DESIGN OF AN INTELLIGENT TUTORING SYSTEM ON THE WWW TO SUPPORT INTERACTIVE LEARNING

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Abstract

Web-based education is currently a hot research and development area. Thousands of Web-based courses and other educational applications have been made available on the Web, but the problem is that most of them are nothing more than a network of static hypertext pages. This paper describes the new features of an adaptive intelligent tutoring system (ITS) on the Web.

The architecture presented in this paper provides a protected learning environment to facilitate efficient learning to the students with adaptation of the learning environment to the learner's goal and capability. To produce this educational system, we distinguish three spaces:

- Adaptive navigation space to support the student's orientation and help them to find an "optimal path", with use of the case-based reasoning technique (CBR).
- Adaptive collaboration space to use the system's knowledge about different users (stored in user models) to form a matching collaborating group. The collaboration is available between the tutor system and the learner or learner/learner or group with tutor.
- Adaptive information space to adapt the content of pages to the user's goals stored in the user model.

The architecture of our system will be presented and the implementation outlined.

Keywords: ITS, WWW, Adaptation, Case based reasoning, Web-based educational systems.

1-Introduction

What attracts the Internet to an educational institute is a large communication network to exchange information in two ways : the online browser and the courseware package distribution. So the challenge we have to face is to change information exchange into learning activities. For this reason, we are interested in second generation servers [Andrews et al, 1995] which respond better to educational needs: better interactivity between video-clip, text, images and so on.

Current Web-based courses are not flexible. In the best case, course materiel is a network of static hypertext pages with some media enhancement. A learner can access any part of a course without order constraints on these parts and without having the necessary knowledge. Consequently, the teaching objectives aimed by the course attendance will not be reached. So the course must take into account the learner profile (capacities of training) and the learner evolution (prerequisite, speed,), and having account for the freedom of the learner in the navigation space.

A challenging reset goal is the development of advanced Web-based educational applications, which offer some amount of interactivity and adaptivity. Adaptation is especially important for Web-based education for at least two reasons. First, most Web-based applications are to be used by a much wider variety of users than any standalone application. Second, in many cases the user is "alone" working with a Web "tutor" or "course".

Our suggestion is to develop Web-based courses, which can adapt to users with very different backgrounds, prior knowledge of the subject and learning goals. Each learner must have an own course, which is adapted to the aptitudes and the objectives of the learner when it was solicited. Therefore to develop our system we distinguish three spaces in which the activities of learners take place: adaptive information space, adaptive navigation space and adaptive collaboration space.

After a short introduction of the impact on education of the WWW, we present the use of intelligent tutoring systems for WWW and the Web-based adaptive educational system, then we present our methodology for designing an educational system and finally, the architecture of the system is discussed.

2- The impact on education of the WWW

The WWW has found enormous success through word of mouth coupled with the enthusiastic support of the media. Along with the increase in popularity, there has been a rush to incorporate new features into the software, many of which can facilitate and enhance specific educational modes discussed later.

2-1 The WWW for information seeking and research

The WWW has grown from its origins as a simple system for distributing documents and communicating into a more general multimedia tool of wider appeal. Nevertheless, its use as a research tool continues and has increased enormously.

Despite the magnitude of the information available, using the Web is a simple matter, so that anyone with the desire and the time to explore is bound to discover a variety of fascinating sites and resources. Yet because of the vast number of WWW sites, knowing where to begin searching, what to look for, and what to ignore can be a daunting task. The development of what are known as Webworms, spiders, and know bots has facility searchers somewhat although it has brought another problem in that an overwhelming amount of reference materiel may be returned [HOBBS & TAYLOR, 1996].
This has been helped somewhat by individual WWW users who have already begun to catalogue the enormous variety of educational resources available online. As this information is compiled, it becomes available to the educational community in the form of online resource guides, some of which are no more than hypertext lists of known educational resources.

2-2 The WWW as teaching tool

The WWW can be used to design tutorials and on-line lessons for a variety of subjects. [Blumberg, 1994] describes an online teaching tool for basic genetics known as Mendelweb that integrates elementary biology, discrete mathematics, and the history of science. Mendelweb is presented as an active document, with links to traditional reference materiel as well as images, tutorial, commentaries, related Web sites, and animations (Students may choose in what order they wish to explore the topics, enabling them to develop their comprehension of the subject at their own rate).

The WWW is therefore beginning to provide the necessary tools with which to design online teaching materiel. However the potential of WWW teaching packages has yet to be realised largely because most WWW books have been technically oriented. In order for this technology to reach the mainstream subject areas, WWW tutorials must be designed for less technical subjects.

2-3 The WWW as an educational Forum

The WWW has long promoted its use as a forum for discussion and as a marketplace for ideas and information.

