missing of interactivity (try again with sound!)*").
In fact, the arguments given concern a difficulty encountered at the beginning of the experiment, or some bugs remaining in the prototype. They do not cast doubt over the approach. Therefore, the approach can be considered as attractive.
A second closed question "*Would this approach help you to better learn a foreign language?*" considers the usefulness of this approach in the case of foreign language learning. 58,6% of the answers were positive, while 41,4% were negative.
To know the reasons for a negative opinion about the approach, the open question "*Reasons why you found the approach negative*" was also asked. The answers can also be grouped in three categories: this is not a suitable method to them, this is nothing compared to a living experience, and it is more a question of motivation. The unsuitable method was described in these terms:

- *"I just have to read the text to retain it",*
- *"nothing, this is just not my learning method",*
- *"this is not a method that I like"*

Some students claim the living experience:

- *"this is the contact with people, that I appreciate in learning a language",*
- *"because a living experience will always be more formative. We don't learn English in books or on computer",*
- *"mastering a language requires a certain experience",*
- *"the practice is nicer (in the country)"*

The answer highlighting the motivation was:

- *"because many tools already exist currently, and this one is just another one; the main important thing is to be motivated!"*

We effectively share the general point of view that the living experience in a foreign country is very valuable. However, our purpose is not to replace this kind of experience, rather to complete the current classical classrooms. Moreover, we agree with the fact that motivation is essential for learning.
Finally, all these former answers can give the general idea that, for about one half of the students, this approach would help learning a foreign language.

(2) How do the students perceive the proposed approach based on the combination of the three learning styles?
The answers of the general closed question "*What is your general opinion about the experiment?*" are shown in Figure 4. Nearly 3/4 of the students had a general positive opinion about the experiment (61% were strongly positive and 13% were positive), against 3% negative and 23% neutral. Therefore, as a whole, the approach was well perceived by the students.

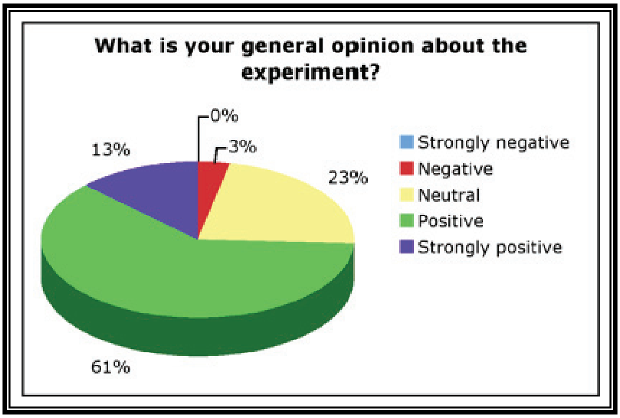

Fig. 4. Results for the general opinion about the experiment

To the open question "*Reasons why you found the approach positive*", the answers can be grouped in three categories: fun, use of senses, and some answers try to relate the experiment to learning styles. About the use of senses, the students commented:

- *"because we listen and read at the same time! allow to better follow and retain the pronunciation",*
- *"we have the 3 senses at the same time: visual, audio, and tactile"*

And concerning the learning styles, the comments were:

- *"for visual people",*
- *"it depends on people, but personally, I better work when courses are interactive"*

By consequence, some students effectively noticed the link between the experiment and the combining of some learning styles.

(3) Do students' own learning styles influence their opinion about the prototype?

The students' Learning Styles are given in Figure 5. One third of the students are visual and one third are visual with another style (half is visual and auditory, and half is visual and kinesthetic). The last third is either auditory alone, or auditory and kinesthetic.

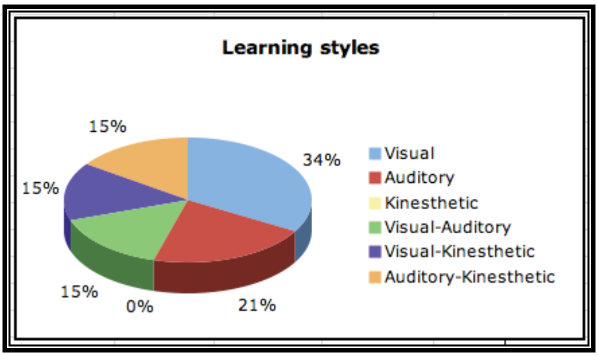

Fig. 5. Results for the learning styles

To the closed question “*Would this approach help you to better learn a foreign language?*”, the answers according to the students’ learning styles are shown in Table 2. Generally, on this small learner sample, we can see that the learning styles do not really influence the students’ opinion, as about half of each category would like to use this approach, except in the cases of Visual-Auditory and Visual-Kinesthetic learners (almost all of them would like to use this approach).

Learning styles	Yes	No	Total
Visual	5	5	**10**
Auditory	2	3	**5**
Kinesthetic	0	0	**0**
Visual-Auditory	4	0	**4**
Visual-Kinesthetic	4	1	**5**
Auditory-Kinesthetic	2	3	**5**
Total	**17**	**12**	**29**

Table 2. Results of the question “Would this approach help you to better learn a foreign language?” compared to the students learning styles

To the closed question “*What is your general opinion about the experiment?*”, the answers according to the students’ learning styles are shown in Table 3. We can deduce that most of the students appreciate this approach, whatever their learning styles are, and there is no specific learning style for which this approach is not convenient. Consequently, in this small learner sample, it seems that the learning style does not influence the learner’s opinion about the approach.

Opinion / Learning styles	Strongly negative	Negative	Neutral	Positive	Strongly positive	Total
Visual	0	0	2	6	1	**9**
Auditory	0	0	4	2	1	**7**
Kinesthetic	0	0	0	0	0	**0**
Visual-Auditory	0	0	0	3	2	**5**
Visual-Kinesthetic	0	0	1	4	0	**5**
Auditory-Kinesthetic	0	1	0	4	0	**5**
Total	**0**	**1**	**7**	**19**	**4**	**31**

Table 3. Results of the question “What is your general opinion about the experiment?” compared to the students learning styles

(4) Does the creation of cartoons as lesson notes influence the students’ opinion about the prototype?

To the open question “*Reasons why you found the approach positive*” already tackled in the research question (2), the answers are of three categories: fun, use of senses, and relations with learning styles. Comments about the fun were the following:

- *“a funnier way to learn”*,
- *“play activity to learn with images, text and sound; the learning becomes less tedious”*,
- *“we learn by creating our-selves, this is thus easier to retain”*

To the open question “*What was liked?*”, the majority of answers concerns three aspects: the fun aspect, the originality of the approach, and the creativity aspect. For the fun aspect, the learners’ comments were:

- *“funny, we create our cartoon”*,

- *"we can learn by playing",*
- *"the fact that it was like a game",*
- *"play activity for learning",*
- *"the amusing aspect; the new method, not much common, to learn",*
- *"learn by playing"*

The originality of the approach was depicted with the following comments:

- *"the idea",*
- *"the originality",*
- *"the original formatting (cartoon) for a new point of view of the course content"*

And the creativity aspect was described with:

- *"creative aspect",*
- *"merging images and texts",*
- *"the fact to create something",*
- *"this is amusing, creative, personalized, to our taste",*
- *"the practical work aspect",*
- *"interactivity"*

A particular answer concerned the software mastering (*"master new software"*).
Consequently, it can be considered that a certain number of students appreciated this approach because of the creation of cartoon lesson notes.

5. Conclusion

We think "doing is the best way of learning". Therefore, by creating their own cartoon for a lesson, learners may be more motivated, they may better appropriate its content, and better memorize the lesson, by replaying it as often as they wish. In this chapter, we proposed a prototype for learners to choose a set of preferred images within an image collection or downloaded from their computer, and to handle them in their own way within frames, to create their personalized cartoon. Then, the learners can select some text from existing pedagogical resources, copy it in bubbles, legends or annotations within the frames, and highlight it as they wish. Moreover, the prototype allows them to add sound files to perform the "audio lecture" of the text, to combine the visual and sound media, to improve the learning of foreign languages.
We performed an experiment with students to assess their level of acceptance of the prototype. It appears that mostly, students appreciated the proposed approach, and gave as pros the fun and the creativity of this approach and the fact of mixing learning styles. However, only half of them really think that this approach would be useful to learn a foreign language. Cons were arguing that such tools could never replace living experiences, an opinion that we share. Nevertheless, in the case of completing the current study of foreign language at school, the proposed prototype can greatly be envisaged as a supplementary means. The prototype can however be improved with other functionalities to further support students in their learning process of foreign language.
Indeed, other useful functionalities can be added to our prototype such as the possibility, within the same cartoon, to switch the tense (past, present, future, etc.) for learners who have difficulties with this aspect, or to perform a rough translation into another language directly from the cartoon, which can help the learner to easily remember the meaning of the words in his/her own language, or in another language s/he is more familiar with.

Another extension should consist of animating the cartoon, so that one frame is present at a time. This requires some buttons to be added, in order to play all the frames, go to the desired speed between frames, or to go forward or backward in the frames, as required.

Memorizing as a way to learn languages is stressed in the chapter. However, learners also need to be able to apply words they learn in one situation into different situations. Therefore, cartoons also can be created for different scenarios where just learnt words can be put into practice. In this way, taking notes is not only a matter of memorizing but also of applying knowledge in new contexts. The teacher could also use the learners' resulting productions as an evaluation of the lesson.

To check the validity of the prototype, the relevance of the prototype also needs to be assessed, by comparing the teacher evaluation of this lesson for learner groups compared to other control groups of learners who did not use the prototype for this lesson. To obtain pertinent results, other experiments must be performed on a larger learner sample and for several different lessons.

Finally, our prototype was first thought for an individual use. However, since the prototype is based on a Moodle platform, learners can work on their own, or share their material with other learners. Besides, learners can also communicate between them, and compare their respective progression and results. Therefore, we could envisage experimenting group learning activities, and even peer activities with foreign students whose mother tongue is the one studied in the class, like in (Ramzan & Saito, 1998).

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13

Virtual collaborative learning environments with the Telepresence Platform supported by the Teaching for Understanding pedagogical framework: experiences in Higher Educational process in Colombia

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1. Introduction

Currently, most distance-education processes are mostly based on web-published contents. Interaction among the instructor and the students happens in an asynchronous manner, using forums, e-mail or http contents like Moodle. We claim that this interaction is not appropriate to explain complex concepts. Experiences reported within our team in Colombia show that the use of shared virtual environments with a Telepresence tool has fostered interesting interactions among the instructor and the students that would be difficult to attain even in face-to-face education. Additionally, when students interact with virtual objects, the abstraction effort is reduced, thereby fostering the acquisition of knowledge and skills.

In a similar manner, designing courses following Teaching for Understanding pedagogical framework, allows the instructor to focus on the development of competences and skills in students, and this is a fundamental objective of current education systems. The pedagogical models used in distance-education are mostly based on traditional approaches. In other cases, the pedagogical approach is reduced to the interaction with a technological tool.

The Telepresence tool, developed by EAFIT University and University of Quindío in Colombia, permits sharing of courses among the institutions. Instructors from one institution can teach students of the other one, thereby sharing the positive features of each course. The Telepresence tool enables that courses and talks are shared among Higher Education Institutions and individuals who are located in different places. When using our Telepresence tool, instructors create a shared virtual collaborative environment that allows the instructor and the students to interact from remote places. The tool allows users to load graphic files to support teaching, and, more interestingly, to load a 3D interactive simulation of the concept at hand. Learning Objects supported by the Telepresence platform, with 3D content, are built under the SCORM 1.3 – 2004 standard.

The use of Teaching for Understanding allows the instructor to keep a log of each and every student's progress, and to focus on the development of competences and skills of the course at hand. These types of experiences that involve pedagogy and technology allow for a rapid incorporation of novel technologies, such as Virtual Reality and high-speed networks. Our experience with this project has been that successful practices can be shared between institutions when using the Telepresence tool. The ultimate goal of the project is to create and maintain a repository for creating and sharing learning objects among institutions.

We want to propose the creation of virtual collaborative learning environments to support courses in Higher Education, designed it under the approach of the Teaching for Understanding. The use of new computational collaborative technologies should be complemented with a pedagogical framework, so that both ensure the development of skills and abilities in the students

2. Presentation

During the years 2003 and 2004, the laboratory of Virtual Reality of EAFIT University developed the project "Telepresence Applied to Higher Education". This project was supported by Colciencias (Colombian Administrative Department for the Development of Science and Technology) and by EAFIT university. As part of the project, it was constructed a prototype of Telepresence System that combines virtual reality, audio and video on Internet to form a collaborative virtual world. This system allows the instructor and his students to interact synchronously, in spite of physically being in different places. The results of the first stage, using the prototype, allowed to conclude that the use of the system with an associated pedagogical approach (in our case, Teaching for Understanding), allows the students of distance education to obtain equal or superior levels of understanding to those that are offered by physical on-site presence courses. During the years 2005 and 2006 the platform of Telepresence was used by EAFIT University and the University of Quindio in courses of Physics applied to the construction. Excellent results in courses of distance higher education were obtained. Between the years 2008 and 2009, the universities previously mentioned develop the research project called "Evolution of the Telepresence tool and its application in distance education in regions of the country by using RENATA". It is supported by the Ministry of Education of Colombia and Colciencias. The aim of this project is to improve and to implant the Telepresence tool in a mass manner (open). In such a way, the universities impart courses in which the professors are in their campuses while the students are in the regions under the influence of the participant universities. In order to get a mass use of the platform of Telepresence, the Academic National Network of High Speed of Colombia - RENATA is used. This network is administered by the Corporation RENATA, of which the Regional Academic Networks of Colombia, the Ministry of Communications, the Ministry of Education, and Colciencias are member. The Academic Networks of Advanced Technology facilitate the collaborative academic work. They allow to have access to laboratory equipment, to transfer high volumes of data, to develop applications with distributed processing and to support complex and crucial experiments for the research. Similarly, they facilitate the communication and the teamwork among researchers who are geographically dispersed in different regions or countries; and the development of academic, scientific and technological joint projects. The series of interconnected Advanced Academic Networks conforms what could be called the World-Wide Network of Investigation and Development (ReD+I). From Colombia, we can only have access to this Network through RENATA.

The objective of our research, in the long term, is to contribute to the improvement of the coverage and the quality of the education in Colombia. In our country, like in many developing countries, the most qualified instructors and the educational institutions having the highest quality are concentrated in the great large cities and what is more, in its privileged sectors. Therefore, there is a large number of Colombians who do not have access to an education of high quality, because they live far away from the privileged zones and/or because they are not able to pay the costs associated to their education. To implement projects like the one we present in this proposal, would allow the high quality educational institutions to extend its coverage and to reach the groups of people who cannot accede to this type of education.

Two fundamental aspects are aimed with the development of this project: (i) To turn the Telepresence platform into a huge product that can be used in the real conditions of the technological infrastructure of our country. It can operate on common lines of communications on Internet, or on Academic Networks of High Speed. (ii) To allow that other Colombian universities use the product and develop new modules, under the only condition that these ones can be reached by other universities of the country. In this way, a bank of experiences in the use of the Telepresence tool, regarding different fields of the knowledge, is built. The achievement of this objective depends on the commitment of the universities that are a pilot in the development of the project. In this way, it is expected that the new developments benefit the educational community of the country.

The Virtual Reality is a tool widely used for training and education. The Collaborative Virtual Reality allows that several users interact in virtual surroundings. There are some projects that have explored the combination of audio and video with Collaborative Virtual Reality but, as far as we know, there are no applications to the education, as in our project.

The proposed project consists of two stages. In the first one, a technical work is carried out to produce a stable platform that creates a collaborative virtual atmosphere with transmission of audio, video, and objects of 3D learning. In the stage of extension and completion the two universities worked with a pilot test to use the platform in real environments of distance education. It was used a pedagogical approach based on the pedagogical framework Teaching for Understanding. Simultaneously, the professors of the universities received instruction about the educative model Teaching for Understanding and about the use of the tool. In this second stage, the new developments carried out by the pilot universities were used. At the end, the experiences of both the developers of the project and the professors were gathered. With the results of these tests, it is expected to advance in the development of the product and its corresponding documentation. Then, it will be put at the disposal of other educational institutions within the country.

3. The Telepresence Platform

The Telepresence tool is an application developed in Java language. It is composed by four environments or modules: an environment of teleconference (audio and video), an environment of virtual reality, a module to run learning objects and an environment for the presentation of slides. They have the following general characteristics:

3.1 Virtual Reality Environment (VR)

This module consists of a collaborative virtual environment in which the professor and the students can interact with 3D shared objects. These objects depend on the specific contents they are used. The participants know, in the virtual environment, the location and/or attention of their counterpart due to the telepointer objects (3D arrows). The professor can interact with the virtual environment through an electromagnetic sensor of position (Polhemus), if it is available. In this case, its telepointer can be used analogously to the mouse pointer, in a 3D space. Otherwise, or in the student's normal case, the telepointer indicates the position of the counterpart's point of view and the interaction is made through the mouse. Only the professor can load and change the contents. The content that is loaded in a VR atmosphere consists of two parts: a panel where the 3D objects are displayed (virtual reality panel) and another panel that displays formal information or specific control of the content; it is called Control Panel. The possible interactions within the virtual environment and the interaction with the objects of the contents correspond to the selection and drag of the virtual objects, the change of the point of view within the three-dimensional scene, and the direct interaction with the information panel. All these interactions can be replied in both views, in such a way that the state of the shared environment always is consistent. Members of another Project at Eafit University have developed a 3D calculator. The calculator allows users to write the equation of a function involving X, Y and Z variables, and plots the corresponding surface. This software is written in C++. In order to add the functionality of the 3D calculator to our Project (written in Java), we are making use of JNI, a software tool that allows a Java program to call functions written in C. This allows the Java program to retrieve a mesh of points in space that will be later plotted in the Telepresence tool using Java and Java3D. Cartesian, polar, spherical and cylindrical coordinate systems can be used. This functionality was requested back in 2005, when the Telepresence tool was used in a course on Physics for Civil Construction professionals.

3.2 Environment for the Slides

This environment allows using visual aids (slides type) to support the development of the session. The controls to handle the slides are only present in the application that the professor runs. The environment for the slides and the Virtual Reality Environment share the same panel being mutually excluding; when the environment for the slides is active, the Virtual Reality Environment is not, and vice versa. Only the professor can change from a panel to another one.

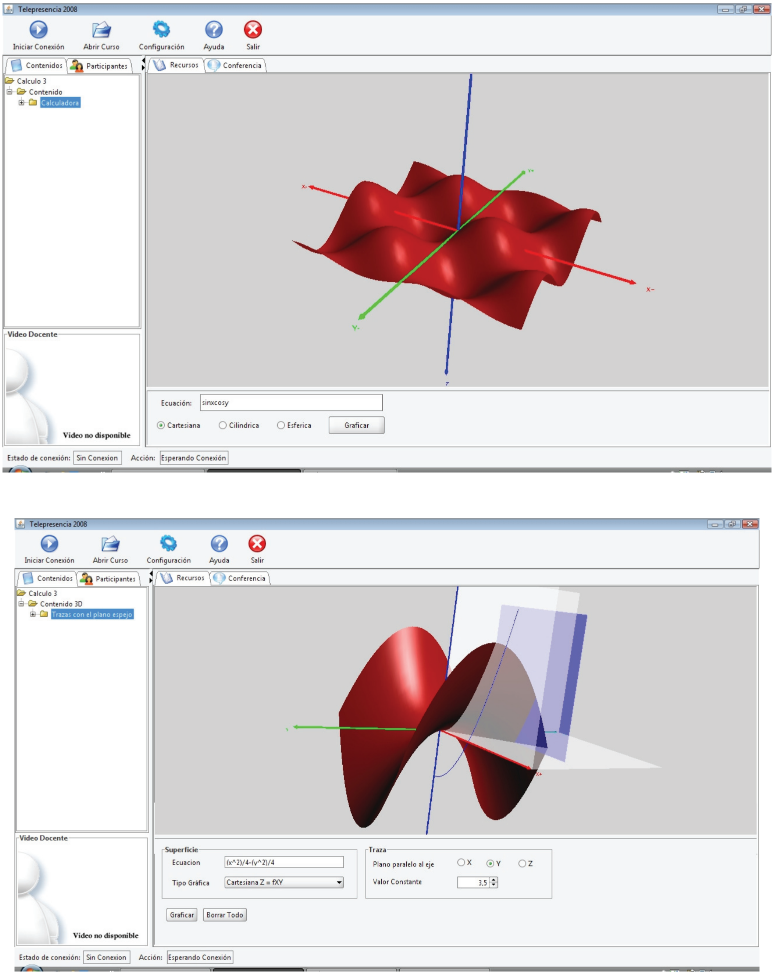

Fig. 1. Examples of 3D shared objects in Telepresence Platform.

3.3 Teleconference Environment

The current teleconferencing system is based on the "Java Media Framework" (JMF), which has not been updated since 2003. Since we are not aware of other java based applications for handling voice and video, we are considering the use of external tools. We are currently evaluating several platforms, including: jffmpeg, jvlc and FMJ. The first tool to evaluate will be JVLC, based on VLC. JVLC provide by developers from Universidad del Quindío have implemented a multi-point communications protocol that allows one instructor to communicate with several groups located in different places. These changes were done by extending the previous network protocol. A new message server was added creating a local cache of the remote users an API that can be used directly from the Telepresence application. VLC is, by itself, a video-stream server.

3.4 Learning Objects Module

We have also implemented a program that packs each content as a SCORM learning object, based on the RELOAD Editor (http://www.reload.ac.uk/new/editor.html). These contents can be sent to remote users, when the content is not stored locally. After the content is sent, the tool will allow users to interact over the 3D scene.

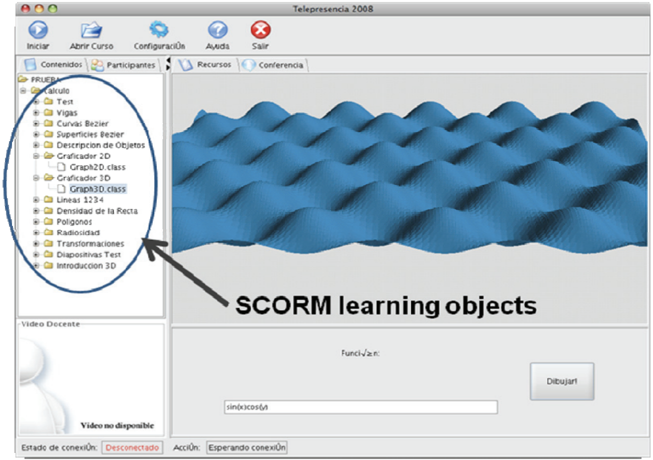

Fig. 2. Example of a SCORM-packaged content loaded in Telepresencia tool.

3.2 General Architecture of the system

Here we summarize the general architecture of the Telepresence platform. The main characteristics of this architecture are the following:

- Model of session client/server. Transmission of point-to-point messages (only between a professor and a client student, who represents a group of students in a same location).
- Contents completely replied (there is a copy of the virtual environments models for each content in each participant machine), and transmission for changes of state (not changes of models).
- Transmission of audio and video in real time between the parts. Different ways of interaction.

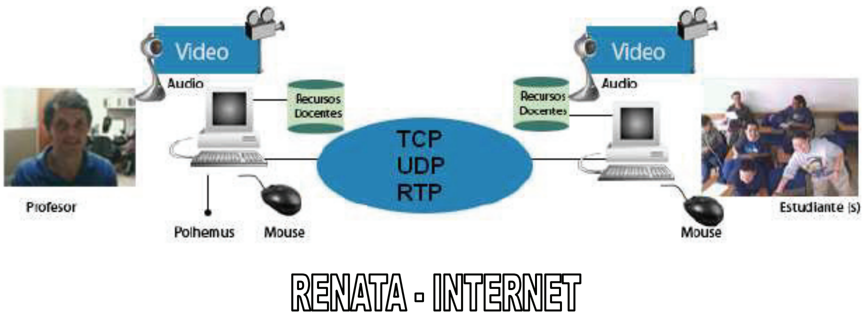

Fig. 3. General Architecture of Telepresence.

Our research project aims to promote the interinstitutional collaboration for the development of proposals in distance higher education. This proposals must integrate the Telepresence tool and the Teaching for the Understanding" to the design of instruction modules to be imparted at distance. The project looks for the integration of the technology and the pedagogy as tools that allow the students to acquire the knowledge, being motivated to understand and transform it according to their personal and social needs. For this reason, we elicited technical and pedagogical questions during the development of the project:

- How to combine messages of audio, video and virtual reality in the proposed system, getting an adequate interaction between the instructor and the students?
- Which logistic and pedagogical factors allow that an education institution, different from the original creator of the prototype, implement the product of Telepresence in a real environment of teaching successfully?
- How to spread the results of the research in institutions that need logistical and technical support to extend the coverage in higher education, and to contribute to the improvement of the pedagogical quality within the country?

4. The pedagogical Framework of Teaching for Understanding

The understanding, the assimilation and the suitable use of the knowledge are the three fundamental purposes of the Educative System. The understanding has a central function due to the following aspects. First of all, the things we can do to understand better a concept are the most useful to remember it. Thus, to understand and to keep information in the memory is useful to look for rules in the ideas, to find examples, and to relate the new concepts with the previous knowledge. Secondly, the knowledge cannot be used actively if there is not understanding. The assimilation is related to our brain capacity to remember a long term concept or event, therefore if we do not have an adequate understanding we will forget in short time. On the other hand, if the concepts are not understood and assimilate suitably, they cannot be used and transformed by the learner.

Several pedagogical studies have explored methodologies to teach instructors adopt strategies that allow students to attain a better and more profound learning. One of these studies is the one led by researchers of Project Zero, at the Graduate School of Education at Harvard University, who have formulated the Teaching for Understanding (TFU) pedagogical framework. TFU proposes both instructors and students to participate actively in building and acquiring knowledge. Ausubel, when creating the meaningful learning approach, suggests that learning implies a restructuring of ideas and concepts within the student's cognitive structure. Ausubel also proposes the use of Conceptual Maps as a strategy to acquire new concepts. Concept Maps serves as organizers of previous knowledge and as a strategy to approach new concepts. Concept Maps can increase meaningful learning, helping the student to discover new relationships between the new concepts and those existing in his/her cognitive structure.

When a student is exposed to learning new concepts, knowledge has to be presented in a way that captures his/her attention. In this sense, Ausubel provides the following criteria to structure teaching: (i) Knowledge to be learned has to be clear and explicit, presented in a language according to the student's previous level, (ii) The student has to have the previous relevant knowledge, (iii) the student has to choose to learn meaningfully, in other words, he/she has to be motivated towards learning. When a student learns, he/she builds meanings, i.e., organized cognitive structures that are related to current knowledge, thereby producing meaningful learning. When relationships are established in an arbitrary form, or are not generated at all, memorization learning takes place. Memorization learning is easily forgotten.

One of the strongest motivations that human beings have in order to attain a concept, is the possibility of applying it in the solution of existing problems. In order to attain desired goals, the student must have an appropriate set of pedagogical tools. In TFU, the "portfolio" is used. The portfolio is a collection of activities and tangible resources that the student uses and builds during his/her learning process; it is the student's learning log.

The construction of a portfolio can be divided in three phases: (i) Concept Exploration (ii) Guided Research and (iii) Final Performance. In each of them, students show their work to their peers, the instructor and experts. The different phases are described next:

a) Concept Exploration. The student's environment is explored in relation with the topic at hand. In these phases the individual or group's interests become evident.

b) Guided Research: Each student or group, with the help of the instructor, selects a Project in which to apply the concepts of the concept at hand.

c) Final performance: Students present their findings and the solution they have implemented. They present the performances they have done during the project.

The portfolio is built by students and they use it either to revise concepts or cognitive relationships, or to create new ones.

The instructor's relationship with the student plays a very important role in the learning process. He/she has to favor the presentation of new knowledge in an orderly and appealing fashion, and should try to foster the student's interest on learning by applying teaching strategies that encourage learning.

TFU integrates various pedagogical theories in order to foster the students deep understanding of the proposed contents, particularly those that are fundamental when building the knowledge of the subject. For this purpose, it is important to link the students' interests with meaningful real-life situations. TFU does not propose a unique way to be applied, and for this reason the way how knowledge is presented to the student and the instructor's own understanding play a key role in the process.

4.1 The understanding in the Colombian school curriculum

Although the understanding is a goal in the school curriculum, it is not clearly defined by the Colombian Ministry of Education and the professors have not a clear idea about the matter. What issues must the learners understand? What is the meaning of understanding a concept? How can an educator know when a student has understood a concept? In the curricular designs of the institutions we can find phrases like this one: "The student understands this or that thing…" However, the understanding cannot be measured by a thermometer or by multiple choice tests. The understanding is not a state of possession but a state of capacity that the student can demonstrate when solving diverse kinds of problems. When something is understood, the individual is able to transform the information into something productive. The activities that can be developed from a concept reveal understanding. These processes are called understanding activities. For example, we suppose that we understand the Pythagorean Theorem "The Square of the hypotenuse of a right triangle is equal to the sum of the squares on the other two sides". When exposing this concept, the professor must reflect about what type of understanding activities the students should develop to understand this geometry theorem. The explanation, the exemplification, the application, the comparison and contrast, and the generalization are some of them. Some of these activities are simple; for example, it is easy to find examples of the Pythagorean Theorem by measuring a soccer field, a classroom or a house. However, other activities are more demanding, for example, the generalization. This variety of activities reveals some important characteristics of the understanding. The understanding is identified through the creative activities in which the students “go beyond the provided information”. The understanding consists of a qualification state to exercise such activities of understanding. The different understanding activities require different types of thought: analogical, metaphorical, logical, and creative; consequently, it is required the application of different intelligences types.

The understanding is not something that is “acquired or not acquired”. For this reason, it is quite important that the professors devote enough time and efforts to prepare the understanding activities they will present to the students. On the other hand, the understanding is open and gradual. With respect to a determined subject, an individual can understand little (the development of few understanding activities) or understand a lot (to develop many understanding activities), but s/he cannot understand everything because there are new extrapolations that have not been explored, therefore it does not exist the ability to do them.

The understanding is a complex mental process that requires the intervention of the memory and thought systems, the codification and perception, and the inferential operators based on previous behaviours and contextual factors. The Understanding becomes a constructive process, in which the information of a stimulus or event interrelates with previous information registered in the human being memory.

5. Course design under the TFU - Overview

The way how we relate to our environment and the capacity to extract various properties from the objects in it, are key issues in the teaching-learning process. Based on these ideas, the course on Multi-Variable calculus was chosen, since it allows students create relationships between the environment and the mathematical concepts, as well as the concepts covered in other courses in the same semester. For this reason, the instruction modules to be used with the Telepresence tool were designed based on the syllabus of the Multi-Variable Calculus subject. Figure 4 presents the training process of TFU for teachers of Calculus in University of Quindío.


Fig. 4. Training on TFU for the whole research team – June 2008. Copyright® University of Quindío, 2008.

The Multi-Variable calculus course is part of the Engineering Curriculum at the universities that take part of the Project. The design of the course was built around the question "*How can I to apply Calculus in my field of study?*". With this question we try to encourage students to relate the course with other subjects in their curricula, and also with concrete objects in their environments. As part of the course, the students look for real-life objects that can be modeled with the equations covered in the course.

Calculus-related concepts that are particularly important are: vectors on the plane and vectors in space, partial and directional derivatives, multiple- and line-integrals. These concepts lead to the concept of "surface", therefore, students appreciate how the surface's concept is key for understand the Multi-Variable calculus course. In this course, students are asked to establish relationships between real-life objects and the concepts of the course. For this reason the concept of surface was defined as one of the key concepts.

For each concept in the course, several ways were proposed for students to demonstrate their deep understanding:

a) *Concept Exploration*. Students created an idea network, in which students put together the ideas they have about calculus and how it's related to their life. Concrete applications of calculus in various engineering fields were presented by the instructor. During this exploratory phase, students chose a problem to be solved by them. The problem was supposed to be related to their field of study.

b) *Guided Research*. Students starting solving the chosen problem, using the course contents and the technological tools to support the process. During this phase, students created a report with the problems they faced and the solutions they found

c) *Final Performance*. Each student demonstrated his/her understanding in a final Project that was presented to their peers.

5.1 Use of the Telepresence tool in the multi-variable calculus course

One of the main objectives of this Project is to use the Colombian high-speed network (called RENATA). It links the research community in the country with the international research community, as a platform to run our Telepresence tool. The added value of the use of RENATA as communication platform is its power to foster communication and collaboration among the various communities involved.

RENATA is the academic high-speed network in Colombia. It is linked to other academic high-speed networks in the world and allows the Colombian academic community to share data, information, lab equipment and transfer large amounts of data with other communities in our country or abroad. Also, RENATA enables the use distant of lab equipment and access to academic information between Universities at Colombia.

The Telepresence tool, running over RENATA, will allow an instructor from Eafit University to teach a Multi-Variable calculus to students at University of Quindío. It will also allow an instructor from University of Quindío to teach students at EAFIT University. In both cases, the instructor and the students will interact in a shared virtual environment. The 3D content to be used is being built by the development groups.

5.2 Applicability of the Teaching for Understanding Pedagogical approach and the Telepresence Platform in a Multivariate and Vector Calculus Course

In order to start the experience of developing the Multivariate and Vector Calculus course from the Teaching for Understanding pedagogical approach, the professors received instruction about this method. The instruction consisted of two parts, a conceptual and practical foundation about the pedagogical approach and the introduction to the use of the Telepresence platform, executed on RENATA, to teach the Calculus course at distance. Additionally, we questioned the students who had attended the Multivariate and Vector Calculus course about the main difficulties they found, the main contribution of the Vector Calculus to their professional formation, and its applicability to daily life. We also ask for the suggestions and recommendations they had to improve the development of the course. The students agreed that it was necessary to modify the methodology used to teach the academic subject. They considered that it was important to identify clearly the applicability of the Multivariate and Vector Calculus course in daily life. Taking into account this information, it was possible to have a preliminary view about the pedagogical approaches and the methodologies used in the development of the subject. It was evidenced a very low level of motivation, apathy and little applicability. The students considered that this course is too complex and consequently, it is necessary to take it several times. Besides, they maintained that the course is quite important for the Civil Engineering students, but not for the Electronic and Computer Systems students.

To develop this experience, we took three groups of students who attended third semester of the Engineering school. These groups were heterogeneous since they were students from Computer Systems, Electronic, and Civil Engineering. The average number of students per group was 45; some of them attended this subject for second or third time (situation that generates low motivation). The students were between 18 and 25 years and the courses were daytime demanding the students' presence in the classroom.

5.3 Expectations in the development of the subject

The three groups of students attending the Multivariate and Vector Calculus course were asked to answer a previous knowledge test to identify the specific concepts related to the subject. This pretest included several concepts (i) the daily life situations where some concepts of the Vector Calculus were observed (ii) the mathematical concepts that were used in the Calculus learning (iii) the real situations where the students had used the Vector Calculus.

The first aim when applying the pretest was to identify the student's previous concepts and the relations they established with some specific concepts of the Multivariate and Vector Calculus course. The pretest included fifteen (15) general knowledge questions about the subject. The second aim was to allow the students to express freely their thinking about the subject, the applicability they had learned in previous subjects and the intuitive relations between the Multivariate and Vector Calculus and its applicability to the students' professional formation. It was an open test that did not allow closed answers; the students were asked to respond all of them. When analyzing the answers given by the students, we evidenced the following aspects.