The WWW can provide a basis for virtual debate and discovery in terms of its use in the education community. All of the original uses of the Internet including file transfer protocol (ftp), email, USENET news, and gopher continue to thrive in the context of the WWW and have now converged into a singular informational tool, since the latest generation of WWW browsers, such as Netscape Navigator are capable of interacting with the full suite of Internet protocols. As a basis for such discussion, Internet users have traditionally used mailing lists to form a discussion group, receiving information from and posting information to the mailing list via e-mail which in turn then distributes the information to every one on the list.

For education, this combination of presentation (the WWW) and critique (mailing lists) can be used successfully in a variety of ways. For instance, a teacher could set up a WWW site which comprises lectures, frequently asked questions, and multimedia presentation via a mailing list, students could automatically add information to that site in the form of additional questions, reports, essays, etc. Students can also use the various Internet technologies to create their own hypertext work and then present it online. So that their peers and lectures may discuss and review it: Learning how to critique other's work and to present a persuasive constructive argument are skills that are often gained slowly for many students [Laurillard, 1995].

2-4 Using the WWW for collaborative learning

The WWW is not very well-suited for collaborative work, which requires a high degree of real-time interaction. Prototypes for synchronous communication such as Webchat exist but are currently unstable and slow. One of the most exciting developments for collaborative education are WWW interfaces to Multi-user Dungeons (MUD's) and Object-oriented MUD's (MOO's) [Curtis & Nichols, 1993].

2-5 The WWW and distance learning

One obvious role for the WWW, using all of the above scenarios is in distance education [Ibrahim, 1994]. Compared to a traditional distance education system of paper and post some of the benefits of the WWW dissemination of materiel include the ability of the training centre to distribute knowledge on a large scale almost instantaneously; the reduction of mailing costs which allows distribution of pages without the overhead associated with printing costs and transport, the correction and updating of all information for all users from just one server site, the availability of a variety of different teaching styles and modes of communication between teachers and learners, facilitation of collaborative writing between authors, and improved mechanisms for students to give and receive feedback more easily.

3-Intelligent tutoring systems for the WWW

There were multiple efforts to use WWW facilities for distance learning. At the same time, most existing educational WWW applications use the simplest solutions and a number of technologies are still not implemented within the WWW framework [Brusilovsky, 1995].
One of these technologies is Intelligent Tutoring System (ITS) technology. ITS is the knowledge about the domain, the student, and teaching strategies to support flexible individualised learning and tutoring.

The most obvious way to bring ITS facilities to the WWW is to port some existing ITS technologies. The most relevant technique for that is *intelligent knowledge sequencing*, which implies adaptive selection of the next topic to be learned using the student model and the knowledge about the learning materiel and problem sequencing which implies choosing or generating the next problem for the student to solve.

4- Web-based adaptive educational system

Web-based systems really need adaptivity because they have to work with a much greater variety of users than earlier standalone systems. A number of research groups world wide are now working on adaptive Web-based applications driven by the importance of adaptivity in the context of Web-based education [Brusilovsky, 1997]. adaptive navigation support (ANS) is aimed at helping students find an “optimal path” through the hyperspace of learning material. The most popular forms of ANS on the Web are direct guidance, annotation and disabling. The implementation of direct guidance was available in the following Web-based systems: ELM-ART II [Weber & Specht, 1997], CALAT[Nakabayashi et al, 1997], INTERBOOK [Brusilovsky et al, 1997], AST [Specht et al, 1997], MEDTEC[Eliot, 1997] and DCG[Vassileva, 1997].
Adaptive presentation is aimed at adapting the page content to knowledge, goals, and other characteristics of an individual user.
In WWW context, the same “page” was suited to very different students. What can be adapted in Web-based educational systems? All adaptation technologies applied in Web-based Adaptive Educational Systems are: Curriculum sequencing, intelligent analysis of student’s solutions, interactive problem solving support, example-based problem solving support, and collaboration support [Brusilovsky, 1998].

5-A methodology for designing an educational system

In this paper we present a methodology which aims to build a global system of training on the Internet. For this, we distinguish three spaces in which the activities of learners take place.

Each learner must have an own course which is adapted to the aptitudes and the objectives, when it was sollicited, this is done in the adaptive information space. The learner in our system can access any part of a course without order constraints on these parts; the system can adapt here a path to present for the learner in the adaptive navigation space. The learner on the Web is not isolated, the system designed can use the knowledge about different users (stored in user models) to form a matching collaborating group or finding the most competent peer to answer a question about a concept in the adaptive collaboration space.

5-1 Adaptive information space

According to the cognitive point of view, the factual and conceptual knowledge takes place in the information space. By navigating from anchor to anchor, a learner may be desoriented in the information space and may forgotten the learning objectives. Therefor, a self-studying learner has to be able from the information and the interactions, to create the own learning activities.

The student is provided with a dynamic “intelligent button” called “Teach me” which activates a knowledge sequencing mechanism. This button brings the student to the course, which is most relevant to the learner state from the system point of view.

The system generates an individual course for each learner based on his profile by using a system of generation (Fig 1). If the student model of a learner is modified as a result of an evaluation, the course will be automatically regenerated in order to take account of the new knowledge acquired by the learner.