- Most of the students affirmed that the Calculus is evidenced in daily life when developing Civil Engineering projects like bridges, buildings and other constructions. Some students mentioned the elaboration of advanced computing programs and the analysis of budgets. It is important to highlight that it is not evidenced a students' high level of argumentation when describing real and specific situations for the applicability of the Calculus. Since there were students from different programs, we expected diverse applicability and contexts.
- Most of the students consider that they have not used the Calculus on their lives. Some other students related the Calculus to the speed or they were not sure if they have used it or not.

Generally, the students perceived the Multivariate and Vector Calculus like an important element in their academic activity, but they could not explain clearly how they could apply it to their professional performance and their daily life. Most of the students related the Multivariate Vector Calculus course to diverse applicabilities like automobiles route; measurement of distances, speeds, and lands; and the construction of bridges and buildings. Nevertheless, they did not support clearly the applicability of the Calculus to their professional formation as futures Electronic, Computer Systems and Civil engineers.

6. Pedagogical Approach: the Multivariate and Vector Calculus from *Teaching for Understanding*

Our main purpose when designing the course from the Teaching for Understanding pedagogical approach and the use of the Telepresence platform is to develop and to strengthen the students' understanding, the flexible thought and the processes of action-reflection taking into account the meaningful experiences they found in their daily life.

In order to determine these components we invited the professors who teach the academic subject to participate in several meetings. Initially, we questioned the professors to explore the concepts and issues they considered relevant for the development of the Multivariate and Vector Calculus course. Then, we gathered and grouped the information to design a conceptual map containing the issues to consider in the development of the course. Then, we developed an instrument to know the perception that each professor had about the applicability of the Calculus to daily life, the main contribution of this subject and the difficulties found in its development. Later, we distribute this information to the professors who finally agreed to implement the Teaching for Understanding pedagogical approach. We defined the pedagogical guidelines to follow, the methodology to use, the type of activities the students would develop, the way of assessment, and the appropriate moments to use the Telepresence tool. Taking into account these meetings and agreements, we designed the following pedagogical proposal.

6.1 Conductive Wires for the Multivariate and Vector Calculus Course

The concepts related to the Calculus through which diverse situations of the plane are expressed, are the vectors in the plane and the space representing them in the diverse surfaces, the directional and partial derivates, and the lineal multiple integrals. These terms lead towards the concept of Surface. In some variables of the Calculus course, the students were questioned because they established relations between objects of the real life and the different concepts studied through the course. For this reason, the Surface was one of the key aspects to be understood.

To present the concepts to the students, it was found that the best way was to formulate an affirmation encouraging them to think and reflect about the importance of the Multivariate Vector Calculus. With this strategy, it was expected that the students were motivated to give the answers and to research about the concepts they intend to learn. Thus, the conductive wire used is "***the students would appreciate how the concept of surface is a key for the understanding of the Calculus***"

6.2 Generative Topics for the Multivariate and Vector Calculus Course

After analyzing the thematic axes of the subject and their relations with other disciplines, the topic defined was the Calculus itself. Thus, it was made a reflection about these relations, the professors' and student's interests and the context. Accordingly, the generative topic was denominated "***How can I apply the Calculus course to my career in a comprehensible way***?"

6.3 Goals of Understanding for the Multivariate and Vector Calculus course

- The student will develop understanding by determining and relating the fundamental concepts of the Multivariate and Vector Calculus course in a daily context.

To achieve the previous goal the students will understand:

- The vectors in the plane and the space representing them geometrically in the daily situations they face.
- The concepts of the partial and directional derivative.
- Multiple and lineal integrals through its applicability in the surroundings.

6.4 Phases of the understanding performances

In order to define the activities proposed for the understanding performances, three phases were proposed. They must be accomplished in different moments of the class. The Understanding performances defined are the preliminary performances, the guided investigation and the final performance of synthesis.

Preliminary Performances

The aim of the Preliminary Performances is to allow the students relating the Multivariate Vector Calculus to their surroundings, and its applicability to their professional formation. The activities proposed are the following ones.

Exploration of the topic (Phase I)

- Through the elaboration of a network of ideas, the students stated all their doubts and preconceptions about the Calculus concepts and about the objects and phenomena they related it to their daily life.
- The professor exposed concrete examples to evidence the applicability of the Calculus to the students' careers (Civil, Computer Systems and Electronic Engineering).
- Later, the exploration of the topic (phase I) is started through the open question "How can I apply the Calculus subject to my career and what important issues I can solve by using the Calculus subject in my career? The students were asked to investigate on this question.
- The students conformed work groups and researched about the Calculus subject. They consulted about the Calculus applicability to daily life and interviewed diverse professionals who spoke about its usefulness. They also read about the history of the Calculus and explored constructions and objects that allowed them to perceive it in their real and daily life.

When finishing this exploration phase, the students chose a problem or project to be solved through the Vector Calculus. Each group described in detail the kind of problem they wanted to solve and the ideas they have to solve it.

Guided Research (Phase II)

The guided research allowed the students choose a structural element with which several concepts of the Multivariate and Vector Calculus could be explained and its relation between their professional role and daily life.

These are the activities that were developed.

- The students analyzed and solved the proposal they chose by using the contents of the course and the technological tools to support the development of the project. During this phase they were asked to report the advances of the proposal, the solutions that were proposed, the definitive design, and the contents to approach. All these elements had to be registered in the portfolio.
- In this phase the proposals began to develop conceptually the contents of the Vector Calculus. In addition, the students had to analyze how to transform them into a real and viable design in our context. The expected result was that they could visualize themselves performing their profession.
- Here is the description of some of the projects or proposals developed

- Construction of a cylindrical or circular building, The group described the physical parts that composed the building, its principal and secondary members, its shape, the different classifications according to its use, the property, the structural system, the disposition, and the general environmental, cultural and social impact. Additionally, the research that began in phase I, about the cylindrical buildings construction was retaken and improved. Later, the students selected the application to work with, the dimensions of the model on scale, and the calculations of the superficial area of the structure by using integrals. They calculated the volume of the building by using double integrals, outline the graphic structure in a three dimensional system, deduced the mathematical model that relates the structure with the mathematics (Calculus), and began the elaboration of the scale model of the building.
- Design of two Towers in hyperboloid of a leaf shape united by a horizontal straight cylinder in the middle of the height with spiral stairs employing the concept of the movement direction. To develop this project the students retook the information of the portfolio and improve it. The necessary concepts were the squared surfaces, hyperboloid of a leaf, cylinders and their classification, direction of movement, shapes of the buildings, classifications, and the exploration of the Quindío region in terms of general information, history, earthquake, representative places, Shopping centers, developing projects and needs of the region.

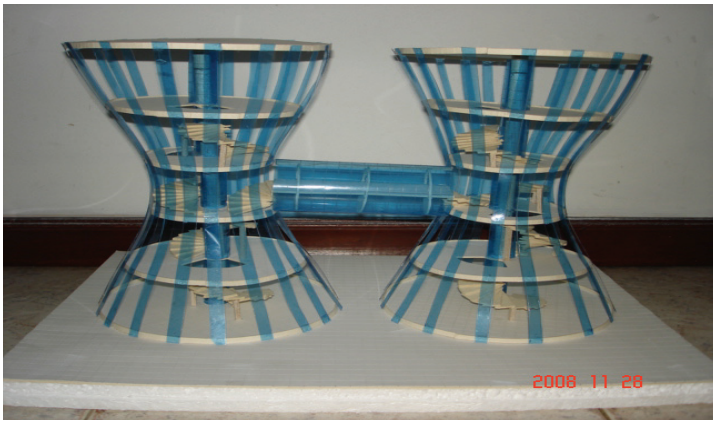

Fig. 5. Towers in hyperboloid of a leaf shape united by a horizontal straight cylinder proposed by students.

- Construction of a scale model concerning a pedestrian bridge based on the concepts of the Multivariate Vector Calculus which allow joining two buildings separated by an avenue. To develop the proposal, the students looked for the bridges history, classification, efficiency, and the urban situations of Armenia city. They retook and improved the information of the portfolio about Hyperboloid of a leaf and analyzed the benefits and advantages of the project in Colombian regions.

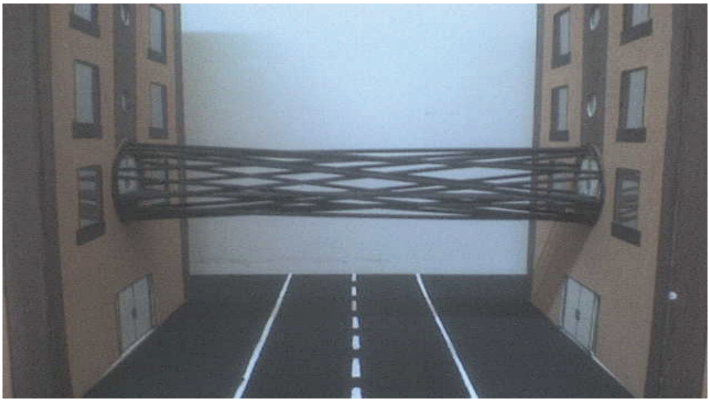

Fig. 6. Proposal for pedestrian bridge that allow joining two buildings separated by an avenue

Final Project of Synthesis (Phase III)

The main objective of this phase is the socialization of the construction design or created solid. Each group of students described the processes they implemented for the design of the concrete object. They were listened to by their classmates, the professor of the course, a professor from the Computer Systems Engineering department, and a professor from the Pedagogical department. The activities proposed to guide this phase were the following ones.

- The students had to design a scale model of the construction or selected solid.
- The students identified the fundamental concepts of the Multivariate Vector Calculus subject according to the construction or the constructed solid.
- The students presented the constructed solid and supported the elements of the Multivariate Vector Calculus in the objects and structures of the building.
- The students presented a report where they summarized the diverse applications and manifestations of the Calculus in the construction or selected solid.
- The report also contained the analysis of each concept, the conclusions and recommendations, and the students' opinion about the work they carried out.
- This socialization of the final project was filmed and photographed. (we attached the filming, 2 CD)
- Interesting and new projects were developed:
    - Shopping center in the form of a coffee grain
    - Hyperbolic towers
    - Parabolic antenna
    - Hyperelipsoidal building
    - Water source
    - Water dam arc type
    - Bus stop
    - Ecological washbasin
    - Elliptical Sofa

6.5 Continuous Valuation

To fulfil the fundamental objective of the valuation, it is necessary to demonstrate to the students the progresses of the understanding of the Multivariate and Vector Calculus concepts in the execution of the projects. These are the criterions for a continuous valuation.

- The students consigned the advances of their proposal in the portfolio where the understanding performances were evidenced taking into account the preliminary performances, the performances related to the guided investigation and the final performances of synthesis.
- The advances achieved in each understanding performance were discussed in group.
- The exercises proposed by the professors were developed and the reports of the workshops were presented.
- The final project of synthesis was socialized. The team works exposed the result of the project to their classmates and expert people.
- The performances made in the development of the of Generative Topic were valued from the levels of the understanding (see the tables)
- The final project of synthesis evidenced the conceptual and practical competence about the contents of Multivariate and Vector Calculus. Additionally, It was evidenced the applicability of the Calculus to the formation of three kind of professionals (Civil, Computer Systems, and Electronic Engineers)

The results of this experience allow deriving the matrices of continuous valuation that appears bellow.

	INGENUOUS	**NOVICE**	**APPRENTICE**	**EXPERT**
Oral Presentation	Very low tone of voice. His/her presentation is not clear.	S/he is not clear in the explanation of the project. S/he reads the script or the written work exactly	S/he is able to separate from the script when it is necessary and S/he can explain and support the project His/her presentation is clear and coherent.	Suitable tone of voice. S/he demonstrates confidence. Coherent Presentation that invites to other analyses.
Handling of the technical language	S/he does not use technical language	S/he uses technical terms, but not always correctly.	S/he appropriates the technical terms	S/he uses the symbolic systems of the subject effectively.
Handling of the questions	S/he does not answer the questions or answer them erroneously.	S/he does not support the answers	His/her answers demonstrate support and discernment.	With her/his answers s/he demonstrates to master the subject.

Interaction with the audience	S/he does not consider the audience.	S/he rarely looks at the audience.	It maintains contact with the audience.	She/he adapts his presentation to cover all the audience and perceives people's mood getting adapted to the situation.
Performances of Understanding (Abilities)	S/he uses a single way to explain the solid or the project of synthesis	S/he uses some different ways to explain the project but s/he does not relate them.	S/he uses diverse ways to explain the project and relates them.	The diverse forms to explain the project allow him/her to generate new knowledge and new applicability.

Table 1. Matrix of continuous valuation.

	INGENUOUS	NOVICE	APPRENTICE	EXPERT
Applicability of the concepts of Multivariate and Vector Calculus in the elaboration of the project or solid.	S/he does not identify the concepts of the subject to construct the project or solid	S/he mentions some concepts, but s/he does not explain clearly how they were applied.	S/he mentions the concepts and describes how they were applied.	S/he explains which concepts were used and argues why they were used and not others.
Mastery of the concepts	The knowledge that the student demonstrates is intuitive, but not formal The concepts s/he takes are not related to the solid.	The student begins to generate connections, but it is evident that they are tried previously.	The student demonstrates a flexible use of the subject. S/he demonstrates creativity when selecting the concepts to use.	The student masters the formal concepts to validate and create new knowledge. S/he demonstrates the way s/he used creatively the concepts and its applicability.

Understanding of the relation between the concepts learned in the subject and its possible uses	S/he does not find the relation. S/he does not consider the purposes and the uses of what it was learned	S/he understands the relation between the concepts and the project developed, but s/he does not extrapolate these uses in her/his professional life.	S/he demonstrates to understand how to use what it was learned in her/his professional life	S/he demonstrates her/his ability to generate creative uses of what it was learned generating new knowledge or new applicability.
Mastery of the generalization of the Multivariate Vector Calculus concepts.	S/he does not understand that the concepts used can be applied to solve similar or even different problems.	S/he understands that the concepts used can be applied to other situations but s/he does not explain how.	S/he explains how the solution of the problem can be applied to other situations of the daily life.	The explanations given about the applicability of the solution of the problem are creative and generate new knowledge.

Table 2.Matrix of continuous valuation from the understanding levels - socialization of final project *"How can I comprehensively apply the Calculus in my career?"*

7. Results of the use of the Teaching For Understanding pedagogical approach with the mediation of Telepresence tool in the multivariate Vector Calculus subject

At the end of the current course of Multi-Variable calculus course, students submitted a final project or portfolio where they demonstrated how to apply the concepts seen in class on real scenarios and situations. For this purpose, students at the University EAFIT and Quindío University made a socialization of projects, with the presence of students and teachers of the course. Some of the most remarkable projects are:

- **Hyperbolic Towers**

This project has two towers in form of hyperbolic of a leaf, joined by a straight horizontal cylinder at half the height of the towers, and ladders in form of spiral. The purpose of this project is that the proposal are used by the governor's department of Quindío and the mayor of the city of Armenia, capital city of department of Quindío - Colombia . It also intends to use the project as an initiative to consolidate tourism in the city of Armenia.

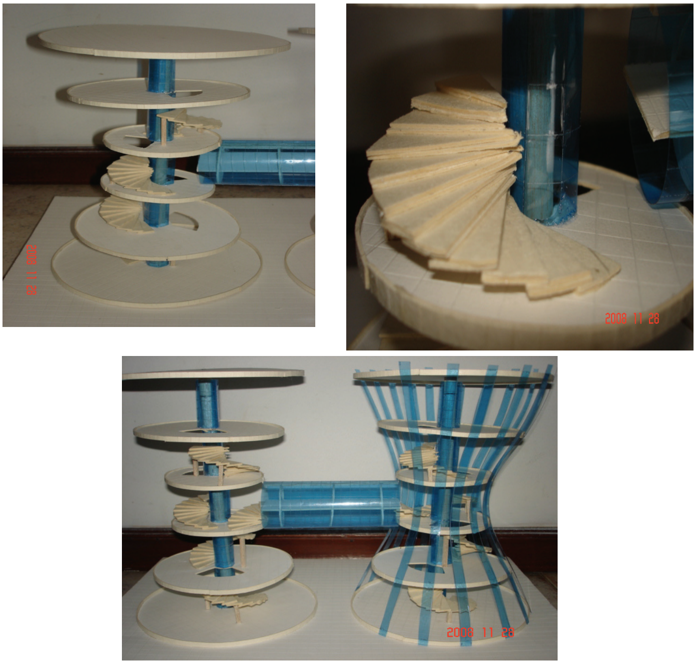

Fig. 7. Hyperbolic Towers's process of building.

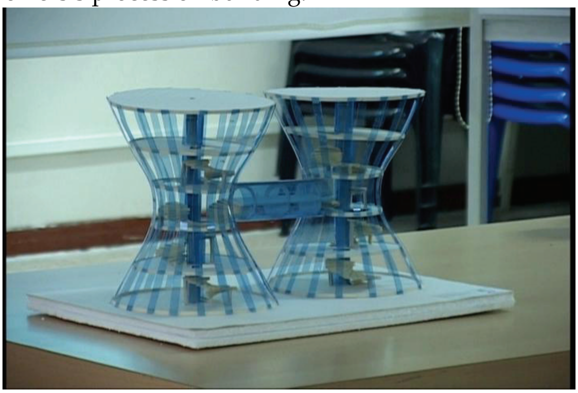

Fig. 8. Hyperbolic Towers (1:50 scale).

- **Mall of Coffee**

Due to the culture and tourism potential at the department of Quindío, and taking into account the low commercial potential of the city of Armenia respect to other Colombian cities, a group of students proposed the project as a shopping center in the form of Parabolic elliptical, which represents Outside the building, with a hole at the top to make visible a small park in the form of coffee beans consisting of several ellipses.

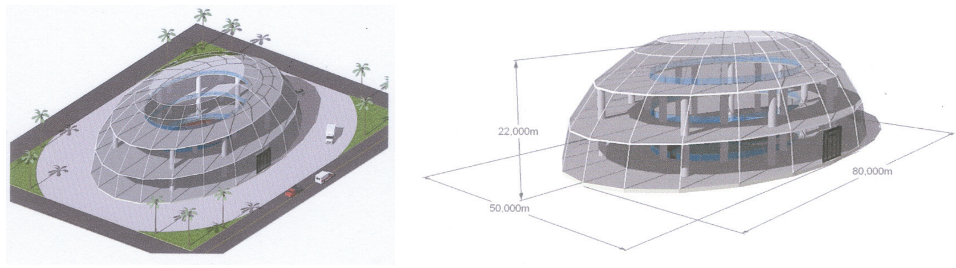

Fig. 9. Front view of Mall of Coffee.

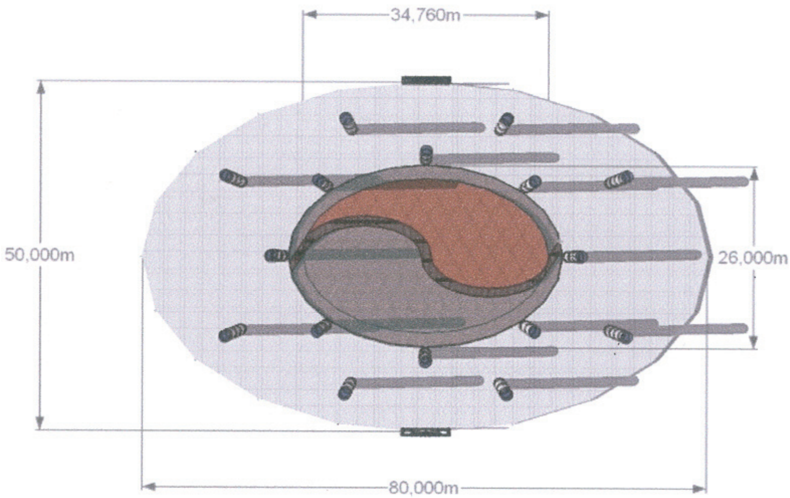

Fig. 10. Top view of Mall of Coffee.

- **Elliptical Sofa - Elipsofa**

Another group of students decided to design a sofa primarily formed by an ellipsoid which would be the seat of it. Two cylinders that form the arms of the sofa, and four hyperbolics of a leaf that would fulfill the function of supporting the sofa. Although the design of the sofa is a complex for students, it reflects how the Calculus is an important part of the everyday objects that look the students.

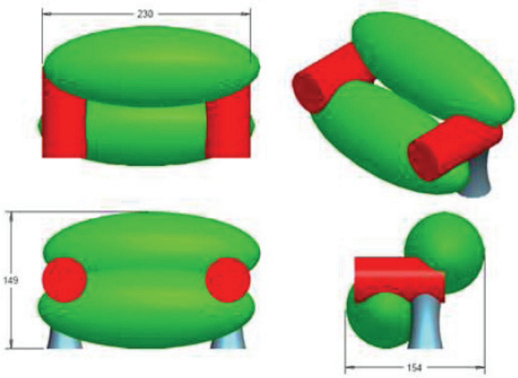

Fig. 11. Plane assembly of ElipSofa

- **Ecological washbasin**

Concerned about the excessive costs of water daily presented in using the toilet, estimating that a person spends approximately 96 litters of water daily just to go to the bathroom, considerable bearing in mind that the liquid is potable, a group of students designed a project which they expose the storage of non-potable water previously used in the process of cleanliness, for reuse in cases that not require potable water like the toilet. The project is to design a sink which stores used water and sends the water to the tank of the toilet when is required. The design is comprised of three quadratic surfaces, the main surface is the base consisting of a hyperbolic of a leaf, which gives the general shape of the sink; within the hyperbolic of a leaf there are a cone that serves as the storage tank, at the same time the hyperbolic holds a container in the form of parabolic elliptical. With the various applications of the multi-variable Calculus, students estimated the size of the solid to design and volume of each of its elements.

7.1 Post-Test

Researchers who worked in the experience designed a post-test that contained eleven questions about the applicability of the Multivariate Vector Calculus to the Civil, Computer Systems and Electronic engineering careers. It was a post-test composed by open questions to allow the students to express freely what they thought about Multivariate Vector Calculus, the applicability they found and the kind of relation they established with the daily life.

The aim of applying the Post- Test was to evidence the level of the student's understanding. The questions formulated had the purpose of confronting the student with their previous concepts and the ones learned through the academic subject using the Telepresence tool and the Teaching for Understanding pedagogical approach. It is important to remark that besides the understanding of the Multivariate Vectors Calculus concepts, we also expect that they apply the knowledge of the Calculus in the daily situations they could find when exerting their professions.

When analyzing the given answers, it is evidenced a great level of conceptual appropriation and a deeper argumentation of each concept. These aspects lead us to conclude that the understanding level was strengthened. Finally, we concluded that the students' perception about the concepts of the Multivariate and Vector Calculus modified the cognitive schemes they had about them. The students also modified their perception and attitude toward the academic subject. In this way, the students reached the assimilation and a complex cognitive accommodation that allow them to have a significant cognitive balance.

7.2 Results of the Experience from the Teaching For Understanding pedagogical approach

The experience obtained in the development of the academic subject Multivariate Vector Calculus from the Teaching for Understanding pedagogical approach was quite satisfactory. It was possible to evidence the improvement of the understanding in the students belonging to different careers. The learning environment was receptive, participating and very dynamic allowing the students to develop the understanding performances not only inside the classroom but also outside. In addition, the support of the Telepresence tool in the process of each performance was fundamental for the final result, since it allowed the students to project themselves in the real life and to extend the concepts of the Calculus.

Similarly, it is fundamental to highlight the interest and commitment that the professors of the subject devoted to implement and develop the project from this pedagogical approach. This experience contributes to modify the cognitive schemes from the education focused in teaching to the education focused in learning. In this case, the professor is a mediator of the process and not just a transmitter of knowledge helping the students to strengthen their understanding.

The following table presents the difference between the Traditional Pedagogical approach and the Teaching for Understanding approach.

	Tradicional Teaching Approach	**Teaching for Understanding Pedagogical Approach**
Purpose	To transmit knowledge to the students	To encourage students to discover and to construct their knowledge.
Evaluative Process	To produce repetitive, fragmented and theorical knowledge. The learning process is determined when finishing the transmission of the knowledge by means of examinations, tests and final assignments.	To produce demonstrable, meaningful learning. It evaluates the learning process of the learning at every stage of its development by applying diverse formal and informal methods. It emphasizes the productive work having applicability in the daily life situations.

	It emphasizes the individual work and evidences the students' results by the amount of their academic work.	
Curricular Contents	To develop the academic subject through a fixed program that is predetermined by the amount of contents and methodologies previously established.	The development of an academic subject generates flexible and motivating environments. The curriculum is considered as a whole and not as a list of fragmented contents.
Teacher-Student relation	The teacher is who imparts the knowledge and delimit it.	The teacher is a mediator who generates flexible uses of the knowledge and invites the students to confront them.
Goal	Search of the acquisition of a particular discipline knowledge.	Search of the strengthening of the understanding levels.
Methodology	The teacher approaches the learning process from diverse methodological principles according to his/her own experiences and interests.	The teacher guides the learning process by means of the conceptual framework of the *Teaching for the understanding* approach

Table 3. Differences between the Traditional Pedagogical approach and the TFU approach.

We evidenced in the students a collaborative work, the relation they establish with other subjects, the integration of the conceptual framework of the Multivariate and Vector Calculus with the contents of the previous Calculus courses and the conceptual bases achieved to continue strengthening the understanding through posterior conceptual developments. It is important to highlight the contextualization of the final projects of synthesis evidencing how the students analyze the characteristics and needs of the region. We found projects to promote the tourism in the region, to benefit the coffee culture, to improve and to give greater identity to the infrastructure and to approach the regional policies to promote the environmental and economic development of the region

Fig. 12. Students presenting pedestrian bridge's portfolio

8. Conclusions

The opportunity to integrate academic and technical groups from different universities, each with different perspective on the education process makes the collaborative work more enriching and interesting. Some of the highlights of the current collaborative work are:
a) Pedagogical training on TFU of the math instructors involved with the experience.
b) Training on the use of virtual resources by the instructors that take part of the design of the Multi-Variable Calculus course at both institutions.
c) Collaboration and integration of the two development groups in creating a stable single code base.
This integration will result on an improvement of the teaching process of the Multi-Variable Course at both universities, as well as a better utilization of the available technological resources by the students at both universities.
This project will foster the use of new technologies in the teaching-learning processes that are built on top of high-speed networks like RENATA. Our goal is to continue improving the Telepresence tool in order to make possible new and novel ways of interaction between the instructor and the students. High-speed networks should allow the academic communities to share learning objects and promote the integration and collaboration of academic communities in our country and abroad.
The pedagogical model used, allowed to develop the subject in a novel, interesting and exciting way not only for the students but also for the professors who worked in the project. This approach allowed developing the students' understanding since a flexible bridge was created between the concepts related to the Calculus and their applicability,

modifying the memory theoretical concepts and the complex and incomprehensible academic processes. The students confronted their knowledge by applying them to their future professional roles. Additionally, the students obtained new perspectives about the applicability of the Multivariate Vector Calculus to the daily life.

The work climate was interesting and motivating, since it was allowed to interact in different ways with the knowledge, for example, with the Telepresence platform. Also, the interaction was made by observing the context, analyzing the surroundings and integrating the knowledge. The Teaching for Understanding pedagogical approach activated the students' understanding and stimulated their capacity to relate the concepts, to extrapolate, and to associate them with objects or situations of their daily life.

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14

E-Learning Tool for Digital Design and Embedded System Training

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1. Introduction

The complexity of today's digital systems is putting new demands on the education of the professionals working in this field. Electronic Design Automation (EDA) techniques are the core of digital systems development processes, while traditional design and prototyping have lost their roles. EDA techniques are finding their way in engineering education: professional tools are available at very favourable conditions for educational institutions, and successfully used in engineering courses.

In our opinion, the use of a professional simulator in a course designed to provide the foundations of digital design is not yet a good choice. A tool conceived to increase the productivity of a digital designer does not meet, albeit as its primary target, the needs of education. What is a plus for the professional (for instance the wide availability of components and functions) may be a minus for the learner.

Another noticeable aspect of digital design education is related to the introduction of Hardware Description Languages (HDL). A growing number of teachers introduce HDL and EDA tools in basic, introductory courses: but beginner students do not possess the skills and the frame of mind of the professional designers. Moreover, the use of HDL for design could be an handicap when the learner lacks programming experience and the high level of abstraction that is required to successfully use HDL. We suspect that the use of professional tools and HDL in introductory courses may hide from learners important basic issues. Nevertheless, to achieve some familiarity with EDA techniques is a necessary target of a digital design course, even an introductory one.

The growing diffusion of Internet have deeply influenced the framework of engineering education, and has shifted the attention toward applications focused on communication and cooperation (Ponta & Scapolla, 2007). Moreover, Internet-controlled remote laboratories for electronics are now available from many educational institutions, and the concept of executing experiments remotely is a consolidated practice (Bagnasco et al., 2005; Asumadu et al., 2005; Zimmer et al., 2006; Gustavsson et al., 2006; Donzellini & Ponta, 2007, a). The use of PLD-based boards (Garcia-Zubia et al., 2006) allows to setup remote labs for digital electronics dealing with relatively complex digital systems.

In the past, the authors have employed hypertexts, author languages and multimedia materials to develop highly interactive learning tools to form a learning environment for electronics (Da Bormida et al., 1997). The pedagogical results suggested that a general purpose simulator would advantageously substitute the entire set of interactive tools. In the following we will use the expression “virtual laboratory” to refer to a set of learning material and software tools simulating the functionalities of a traditional laboratory. Virtual laboratories for digital electronics are based either on professional applications, or simulation tools designed for educational purposes (some commercial and non-profit products, often used in the educational field, are listed in the Appendix).
Commercial simulators usually lack the capability to interact with learning material, being oriented to professional users that already possess the proper frame of mind and the skills that students of introductory courses cannot yet master. We considered the possibility of adopting a professional simulation tool but, at the end, we decided to develop our own environment integrating simulation features with tutorial materials.
This is the foundation of the Deeds (Digital Electronics Education and Design Suite), a virtual laboratory for educational application (Donzellini & Ponta, 2007, b) available at http://www.esng.dibe.unige.it/deeds.

2. E-learning with the Deeds environment

The design and simulation suite that we developed, Deeds, represents our approach to foster learning of digital design. Our target is to prepare students to the use of current and future EDA tools by building a solid understanding of the principles of digital design. This means to guide a learner, with no previous knowledge, typically in a one year long course, to achieve the foundation for designing embedded systems.
The experience of the authors in the educational use of Deeds dates from several years ago, when the first versions of the simulators were released (Bovone et al., 1999; Ponta et al., 2001; Donzellini & Ponta, 2003). Deeds functionalities and pedagogical applications have co-evolved in close contact, since the technical evolution of the tools has been dictated, mainly, by the needs emerged during the educational practice. In our university, Deeds is extensively used by the students of the first and second year of electronic and information engineering to support laboratory activity and project-bases courses.
NetPro (Ponta et al., 2001; Markkanen et al., 2001), an European project of the Leonardo DaVinci programme, running from 1997 to 2003, has served as a catalyst and support for the development of the Deeds toward its current architecture. Deeds is a set of Windows® applications, developed in Delphi®), to be installed on the user’s personal computer. Deeds is available, from its web site, free of charge to all interested users.
The suite is composed by three simulators and a wide collection of associated learning material to practice with: combinational and sequential logic networks, finite state machine design, embedded microcomputer interfacing and programming. These tools are characterised by a “learning-by-doing” approach and can run independently or in connection with web repositories of learning material. The environment itself can be looked at from two different points of view: either as learning materials that includes general simulation capabilities or as a simulator capable of delivering learning contents. This makes possible to understand the interaction between hardware and software components of

embedded systems, a subject that is receiving a growing attention from the engineering education community (Bruce et al., 2004; Nooshabadi & Garside, 2006).
Deeds-based embedded systems, in spite of their apparent simplicity, provide a good understanding of the interaction and trade-off between hardware and software, building the skills that are at the base of current state-of-the-art implementations. The growing complexity of current embedded systems calls for the use of embedded platforms and high-level languages for their design. This process, inevitably, shifts the focus of attention toward designing at system level and rightly suggests a top-down approach. The authors are convinced that, to found the education of the professional designer of embedded systems, a bottom-up path, such the one provided by Deeds, plays an essential role.
Deeds is, by its own conception, a suite of tools aimed at the basic understanding of projects including both aspects of hardware and software, since the logic simulator can handle a system composed of standard digital components, state machines and microcomputers, as it is the case in contemporary digital design. Deeds allows a total control, at low level, of the interaction between logical circuits behaviour and the procedural flow of machine level instruction execution of a microcomputer. The pedagogical aim of this approach is the understanding of many issues characterizing embedded systems, like microcomputer interfacing, interrupt handling, real time operation and trade-offs between hardware and software, as a foundation for more advanced digital design courses. From this point of view, the inclusion of specific tools for hardware-software co-design and platform oriented design goes beyond the purposes of the current development phase of Deeds.
The Deeds simulators can be used stand-alone or in conjunction with its specialized web browsers or with any other standard browser: the student access from its Internet site pages with information, lessons, exercises and laboratory assignments. The available learning material is designed to help students to acquire the theoretical foundations of digital design, together with analysis and problem-solving capabilities and practical synthesis and design skills. Deeds can be adapted to different formats of instruction (lectures, exercises, lab assignments, etc.) and can be delivered at different student levels. To do so, teachers can combine together and personalize the available simulation tools to suit their pedagogical needs by contributing to the lecture space their own learning materials (the lecture space can be composed with any web page editor).
The more exhaustive pedagogical experimentation of Deeds has been made in what is called a "blended" environment, a pedagogical situation where traditional lectures coexist with some form of distance learning. According to (Gillet et al., 2005), blended learning favours the evolution from traditional teaching to active learning, a target the authors are looking forward to. Currently, the Deeds laboratory is used in a PC classroom, with tutorial assistance, and in distant mode, through Internet. Both scenarios are supported by Moodle (http://www.moodle.org), the Learning Management System (LMS) adopted as a standard by the University of Genoa (http://www.aulaweb.unige.it), as well as many other universities worldwide.
The integration of Deeds with a LMS provides added value for teachers and students alike. The LMS guides students, at the beginning of each course, to install Deeds and then provides, as resources, a set of guided laboratory sessions.
Teachers can easily keep track of students' activity, provide news and guidance, have access to the project deliverables and, generally, take advantage of the LMS features to manage the course. Students gain a large amount of flexibility in the execution of the projects, and they

can exchange information with their peers and get help by the teachers through the discussion forums.
Deeds e-learning features are intrinsic to its main characteristic, i.e. the close association of the simulators with on-line learning material, obtained through the web browser. A large repository of problems is available, with total freedom of navigation among individual problems, on the Deeds web site.
Deeds presents a project as a web document with text, figures and other visual objects that can be active, i.e. working as commands to the editing and simulation tools (see Figure 1). When the user clicks on the schematic in the browser, Deeds launches the corresponding simulator, and opens that schematic in it (Donzellini & Ponta, 2008). If guidance is needed, the Deeds opens another page in another browser that may provide more information on how to design, explore or test the circuit itself.

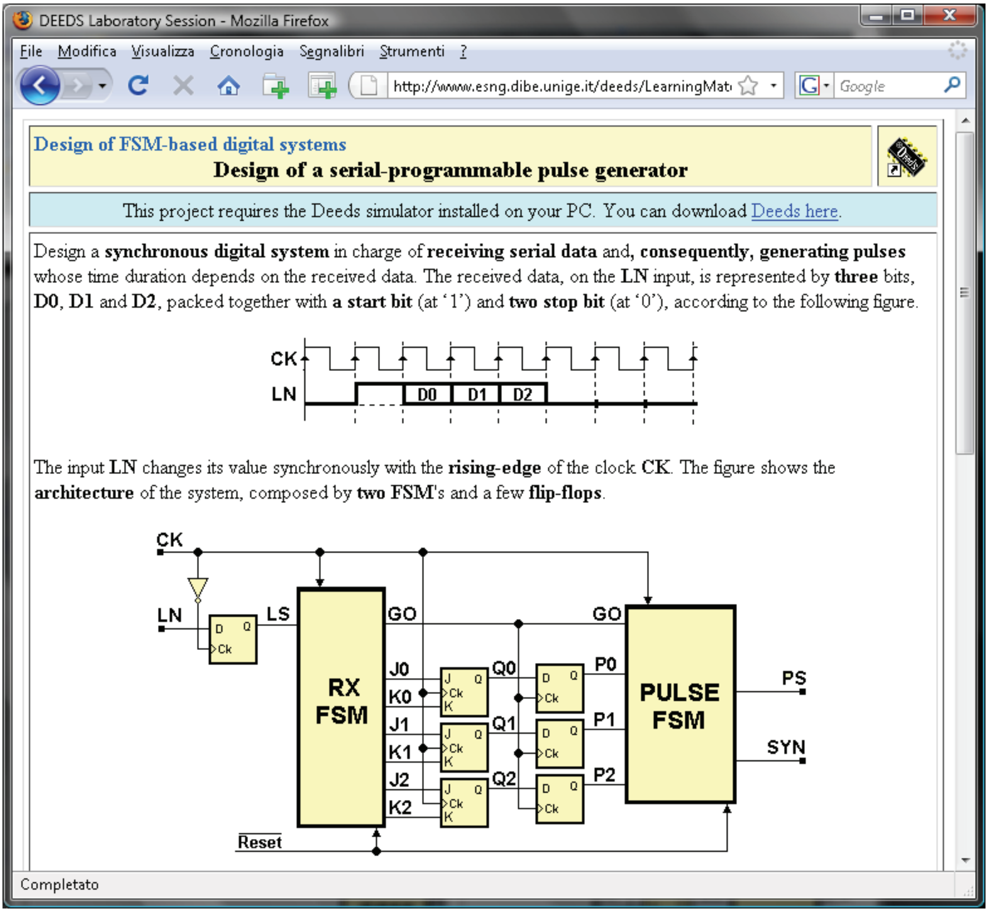

Fig. 1. An example of Deeds project (available at Deeds web site)

The target of traditional exercises is to help students understanding the underlying theory. Usually a feedback from the teacher on the correctness of the solutions is necessary. A Deeds exercise, instead, it is always a project. The students' role is not only to work out a solution but, also, to check its correctness, i.e. its consistence with the project specifications. Teacher's feedback becomes, if not irrelevant, at least not essential for the students, since they must know by themselves if their work is correct. The above is the most important advantage of developing a project with the support of a simulation tool.

Usually a lab report on the project is requested: a proper template speeds up its preparation and allows the student to concentrate more in the technical work. When learners are satisfied with their work they use Deeds to deliver the reports through the LMS and Internet. Another important features of Deeds, making it more flexible in facing students of different technical levels, is the ability to deliver a suitable trace of the solution (i.e. a partial schematic of the solution). Using this approach, students can be guided to the desired level of problem solving, for example avoiding repetitive tasks.

Deeds learning materials, by default written in English, have been translated in other languages by the interested teachers, when they believed a presentation of the projects in the pupils' mother tongue would improve the pedagogical effectiveness.

Subsets of learning materials are therefore available in Italian, Catalan and Finnish languages, while an almost complete collection in Turkish can be found at: http://portal.cizgi.com.tr/library/topic.aspx?id=1131.

3. The Deeds simulators

The simulators upon which the Deeds environment is based are: the Digital Circuit Simulator (d-DcS), the Finite State Machine Simulator (d-FsM) and the Microcomputer Emulator (d-McE). This paragraph contains a short introduction to their features. Practical examples of their use are contained in the next section, presenting step by step the student's activity for the development of a project assignment on embedded system design.

The d-DcS is similar to a professional digital simulator but has been specifically developed with educational needs in mind and, therefore, is characterised by a very simple and intuitive user interface and a rational choice of digital components available. The user can design custom components for the d-DcS as finite state machines using the proper tool, the d-FsM. The most complex components of the d-DcS library is a 8-bit microcomputer for embedded applications, that can be connected through standard input-output parallel ports. The firmware must be programmed at machine language level using the d-McE tool.

The simulation is event-driven, and includes the delay times of components. In the "animation" mode, the student can observe the behaviour of a network in term of static logic values by applying inputs with mouse clicks. In the timing diagram mode, a window shows the simulated outputs resulting from a set of input stimuli (graphically defined by the user). This mode is the same one adopted by professional simulators.

The d-DcS feature that allows the saving of input signal sequences provides further pedagogical advantages: teachers can propose one or more meaningful sets of input sequences, included in the same circuit schematic file. In addition to system specifications expressed by text, the teacher can provide the appropriated input sequences against which testing the implementations, including them into the solution trace. Not to be overlooked, is

the fact that, when delivering a solution to the teacher, students can demonstrate their awareness of the circuit functionality by proposing reasonable input test sequences.
Graphical editing and simulation of FSM components, using the ASM (Algorithmic State Machine) paradigm are the domain of the d-FsM tool, which is able to functionally simulate the FSM designed by the user, with runtime display of the relations between states and time evolution. The components created by the d-FsM can be used in the d-DcS and inserted into the digital circuit schematic. Also, the d-FsM tool can export its files describing FSM as VHDL processes, allowing their reuse in professional design tools.
With the third simulator, d-McE, the user can practice microcomputer programming at assembly language level. The emulated system includes a CPU, ROM and RAM memory banks, parallel I/O ports, reset circuitry and a basic interrupt logic. The custom 8-bit CPU, the DMC8, has been designed to suit the educational needs of an introductory course, and it is based on a simplified version of the 'Z80-CPU' processor. The complex architecture of today's CPU's does not suggest the use of a contemporary device to understand the basic principles of machine-level programming.
The user enters the source code in the editor, and then assembles, links and loads it in the emulated system memory. The execution of the programs takes place in the debugger, where the user can check all the structures involved in the hardware/software system: ROM and RAM memory contents, I/O port state, CPU registers and the assembly code in execution.

4. Introducing embedded system design: a project assignment example

To understand and design embedded systems with a bottom-up approach, students need to familiarise themselves with analysis and design of systems based on standard logic circuits, finite state machines and microcomputers. We believe that the task of introducing embedded systems can be made easier by starting with the analysis of a pedagogically-oriented implementation, before attempting the design.
In this section, we present, step by step, a learning process where students are facing a mixed work of analysis of the hardware structure and design of the microcomputer controlling software of a simple embedded system.
The system chosen for the project is an Asynchronous Serial Data Receiver/Transmitter, were the embedded microcomputer buffers and encrypts data. This project is included in the learning material available at http://www.esng.dibe.unige.it/deeds, see Figure 2.

In the project assignment (Figure 3), the system hardware is given and explained; the student must complete the system by writing the control software. The pedagogical target is to understand dynamics and interactions among modules of an interrupt-driven embedded system.
In the following, we describe the process from the students point of view. We assume that, formerly, they have become familiar with analysis and design of systems based on standard logic circuits, finite state machines and a microcomputer, as the knowledge and skills gained in the previous phases are necessary to understand and design embedded systems, in a bottom-up approach.

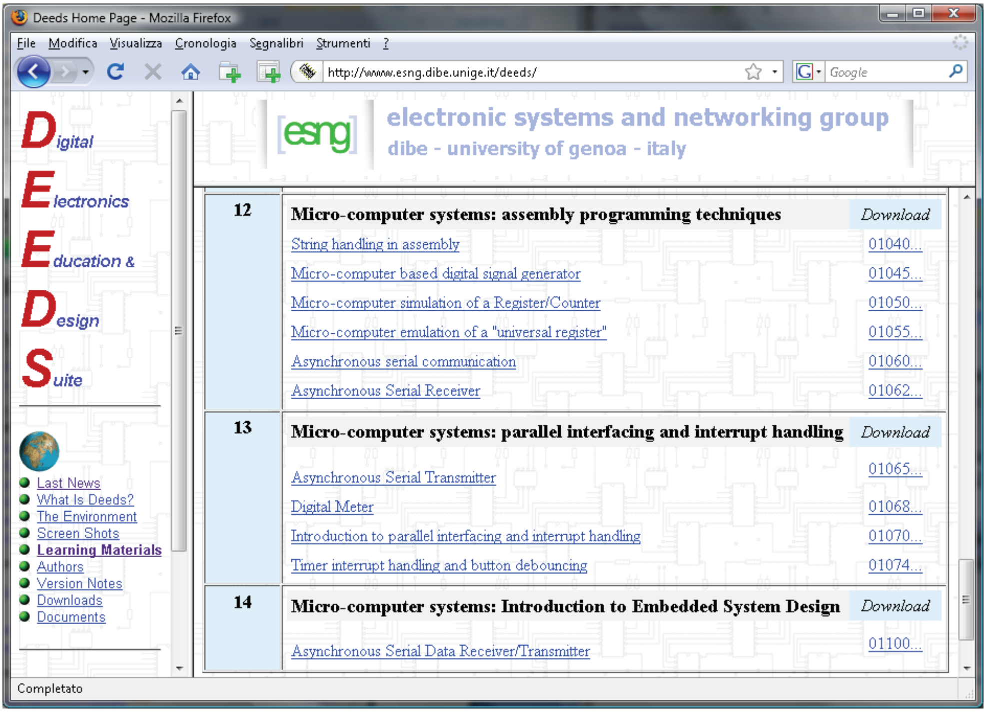

Fig. 2. The Deeds collection of learning material

In Figure 3, the project assignment is opened in the web browser. The text describes the overall system, explaining to the students that they will face a mixed work of analysis of the hardware structure and design of the microcomputer controlling software.
The data processing path include a receiver and a transmitter that are implemented by hardware, while the micro-computer, in the middle, has the task of buffering and processing data via software. The interrupt logic module is well in evidence in this figure, because this project deals specifically with dynamics and interactions among modules of an interrupt-driven system.
In the next step, the asynchronous serial receiver is explained to the student (see Figure 4). Similar networks have been already encountered and analysed by students in previous projects, developed in the course of the learning process. To be more incisive, the receiver has been separated from the overall system and presented as a stand-alone module.

The receiver system is built around a sequencer controlling a counter and a shift register. The peculiarity of the circuit consists in the interaction between the standard hardware (the counter and the shift register) and the sequencer, that has been designed according to the FSM model. The text suggests to open another web page, where the controller unit algorithm is described in detail, in the format of ASM diagram (see Figure 5).

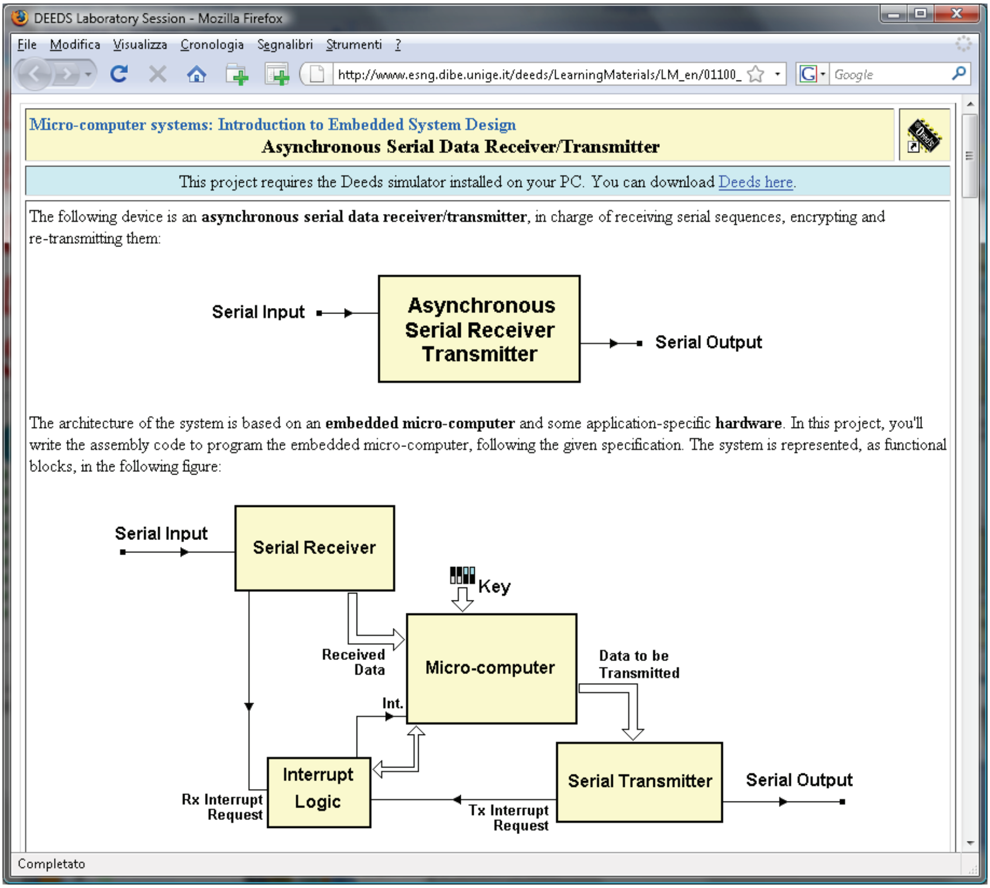

Fig. 3. The embedded system project assignment

The text description of the algorithm is exhaustive but, of course, the best approach available to the student is to open the ASM diagram in the finite state machines simulator and experience directly its behavior. In fact, for a full understanding, it is essential to look at the state diagram together with the time evolution of the signals of the control unit.
With a click on the ASM diagram of Figure 5 the learner finds it opened in the d-FsM and can check its operation with the tool (see Figure 6). The timing diagram is interactive: single clock cycles can be generated and input signals can be changed in between. The current state is highlighted on the ASM diagram, too, facilitating the observation of the evolution of the FSM in the state and time domain at the same time.
The complete circuit of the serial receiver module can, of course, be opened in the digital circuit simulator (see Figure 7), again with a click on the schematic.

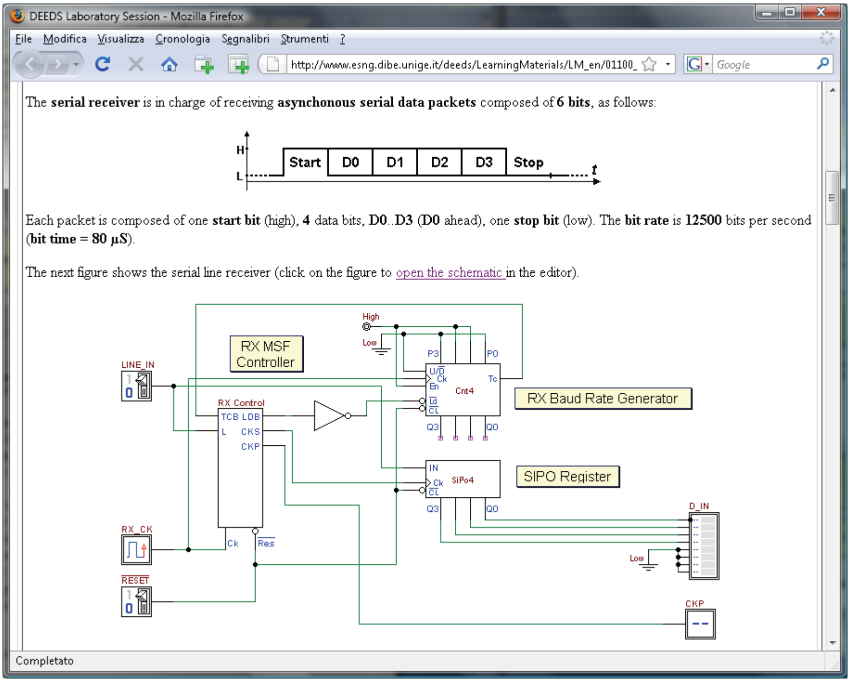

Fig. 4. The asynchronous serial receiver module

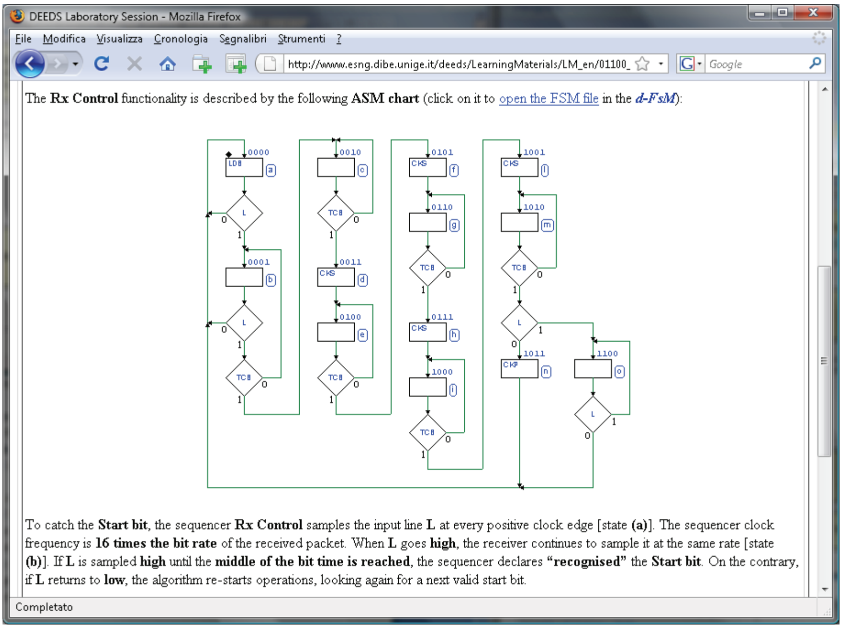

Fig. 5. The ASM description of the control unit of the serial receiver

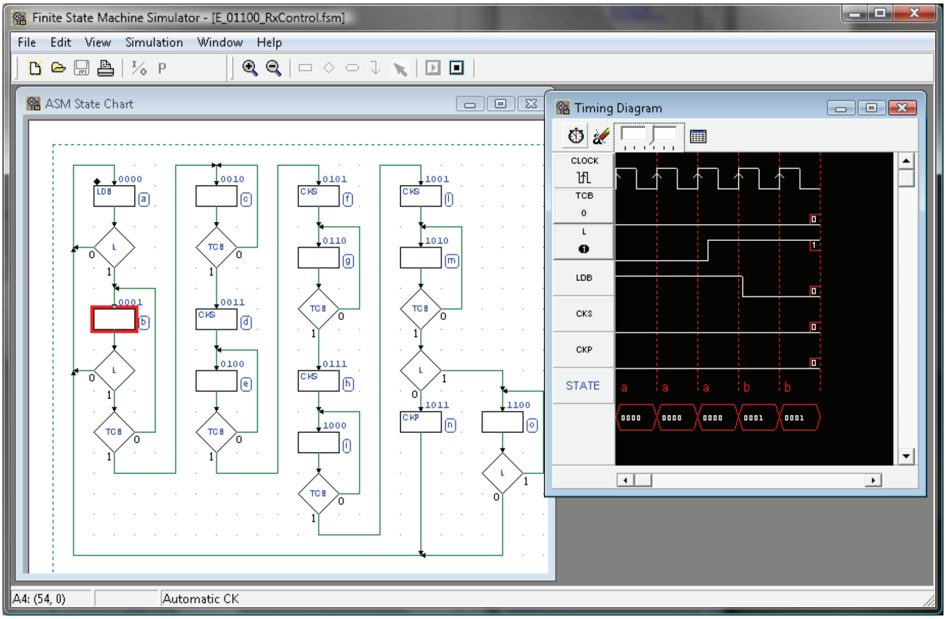

Fig. 6. The d-FsM during an interactive session.

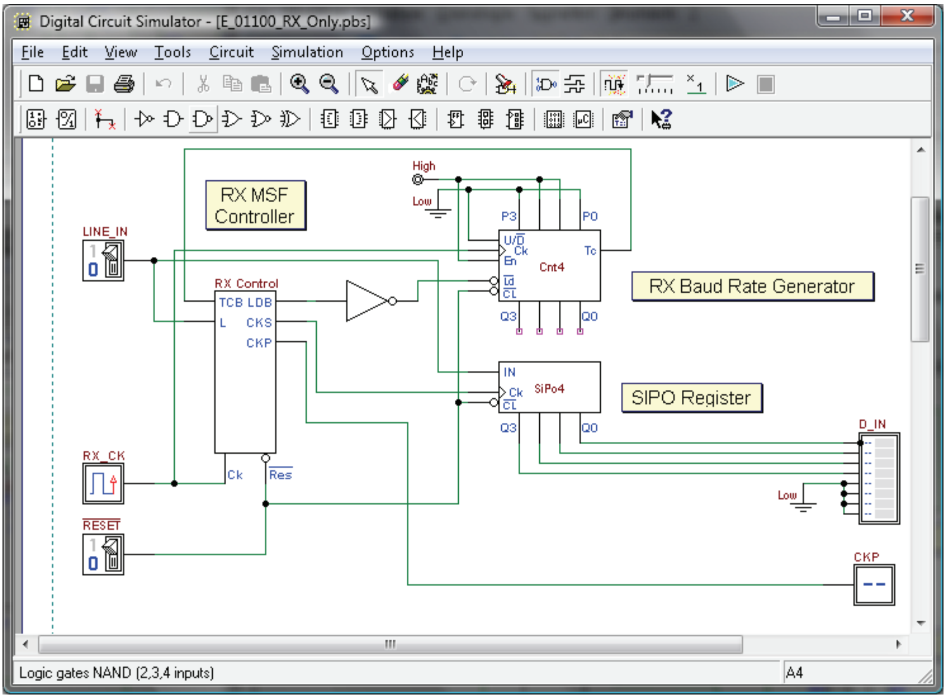

Fig. 7. The asynchronous serial receiver module opened in the d-DcS

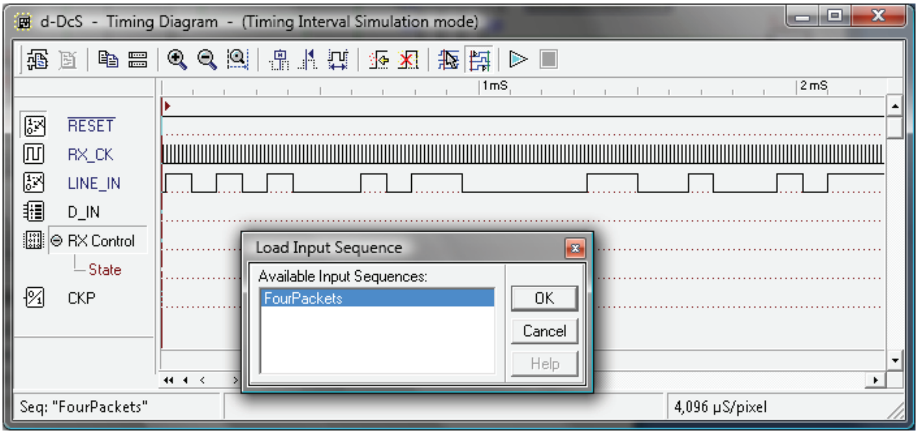

Fig. 8. The timing diagram of the d-DcS and the choice of the test sequence

The possibility, already mentioned, to make available to the learner packages of input sequences prepared by the teacher is especially useful in this particular case (see Figure 8). In fact, to set up an exhaustive test sequence is not a trivial task for a student and such feature may be of great help, since input stimuli can be used as they are or can be modified by the more adventurous students.

Simulation results can be analysed in the timing diagram, where it is possible to select areas of interest and expand the scale to compare the states and signals evolution with the one expected in the previous design phases. Specialized cursors provide useful features, such as measuring the time span between two events (see Figure 9).

Next, the assignment explains, with criteria similar to the ones used for the receiver block, the asynchronous serial transmitter module. The control unit, in this case also, is designed as FSM. The student can perform the analysis of the serial transmitter module with the d-FsM and the d-DcS simulator, as in the previous module. In Figure 10 the transmitter is opened in the d-DcS.

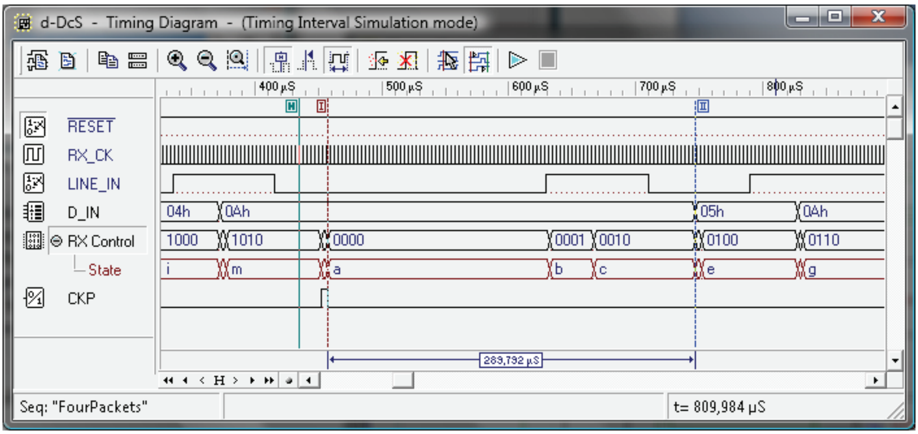

Fig. 9. Analysis of the simulation results in the timing diagram

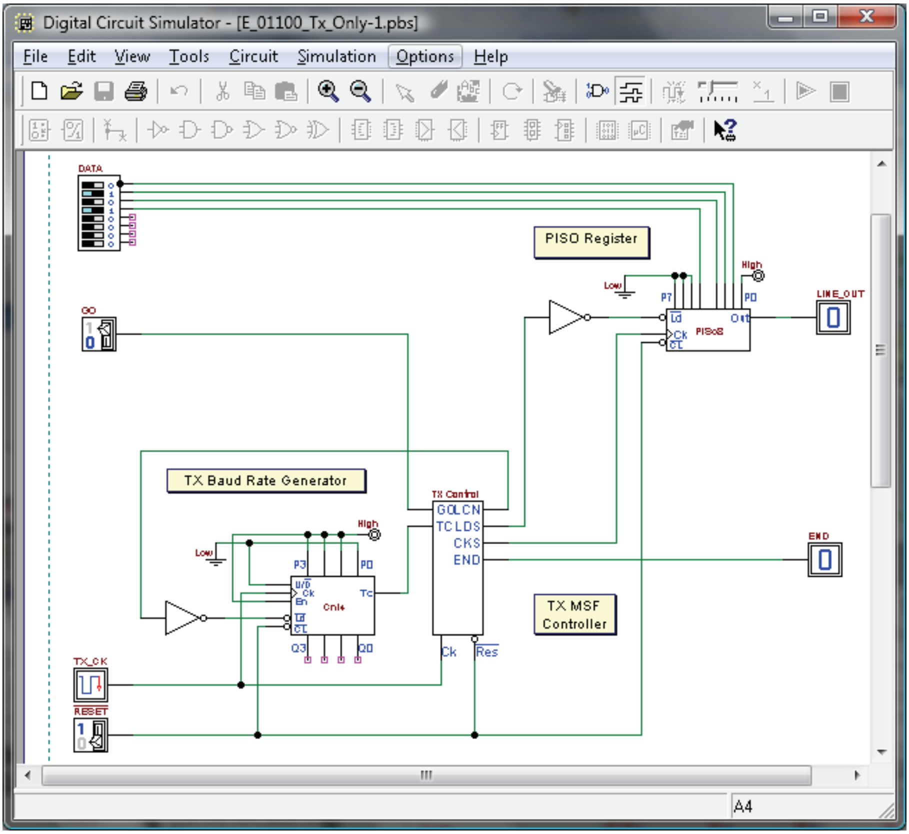

Fig. 10. The asynchronous serial transmitter module opened in the d-DcS

The analysis of the transmitter is particularly interesting from a pedagogical point of view, because the design issues are similar as far as the method is concerned, but very different in term of specifications. In short, the analysis of the receiver highlights the problems of synchronization and decoding of asynchronous data, while the analysis of the transmitter focuses on data coding and timing.

The assignment presents the whole system as a large schematic, whose divisions into functional blocks are highlighted (Figure 11). In the figure, besides of the receiver and transmitter modules (marked as RX and TX), are identified the embedded micro-computer (MC), that links the receiver and transmitter modules, controlling the data flow, and the interrupt logic block (IL), a key element of the project.
If the student clicks on the figure, this schematic is opened in the d-DcS, but it cannot be simulated yet, because it is incomplete: the microcomputer ROM memory needs to be programmed with the code written by the student. We can say that, from a pedagogical point of view, all the previous activities are only a preparation to the real work, that is beginning now.

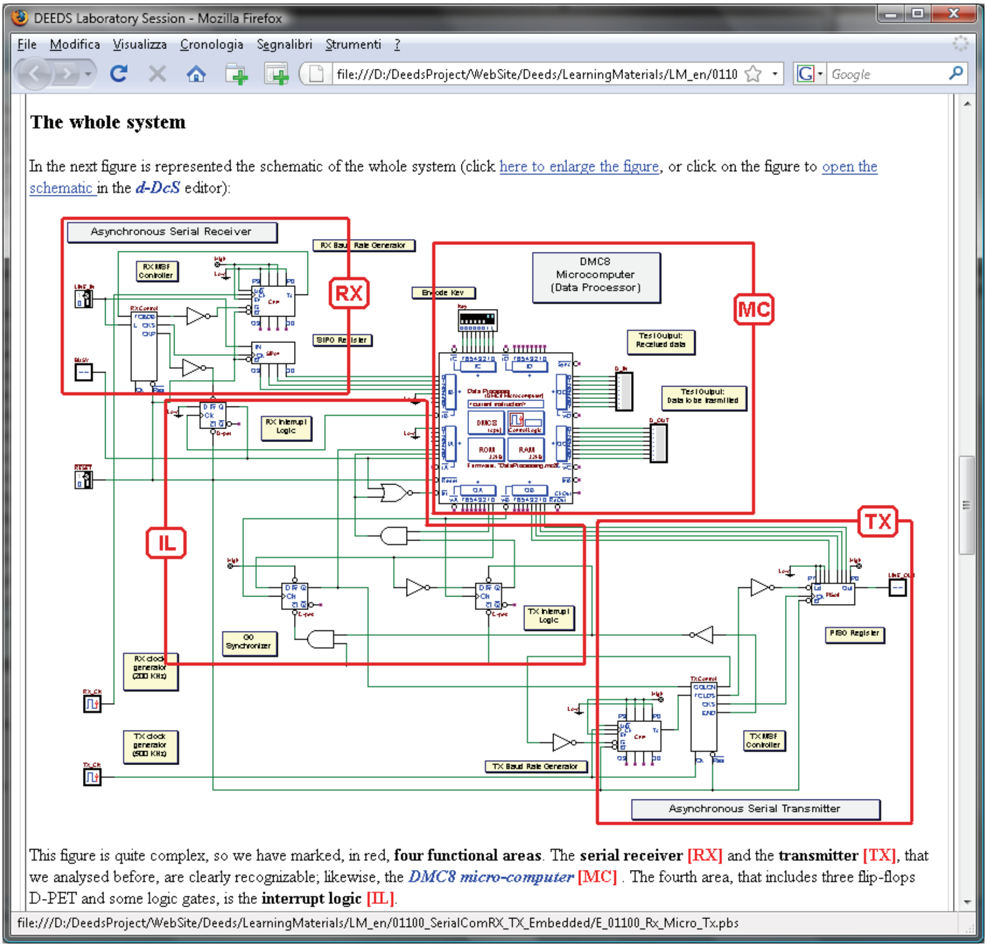

Fig. 11. The assignment description of the complete system

Now it is the moment to understand how the embedded microcomputer should act efficiently to process the data incoming from the receiver module and then send information to the transmitter, avoiding timing and logical conflicts.
The understanding of the interrupt controller logic behaviour is essential for developing the micro-computer program, so the text explains the purpose and operation of this logic block, that is composed by two parts, one devoted to the receiver, the other to the transmitter.
Starting with the receiver, the student should be aware that this logic acts as a functional bridge between the module and the microcomputer. In Figure 12 the logical path, involved in this operation, is highlighted and explained to the learner.
The interrupt controller signals to the microcomputer when new data has been received, activating its interrupt request line. Since the interrupt request line is a shared resource, the microcomputer must control if the receiver (or the transmitter, or both) has requested attention. So the student should realize that, before reading the received data (using the

input port IB, Figure 12), the software must read the input port IA, where all the interrupt requests are conveyed, to identify the source of interruption.
Finally, the learner will be aware that the logic has been designed mainly to speed up the microcomputer operations. To do so, the reading of the input port IB, in addition to simply bringing up the desired data, also will clear the receiver interrupt logic, allowing the receiver module to be able to decode new data incoming from the input serial line.

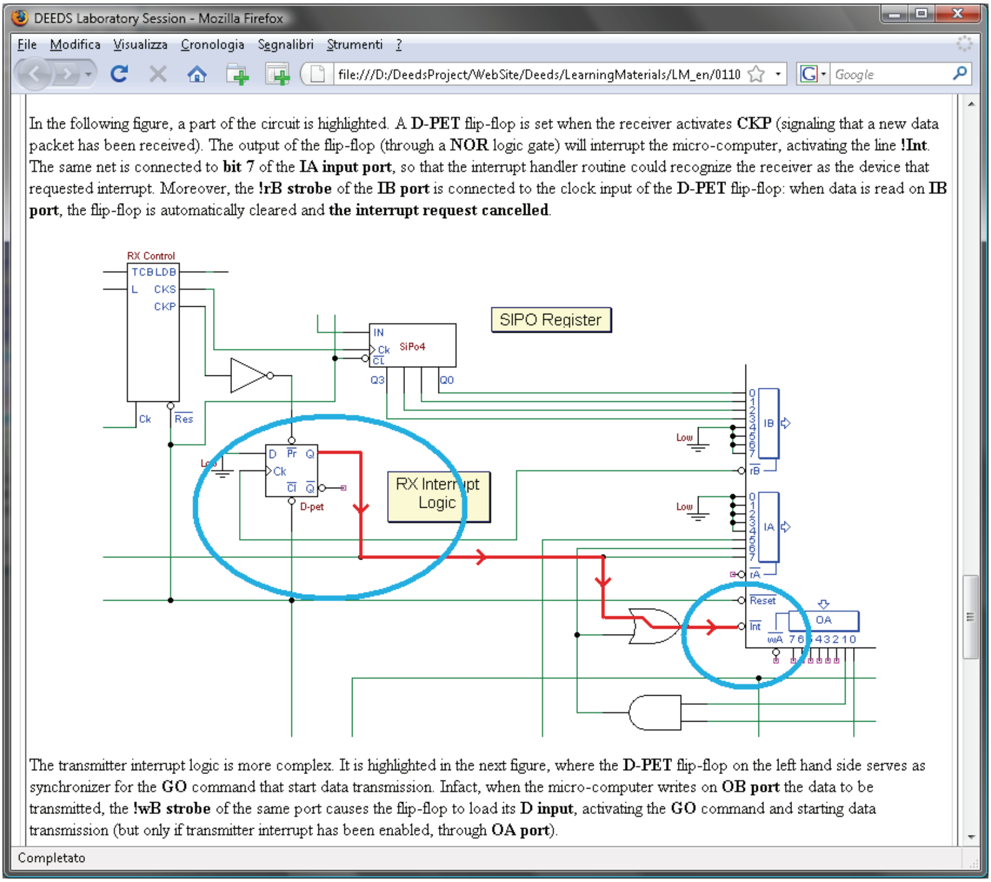

Fig. 12. The receiver interrupt logic explained to the student

The text continues with the explanation of the operation of the transmitter interrupt logic, that is more complex than the one of the receiver, because in this case the interrupt controller is (partially) programmable (Figure 13).
Data transmission needs to be started by a command, sent to the transmitter module, after the microcomputer has set up the info to be transmitted on its OB output port. The student must realize that, during the transmission of a data packet, the transmitter module is busy and can't accept another data. To solve the problem students needs to devise a hardware/software strategy to synchronize the transmission of the next packet.

They could program the microcomputer to poll continuously the transmitter status, but this would result in a lack of performances. So the assignment suggests to program the interrupt logic to signal the microcomputer every time a data packet transmission has been completed. To do so, students must analyse carefully the proposed logic whose operation modes, summarized in a truth table in the text, depend from two control bits connected to the OA output port.
When the transmitter module requests interrupt, the microcomputer needs to recognize the source of interruption, reading the IA input port, as described before for the receiver. If the interrupt logic is programmed in the proper mode, when the microcomputer writes on the OB output port the data to be transmitted: a) the interrupt request is cleared, b) the transmitter operations are started, activating its GO command, and c) the new interrupt request is enabled (so that it will be generated when the transmission will end).

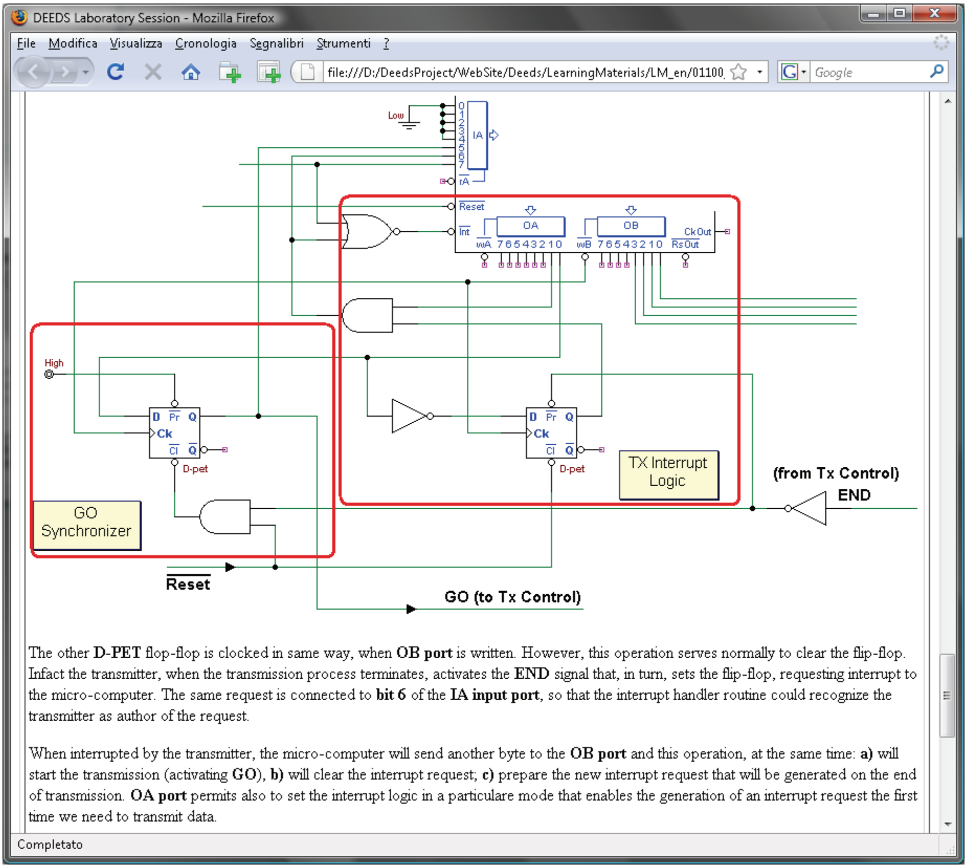

Fig. 13. The transmitter interrupt logic, highlighted in the assignment

At this point, the system analysis is over; the next stage for the student is the writing of the embedded processor code, in assembly language. The use of assembly language is a design choice for Deeds, because it allows a full understanding and control of the system.

To write the code, starting from scratch, requires a full understanding of the interrupt operation. This task, even if it has been explained in details in the assignment, could be a difficult one for many students. So, we support them by providing a commented trace of the program, that can be downloaded directly in the d-McE. Obviously, students can choose to work independently or to use only parts of the given trace.

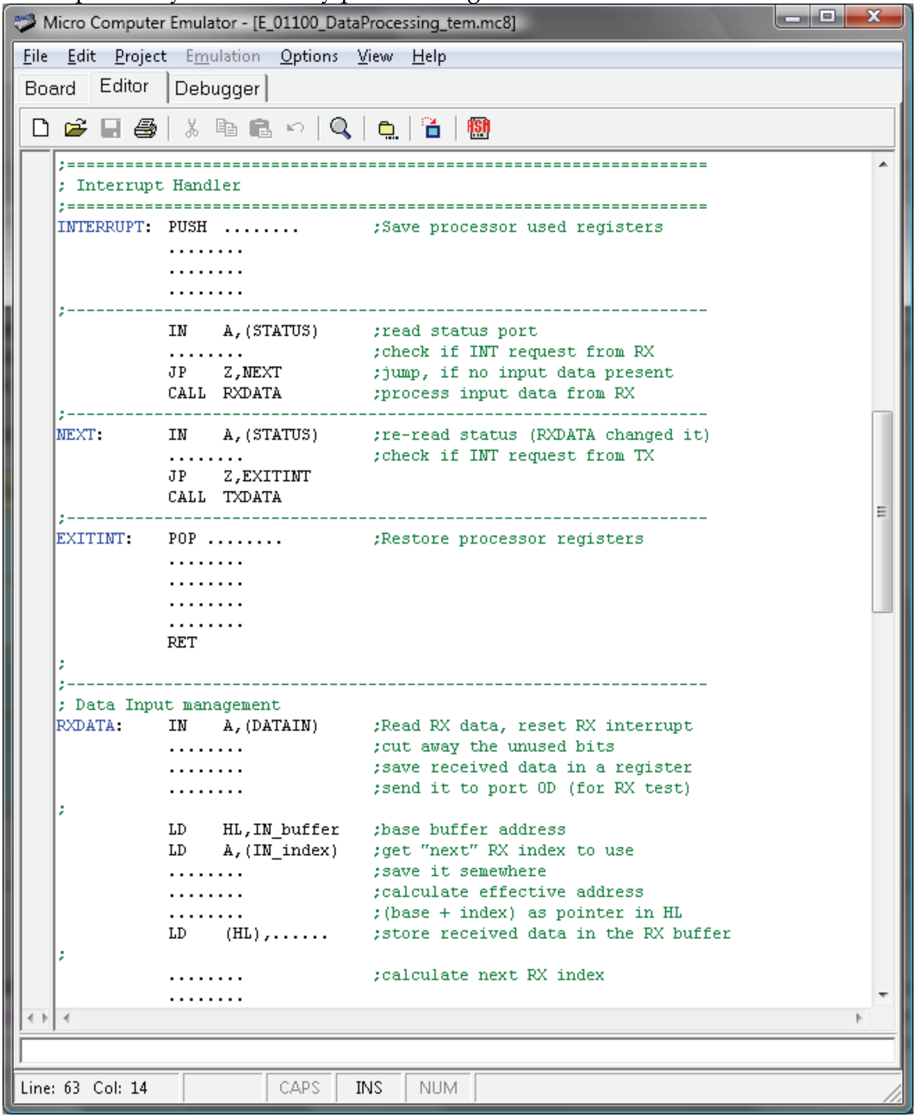

Fig. 14. The trace of the solution, downloaded in the d-McE

Figure 14 shows a piece of the program trace, i.e. a partial solution where a few critical sequences of instructions are provided to help students to transfer concepts into practice with a reasonable effort.

Instead of a single trace, in other projects we provide several, graduated by difficulty so that the students may decide themselves how much help they need or want. It must be stressed that more guidance with the trace implies less freedom for the programmer.

Figure 15 shows an example of solution, produced by the student from the proposed trace.

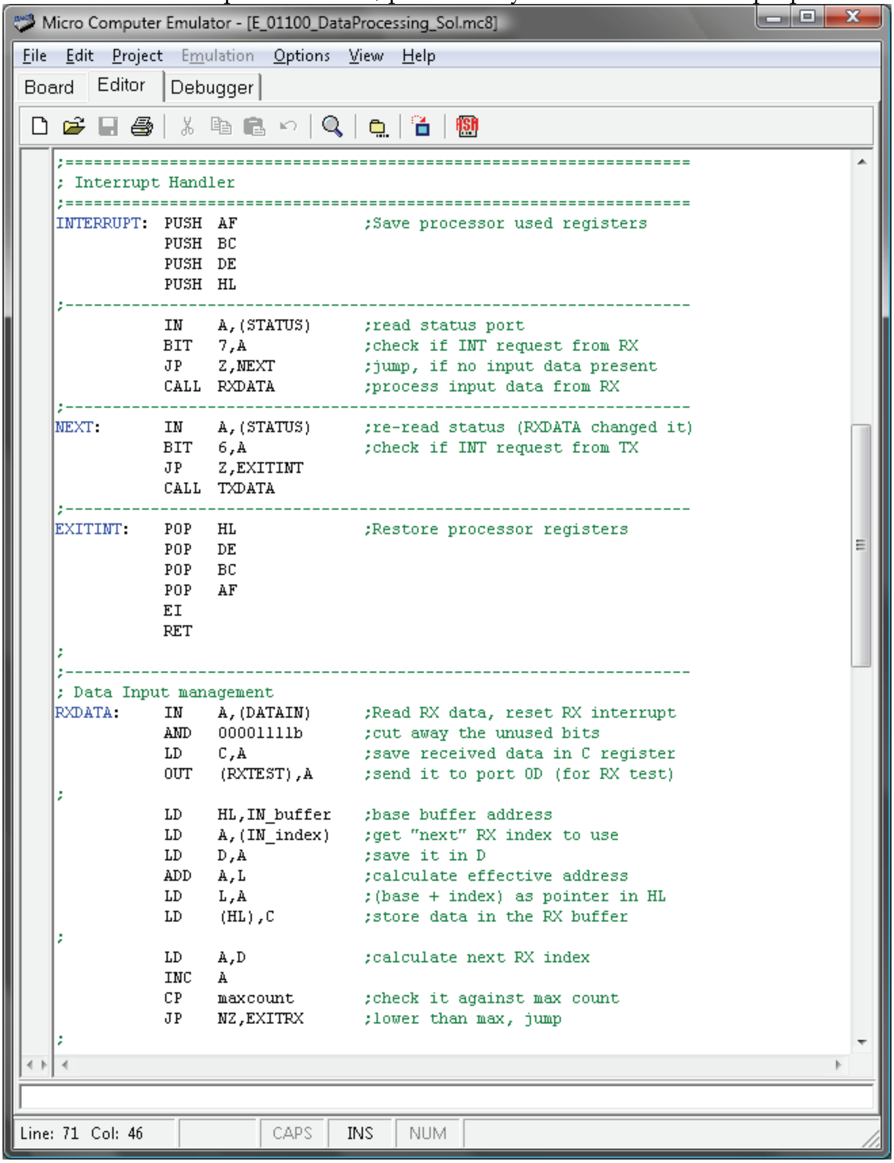

Fig. 15. The solution, completed by the student in the d-McE

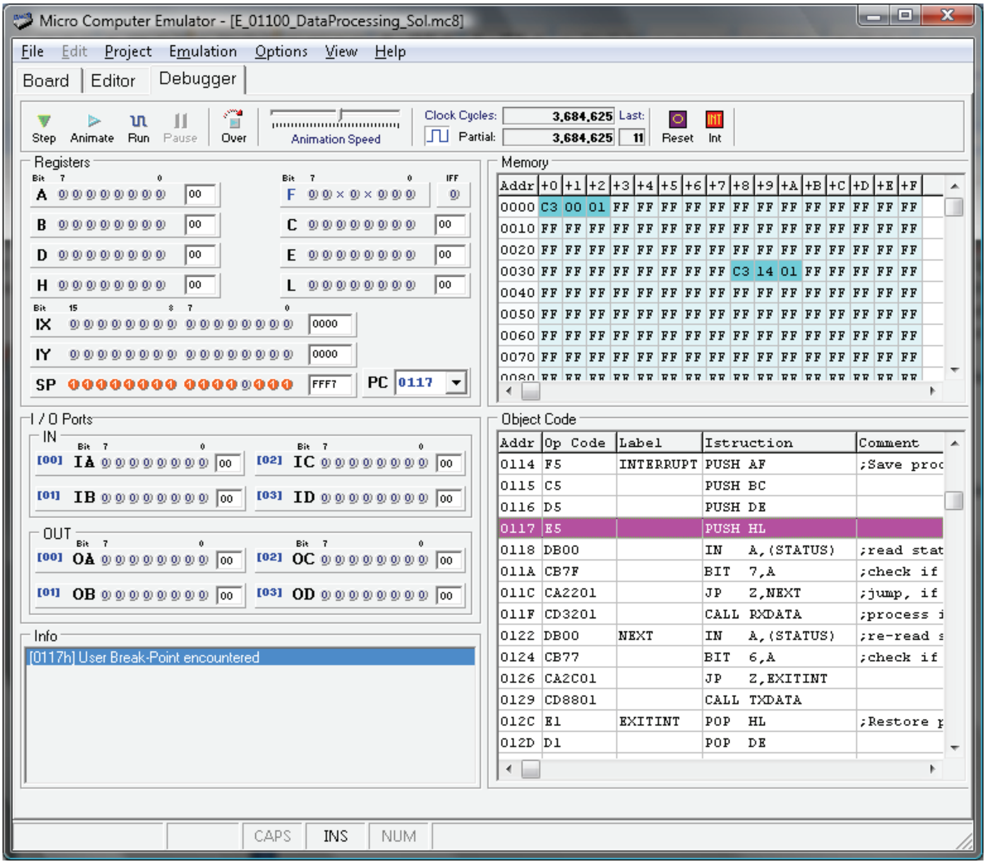

Fig. 16. Testing step by step the program code, in the interactive debugger of the d-McE

Before loading the program into the microcomputer flash ROM, a functional test could help in verifying its correctness, so the use of the emulation facilities included in the d-McE is suggested to the student. In Figure 16 the program is under test in the interactive debugger, where the learner could execute it in various modes, for example stepping the instructions manually one at time, or animating the process at an adjustable speed. The debugger is similar to the ones included in professional tools. By using it, the student can reach a high degree of confidence and control over the logic of the program, because all the elements in the microcomputer are observable and easily modifiable.

After completing the program and testing it in the d-McE, the student must load it in the flash ROM of the microcomputer component in the d-DcS schematic (seen before in Figure 11). The system, completed now of the microcomputer code, is ready for testing in the d-DcS (Figure 17), using the timing simulator (Figure 18). This is the final phase, in which the student is requested to validate all the elements, procedures, logic and algorithms that make up the functionality of the whole system.

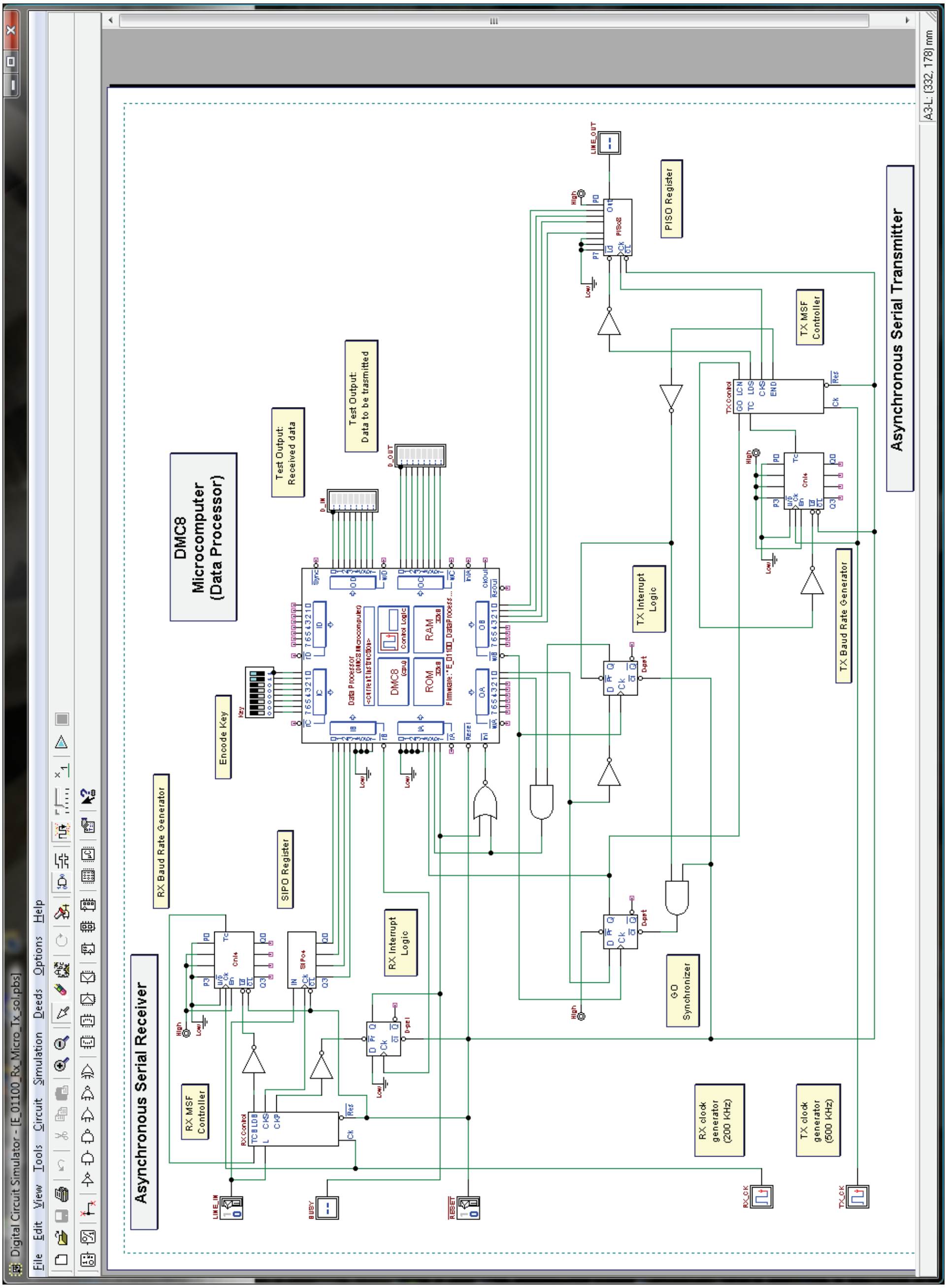

Fig. 17. The final schematic, ready to be simulated in the d-DcS

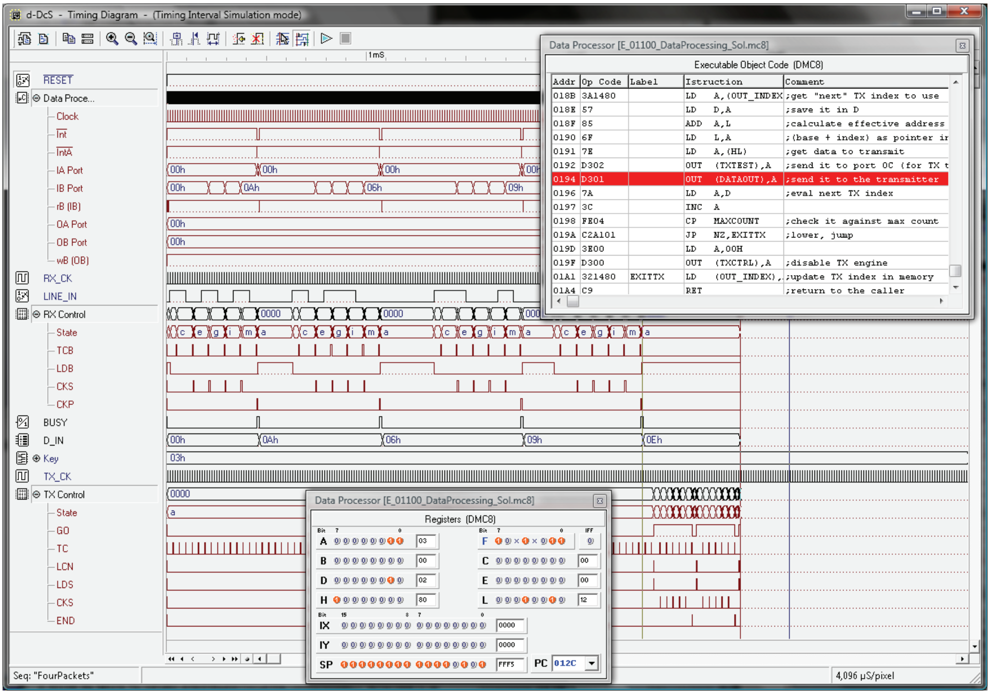

Fig. 18. Simulation and testing of the complete system

At this stage, usually, only motivated and hard-working students will make really good use of all the possibilities offered by the timing simulation; possibly only those people that are inclined to choose digital design as their job in real life. Most students, instead, will be satisfied simply if the system "seems" to operate, without trying to investigate the system behaviour thoroughly. Anyway, it is a good result if the student will reach the previous phase (the writing of the program and testing in the d-McE tool).

5. Conclusion

The combination of Deeds and its associated learning material covers the foundations of the design of embedded systems. The experience has shown that the use of the simulation environment is an essential step to build in the students the necessary knowledge and skills for digital design. Deeds has now been used by thousands of students at the University of Genoa and other institutions. The development team is taking advantage of the continuous feedback from students and colleagues to enrich the collection of learning materials, to improve existing functionalities and to add new features. For instance, we are working on a new version of the digital simulator engine, using the inertial model to manage components delays instead of the transport model currently in use.

6. Appendix: tools for digital electronics

The appendix provides links to a few commercially available (Table 1) and non-profit (Table 2) simulation and design tools for electronics. The lists are not exhaustive and the links may change or be no longer active.

Altera	http://www.altera.com
MacroSim	http://www.engineering-software.com/pr/addProd106.htm
MultiSim (Electronic Workbench)	http://www.ni.com/academic/multisim
OrCAD	http://www.cadence.com/products/orcad
Proteus	http://www.labcenter.co.uk/index_uk.htm
Tina Design Suite	http://www.designsoftware.com
Xilinx	http://www.xilinx.com

Table 1. A few professional products often used in the educational field

Circuit Shop	http://www.cherrywoodsystems.com/cshop1.htm
Digital Simulator	http://www.mit.edu/people/ara/ds.html
Digital Works	http://www.spsu.edu/cs/faculty/bbrown/circuits/howto.html
EasySim	http://www.research-systems.com/easysim/easysim.htm
Logisim	http://ozark.hendrix.edu/~burch/logisim
Digital WorkShop	http://www.cise.ufl.edu/~fishwick/dig/DigSim.html
WinLogiLab	http://www.griffith.edu.au/professional-page/charles-hacker/resources/winlogilab

Table 2. Partial list of non-profit simulators for digital electronics

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15

Remote Control of a Multi-robot Infrastructure for E-Learning Training Sessions

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1. Introduction

Robotic systems are in general composed by a multitude of software and hardware components that are susceptible to faults. For the majority of discrete, repetitive production systems including networked robots in manufacturing structures (such as lines, cells or systems) such component faults can lead to an unexpected behaviour, potential faults or even interruption of the supplied services.

Some systems are designed to be fault tolerant, meaning that in case of malfunction of a component the system will present a well known behaviour or will "hide" from the user the malfunction of such components (correcting actions are executed automatically) – i.e. it will continue to provide the specified service despite malfunctions. In many cases wrong behaviour in case of malfunction can lead to important economic loss (Lascu et al., 2005).

Understanding and designing fault tolerant distributed systems is a recognized difficulty because at the same time one must know the normal behaviour of the system but also the complex situation that occurs in case of a malfunction of a component. The difficulty of this activity is also increased due to the lack of structural coherent concepts and to the confusing terminology. That's why some basic architectural concepts, and a short fault- and paradigm classification used for structuring the fault tolerant software are presented here.

Production flows are nowadays modular, which means that each module in the enterprise is specialized and used to achieve a particular task. In many cases the modules are connected and materials are sequentially processed in each module resulting in a final, unique product or assembly. One typical such production module is a flexible cell/system using multiple robots. To obtain fault tolerance, the architecture of a distributed system must include redundant handling components.

The chapter describes a system that can be used to unify, control and observe the cell's devices (in particular each robot-vision system) from a remote location, e.g. the CAM/CAQC server linked to other design and planning compartments.

2. Faults: Classification and Semantic

A server has a correct behaviour if its answer to a request is consistent in respect to the description of the service provided by this server. We are talking about malfunction when the behaviour of the server disrespects the service description. Considering the server behaviour the following types of malfunctions are distinguished:

a) *Byzantine malfunction*: when the malfunction is arbitrary and the server behaviour is fully random.
b) *Timing malfunction*: when the server response is correct from the behavioural point of view, but has a delay greater than the limit waiting time specified for a correct behaviour.
c) *"Omission" type malfunction*: when the server "forgets" to answer to the clients requests.
d) *Answer malfunction*: when the server answer is wrong (as value).
e) *Crash*: when the server is not answering to any request until the system is restarted. Depending on the way the server begins to function at restart, there are a number of types of crash:
   - crash with amnesia: the starting state is predefined and does not depend on the state preceding the crash;
   - crash with partial amnesia: the server keeps only a part of its state preceding the crash, the rest being reset to a previous predefined state;
   - crash with pause: the server, after an amount of time, takes the state preceding the crash.
f) *Halting – crash*: when the server never retakes the state of functioning.

2.1 Fault semantic

When the actions for retaking the operational state after detecting the malfunction are programmed, it is important to know the server's behaviour to each defect. Therefore, in a fault tolerant system it is necessary to extend the server standard specifications in such a way to include, onto the normal functioning semantic (without defect), also the fault semantic that may occur. Here the "semantic" term is used with the sense of "behaviour".
The designer of such fault tolerant systems must assure the implementing of a well defined and convenient fault semantic at the level of each system part.
Depending on the imposed restrictions for such behaviour, the fault semantic can be classified in "strong" semantic and "loose" semantic. If the specified behaviour in case of defect is more restrictive, the malfunction semantic is stronger, whereas if the behaviour is freer, the semantic is looser. The most loose semantic is the random semantic (any behaviour is permitted).
In general if the malfunction semantic is looser, then the server is more expensive and more complicated to implement.

3. The paradigm of the structure of fault tolerant software

Such paradigms have been developed to help programmers to structure the fault tolerant software. So, each of these paradigms is used for miscellaneous applications reducing the complexity of applications development.
Fault tolerance in any system implies a certain form of redundancy. There are two types of redundancies: in time and space. *Redundancy in time* means that the activity (computation) of a defected server is launched again on the same processor (after the malfunction cause has been eliminated) or on another processor and repeated after being successfully completed.

Redundancy in space implies simultaneous execution of server activities on several processors in parallel; then the final result is chosen by voting.
The most important paradigms for the proposed objectives are:

- **Transactions**: theses are software structuring mechanisms for applications, that access shared data (typically databases). The system guarantees three properties for transactions: atomicity, order and consistence. If a malfunction appears during a transaction or if the order cannot be guaranteed, then the system executes again the transaction to keep the coherence of the system states.
- **Check pointing**: a mechanism which, in case of malfunction, allows restarting the activity (computation) from a coherent state preceding the malfunction (this state is periodically memorized on a stable magnetic support). The states previously memorized are check points. The rehabilitation of the system starting from a check point is named recovery.
- **Replicated State Machine**: the provided service is executed in parallel on few processors (collection of duplicated servers). The requests of each client are sent to every copy (atomic broadcast) where are treated in a deterministic way.

Passive replication means that a service is implemented on several processors but only one is active (primary) and treats the clients requests. If the first copy is malfunctioning, its activity is retaken from the point of failure by another process (secondary backup).

4. The structure of the system

The system is composed by two applications (Figure 1.):

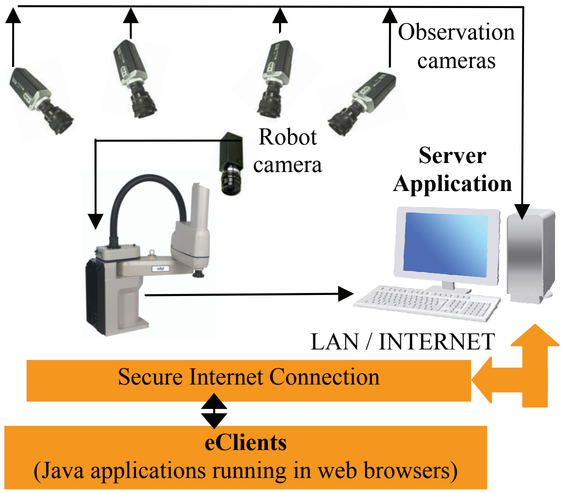

Fig. 1. The Structure of the System

1. The **Server Application (SA)**: Remote visual control and monitoring of multiple robot controllers from mobile and stationary matrix cameras (runs on Supervisor PC).
   - *Visual control*: the Server Application supports almost all V+ and AdeptVision program instructions and monitor commands. The robot training and control is interactive –

menu-driven and acknowledged by image display in a VISION window. Some of the main functions available in this window are: choice of the physical and virtual cameras and of the image buffers; selecting the display mode and resolution; histogram and average curve contrast analysis; selection of switches and parameters for virtual camera construction; display of system status; training and planning multiple ObjectFinder models for recognition and locating; learning fingerprint models for collision-free grasping; editing, saving, loading and running V+ programs. Experiments were done with Adept Technology hardware (robot controllers) and vision software (Adept, 2001).

- *Monitoring*: a Monitoring/Treatment scheme can be defined for each Client/Controller (the latter can be selected from a drop-down list of robot controllers connected to the server, by adding/removing them from the Client window) (Matsubara et al., 2002; Lascu et al., 2002). For each client a list of events and controller variables to be monitored according to a user-definable timing, and reactions taken by user-definable actions/sequences can be specified in an Automatic Treatment Window.
- *Access to image pixels*: Images taken over from clients are stored in a standard format allowing accessing the individual pixels for specialized treatment; the processed images, extracted features or computed measurements can be stored or transferred back to the client for further use.
- *Communication management*: the Server Application manages the communication with the robot controllers and the observation cameras, transfers real-time images from the cameras observing the robot workplace and production environment, reports status information, stores in a database and displays images taken by the robot camera via its controller. Finally, the SA outputs commands which are received from the eClients or acknowledges task execution.

The **eClients Applications (eCA)**: Java applications running in web browsers. They provide portal services and the connection of networked production agents: image data and RV program / report management; real-time robot control and cell / workplace observation. The eCA are composed by two applications:

- one application that retrieves the images from the observation cameras (AXIS 214 PTZ), displays them in real-time and also gives the user the possibility to change the orientation and zoom factor of the cameras.
- the second application is a VNC client.

The VNC viewer (Java client) is a web teleoperation application which can be executed into a web browser. The application connects to a Domino web server which provides a secure connection using a TCP/IP tunnel with a server having a private IP address, which cannot be accessed from Internet but only using the Domino server. The private IP machine has a VNC server that exports the display, and also the teleoperation application. Using the exported display, the user can view and use the application as when the application runs on his computer. The access is made using a username and a password, process managed by the Domino server.

For team training and application development, the system allows accessing related documents, presentations and multimedia materials, Web conferencing, instant messaging and teamwork support for efficient and security-oriented creation and use of group workspaces (students, trainers, researchers).

The Server and eClients Applications run on IBM PC workstations on which IBM Lotus software offerings are customized and integrated with other applications (error-free data and command transfer, V+ program editing, real time image display and refresh in multiple Client windows, replication functions, Client authentication, etc) in a virtual training and research laboratory across geographical boundaries.
Lotus-oriented solutions have been considered for transferring messages, status reports, data and video camera images, interpreting them and accessing databases created by all partners. The final objective of the platform is to develop an E-Learning component allowing students to access and download technical documentation, create, test, debug and run RV and AVI programs, attend real-time laboratory demonstrations, and check their skills in proposed exercises.
Thus, IBM Lotus software unifies all three Application modules, providing the necessary management and interconnecting tools for distributed industrial controllers, and the collaborative tools with back-end relational databases for team training and research.

5. Using the system

To have access to the system, a user must have a username and a valid password to enter the system. First the user must access the portal site using a Java aware browser (Internet Explorer, Opera, Firefox, with the JRE installed). After entering the correct username and password, the user is allowed in the system and has access to the teleoperation application which is a menu driven interface that allows him to interact with the system (see Fig 2).

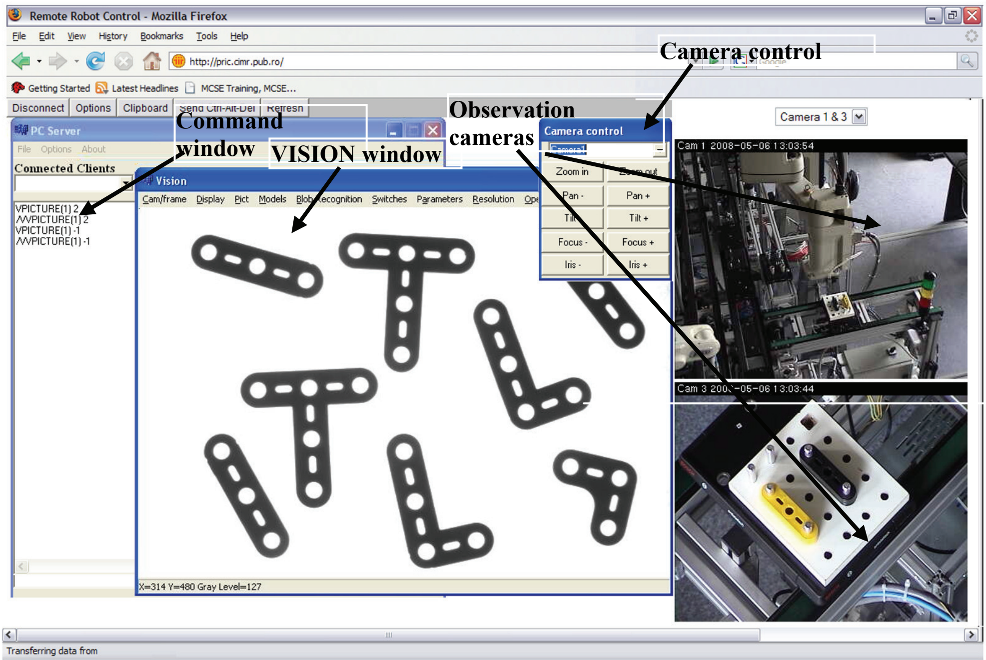

Fig. 2. Accessing the system

The teleoperation application is composed by two windows:
A command window (Fig 3), where the user can select the robot system to be controlled and issue commands from the command line or activate the vision window.
The robot stations are commanded using the command line and the menus. When a client is connected, the IP address is checked and if the client is accepted the name attached to the IP address is added to a drop down list from which the user can select what client he wishes to command. When a client who has a video camera attached the VISION button is enabled and if this button is pressed the VISION Window will open.

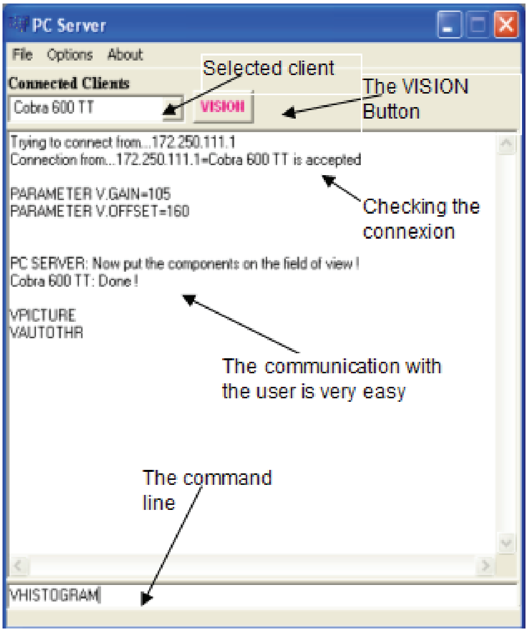

Fig. 3. The command window

From the VISION window, vision commands can be issued by selecting the desired actions from the menus (Fig 2). The most important functions are:

- selecting the physical and virtual cameras, and the virtual image buffers;
- selecting the display mode and the resolution;
- image acquisition;
- issuing primary operations (histogram, thresholding, etc.);
- displaying the vision system status;
- training models;
- configuring switches and parameters for virtual camera set-up.

The advantage of the Vision window is that all commands can be issued using menus, and the fact that the image acquired by the camera and sent to the server can now be accessed at pixel level. Another major advantage is that the training of the part recognition and grasping models become a single-step process during which a unique window is used for parameters and constraints specification.

The client application can acquire full or partial images via the VGETPIC V+ operation and send them to the server (Adept Technology, 2001).
Captured image can be processed via the menus (filtering, binarization, convolution, morphing, etc.), saved into a common format and sent to a specialized image processing application. After processing, the image can be sent back to the client and integrated to the image processing board using the VPUTPIC operation, for further use (an application using this mechanism is in course to be developed, and consists in a new part identifying algorithm based on skeleton computation and matching.
In order to execute vision programs the user must setup the vision parameters in such way that the system will "see" the objects with the best image quality. The system have specialized functions to establish those parameters automatically or, manually if some special settings are required.
After setting the parameters and loading the calibration camera-robot, the user can measure objects, apply filters, apply morphological operators, train and recognize objects.
The measurements include signature analysis, polar and linear offset signatures are computed, and stored to be used in other applications, also the skeleton computation is included in the measurements category (Borangiu, et al., 2005).
An important feature of the system is the mechanism of training object models and multiple grasping positions related to each model in order to accomplish a collision free grasping position on the runtime.
The training of object models can be done in two wais:

- first is the standard ObjectFinder model, which is computed by the vision board included in the system. The procedure to train such a model requires a set of steps which have been compacted in a single form in the application.
- the second way is to store a set of object features into a structure which characterize each model (Borangiu, 2004).

After the models are trained and stored the user can write applications using the trained models, and/or can learn also grasping positions in order to manipulate the objects.

6. The supervising function

The server application (Supervisor PC) is capable to command and supervise multiple client stations. The material flow is supervised using the client stations and the status from each station is recorded into a data base.
For the supervising function a variable and list of signals is attached to each client (Figure 4).
The variables and signals are verified by the clients using a predefined strategy, and if a modification occurs the client sends to the server a message with the state modification. Supervising can be based on a predefined timing or permanent.
If the status of a signal or variable is changed the server analyzes the situation and takes a measure to treat the event, so each client has a list of conditions or events that are associated with a set of actions to be executed (Figure 5). This feature removes much more from the human intervention, the appropriate measures being taken by a software supervisor.
When the *supervise* mode is selected, the server sends to the client the list of variables to be supervised and the time interval when the client must verify the status of the variables (in the case when the supervise mode is periodic).

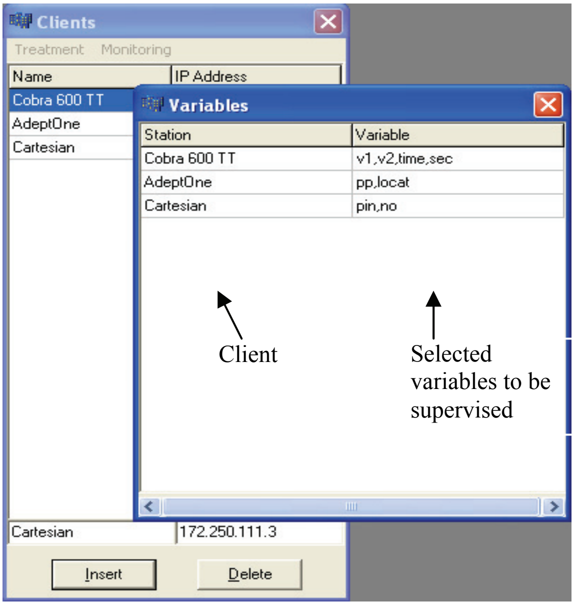

Fig. 4. Selecting the variables and the signals to be supervised

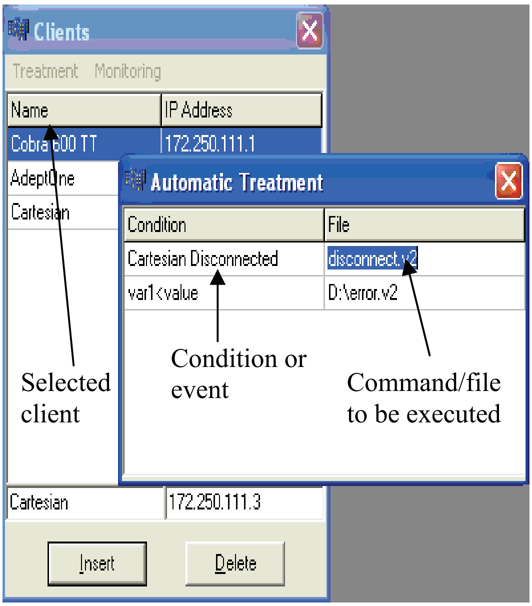

Fig. 5. Events and the corresponding actions

The events which trigger response actions can be produced by reaction programs run by the controller or by special user commands from the terminal. The list of actions contains direct commands for the robot and program execution commands (EXECUTE, CALL).

7. The solution for the design of a fault tolerant communication level

The communication level represents the key element of the management and command systems integrated with robot controllers networked in FMC structures.

A critical aspect in designing a communication level is the building, partitioning and on-line/off-line data bases transfer, which involve the multiplication of the communication links insuring a global fault tolerant behaviour. Dynamic interoperability modes must be considered, allowing the modules connected to the communication system to cooperate between them. The features announced above belong to a communication level which must combine the reliability and the performance of an industrial network with the building simplicity of a communication system used for parallel applications executed on multiprocessor machines.

To design such a communication system at the level of Controllers (C), the results from the parallel informatics with reference to the communication and process cooperation will be used. In a normal way (in the absence of malfunctions in the FMC), each controller is connected to the communication network. If in the setup stage of manufacturing or during manufacturing, a controller is malfunctioning another controller will take over the tasks. To make possible this operating mode, it is necessary to make available the data bases on each controller, and also a commutation of the informational routes with the help of the network. The availability is provided by software redundancy which involves keeping at least one replica of each data base.

7.1 CIM data base preservation

The data base preservation is realized by using a shared memory named **Tuple Space** (TS) (Borangiu & Nis, 1999), memory used by processes for communication and synchronization. The TS represent an associative set of numbers (addressable by content) of tuples. A tuple is formed by a logic name and a list of data elements which can be values or formal (logic_name, $param_1$, $param_2$, ..., $param_n$).

An example of tuple from the data base for the robot movement can be:

logic_name: data identifier {string};
$param_1$: robot identifier {integer [0..9]};
$param_2$: space coordinates identifier (Cartesian, joint, polar){char};
$param_3$: coordinate 1 : x/j_1 {reals};
$param_4$: coordinate 2 : y/j_2 {reals};
....
$param_n$: Open/Close gripper {boolean}.

TS is a conceptual space capable to receive and memorize tuples; the basic operations defined on TS are: `out`, `in`, `read`, `eval`.

The `out` operation inserts a tuple in TS and the extraction is realized by the in operation. Searching of an appropriate tuple is made using a model (template). A model matches a tuple if they have the same logic name, the same number of parameters and the parameters have the same type and values. If there is no tuple that match the model then the process which has executed the in operation remain blocked until the corresponding tuple will appear. The `read` operation is like the `in` operation with the exception that `read` does not erase the tuple from TS. The `eval` operation creates a dynamic tuple (a process which is executed in parallel with the process which has executed the `eval` operation). The result of this process is stored in TS as a regular tuple.

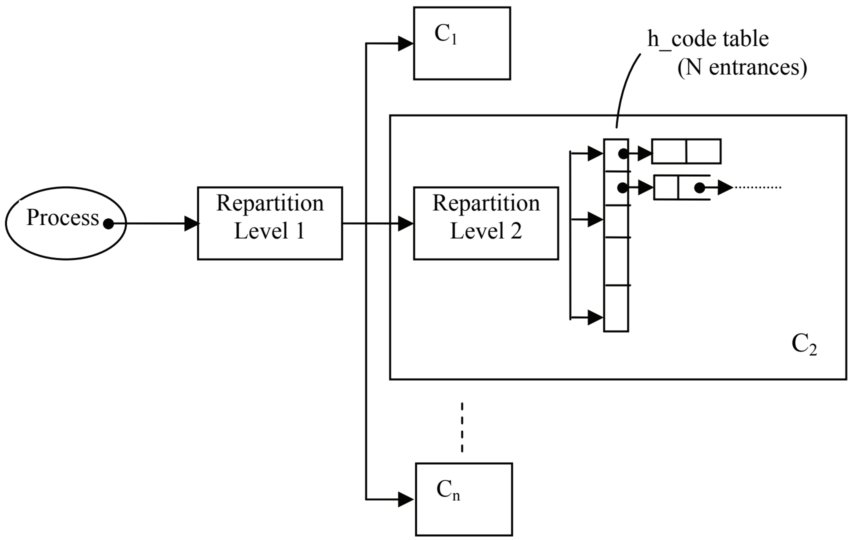

Fig. 6. Tuples distribution

7.2 Tuple distribution

In the proposed architecture the TS of the system, in particular the Computer Integrated Manufacturing data base, is distributed on the controller's network. The distribution is achieved at two levels (Figure 6.): first establish the C and the second establish, at C level, the entry where the data will be stored.
The first level selects the C that has the physical resources referred by data and the second level selects an entry depending on the tuple logical name, each entry being the beginning of a FIFO list of tuples.

7.3 Copy management and coherency between the copies

The copies management algorithms represent an important part that achieves the fault tolerance by data redundancy. The solutions in this domain are divided in two classes: centralized management and distributed management.

- *Centralized management*: the original C makes the data duplication.

- *Distributed management*: the process which requests the access to write in TS sends the tuple to the copies locations.

For the described CAM architecture a redundancy of minimum two different locations of the same data (tuple) was chosen as is presented in Figure 7.

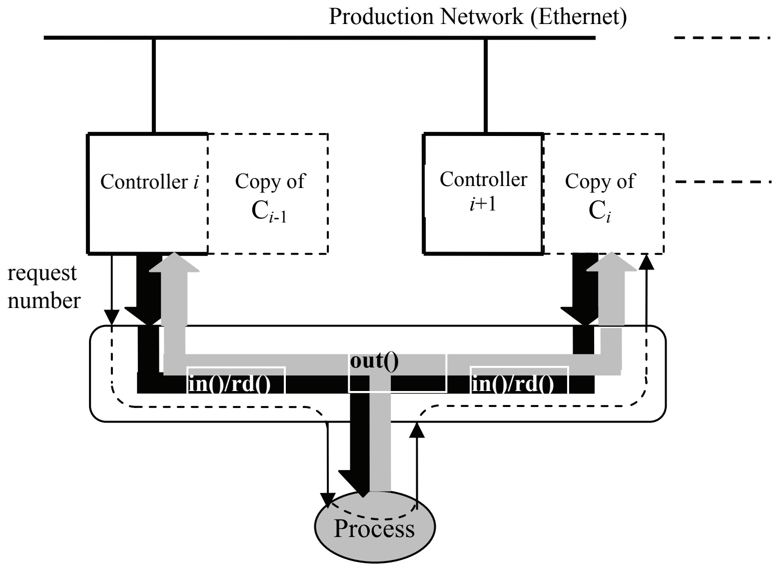

Fig. 7. Distributed copy management

It is obvious that the two classes of solutions are convenient because they allow transaction execution with only one C. In the first solution the original C must do all actions and becomes a critical resource; on the other way, the supplementary load of one of the duplicated C is avoided. The nondeterministic access to tuples and the associative selection makes uncertain the extraction of the same tuple from the two C (original and copy).
To solve this problem the request numbers (*rn*) that uniquely identify every `out` request at every TS were used. The request number is established by the original C and transferred to its replica using the calling process. In this way the tuple will have the same *rn* in each location and the coherency is assured.

7.4 The data base restoring mechanism

The logical stages that a system must accomplish are:

- malfunction detection;
- blocking each process during the reconfiguration;
- data redistribution;
- unblocking the previous blocked processes.

The data redistribution stage represents the data base "rebuilding", in fact the data base replica rebuilding. So the purpose of this stage is that for a network with n C, in the case of a C malfunction, the same fault tolerant structure is kept for the rest of n-1 left C. This stage is shown in Figure 8, and has two sub-stages: first, the replicas are eliminated to avoid

memory saturation during the second sub-stage. Then, a redistribution process (p_thread) handles the remaining data on each C, and sends them to the new two locations.
Malfunction detection is the first function that a fault tolerant system must offer. In the presented architecture, malfunction detection is made by the processes that use the network. The malfunction is then reported to the Supervisor PC which will decide whether a new reconfiguration is necessary or not.

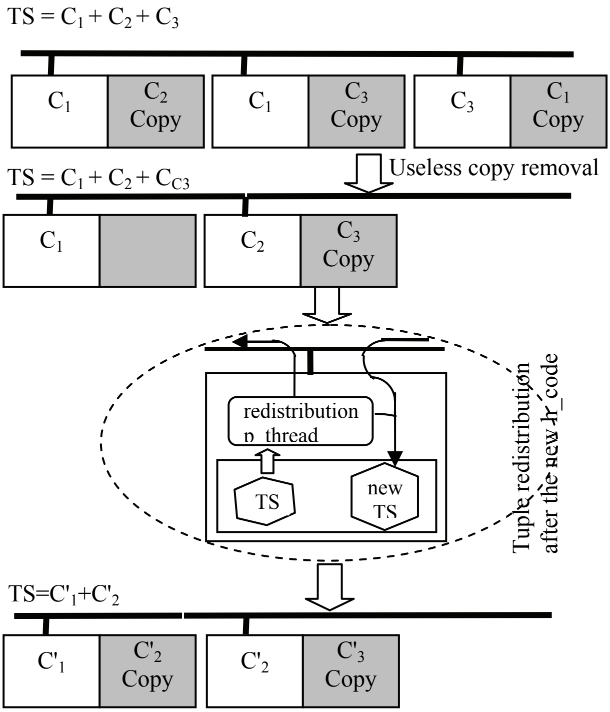

Fig. 8. Tuples redistribution

The detection strategy selected uses a *confirmation with time-out* method, meaning that at each message exchange during the process access to TS, the process waits a confirmation (acknowledge). A process is capable to detect a malfunction only when it tries to access one of the servers that implement the TS. These moments occur when:

- the process send a request to the server;
- the data transfer between server and process a result of request processing;

In the following paragraph the communication protocol for the `in` operation at the process level and at the TS server level will be presented in detail.
The description of the protocol at server level for the operation `in` resides in considering that the end of the dialog can eventually coincide with the end of the reconfiguration (see Figure 9). In this case the process must restart the dialog by reconnecting to the Supervisor PC in order to know the new system configuration.

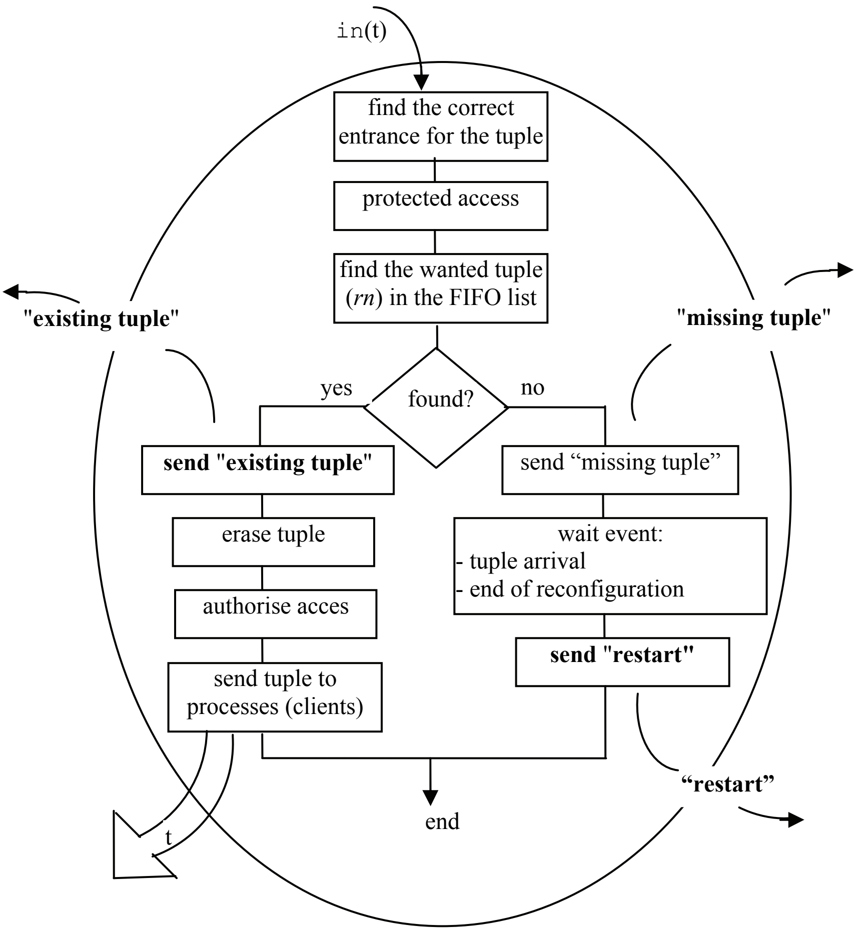

Fig. 9. The `in()` operation at the server level

It must be mentioned that during the configuration, the process will be blocked. This is achieved by each server that does not respond at any request issued by processes until the end of the reconfiguration.

To unblock the processes, their second connexion with the TS server will be used.

Another problem to be solved at the server level is to make the difference between the tuples arriving in the TS as result of redistribution during reconfiguration and the tuples sent by the processes. This aspect is important to avoid unblocking a process which awaits a tuple as the result of another tuple's arrival due to redistribution. The simplest solution is to reserve a communication channel (private port) between every server dedicated only for tuple transfer during reconfiguration.

On the other hand, the same malfunction can de detected simultaneously by more than one process but that malfunction must be considered only once. That’s why every system state

between any two reconfigurations has a version number (vn) and thereby any report with a vn less than the current vn is ignored.
At process level, when a tuple is required, the process awaits with time-out the confirmation messages from the two tuple locations. The diagram in Fig. 10 shows that the process detects a malfunction upon receiving the presence ("missing", "existing") or restart messages only from one location.

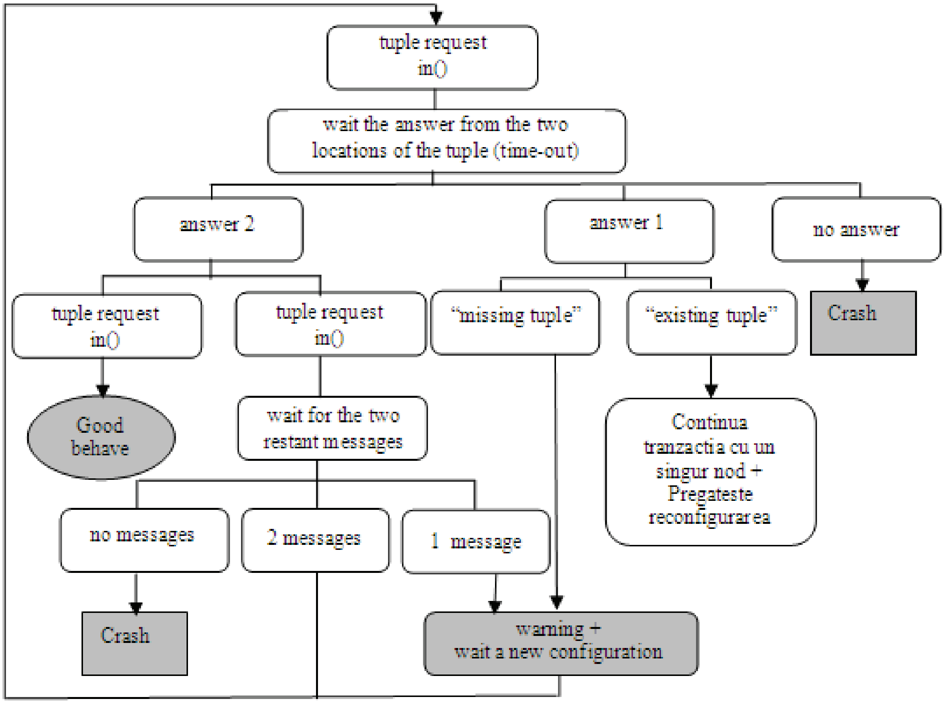

Fig. 10. The `in()` operation at process level

Two different behaviours are distinguished:

- if the tuple does not exist in any location, then the process reports to the supervisor and awaits the new configuration;
- if the tuple is present at least in one location then the process continues the execution after its reports to the supervisor to prepare the reconfiguration.

When there is no presence or restart message, the state of the system is considered as crash.

7.5 Reconfiguring the network

Rebuilding the communication route in the network represents the last step required to restart the normal behaviour of the FMC control system.
In case of malfunction of the communication network the following most important cases can appear:

1. If the connection between the Switch and the Supervisor PC is down the remote control will be lost, but the FMC will reconfigure as follows: the controller will use the Ethernet

network for communication, and the controller with the first IP from the class will take the functions of the Supervisor PC. If the connexion is re-established the Supervisor PC makes a query, finds the replacing controller and transfers the databases and restarts the normal behaviour.

2. If the switch is not functioning, all the Ethernet connexions are lost but the controllers will use the serial "network". The behaviour is like in the first case only that the web users can view the status from the Supervisor PC, including the images acquired by the observation cameras.
3. If a controller loses the Ethernet connexion, it will use one of the two serial lines to reach the Supervisor PC depending on the CPU time of the neighbours.

8. Lotus Domino platform and E-Learning aspects

The strong impact of this project consists in stimulating the cooperation between different networked areas of an enterprise. The objective was to build a system that provides access to public information for a wide audience and at the same time supports collaboration between registered members, provides safe access to protected contents and enables the publication and editing of contents. The system can be accessed from a great variety of places. Therefore care was taken to also ensure optimal use in case of lower bandwidth and poorer quality hardware. The high level of security and availability are key components, which were ensured by the selection of high quality technical devices and well-planned loading. As the portal must be prepared for a growing number of users, the tool must be highly scalable. It needs to integrate contents and services and provide access for document repositories. User groups must be able to access personalised contents.

High-level availability must be guaranteed. The system should be scalable according to load and requirements. The use of NLBS (Network Load Balancing System) provides a solution for an even (balanced) load of the network. The portal user interface needs to be customized, and templates must be created and uploaded. The authorisations and user groups must be defined.

The eClient application Lotus Domino Server implements a security access policy to the virtual workspace. The access to the eClient application is granted based on the Domino defined ACL's (Access Control Lists), such that in order to connect to the application the user must specify a user name and a password. There were defined two classes of privileges:

1. A **user class** where the operator can observe images acquired from the observation web cameras and images from the VISION system taken by multiple area cameras; he can also view the commands issued by the trainer and watch the results of the commands;
2. A **trainer class** where the operator is authorized to issue commands for every connected robot system, upload, download and modify programs. The trainer can also take pictures from an individual camera and use the specific vision tools to process that image. The observation cameras can also be moved and positioned in the desired location by the trainer. The trainer can give full or partial permissions to users for program testing purposes. The communication between the users is achieved by help of the integrated console (text mode) or using an Instant Messaging and Web Conferencing application (Sametime).

IBM Lotus Domino server software was used to combine enterprise-class messaging and calendar / scheduling capabilities with a robust platform for collaborative applications on a

wide variety of operating systems. The design of the Lotus Domino Server made available three offerings: Domino Messaging Server (messaging only), Domino Utility Server (applications only), and Domino Enterprise Server (both messaging and applications) (Brooks, *et al.*, 2004).
The most important Lotus Domino features used in the project are:

- Encryption, signing, and authentication using the RSA public-key technology, which allows to mark a document in such way that the recipient of the document can decisively determine that the document was unmodified during transmission.
- Access Control Lists (ACLs) determining who can access each database (application) and to what extent.
- Usage of Domino's new features to reduce network utilization. Network compression reduced the number of bytes sent during transactions by up to 50 percent. Connections across heavily loaded links such as WANs and XPCs see the most benefit.
- Availability for the Windows NT and XP platforms, automatic fault recovery after shutdown and server restart without administrator intervention after the occurrence of an exception. Fault recovery uses operating system resources, like message queues.

Because, the application eClient is accessed over the Internet, security represents a critical element. The access to different levels of the application is controlled by xACLs (extended ACLs) to allow or disallow access. The existing database Access Control Lists (ACLs) and the new ACL file feature ensure that application-private databases remain secure. In addition, file protection documents for the Domino Web server which is used to serve the eClient (Java application) provide additional access control for files accessed via HTTP.

9. Portal performances

In this section, portal performances aspects are presented. The tests have been conducted using two networks: an internal 10/100 Ethernet network which has the Internet bandwidth of 61.38 Mbps (resulted from tests), and an external wireless network using a 3G+ HSDPA modem, and having a bandwidth of 3.6 Mbps.
For internal testing, two computers have been used:

A) A PC workstation having the HW configuration: CPU 3.4GHz, 4GB RAM, 75GB HDD SCSI, installed with Windows XP SP2, Internet Explorer as browser, with ActiveX controls: AXIS for viewing the Motion JPEG images, QuickTime to view MPEG-4 streams, and jre 1.4.2 to control the teleoperation application.

B) A PC workstation having the HW configuration: CPU 3.4GHz, 4GB RAM, 75GB HDD SCSI, installed with Linux: KNOPPIX, the internet browser Firefox with plugging: AXIS for viewing the Motion JPEG images, QuickTime to view MPEG-4 streams, and jre 1.4.2 to control the teleoperation application.

For the external testing a DELL Inspiron 1720 Laptop has been used, CPU 2GHz, Dual Core, 2GB RAM, 240 GB HDD, Modem HSDPA Vodafone installed with Windows XP SP2, the Internet browser Firefox with plugging: AXIS for viewing the Motion JPEG images, QuickTime to view MPEG-4 streams, and jre 1.4.2 to control the teleoperation application.

9.1 Teleoperation and image transmission tests

The first test has been conducted to evaluate the impact of the two applications (teleoperation and image transmission) on the bandwidth. For the teleoperation application a bandwidth test has been conducted for two cases: a case where there is no teleoperation activity, and a case where a high activity has been simulated. The results are presented in Table 1.

PC workstation	High activity	Idle
A	86.22 kbps	0 kbps
B	81.5 kbps	0 kbps

Table 1. Test results for the teleoperation application

The image transmission application test consists in two separate tests to detect the differences between the transmissions for colour/grey level images. The compression level used was Motion JPEG and MPEG-4, and the measurements have been done for the used bandwidth and the rate of frames per second (fps) for the following resolutions: 4CIF, 2CIF Expanded, 2CIF, and CIF. The results are presented in table 2 and 3.

Colour/Resolution			4 CIF (704x576)	2 CIF E (704x576)	2 CIF (704x288)	CIF (352x288)
A	B&W	fps	25.02	25.01	25.02	25.02
		kbps	6151	6215	4467	2443
	Colour	fps	25.01	25	25.02	25.02
		kbps	6428	6221	4353	2461
B	B&W	fps	25.02	25.02	25.02	25.02
		kbps	6203	6198	4420	2420
	Colour	fps	25	25	25.02	25.02
		kbps	6421	6217	4375	2443

Table 2. Image transmission test for Motion JPEG compression

Colour/Resolution			4 CIF (704x576)	2 CIF E (704x576)	2 CIF (704x288)	CIF (352x288)
A	B&W	fps	13.83	15.09	17.31	25
		kbps	1342	1342	1450	1285
	Colour	fps	13.83	15.09	17.07	24.03
		kbps	1421	1412	1441	1298
B	B&W	fps	13.83	15.09	17.25	25
		kbps	1335	1351	1445	1288
	Colour	fps	13.83	15.09	17.20	25
		kbps	1330	1375	1451	1293

Table 3. Image transmission test for MPEG-4 compression

9.2 Teleoperation and image transmission combined tests in the internal network

These tests have been carried out to check the application performances such as bandwidth and rate of frames per second in two types of tests: (i) a test in which the bit rate is constant without specifying a maximum rate of bits, using the priorities: *image quality* and *fps*; (ii) a second test using a variable rate of bits, but in which a maximum bit rate has been configured and where the video stream has been optimized for the bandwidth utilization or for the rate of fps. The compression rate was MPEG-4 and the resolution CIF. If the compression is Motion JPEG the bandwidth is 9910 kbps and the fps rate is 25.02. The tests have been conducted for the following bit rates: 48 kbps – GPRS Class 12, 52 kbps – 2G, 384 kbps – EDGE, 512 kbps, 1 Mbps, 3.6 Mbps – 3G, 7.2 Mbps – 3G+, 10Mbps – LAN. The results for the internal network are presented in Tables 4 and 5, and the results for the external network are presented in Tables 6 and 7.

Priority\Bit rate			48k	52k	128k	384k	512k	1M	3.6M	7.2M	10M
A	Image quality	fps	2	3	5	14	18	35	39	39	40
		kbps	116	140	275	761	1035	1974	2424	2436	2442
	Fps rate	fps	10	20	22	41	50	50	39	39	39
		kbps	89	105	242	775	1032	1980	2400	2415	2420

Table 4. Application testing using the internal network and a constant bit rate

Optimization\Bit rate			48k	52k	128k	384k	512k	1M	3.6M	7.2M	10M
A	Bandwidth	fps	1.5	2	5	15	20	35	50	50	50
		kbps	108	113	260	772	1016	1824	1960	1970	1970
	Fps rate	fps	2	2	6	16	22	35	50	50	49
		kbps	120	120	267	773	1180	1746	1893	1859	1836

Table 5. Application testing using the internal network and a variable bit rate

Priority\Bit rate			48k	52k	128k	384k	512k	1M	3.6M	7.2M	10M
A	Image quality	fps	[illegible]	2	5	14	19	35	39	39	39
		kbps	177	156	278	557	718	1412	1475	1510	1722
	Fps rate	fps	8	6	13	41	50	50	39	39	39
		kbps	104	112	254	755	1026	1815	1526	1594	1640

Table 6. Application testing using the external network and a constant bit rate

Optimization\Bit rate			48k	52k	128k	384k	512k	1M	3.6M	7.2M	10M
A	Bandwidth	fps	2	2	4	15	19	34	50	50	50
		kbps	93	116	280	596	980	1355	1944	2043	2024
	Fps rate	fps	2	2	5	15	19	34	49	50	50
		kbps	93	114	268	743	722	1152	1529	2006	2002

Table 7. Application testing using the external network and a variable bit rate

The first test has been executed in order to evaluate the differences between the PC workstations A and B concerning the bandwidth, where it has been observed that the Linux machine uses a bandwidth smaller with 4.72 kbps which is not concluding enough to make a difference between the two workstations.

The second test (Table 2) has been executed in order to estimate the difference between colour and grey level video streams for workstations A and B. As can be seen from Figs. 11, 12, 13 and 14 the performance differences between the two workstations are insignificant, so we can conclude that the teleoperation system has the same performance regardless the operating system of the user.

From the point of view of image encoding (in accordance with the type of the image – colour, grey level) it can be seen that the differences between colour and grey level images are too small to be considered, but, if the two types of encodings are compared one can see that Motion JPEG uses a bandwidth of 2500 kbps for the CIF resolution, while the MPEG 4 brings an improvement of 200% (the bandwidth used in this case being less of 1300 kbps). Due to this, MPEG-4 is used to minimize the bandwidth, while Motion JPEG is used for a better image quality.

From the point of view of image resolution, the CIF resolution was selected because the system uses a relative small bandwidth and also the size of the image is acceptable, considering that on the user workstation two images must be displayed and the teleoperation application has a resolution of 800x640 pixels.

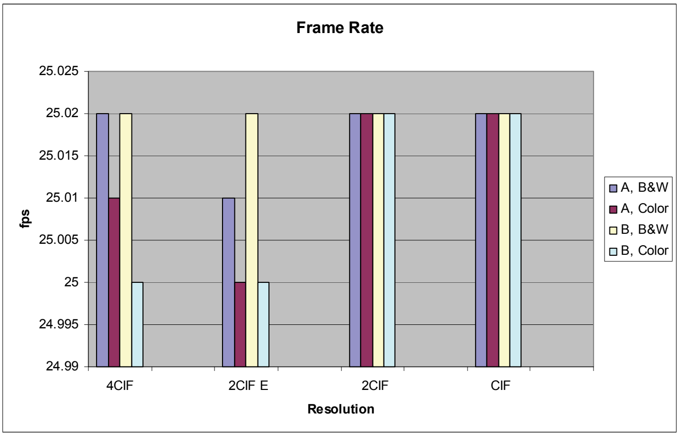

Fig. 11. FPS rate for Motion JPEG encoding

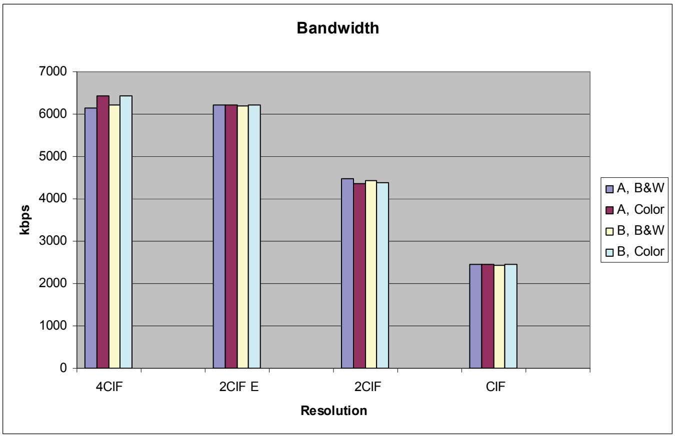

Fig. 12. Bandwidth for Motion JPEG encoding

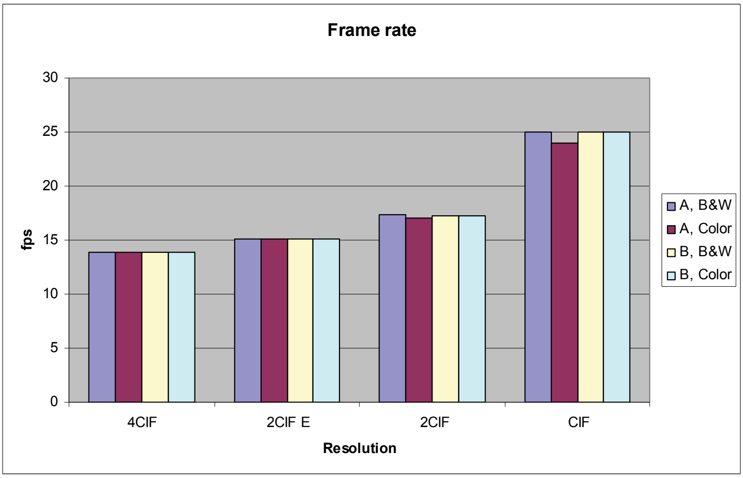

Fig. 13. FPS rate for MPEG-4 encoding

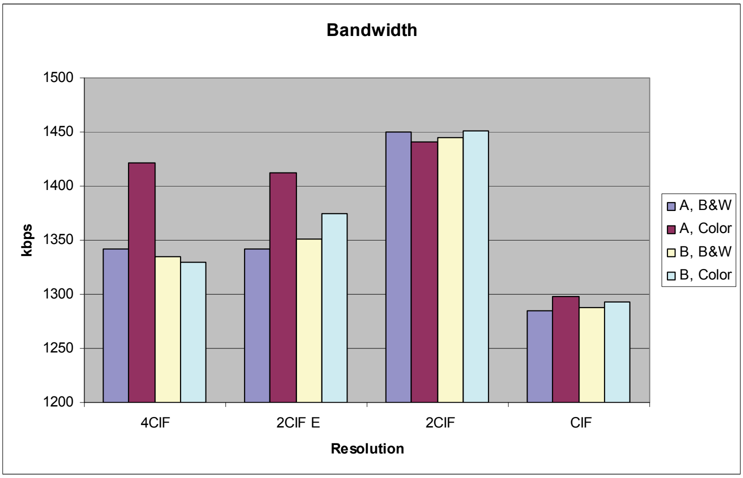

Fig. 14. Bandwidth for MPEG-4 encoding

For the internal network (Figs. 15, 16, 17, and 18) it can be seen that the solution which must be chosen both for image quality and bandwidth is the solution with constant bit rate, which works satisfactory from a bit rate of 384kbps, the total rate being approximately 750 kbps. From the point of view of quality the priority is the frame rate (fps), the differences being over 200% for bit rates under 1Mbps against the priority *image quality*.
For the external testing (Figs. 19, 20, 21, 22) it can be seen that the same rules are met, and the conclusions are the same as for the internal network.

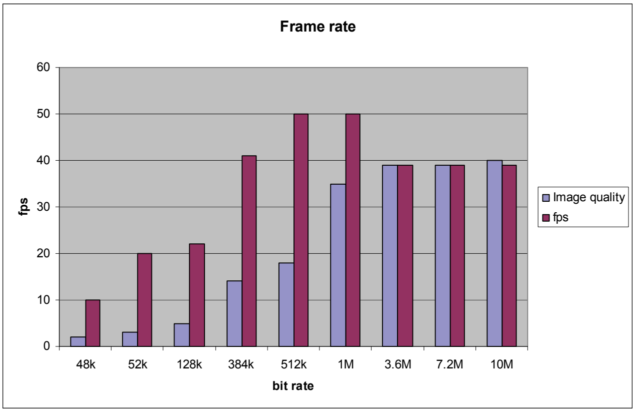

Fig. 15. FPS for internal network, constant bit rate, priority: *Image quality, fps*

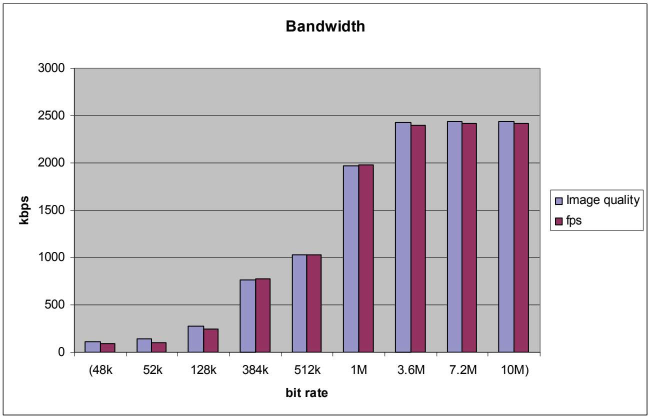

Fig. 16. Bandwidth for internal network, constant bit rate, priority: *Image quality, fps*

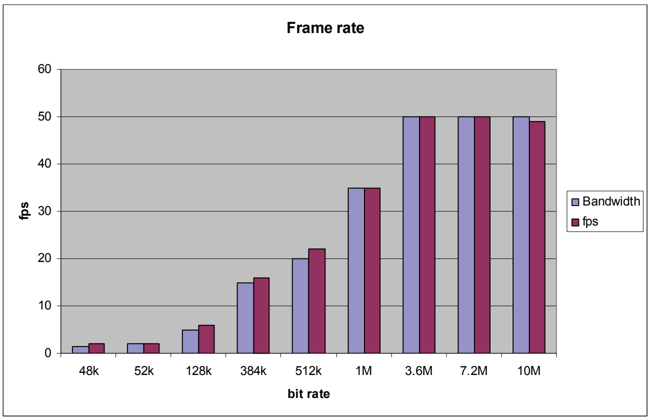

Fig. 17. FPS for internal network, variable bit rate, stream optimization: *Bandwidth, fps*

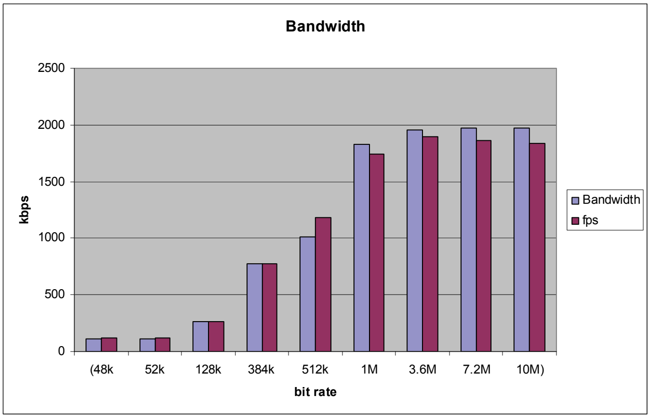

Fig. 18. Bandwidth - internal network, variable bit rate, stream optimization: *Bandwidth, fps*

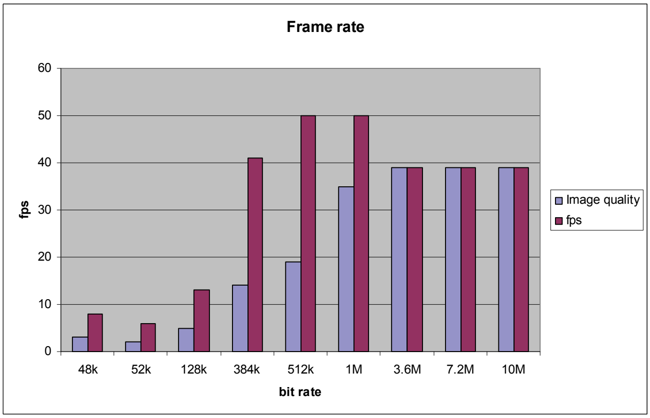

Fig. 19. FPS for external network, constant bit rate, priority: *Image quality, fps*

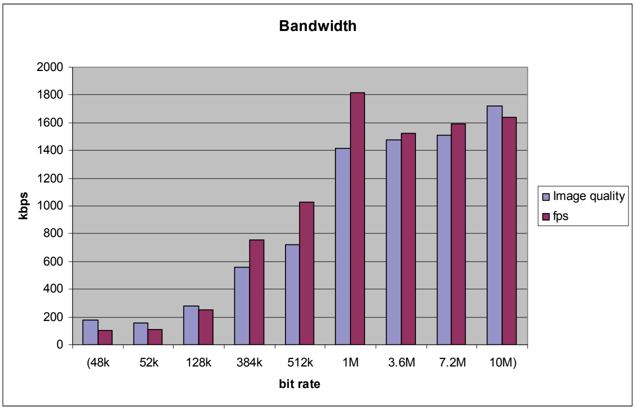

Fig. 20. Bandwidth for external network, constant bit rate, priority: *Image quality, fps*

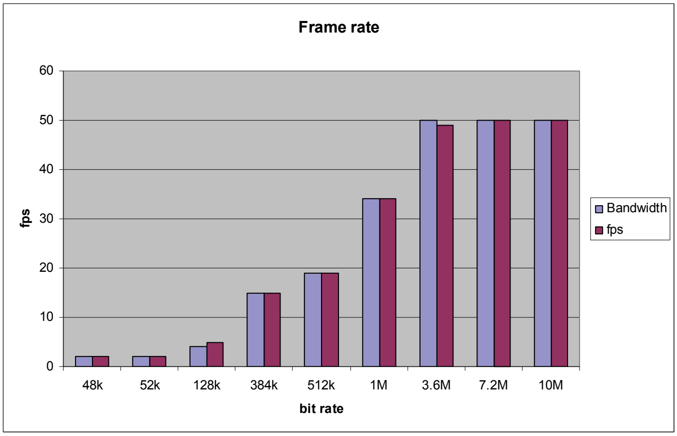

Fig. 21. FPS for external network, variable bit rate, stream optimization: *Bandwidth, fps*

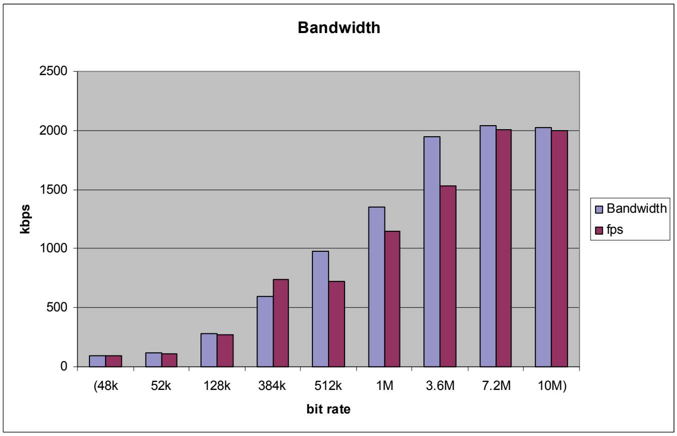

Fig. 22. Bandwidth - external network, variable bit rate, stream optimization: *Bandwidth, fps*

In conclusion, the tests have shown that in order to obtain a high image quality and a maximum fps, in other words a maximum performance for the teleoperation application, the user can use an internal or external network with a bandwidth of at least 1Mbps, or 128KB/s using MPEG-4 image encoding, a constant bit rate of 512kbps and using as priority *fps*.

10. Implementing results. Conclusions

Fault-tolerance is provided to the cell communication system (Figure 23), providing redundancy at both Station Controller level (a break down of a Robot Controller is detectable, the production tasks can be rescheduled to the remaining valid units for graceful degraded behaviour) and at Station Computer level (replication of data bases for the IBM PC-type device terminals, reassignment of computers in case of break downs).

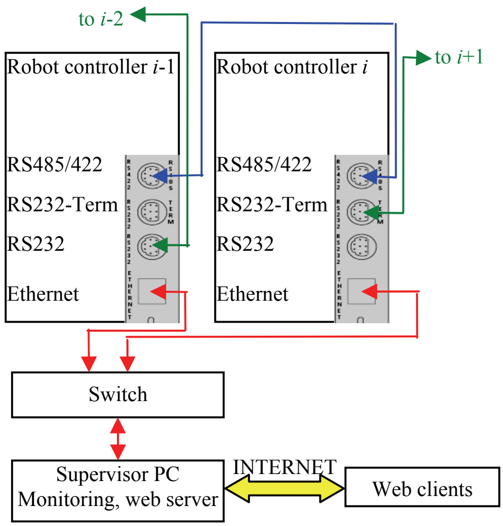

Fig. 23. Fault-tolerant communication architecture

The fault tolerance solution above presented is worth to be considered in environments where the production structure is reconfigurable, and where the manufacturing control must assure a continuous production flow at batch level (job shop flow).
There are also some drawbacks in this solution. The spatial layout and configuring of robots must be done such that one robot will be able to take the functions of another robot in case of failure. If this involves common workspaces, programming must be made with much care using robot synchronizations and monitoring continuously the current position of the manipulator.
The main advantage of the proposed solution is that the structure provides a continuous production flow with an insignificant downtime (during reconfiguration).
The solution was tested on a four-robot assembly cell located in the Robotics and IA Laboratory of the University Politehnica of Bucharest. The cell also includes two CNC milling machines and one Automatic Storage and Retrieval System, for raw material feeding and finite products storage.
During the tests the robot network has detected a number of errors (end-effector collision with parts, communication errors, power failure, etc.) The robotic network has evaluated the particular situation, and the network was reconfigured and the abandoned applications were restarted in a time between 0.2 and 3 seconds.
The network failure was simulated in the tests, as a complex example.
One robot (R2) was disconnected from the Ethernet network, the heartbeat packet sent by the robot to the other cluster members has detected the malfunction and the robot has switched the communication using the serial line; this was done in 0.3 seconds after the Ethernet cable was removed. The communication between the affected robot and his neighbours was done using the serial lines, and the communication with other robots was done by routing the communication using the Ethernet line of the neighbours (R1 and R3). In this way the communication latency was reduced.

After the communication was re-established, the serial lines of the robot have been disconnected. The robot has detected the communication failure, has stopped the manipulation program and retracted the manipulator in a default position in the exterior of the working area in 0.8s.

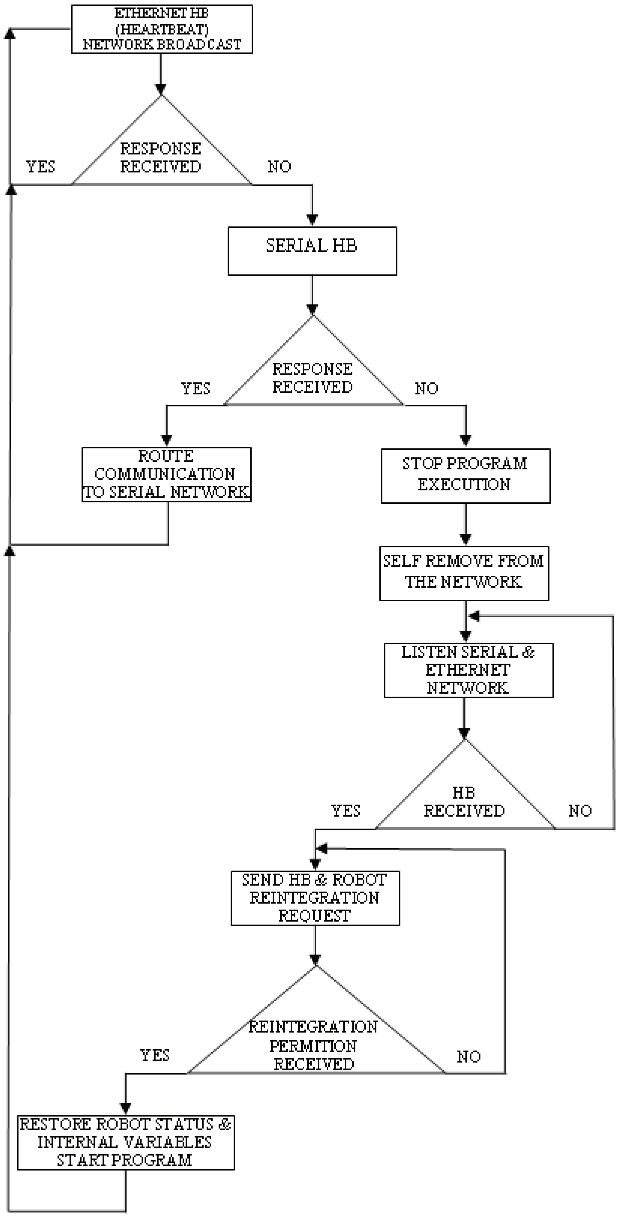

Fig. 24. Algorithm for network failure

The neighbours have sent the heartbeat packets using the serial lines and detected that they do not have any connection with the robot and announced the group leader (GL) which has removed the robot from the cluster and reconfigured the cell (Figure 24). The neighbour R1 having the same working area as the affected robot R2 has loaded the variables values and the production program from the shared storage, and started the production resuming from the point where R2 has been stopped. The cell reconfiguration from the point where the serial lines where disconnected has taken 2.2 seconds.

Another communication test consisted in disconnecting both the serial lines and the Ethernet line at the same time; in this case the cluster tested the communication sequentially and cluster reconfiguration took 2.5 seconds. When configuring the cluster to test the communication lines in parallel, the reconfiguring took 2.3 seconds but the controllers processed a higher communication load.

The most unfavourable situation is when a robot manipulator is down; in this case the down time is greater because the application which was executed on that controller must be transferred, reconfigured and restarted on another controller. Also if the controller still runs properly it will become group leader to facilitate the job of the previous GL.

The solution is not entirely fault tolerant, but in some situations the solution could be considered as a fault tolerant system due to the fact that even if a robot controller failed, the production continued in normal conditions.

The research project will provide a portal solution for linking the existing fault tolerant pilot platform with multiple V+ industrial robot-vision controllers located in different R&D labs.

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16

Development Sensor Experimental Platform Based on the Graphical Monitoring and Control System

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1. Introduction

Sensors have traditionally been used for industrial process control, measurement, and automation, often involving light, temperature, pressure, flow, and level measurement (Ramon and John, 2001). Harsanyi and Lepsenyi (2000) surveyed research work at the sensor's laboratory. Results originate from student work at different levels, ranging from undergraduate to Ph.D. Individual areas are under research and development, and results demonstrated here are not always complete.

Ahmad (1988) reported a laboratory experiment to teach concepts of sensor-based robot assembly systems. These sensor-based motion strategies improve robot assembly system reliability. This article discusses the sensor-based assembly experiment, the laboratory setup, and the sensor-based motion strategies in detail. Peyton et al. (1996) take the view that principles of sensor operation and instrumentation are important subjects for an electronics/mechatronics undergraduate course and should be presented as early as possible within the overall degree program.

This chapter addresses an experimental sensor module based on the graphical monitoring and control system. First, this system gleans and sorts different data, then integrates the experimental sensor module via student-created projects. Second, this system edits graphical monitoring and control system software. Finally, it connects the software with the hardware of different optoelectronic devices to achieve a sensor module based on the graphical monitoring and control system. This article also develops experimental instruction material to offer practical graphical monitoring and control system experience to students involved in a team project.

The remainder of this chapter is organized as follows. Section 2 describes sensors. Section 3 gives the graphical monitoring and control system overview. Section 4 presents experimental descriptions of several different sensor modules. The project experiment is shown in Section 5. The evaluation is shown in Section 6. Section 7 offers conclusions.

2. Sensor Description

A complete instruction material in sensor and graphical monitoring and control system fundamentals is an introduction to control. With this system, students can explore the principles and applications of different sensor devices, all commonly found in industry. The most common sensor types are the photo-resistor and temperature-sensor.

The most common types of photo-sensors are the photo-resistor, the phototransistor, the solar cell, and the fiber-optical sensor. The photo-sensor devices form a specialized branch of the semiconductor technology. These photo-sensor devices find application in a variety of measurement and control systems such as: (1)Light level measurement, (2)Optical switching, (3)Non-contact switching, (4)Shaft encoders, (5)Position readers, (6)Remote control, (7)Paper handlers, (8)Coin handlers, (9)General purpose interruptive sensing, (10)Logic circuits, and (11)Counting systems.

Temperature sensors are often used within electronic systems to monitor temperature and provide protection from excessive temperature excursions. The most common temperature sensors a system uses are listed as follows: thermocouple, RTD, thermistor and AD590.

2.1 Photo-resistor (CDS, Cadmium Sulfide)

The resistor is one of the most common electronic components. A resistor is a device that limits, or resists current. The current limiting ability or resistance is measured in ohms, represented by the Greek symbol Omega (Ω).

The photo-resistor does not have a specific fixed resistance. Resistance is based on the amount of light that falls on it. The photo-resistor is basically a chunk of silicon crystal with a lead on each end exposed to the light. Resistance is very high in the absence of light. Resistance falls dramatically, often to several hundred ohms when the resistor illuminates. The photo-resistor may also be called CDS (Cadmium Sulfide) cells. Important aspects of the photo-resistor operation include: (1)The photo-resistor may require a few milliseconds or more to fully respond to changing light intensity. It may require many minutes to return to its normal dark resistance when light is removed. (2)The semiconductor most often used in the photo-resistor is cadmium sulfide, and its light sensitivity is very similar to that of the human eye! The light sensitive semiconductor is typically coated between interleaved electrodes to increase its exposed surface. A plastic or glass window may or may not be used. Photo-resistors are commonly used in light controlled relays and light meters.

2.2 Phototransistor

The transistor is basically a semiconductor switch or amplifier. In the case of an NPN transistor, a small current applied to the base allows a much larger current to flow from the collector to the emitter. The transistor functions as a switch when the maximum amount of base current is applied to the transistor and saturates it. Smaller amounts of current applied to the base change the transistor's output changes. Photons entering the base replace the base-emitter current of ordinary NPN transistors. Therefore, a phototransistor directly amplifies variations in the number of photons. The phototransistor is often used to detect fluctuating light signals. This acts like any other base and also affects current flow through the transistor. Phototransistors are most sensitive to light, but also respond to regular light. They are used in receivers, light sensors, etc. The collector is the one angled line without the arrow. The emitter is the angled line with the arrow pointing down away from the straight line. Light-sensitivity of the device is represented by downward arrows. Phototransistors may or may not be drawn with the circle surrounding them.

2.3 Solar Cell

A solar cell is a PN junction photodiode with a large light sensitive area. Light striking the cell causes electrons to flow. Several solar cells may be connected in series or parallel to form a solar panel. If they're connected in series, the output voltage is the sum of voltages for each solar cell. When they're connected in parallel, the output current is the sum of currents for each solar cell. Arrows pointing at the cell on the schematic represent light. Photodiodes are diodes that generate electricity when illuminated. A diode is a component that only allows electricity to flow one way, a kind of one-way street for electrons.

Silicon photovoltaic cells are typically considered as voltage supplies, but are also useful as sensitive detectors of light and near infrared. Solar cells are silicon wafers doped to produce a p-n junction. Commonly used "cells" are produced as wafers with a diameter of about 8 cm and 3 mm thickness, cut from a crystalline silicon rod. The thin wafer is doped on one side to produce p-material (e.g., boron doped silicon) and on the other side to produce n-material (e.g., phosphorous doped silicon). The p material is typically connected to a metal base and the topside of the wafer (n-type) has an electrical contact grid. Light striking the top of the wafer penetrates through the p-n junctions and free electrons, crossing the junction into the n-type region. Electrons are then held in the n-region, unable to re-cross the junction into the p-region. Figure 4 shows the solar cell symbol and transducers used for a light detector.

2.4 Fiber-optic Sensor

A fiber optic sensor is a sensor that uses an optical fiber, either as the sensing element , or for relaying signals from a remote sensor to the electronics that process the signals. Fibers have many uses in remote sensing. Depending on the application, a fiber may be used due to its small size, or because the remote location does not need electrical power, or because many sensors can be multiplexed along the fiber length, using different light wavelengths for each sensor. Fiber optics sensing is the latest emerging technology that plays a key role in monitoring large structures using only one continuous sensor, the fiber optic line itself. This technology translates into a cost reduction alternative compared to other measuring techniques and technologies requiring hundreds of sensors to cover the same area.

Fiber optic sensor characteristics are as follows: (1)Compact design, water and corrosion resistant;(2)Immune to electromagnetic interferences; (3)Passive operation (no electrical signal); (4)The fiber is both the transducer and the signal transmission medium; (5)Measurement signal insensitive to intensity losses over the fiber (transmission over distances up to several kilometers); (6)No calibration required; (7)Ability to multiplex dozens or more sensors on a single optical fiber (parallel and serial multiplexing); (8)Long lifetime.

2.5 Thermocouple

The thermocouple uses the see-back effect. This is where two dissimilar metal alloys produce an Electro-Motive Force (EMF is a fancy way of saying "voltage") nearly proportional to temperature. Thermocouples are made by joining two wires of dissimilar

metals. Thermocouple types differ by metallic composition and are designated by a single letter such as J, T, or K. Temperature can be calculated by knowing the thermocouple type.
The contact point between the wires generates a voltage approximately proportional to temperature. Characteristics include wide temperature range, low-cost, very low output voltage, reasonable linearity, and moderately complex signal conditioning (cold-junction compensation and amplification). Thermocouples are available in probes and with bare leads.
Thermocouple voltage output means the temperature is not a linear relationship; however it may be approximated as one. This voltage amplifies by signal conditioning equipment and then inputs to the computer through the DAQ card, thus turning a real life temperature measurement into a digital value on a computer that can be analyzed and presented. Figure 6 shows the thermocouple symbol and transducers used for temperature detection.

2.6 RTD (Resistive Temperature Detector)

The resistive temperature detector is made of coils or films of metals (usually platinum). When heated, metal resistance increases; when cooled, resistance decreases. Measuring this voltage determines its resistance, and thus its temperature. Resistance temperature detector, or RTD, is a highly accurate temperature sensor, known for its excellent stability characteristics.
RTD characteristics include wide temperature range, excellent accuracy and repeatability, reasonable linearity, and the need for signal conditioning. Signal conditioning for an RTD usually consists of a precision current source and a high-resolution ADC circuit. RTDs are available in probes, in surface-mount packages, and with bare leads. RTD lead resistances require care, due to their low resistance values. The resistance/temperature curve for a 100Ω platinum RTD, is commonly referred to as Pt100.

2.7 Thermistor

The thermistor is a temperature-dependent resistor, typically molded from conductive materials. The most common thermistor has a negative temperature coefficient (NTC) of resistance. Thermistor characteristics include a moderate temperature range, low-to-moderate cost (depending on accuracy), poor but predictable linearity, and the need for some signal conditioning. The thermistor is available in probes, in surface-mount packages, with bare leads, and in a variety of specialized packages. Maxim manufactures ICs that convert thermistor resistance to digital form.
Like RTD, it reads voltage across the thermistor and thus determines its temperature. Unlike RTD, the thermistor has a higher resistance (anywhere from 2KΩto 10KΩ) and a much higher sensitivity. However, the thermistor is generally only used up to the 300°C temperature range. Due to thermistor high resistance, lead-wire resistance does not affect measurement accuracy, unlike RTD. The 2-wire measurement is generally adequate.
The thermistor has either a negative temperature coefficient (NTC) or a positive temperature coefficient (PTC). The first has a resistance, which decreases with increasing temperature and the latter exhibits increased resistance with increasing temperature. Figure 8 shows the thermistor symbol and transducers used for temperature detection.

2.8 AD590

The AD590 is an integrated-circuit temperature transducer, which produces an output current proportional to absolute temperature. The device acts as a high impedance constant current regulator, passing 1µA/°K for supply voltages between +4V and +30V. Laser trimming of the chip's thin film resistors calibrates the device to 298.2µA output at 298.2°K (25°C).

The AD590 should be used in any temperature-sensing application between -55°C to 150°C that employs conventional electrical temperature sensors. The inherent low cost of a monolithic integrated circuit combined with support circuitry elimination makes the AD590 an attractive alternative for many temperature measurement situations. Linearization circuitry, precision voltage amplifiers, resistance measuring circuitry and cold junction compensation are not needed in applying the AD590. In the simplest application, a resistor, a power source and any voltmeter can be used to measure temperature. In addition to temperature measurement, applications include temperature compensation or correction of discrete components, and biasing proportional to absolute temperature.

The AD590 is particularly useful in remote sensing applications. The device is insensitive to voltage drops over long lines due to its high-impedance current output. Any well-insulated twisted pair is sufficient for operating hundreds of feet from the receiving circuitry. Output characteristics also make the AD590 easy to multiplex: the current can be switched by a CMOS multiplexer or the supply voltage can be switched by a logic gate output. The AD590 features include: (1) Linear current output 1µA/°K, (2) Wide temperature range -55°C to 150°C, (3) Two-terminal device voltage in/current out, (4)Wide power supply range +4V to +30V, (5)Sensor isolation from case, (6)Low cost.

3. Graphical Monitoring and Control System

This section describes graphical monitoring and control system requirements for the experimental sensor module.

3.1 General Description

(1)Work under this section includes providing graphical monitoring and control system equipment to provide the following functionality: (i) Monitoring sensor status, (ii) Gathering and storing sensor information, and (iii) Detailed analysis and trouble-shooting of the sensor system.

(2)An existing personal computer workstation stores collected data, system operation and analytical software.

(3)Sensor information should be transmitted to and integrated into the building sensor experimental module based on the graphical monitoring and control system.

3.2 System Description

(1)The existing system includes the experimental sensor module for graphical monitoring and control, device interface hardware, inter-communication wiring, a personal computer workstation, software, interfacing, printer, and ancillary equipment.

(2)The existing system utilizes the high-speed backbone network.

(3)A personal computer workstation connected to the network has equal access to information provided by graphical monitoring devices for centralizing data display, data logging, alarming, event recording, and other monitoring operations.
(4)The high-speed network allows direct access to data provided by graphical monitoring devices for implementing different automatic sensor controls.

4. Experiment Description

The system mainly implements the experimental sensor module based on the graphical monitoring and control system in laboratory sessions. Figure 1 illustrates this system. This study asserts that the time students take to participate in "active learning" such as experiments, is as important as "passive learning" through attending lectures. The same features result from some experiment or practice-oriented systems (Halang, 1990; Sloane, 1995).

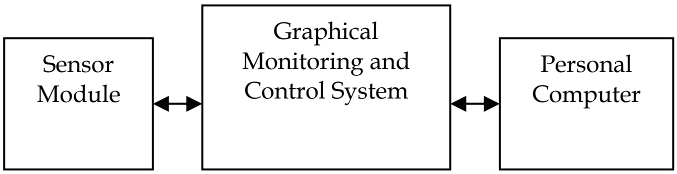

Fig. 1. Sensor experimental module based on the graphical monitoring and control system

4.1 Photo-resistor (CDS) Sensor Module

A photo-resistor is an electronic component whose resistance decreases with increasing incident light intensity. The photo-resistor can also be called a light-dependent resistor (LDR), or photoconductor. It is made of a high resistance (A substance such as germanium or silicon with intermediate electrical conductivity between that of a metal or an insulator; its conductivity increases with temperature and in the presence of impurities) semiconductor. High frequency light falling on the device enables photons absorbed by the semiconductor to give bound electrons enough energy to jump into the conduction band. The resulting free electron and its hole-partner conduct electricity, thereby lowering resistance. Without getting into a lot of boring theory, the students connect a CDS to them and run it to the module.

Figure 2 shows the basic photo-resistor circuit. The circuit gives an output voltage that increases with higher-level light. Figure 3 shows the photo-resistor (CDS) sensor module.

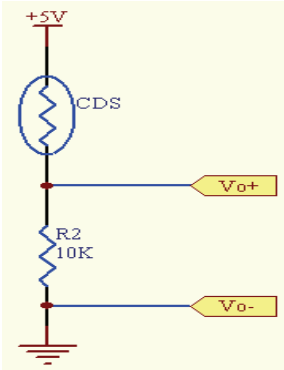

Fig. 2. The basic photo-resistor (CDS) circuit

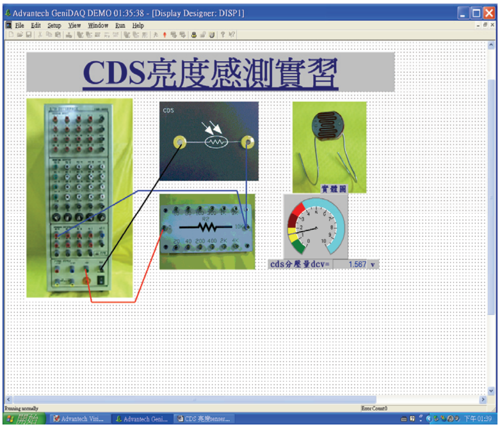

Fig. 3. The photo-resistor (CDS) sensor module

4.2 Phototransistor Sensor Module

Actual operation of a phototransistor depends on the biasing arrangement and light frequency. For instance, if a PN junction is forward biased, the increased current through the junctions due to incident light will be relatively insignificant. On the other hand, if the same junction is reverse biased, the increase in current flow will be considerable and is a light intensity function. If the p-n junction is the collector-base diode of a bipolar transistor, the light-induced current effectively replaces the base current. The physical base lead of the transistor can be left as an open terminal, or it can be used to bias up to a steady state level. A change in the base current in transistors can cause a significant change in collector current. Thus, light stimulation causes a change in base current, which in turn causes a bigger increase in the collector current, resulting in a rather large increase, considering the current gain.

The following schematic shows the basic phototransistor circuit in Figure 4. The circuit gives an output voltage that increases with higher light level. Figure 5 shows the phototransistor sensor module.

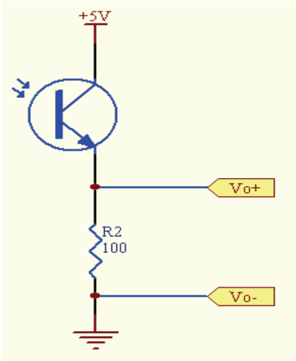

Fig. 4. The basic photo-transistor circuit

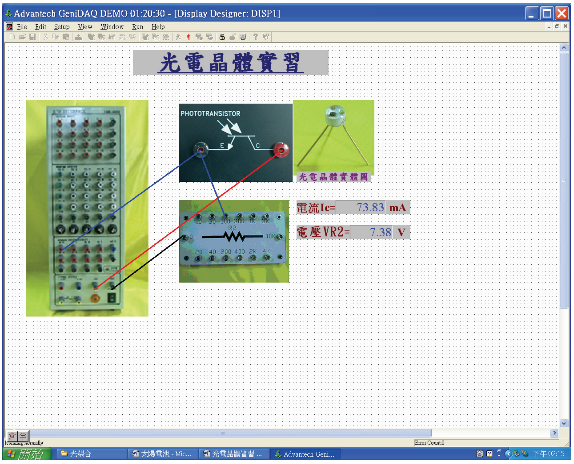

Fig. 5. The phototransistor sensor module

4.3 Solar Cell Sensor Module

Solar cell power is generated using the photovoltaic effect of semiconductors. A semiconductor exposed to a light source of suitable intensity, generates a large number of electron pairs and a positive hole, resulting from reciprocal action between photons and silicon atoms.

At a p-n junction between two different semiconductor materials, the electrons diffuse in the n-type material and scatter the positive holes in the p-type material. They are then collected at both electrodes respectively, resulting in a voltage difference between the electrodes. When an external load is connected, electricity flows through the load. In this way, a silicon solar cell converts light energy into electricity and supplies power to external loads.

Figure 6 shows the basic solar cell circuit. The circuit gives an output voltage that increases with higher light levels. Figure 7 shows the solar cell sensor module.

4.4 Fiber-Optic Sensor

A measurement system based on a fiber-optic sensor consists of a light source (LED or laser), an optical fiber, and a photo-detector. LED (infrared or visible) are highly reliable and easy to integrate in the system but have low coupling efficiency. Common photo-detectors in fiber-optic sensors are phototransistors, and photodiodes.

Figure 8 shows the fiber-optic sensor circuit. The circuit gives high/low output voltage according to the 1 Hz square wave. The output voltage is high, when the square wave is low. The output voltage is low, when the square wave is high. Figure 9 shows the solar cell sensor module.

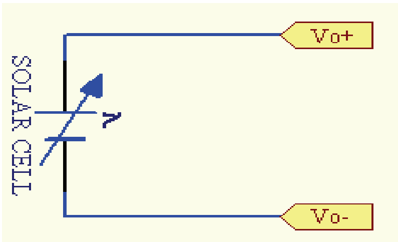

Fig. 6. The basic solar cell circuit

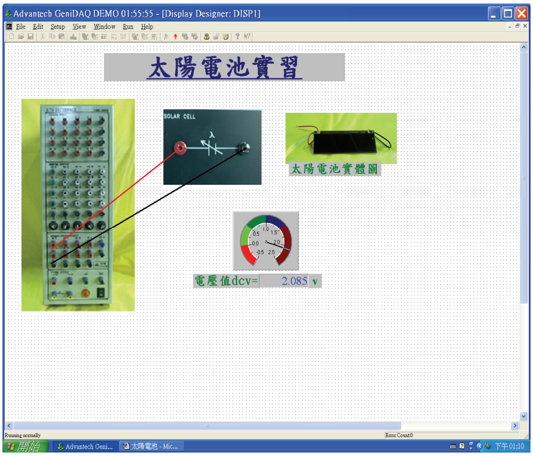

Fig. 7. The solar cell sensor module

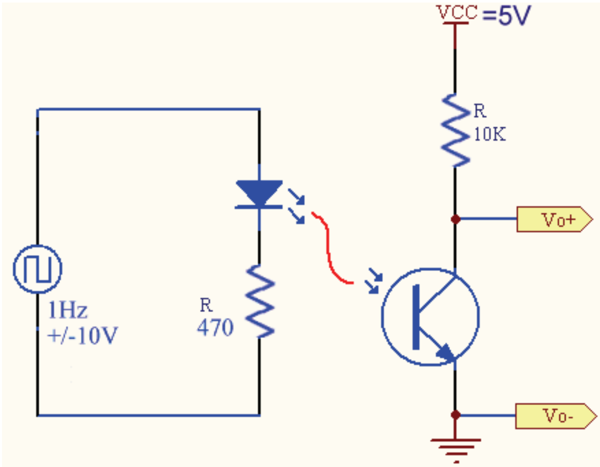

Fig. 8. The fiber-optic sensor circuit

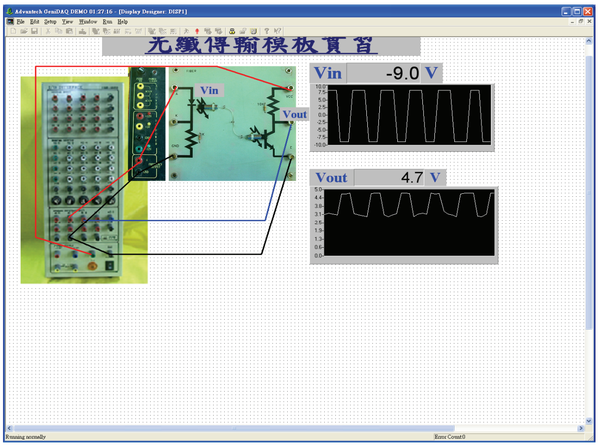

Fig. 9. The fiber-optic sensor module

4.5 Thermocouple Sensor Module

Figure 10 shows the basic thermocouple circuit. The thermocouple sensor module is shown in Figure 11.The problem with the thermocouple is that students connecting a pair of copper wires to the thermocouple and running it to the module create three dissimilar metal junctions, which introduce measurement errors. Also, a second junction at a known temperature is required for useful thermocouple temperature sensor measurements. Previous experiments used an ice bath in the lab for the cold junction. Many DCV have a built-in cold junction for thermocouple temperature measurements that only require hooking up the proper thermocouple and setting the DCV to temperature.

Any lab rat can make two mistakes when hooking up a thermocouple: hook them up backwards, or use the wrong type of thermocouple. Either way might give a believable but incorrect reading, which is reason enough to avoid using thermocouples for critical experiments.

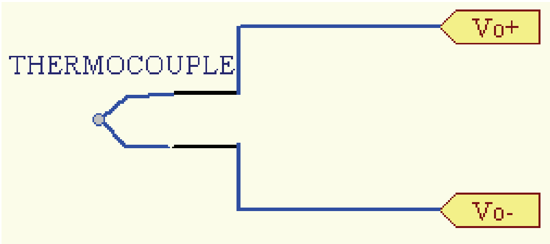

Fig. 10. The basic thermocouple circuit

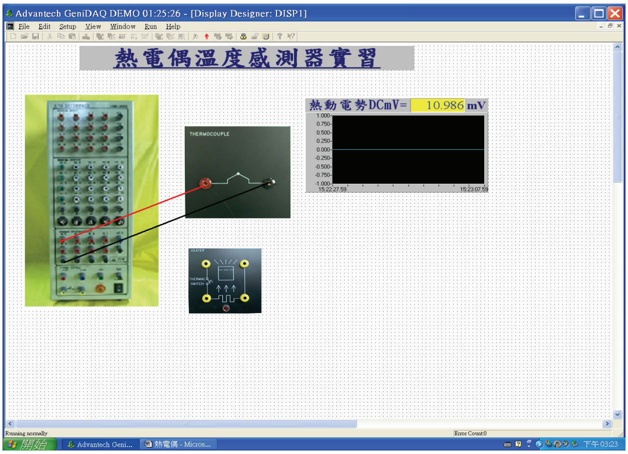

Fig. 11. Thermocouple sensor module

4.6 RTD Sensor Module

The RTD (PT 100Ω) is made from thin films of elemental metals, such as platinum. Platinum has very low bulk resistivity, necessitating a thin film with a lot of squares to obtain a useful total resistance. The temperature coefficient of resistance (TCR) of platinum RTD is around 0.0038Ω/°C. Figure 12 shows the basic RTD circuit. Figure 13 shows the RTD sensor module is shown.

4.7 Thermistor Sensor Module

Figure 14 shows a typical thermistor circuit is. Figure 15 shows the thermistor sensor module. The therrmistor consists of resistors (or perhaps semiconductors) that have predictable negative temperature coefficients. The temperature coefficients are abbreviated NTC (negative). The thermistor is typically made of some type of ceramic.

The thermistor resistance/temperature function is not as linear as an RTD, but much cheaper. Choosing a thermistor or RTD means accounting for self-heating of the device due to the current passing through it to obtain a voltage reading.

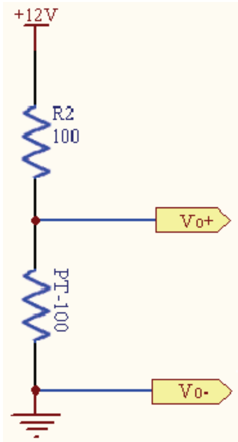

Fig. 12. The basic RTD (PT100) circuit

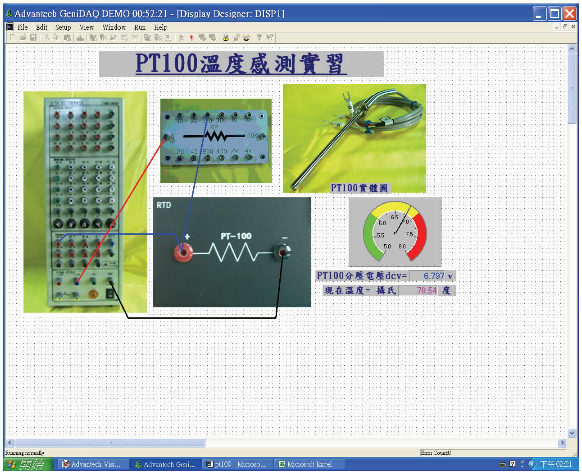

Fig. 13. RTD (PT100) sensor module

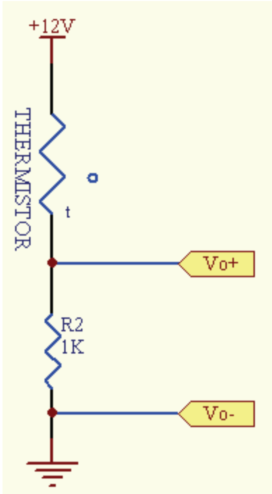

Fig. 14. A typical thermistor circuit

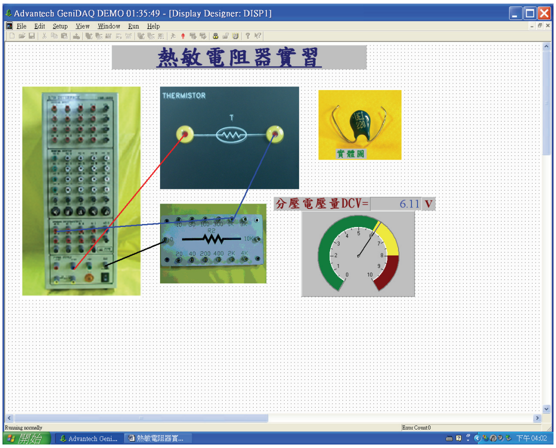

Fig. 15. Thermistor sensor module

4.8 AD590 Sensor Module

Figure 16 shows a typical thermistor circuit. Figure 17 shows the AD590 sensor module. This part provides a current in μA that is nearly equal to its temperature in degrees Kelvin. This type of sensor is far less prone to errors due to lead resistance than a voltage sensor, thermistor or RTD.

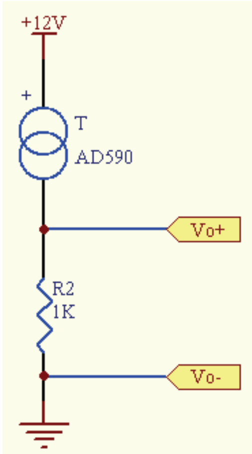

Fig. 16. The AD590 circuit

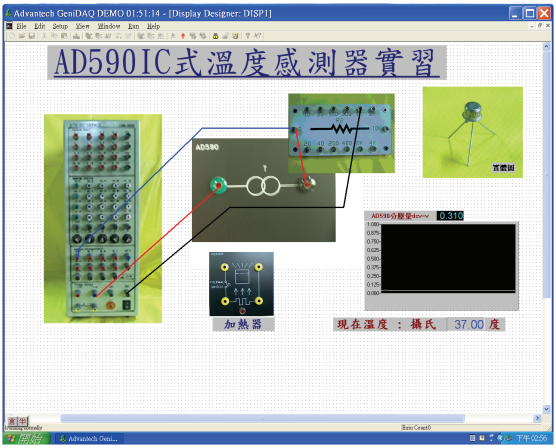

Fig. 17. AD590 sensor module

5. Project Experiment

The most important part of the system implements the temperature-sensing module based on the graphical monitoring and control system used in laboratory projects.

Figure 18 designs a comprehensive temperature monitoring and control system. Every measurement point has a thermocouple connected to an analog input module, along with a relay output module. All modules connect to the host computer through an RS-485 twisted pair interface. An independent power source supplies the analog input modules and every digital alarm output connects to an independent system of sirens and alarm lights, which guarantees efficiency even during computer system failures. The analog input module reads the thermocouple voltage and converts it into temperature, which is then sent to the host. The graphical human interface temperature control system displays the temperature and constantly checks it. When the temperature rises above a preset limit, the system orders the relay output module to turn on the air conditioning in that specific area. When the temperature returns to the set point, the system orders the relay module to turn the air conditioning off.

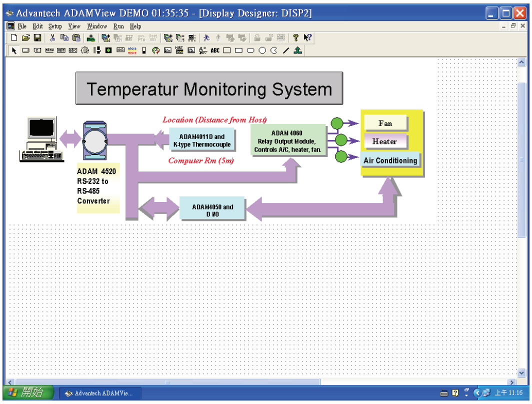

Fig. 18. Temperature monitoring system

6. Evaluation

This study utilizes learning evaluation to increase standards in terms of teaching, learning and student achievement. Evaluation quality has a marked impact on student willingness to work hard and encourages teachers to focus on ways to improve individual learning attitudes. Evaluation occurs continually as students judge themselves and others (Wong, et al., 2005). User evaluation is a domain that is not as well articulated and explored as assessing whether a system is usable, or whether it actively increases work productivity (Isbister, et al., 2007).

Student surveys administered at the end of the semester, asked students to evaluate the experimental module. Students generally responded very positively to the lecture and the laboratory work. Based on literature review and referring to related researches and questionnaires, this article drew up a laboratory activity evaluation questionnaire. Ten experts reviewed the first draft of the questionnaire, after which it was modified and finally finished.

The experts were university professors and/or researchers, averaging more than three years of experience in sensor teaching and with a good knowledge of the graphical human interface system. Overall, the expert evaluations were generally positive.

This innovative experimental and teaching method was inaugurated at the Department of Industrial Education and Technology at National Changhua University of Education. Twenty students completed the system in 2007. The students offered many positive comments in their evaluations of the instruction. They communicated that they learned more effectively using practice-oriented sensors, and the graphical monitoring human interface technology-based system. For example, they very much liked avoiding low-level implementation issues and felt that the course and laboratory synchronized with each other. They appreciated the laboratory lectures and felt that they helped show how they could apply the methods to other sensor applications. The negative responses concerned the amount of time required for the design project at a time when the demands of other courses were also high at the end of the semester. The students suggested that the design project be assigned earlier in the semester to solve this problem.

Overall, the students responded that this system provided a unique and valuable learning experience. Students who completed this system felt satisfaction and accomplishment because they actually designed and constructed an experimental sensing module based on the graphical human interface system. The author has created a laboratory manual for the experimental sensing module that includes laboratory assignments and discusses necessary details of how to complete the laboratory tasks.

7. Conclusions

This chapter addresses the development of an experimental sensor module based on the graphical monitoring and control system. Several different sensors are available for the graphical monitoring and control system. This system emphasizes both theory and practice and the sequence covers general sensor physics and technology as well as new and novel state of the art sensor design. This system will hopefully bridge the gap between university education and industrial applications. The innovative experiment and teaching methods have been inaugurated in the department of industrial education and technology at National Changhua University of Education. Students work on a design project to test and integrate an actual sensor device. The goal of the system sequence is to use the research and facilities in smart sensor development to give students a comprehensive background in the art and science of sensor and device technology, design, and integration.

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Virtual and Remote Laboratories for E-Learning Using EDA Tools

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1. Introduction

Distance learning has gained in popularity not only as a way to offer instruction in locations without local expertise, but also as a cost-effective method where limited enrolment at one location would not normally warrant offering the course. In engineering technology programs, where most courses have a lab component, distance learning offers many new challenges in course delivery (K.D Taylor et al., 1996) and (L. Peretto et al., 2008). Nowadays the challenge for engineering education is about the online education: the role of laboratory is very important in engineering studies. In the past two decades great efforts have been made in this direction and many proposals of virtual and remote labs have been presented (D. Bonatti et al., 2007). Recent advances in digital system design have had a huge impact on the learning situation for students enrolled in hardware design courses. Since the invention of the Internet, many academicians, educators, and researches have been searching for effectual virtual lab experiments, however, the very nature of real experimentation was not possible or missing (A. Abu-El Humos et al., 2005). Hardware Design Laboratory is one of the main concerns for e-learning courses in digital design area (W.M. El-Medany, 2007).
The use of Hardware Description Languages and Field Programmable Gate Arrays for digital design today changes the way of designing and testing the digital circuits. The students can use software tools to design and test their circuits, and then use a hardware tools “FPGA Boards” to implement their design in a real hardware implementation using FPGA chip, which is a programmable chip that can be configured with a custom digital design. Hardware design laboratory using VHDL and FPGA has been used for partial e-learning courses, where the students can do most of the work for their experiment at home using the free software tool available on the internet, that work include the simulation and implementation, then they come to the lab with a binary file that will be used for configuring the FPGA chip, and then they can test their design in a hardware level using the available FPGA development board (W.M. El-Medany, 2007). In this chapter we are going to describe the use of Hardware Description Languages (HDL) and Field Programmable Gate Arrays (FPGA) for delivering the digital design courses as partial and full E-learning courses. The most important part of the digital design courses is the hardware laboratory. We are introducing a virtual and remote laboratory for digital design that is suitable for partial and full e-learning courses in computer engineering hardware design. The virtual

and remote laboratory based on using Spartan 3E FPGA starter kits from Diligent that are connected to the lab PCs through the USB port, and by using a digital camera that are connected to the PC. The PCs are connected to the Local Area Network (LAN) in the campus. The students can remotely login to the lab PCs by using Microsoft remote desktop connection to program the FPGA chip with their design, and then test the design remotely through the parallel port of the lab PCs. For testing the hardware circuit through the PC parallel port a Graphical User Interface (GUI) has been built using Visual Basic to apply forces to the design input pines that are connected to parallel port of the PC, and then read the design output also through the parallel port.

2. Digital Design Laboratory

Normally in digital design laboratory, the students can do their experiments by bringing up the required components; start to connect the components together by wiring them on a breadboard; then test the circuit by giving some inputs and view the corresponding output on LEDs (Light Emitting Diodes) or 7-Segment display to verify the functionality of the circuit. This process takes longer time, especially if the student has some mistake in the wiring, or some faulty ICs. An example of the normal method in digital design laboratory is given in Figure 1.

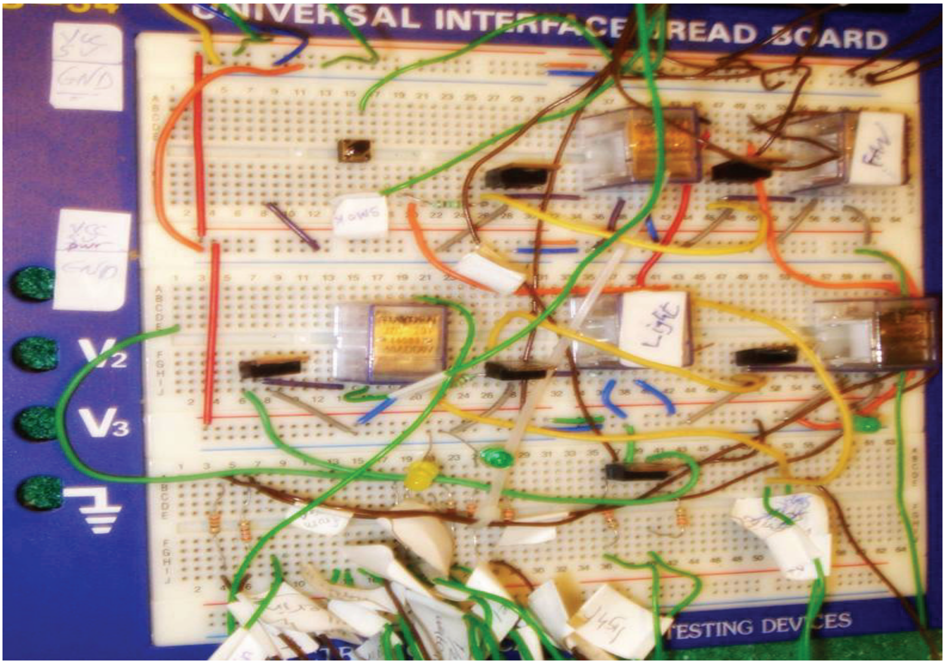

Fig. 1. Digital Design Experiment on Test Board

3. Modern Digital Design Laboratory Using EDA Tools

Nowadays, Hardware Description Languages (HDL) are being used for describing the design hardware, where the student can use EDA tools to enter his or her design and go through all design processes to finish and test the design, by going through all design process on the PC without using any hardware tools (Pastor, J.S.A, 2004) and (Fujii, N. , 2005). Then the design can be implemented in hardware using FPGA (Field Programmable Gate Array) with the aid of the hardware tools that is connected to the computer, which in this case is the downloading FPGA development board (Lockwood, J.W, 2001) and (Fujii, N. , 2003). Some of the available FPGA development boards have a number of switches and LEDs for testing the implemented design (Seinauskas, R, 1997) and (Fujii, N. , 2005). In our hardware design laboratory we are using VHDL language for describing the design and Xilinx tools for the hardware design implantation. Xilinx ISE 6.2i has been used for the design entry and synthesis process and ModelSim XE 5.6 has been used for the simulation process, where Xilinx Spartan 3 starter kit has been used for the hardware implementation. Students upload their design files on WebCt in the form of VHDL file, waveform file, and binary file for programming the FPGA, and then they can download the file on the PC that is attached to the FPGA development boards in the laboratory for testing their design (W.M. El-Medany, 2007). Figure 2, shows Xilinx Spartan 3 starter kit attached to a PC in the Laboratory, in which Xilinx software tools and WebCt are both running such that the design files already on Webct can be downloaded to Xilinx. This technique is useful for partial delivering of e-learning digital design courses.

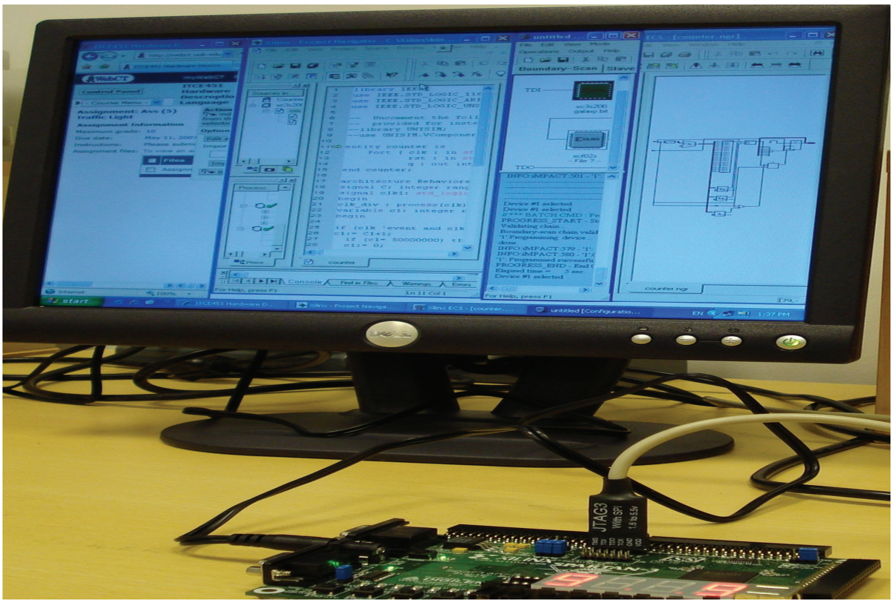

Fig. 2. Xilinx Spartan 3 FPGA Development Board Attached to the Lab PC

4. VHDL Design Steps

The design steps when using VHDL as a hardware description language, starts by writing a VHDL code that describes the required digital circuit, checking the code for syntax error, converting the code into gate level design using the available synthesis tools from Xilinx, assigning the pines for the target device, implementing the design, and then programming the device using the available FPGA development board. All of these steps can be done by the student at home; the last step which is programming the FPGA device is the only step that must be done in the laboratory for testing the design (W.M. El-Medany, 2007). Figure 3 shows a block diagram for the design steps as indicated above, the student also simulate the design using ModelSim to verify the correctness of the design. After finishing the first four steps as shown in Figure 3, the student uploads all the necessary files on his account to Webct, downloads these files on the PC in the Laboratory, and then do the last step for testing the design.

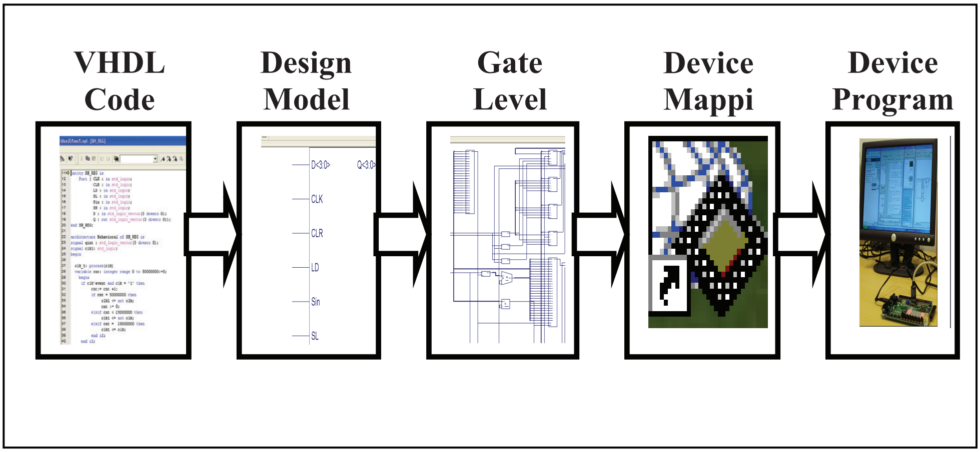

Fig. 3. Block Diagram for VHDL Design Steps

5. FPGA Design Methodology

The design methodology when using FPGA as the target hardware implementation can be described in a series of steps as shown in Figure 4. Where the design has to be specified and documented at the initial step. The second step is the design entry, which can be VHDL / Verilog or schematic entry. After checking the code or circuit, the design has to be simulated for the functionality of the design, if the function is not correct, then code or circuit has to be modified again and again until a correct function achieved, this is the third step. The design will be synthesized to build the gate circuit of the design; this step is valid only for the HDL entry, in which the code is converted to logic circuit. The implementation step is for mapping the design into the FPGA chip, in which place and rout tack place. Then the FPGA device will be configured with the design, for this step the FPGA development board has to be connected to the PC, in which the software tools is running. At the end after configuring the device, the design will be tested in a hardware level by assigning forces to the inputs and testing the output for the given input. After checking the code or circuit, the design has to be simulated for the functionality of the design, if the function is not correct, then code or circuit has to be modified again and again until a correct function achieved, this is the third step, and it is shown in Figure 5, as an example, the simulation in the figure is for 4*1 multiplexer. To build the hardware circuit, the design will be synthesized to generate the gate level circuit of the design as shown in Figure 6, the top-level design in that figure is for a clock division design, in which the code is converted to logic circuit. The implementation step is for mapping the design into the FPGA chip. Then the FPGA device will be configured with the design. At the end after configuring the device, the design will be tested in a hardware level by assigning forces to the inputs and testing the corresponding outputs (WM El-Medany and A. Kamal, 2008).

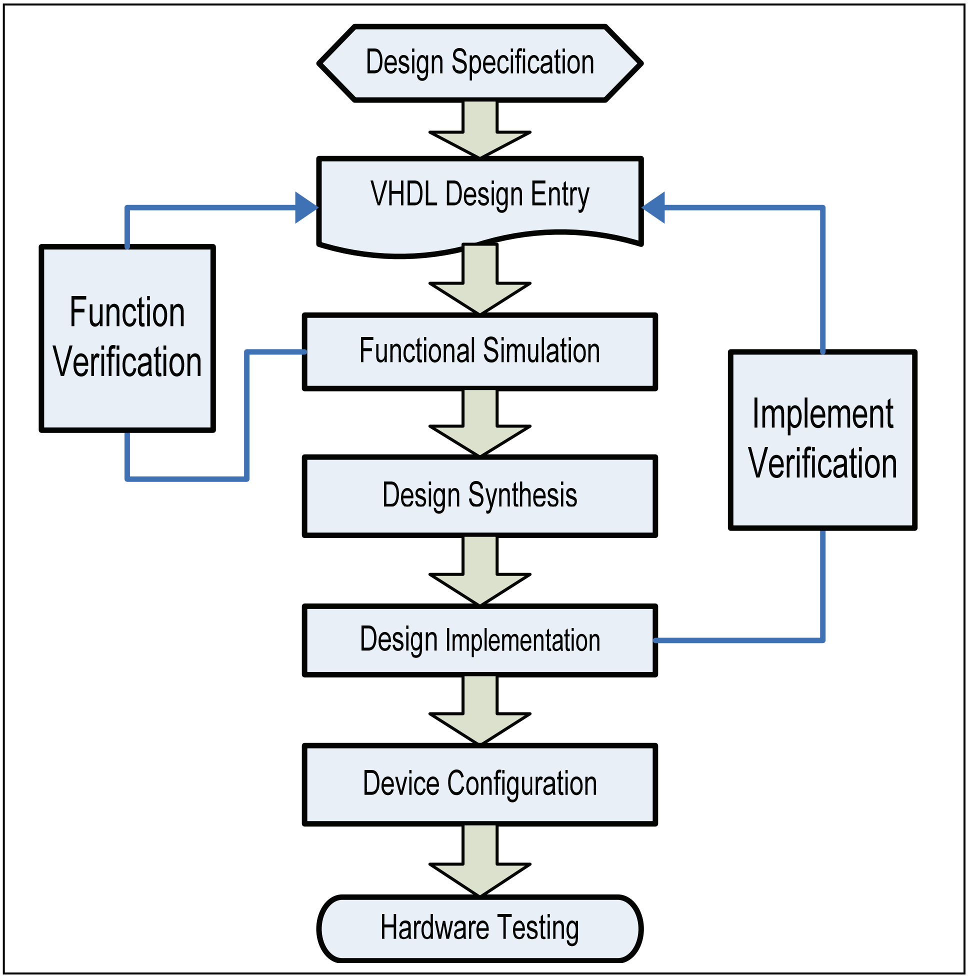

Fig. 4. FPGA Design Methodology

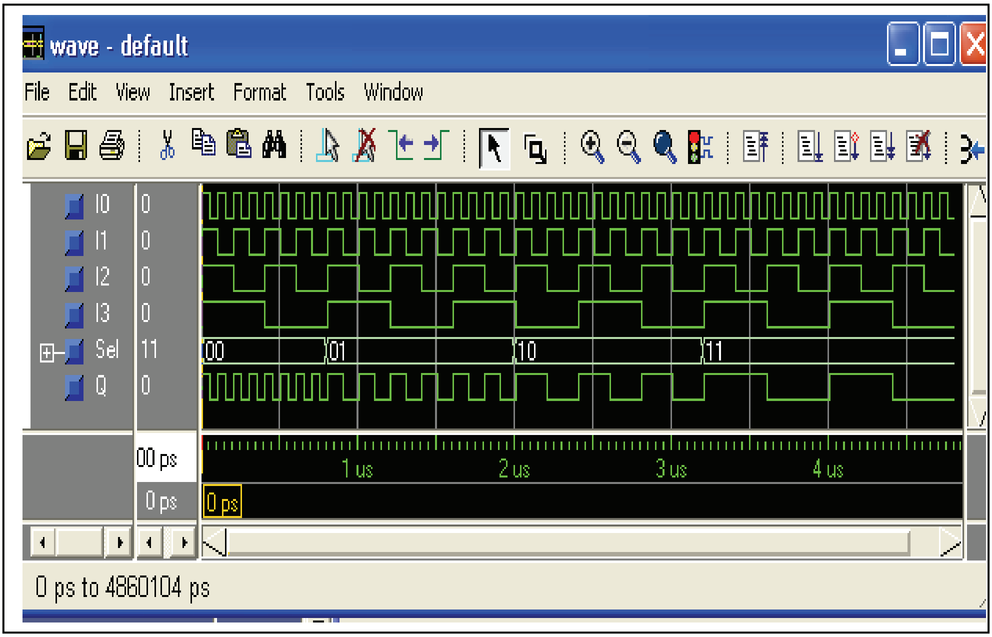

Fig. 5. VHDL Design Simulation for 4*1 MUX

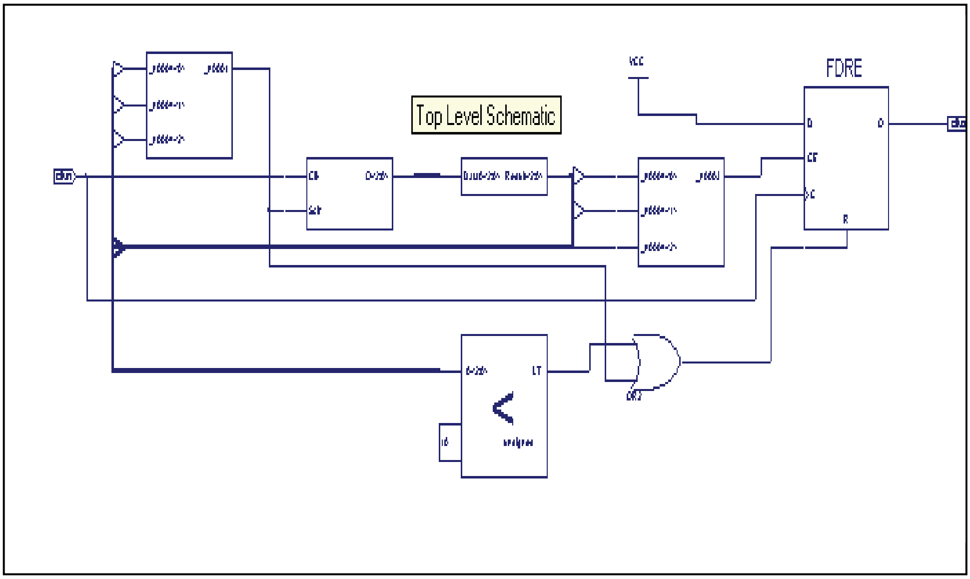

Fig. 6. VHDL Top-Level Design for Clock Division

6. FPGA Remote Laboratory

Remote laboratories have been used widely for software simulation tools, where the students can remotely login to the lab machine to access and run the software tools and do any required simulation or any software tasks. But the story for the hardware is different, where the students need to build and test their hardware physically. For these reasons the hardware courses are normally delivered as partial e-learning courses because the students can not do all the assignments without coming to the laboratory. The FPGA remote laboratory is a technique based on using the FPGA board with lab PC as remote laboratory for digital design. The FPGA remote laboratory is needed only for the last two steps of the VHDL design flow shown in Figure 4, where all the other steps can be done using the free available software tool from Xilinx. The students can also run the software tools on the lab PC and finish all the design steps including downloading the bit stream file into the FPGA, and then testing the circuit through the PC parallel port using Microsoft XP remote desktop that accesses the Lab PC from a remote machine. Figure 7 shows the parallel port pin assignments that have been used for sending and receiving data to the design for Verification.

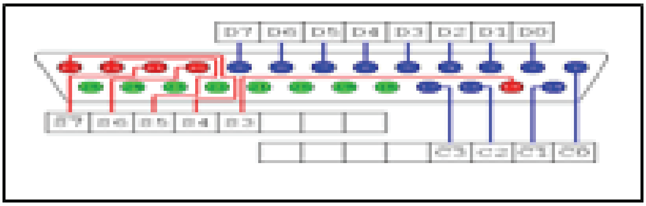

Fig. 7. Parallel Port Pin Assignments

Figure 8 shows the student access of the FPGA remote laboratory and the configuration of the FPGA chip from the student machine. In the botom right of Figure 8, you can see the FPGA development board that is connected to the PC parallel port, with the JTAG cable is connected through the USB port of the PC instead of the parallel port JTAG cable to make the parallel port available for the design testing. In the botom left of Figure 8, we can see the FPGA development board with the connection to the parallel port through the used bread board. A Graphical User Interface (GUI) has been designed using Visual Basic to simplify the process of applying forces to the design inputs, and then check the output. The GUI also simulate the switches and LEDs of the FPGA development board, through the GUI the student can just click the mouse to force the input, then he can see the output on his PC screen.

The system architecture of the remote laboratory is shown in Figure 9. The remote laboratory consists of 20 PCs; each PC is attached with one FPGA development board, with a total of 20 FPGA boards. All lab PCs are connected to the local area network of the campus. The students can use the free available webpack software from Xilinx to finish most of the design steps including the implementation and generation of the bit stream file that are required for programming the FPGA chip, then they can remotely login to the lab machine to access and run the Xilinx ISE software tools to configure the device, after that they can remotely test their design through the PC parallel port using Microsoft XP remote desktop that accesses the Lab PC from a remote machine.

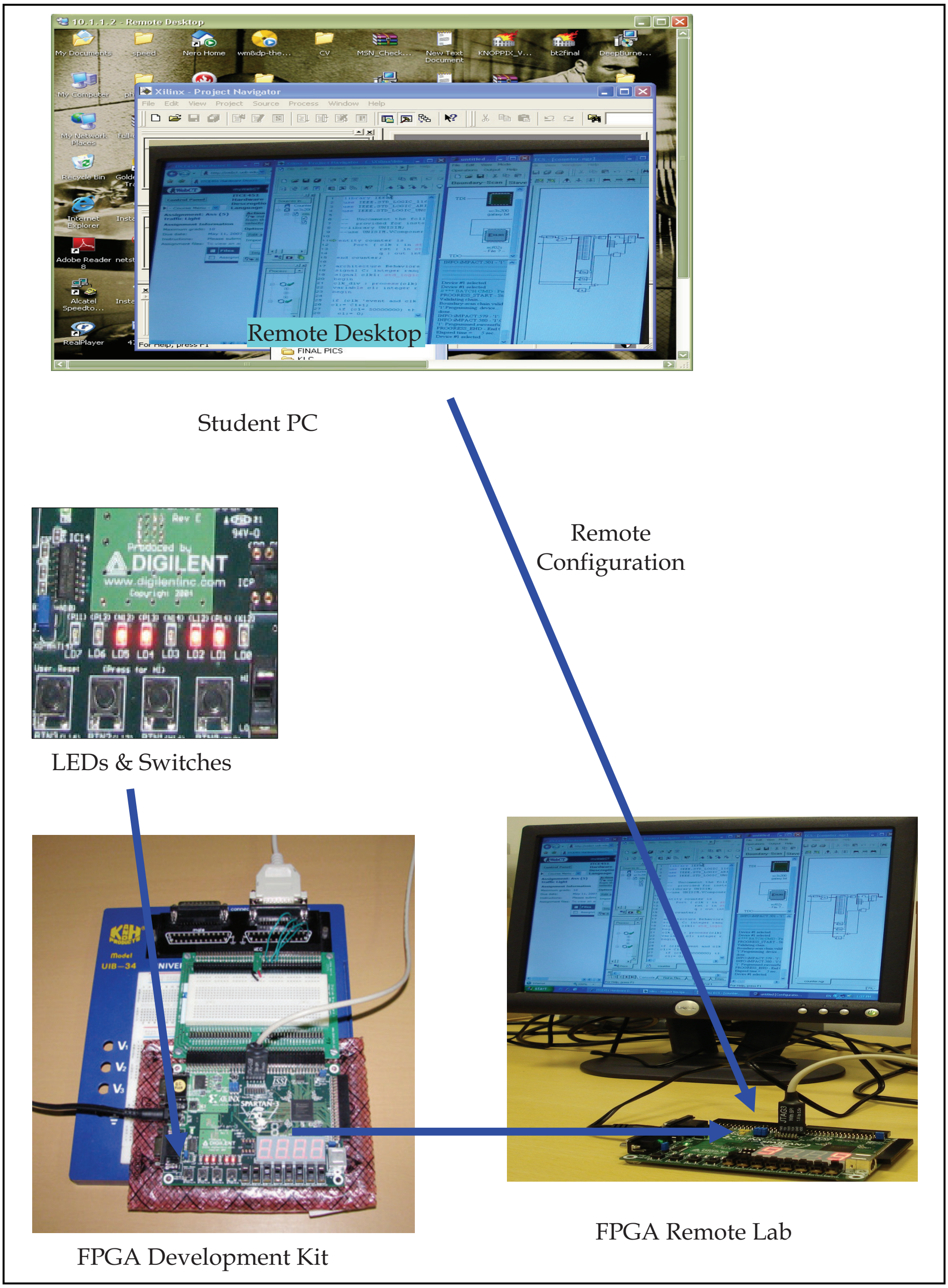

Fig. 8. FPGA Remote Laboratory

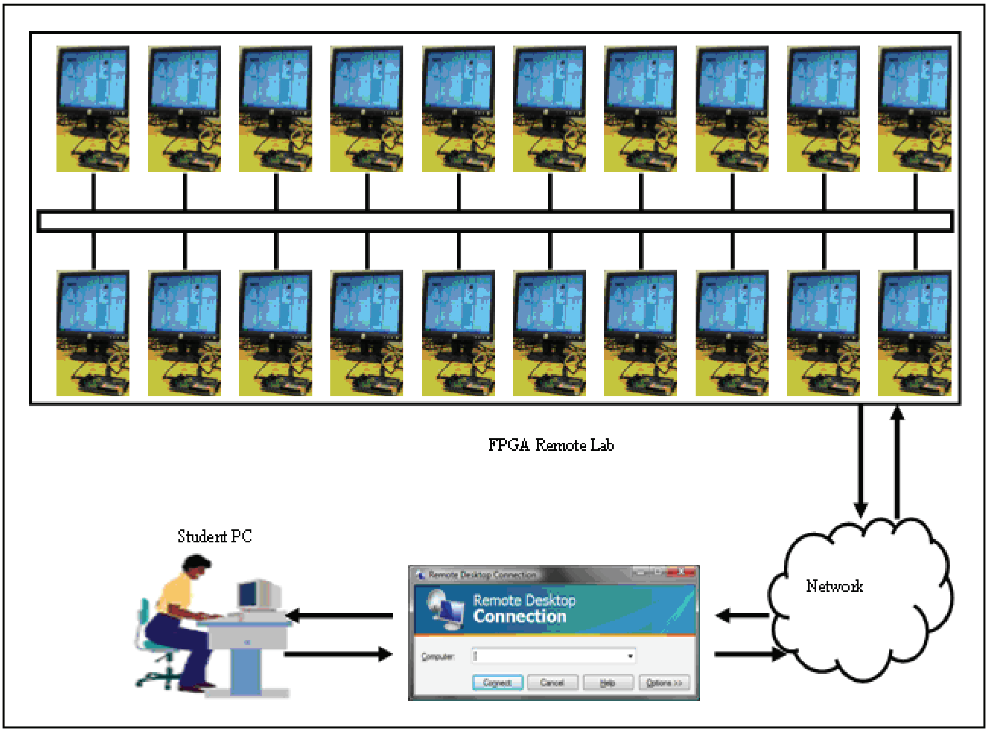

Fig. 9. System Architecture

7. Conclusion

FPGA remote laboratory has been introduced for hardware courses in area of computer engineering to be delivered as full e-learning courses. The FPGA remote laboratory consists of 20 PCs, each PC is connected to one FPGA development board, where FPGA Spartan 3E starter kit from Digilent has been used for programming the Spartan 3E FPGA chip. VHDL has been used as the design entry for the Xilinx ISE Foundation software tools for simulation and implementation. The laboratory has been tested for remote configuration of the FPGA chip through the USB port as well as remote testing of the design through the PC parallel port. GUI has been designed using Visual Basic by which the user can easily test the design remotely by applying forces to the design inputs, and then read the corresponding output. The remote access has been achieved by using Microsoft XP desktop remote connection. More developments are needed for the introduced FPGA remote laboratory. One of the developments is to use a webpage to remotely access the laboratory through the internet for programming or testing the FPGA. Another issue is to use a web camera with each FPGA development board, by which the user can monitor the FPGA board and see the output of the design on the available LEDs or 7-Segments.

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18

Development of A Distance Microprocessor-based Platform using Graphical Interface via the Internet

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1. Introduction

The microprocessor like 8051 has been still playing an indispensable role as a controller in industry applications because of its programming process, low-cost, small size and low power consumption, etc. That is why many microprocessor-related courses still open in electrical fields in Universities around the world. The microprocessor, however, usually lacks of capability in the Internet connection and/or graphical interface. With increasing demand of industrial e-platform facilities, it may suffer from such as restriction.

This chapter is to describe how to set up a distance microprocessor-based platform using graphical-interface via the Internet. It can perform on line real-time monitor and control function via World Wide Web. The client (remote PC) and sever (nearby PC) communicate with each other according to TCP/IP. The server is linked with the microprocessor (Intel 8051) through RS232. The graphical interface is designed by using LabVIEW package. Accordingly, the microprocessor can not only carry on its own task but also allow remote client to monitor or control its programming process. The conventional microprocessor can be thus delivered into many e-platform applications by the supplementary functions.

A case study for signal analysis using Fast Fourier Transform (FFT) will be presented in this chapter. A PC-based virtual instrument (VI) that can carry out a remote measurement and monitoring using LabVIEW and the microprocessor (Intel 8051) for power system harmonics is proposed. The history of Total Harmonic Distortion (THD) in the waveform signal can be also recorded and tracked in the data base. This distance e-learning environment using a graphical programming tool is to help electrical students and engineers for enhancing the microprocessor applications using the Internet Explorer (IE). In deed, a good vision for the microprocessor-based remote e-platform with graphical interface will be demonstrated in details. For further applications, the proposed system can be simply extended to perform an instant control and surveillance activities on line in automated industry.

2. Structure of the system hardware

The system hardware is shown as Figure 1. A remote on-line harmonic detection and monitoring can be operated by two clients (remote PCs), respectively. These clients communicate with the server (nearby PC) by way of TCP/IP and Web connection. The server is to collect the real-time waveform data from the microprocessor (Intel 8051) through RS232 via the I/O interface (IC8255). The analog data (distorted current signal) that is initially captured by the Current Waveform Sensing Circuit is converted to digital data. The Zero-Crossing Detector is used to ensure the current waveform to be captured from the zero-point for very cycle, thus avoiding spectrum leakage.

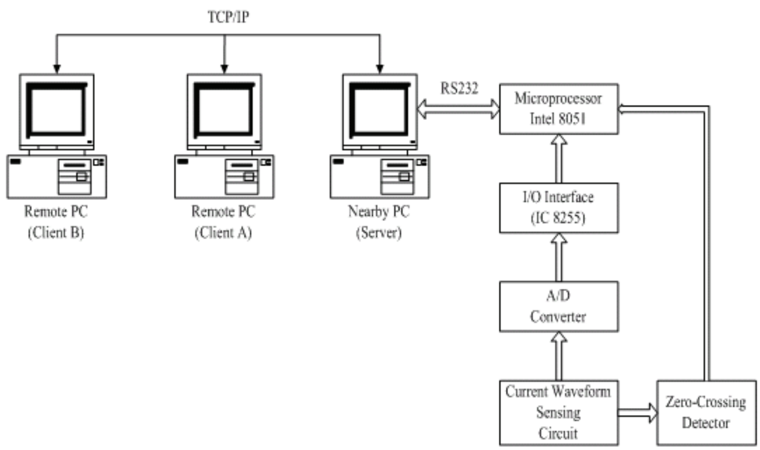

Fig. 1. Structure of the proposed system hardware

The basic facilities or modules required for the proposed system are as follows.

(1) Three PCs. One works as a server for the collection of current waveform data, and the other two PCs are as the clients (A and B) through TCP/IP. Client A is to perform the remote real-time harmonic analysis, and Client B is to view the instant analysis results obtained from Client A.
(2) One microprocessor (Intel 8051) connected with the server via RS232.
(3) I/O interface module using IC8255.
(4) A/D converter module.
(5) Current Waveform Sensing Circuit (module).
(6) Zero-Crossing Detector.

3. Description of the system software

Besides the hardware system, two system softwares, i.e., 8051 programming and LabVIEW programming, are needed to operate the proposed system, described as follows.

(i) Flowchart of the 8051 programming

The microprocessor (8051) is to construct the bridge for communication between the server and I/O interface. The programming flowchart is shown as Figure 2. The main procedure is briefly described as follows.

(a) Set COM1 as the serial communication with the outside world. SCON is set to as transmission mode 1, and TMOD is set as timer mode 2. All related registers are set as the following table.

Table 1: control registers status

SCON	TMOD	SMOD	TH1	Bps	TI	RI
50H	20H	1	FDH	19200	0	0

Note that the value of TH1 is to determine the transmission rate. Bps is the Baud rate per second.

(b) 8051's communication operation is chosen as Mode 1 to transmit the message via TXD and to receive the message via RXD. TXD is the transmission bit in the Universal Asynchronous Receiver transmitter (UART), and RXD is the receiving bit.
(c) The data (waveform) in the serial port buffer (SBUF) is read from 8255 through 8051.
(d) Upon complete transmission of data from UART serial port (TXD) to LabVIEW, TI will be set to 1 by the system.
(e) Set the sampling rate f_s (= $1/\Delta t$) as 1000 and sampled points N=1000.
(f) Go back to step(b) until the sampled points are reached.
(g) Set time delay.
(h) Go back to step(b) until the power in 8051 is turned off.

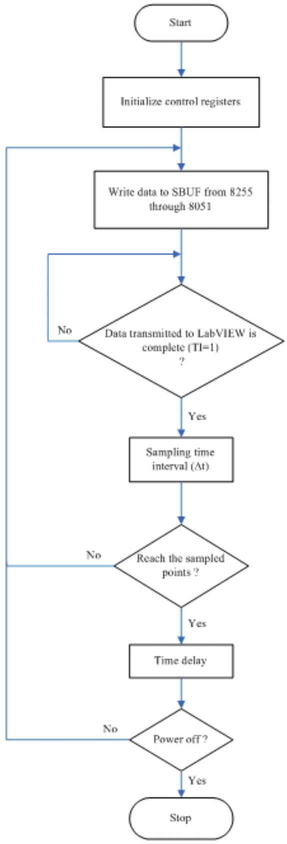

Fig. 2. Flowchart of the 8051 programming

(ii) Flowchart of LabVIEW programming

In the server (nearby PC), the serial port (COM1) in LabVIEW uses the TXD and RXD of the UART to receive data from the microprocessor (8051) via its own UART. The Bps, i.e. 19200, of the serial port must match the 8051 transmission rate. The data ready for transmission is held in the Transmission Holding Register (THR) temporarily until the data is transmitted completely. Similarly, the received data is temporarily held in Receiving Buffer Register (RBR). Figure 3 shows the programming flowchart.

The main programming procedure is briefly described as follows.

(a) Set the serial port (COM1) for LabVIEW communication with 8051.
(b) Initialize the TCP/IP connection with Client A.
(c) Read the SBUF data that is transmitted from 8255 through 8051.
(d) Set the sampling rate $f_s\,(=1/\Delta t)$ and sampled points N. They should match the 8051 status.
(e) Go back to step(c) until the sampled points are reached.

(f) Display the current waveform signal in the waveform chart.
(g) Send the waveform data to Client A via the TCP/IP.
(h) Go back to step(c) until the TCP/IP is disconnected.

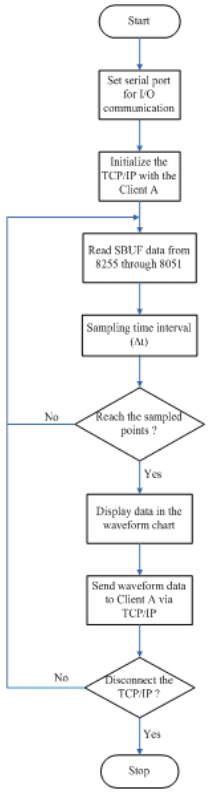

Fig. 3. Flowchart of the server programming

In Client A (remote PC), the waveform data is received from the server, and the waveform harmonic is analyzed instantly. The flowchart is shown in Figure 4. The main programming procedure is briefly described as follows.

(a) Initialize the TCP/IP connection with the server.
(b) Read the waveform data that is transmitted from the server via the TCP/IP.
(c) Display the current waveform signal in the waveform chart.
(d) Harmonic analysis using FFT.
(e) Display instant THD history and record it in the data file.
(f) Set time delay to wait for next data reading cycle.
(g) Go back to step(b) until the TCP/IP is disconnected.

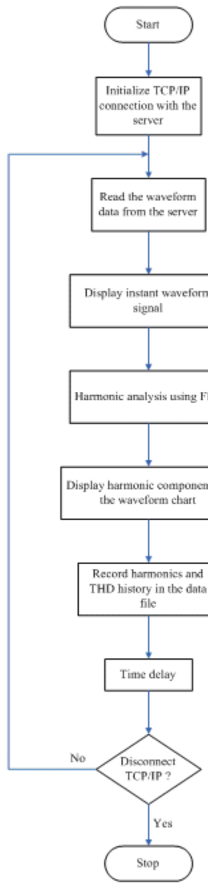

Fig. 4. Flowchart of the Client A programming

In Client B (remote PC), the harmonic analysis results same as Client A can be viewed by the Web Site (Internet Explorer) simultaneously. The flowchart is shown in Figure 5. The main programming procedure is briefly described as follows.

(a) Initialize the Web connection with the Client A.
(b) View the front panel of the Client A via the Internet Explorer.
(c) Go back to step(b) until the Web connection is disconnected.

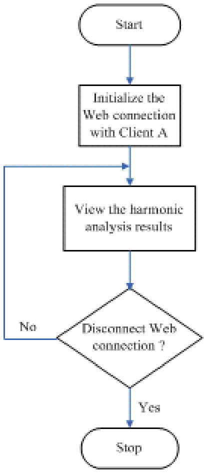

Fig. 5. Flowchart of the Client B programming

4. Internet connections

(a) TCP/IP connection between the Server and Client

In the server side, initially Port Number is set to listen for connection, and time out is set a limit of 5 seconds. The server will send data to the TCP port specified once a connection requested has been detected. Numeric data is thus cast into string data and sent via TCP Write. The first TCP Write sets the amount of data to send, and second TCP Write sends the data. Error checking of the loop will stop the loop if a connection error occurs. The connection is closed once the waveform data has been sent. Connection errors will be converted to warning message, and additional errors will be checked as well. The key program for TPC/IP connection is shown in Figure 6.

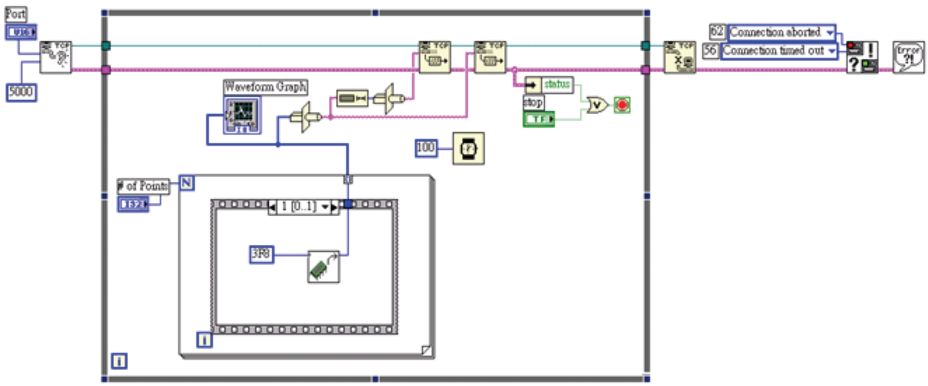

Fig. 6. TCP/IP connection program for Server

In the Client A side, the connection function is opened with port and IP address. The data is read at the port specified with a numeric representation. First TCP Read acquires the size of the data, and the second TCP Read reads the data and passes it to the chart. Error checking of the loop will stop the loop if a connection error occurs. The connection will be close when the reading procedure is done. Connection errors will be converted to warning message, and additional errors will be checked further. The key program for TCP/IP connection is shown in Figure 7. For simplicity, only TCP/IP connection is presented for illustration in Client A program (Block Diagram).

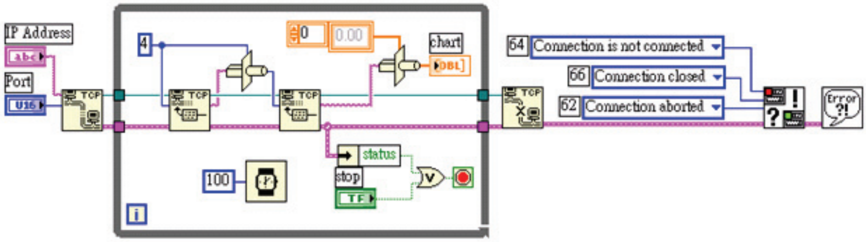

Fig. 7. TCP/IP connection program for Client A

(b) World Wide Web connection between the Clients

In Client A, LabVIEW front panel can display the working status on line, as shown in Figure 8. The spectrum of waveform can be viewed in the chart, including the individual frequency and amplitude. The waveform THD (%) is shown up immediately and can be recorded in a data file, i.e. a:\IO.txt. Once the THD (%) is over the predefined limit, for example 25%, the warning LED will be operated as "on" stage.

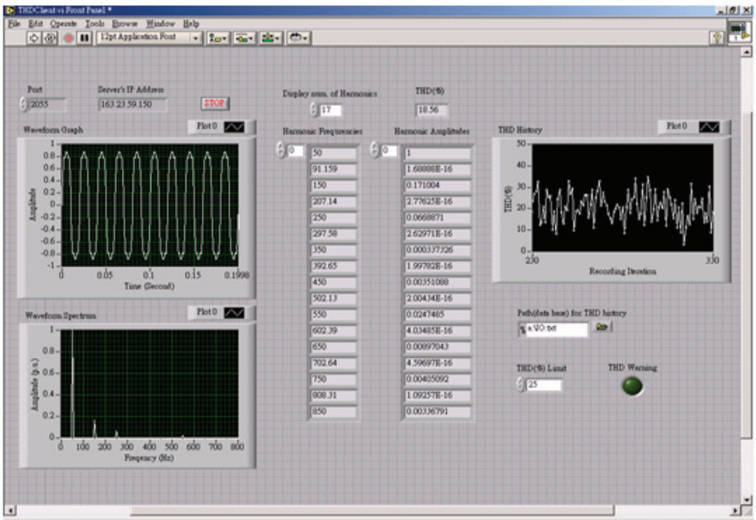

Fig. 8. VI panel of the Client A

The VI panel can be published to World Wide Web to be viewed by for Client B via Internet Explorer. Figure 9 shows the Web Publishing Tool to display the VI front panel. The document is then saved in the web server's root directory. The URL should be created, and this VI panel page can be accessed from an Internet Explorer browser, shown as in Figure 10.

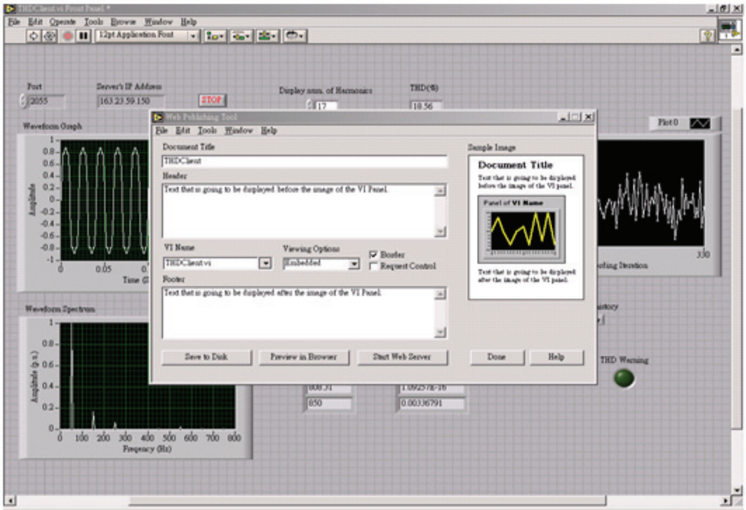

Fig. 9. VI panel for Web Publishing Tool

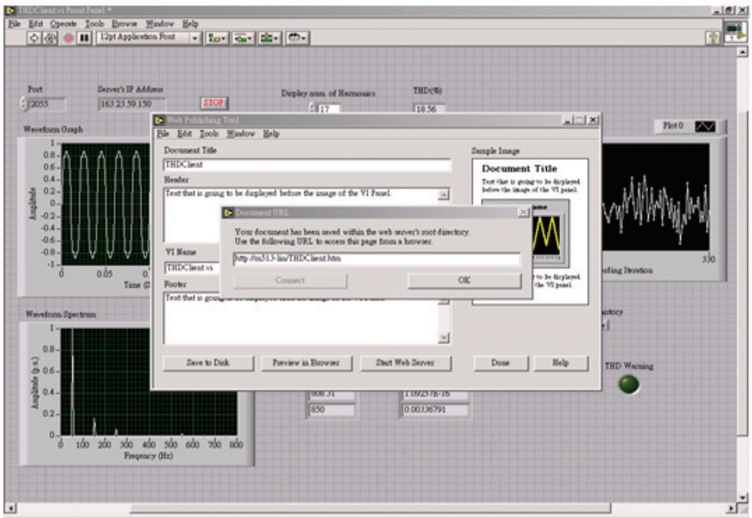

Fig. 10. VI panel for URL access

Note that **m513-lin** in the URL path (shown in Figure 10) should be replaced by the server's IP address, for example 163.23.59.150, to be viewed and controlled by the client B (remote PC) via World Wide Web. For security considerations, the Fire wall has been set up to avoid a stranger (or hacker) invasion, shown as in Figure 11. Only the certified IP (163.23.59.141) allows viewing and controlling, while the IP (163.23.59.128) allows viewing only; all others are prohibited.

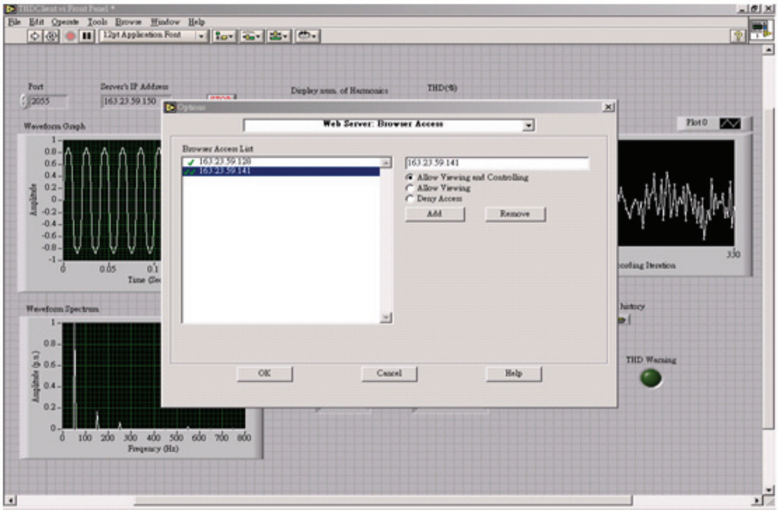

Fig. 11. VI panel for Brower Access

5. Experimental results with TCP/IP and Web connection

The proposed system under on-line real-time control via TCP/IP as well as Web connection was implemented successfully. The front panel of the server was illustrated in Figure 12. As can be seen, the waveform data can be collected and displayed in the Server.

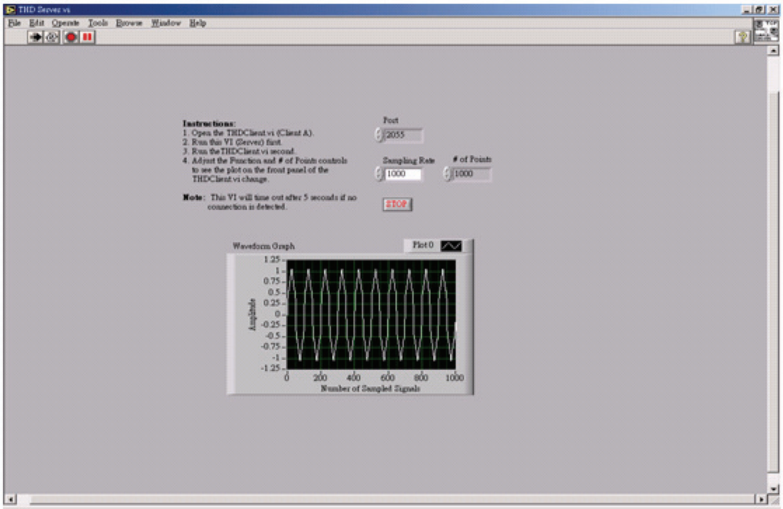

Fig. 12.VI panel of the Server

The VI panel of the Client A is showed in Figure 13. The waveform that contained up to 17th harmonics was displayed in the waveform chart. Not only THD of the current waveform but also the individual frequency and amplitude can be monitored by the VI panel. The path to save the THD history in a data file was set up in the system. A warning sign was switched on if the THD was beyond the predefined limit. Also, 100 harmonic measurement results were showed up in the waveform chart (THD history) at the same time.

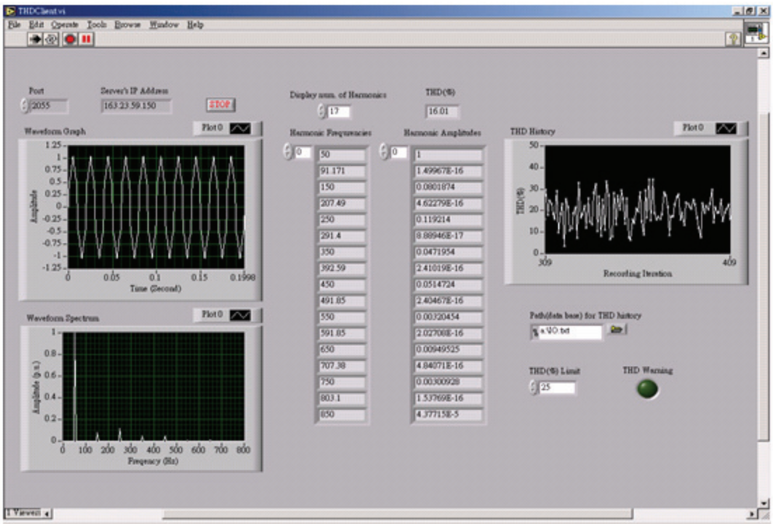

Fig. 13. VI panel of the Client A

From the World Wide Web, the Client B located at the other remote PC can view the VI panel that is the same front panel as the VI panel of the Client A, as shown in Figure 14. In particular, the control of VI panel can be transferred to the client under the protection of Fire wall. Therefore, Client B can be allowed to take over the server for controlling operation.

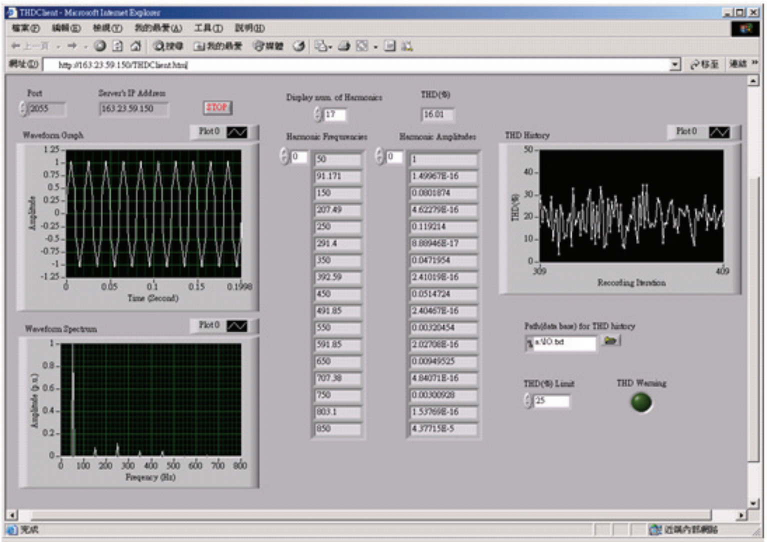

Fig. 14. Web front panel of the Client B

The waveform's THD was recorded once for every 30 minutes (i.e., time delay in Figure 2) so that the history can be easily tracked by a data file. For simplification, only 20 THD results were shown in Table 2. Time delay can be adjusted according to the user's requirement.

Iteration	Date	Time	THD(%)	Status
0	2009/3/9	PM 12:15	23.06	Normal
1	2009/3/9	PM 12:45	29.15	High
2	2009/3/9	PM 13:15	18.72	Normal
3	2009/3/9	PM 13:45	27.46	High
4	2009/3/9	PM 14:15	10.88	Normal
5	2009/3/9	PM 14:45	12.30	Normal
6	2009/3/9	PM 15:15	24.89	Normal
7	2009/3/9	PM 15:45	31.78	High
8	2009/3/9	PM 16:15	19.18	Normal
9	2009/3/9	PM 16:45	27.15	High
10	2009/3/9	PM 17:15	26.42	High
11	2009/3/9	PM 17:45	5.61	Normal
12	2009/3/9	PM 18:15	11.24	Normal
13	2009/3/9	PM 18:45	7.11	Normal
14	2009/3/9	PM 19:15	14.23	Normal

15	2009/3/9	PM 19:45	8.69	Normal
16	2009/3/9	PM 20:15	28.80	High
17	2009/3/9	PM 20:45	16.95	Normal
18	2009/3/9	PM 21:15	6.45	Normal
19	2009/3/9	PM 21:45	23.13	Normal

Table 2. THD history

6. Conclusions

The material based on proposed hardware/software schemes has provided comprehensive concepts and techniques in focusing on the power system harmonic measurement using graphical programming and Internet connection. In addition, the Fire wall was built up to secure the system. This paper has also presented a good vision for that the graphical interface programming upgrades remote monitoring and control technology that is easy for extension to on-line applications in industry. Internet-based techniques, in fact, are becoming more important to develop research/technical skills about advanced ideas in engineering fields. For further applications, the proposed system can be simply extended to perform an on-line control and surveillance activities in automated industry.

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