Before starting the educational process, the system must initialise the student model in order to construct the profile of the learner. The author of the generic course must parameterise the various parts of his course according to the objectives and the prerequisites necessary for reaching a concept of the theme. The instantiation of the generic themes and the learner profile were being developed in the architecture of the educational system.

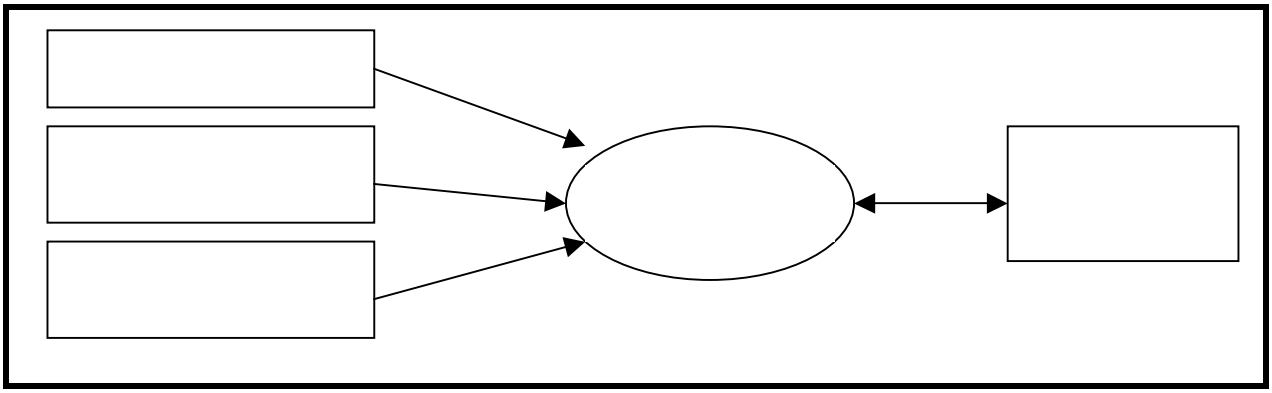

Fig 1 Functional Diagram of the adaptive

5-2 Adaptive navigation space

The goal of the adaptive navigation support technology is to support the student in hyperspace orientation and navigation by changing the appearance of visible links. In particular, the system can adaptively sort, annotate, or partly hide the links of the current page to make easier the choice of the next link to proceed. In our work, we present another technique to help learners to find an "optimal path" through the learning material. The approach relies on using a case-based reasoning technique (CBR) in order to recommend to a user pages of the course that have satisfied users having similar learning objectives (Fig 2). In this space, we assist the learner in the learning process by adapting a “path” of navigation according to the student model. For this, we reuse the experience of the learners who have success in their learning process.

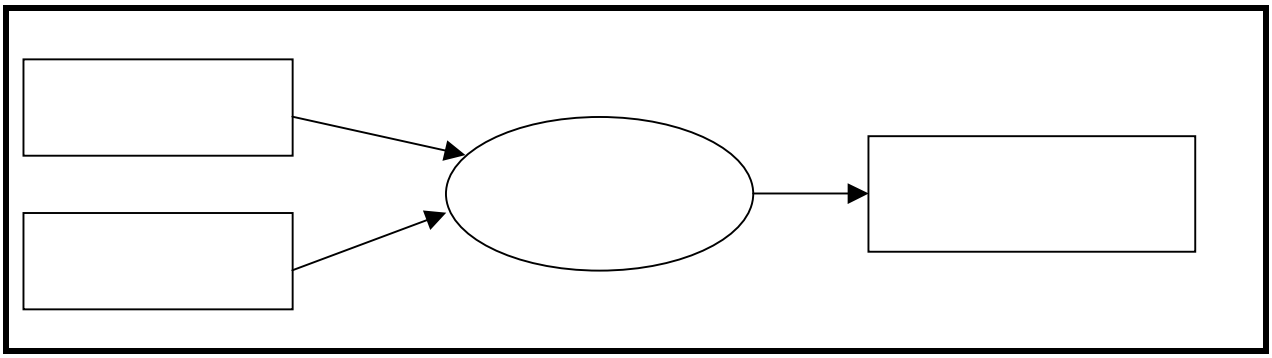

Fig 2 Functional Diagram of the adaptive navigation space

5-2-1 Case-based reasoning

The reuse of the user behaviour is supported by the case-based reasoning which is an approach based on problem solving which use the past experience called case in the reasoning cycle [Trousse, 1998]. The case is composed of two parts: the first part is the problem (initial profile and final profile, a profile is a set of pedagogical objectives) and the second is the solution (a path of navigation, which the learner used to reach the objectives) which is applied to it. The case is the past experience which allows to the system to solve problems more efficienly and avoid the past failures. An indices determined in what situation the case is applied for another problem. When a new problem occurs, a target case is constructed with the solution part unknown, it will be given by the reasoning. The spring case represent the past experience which is stocked in the memory. The spring case and the target case share the same formalism of representation.
This reasoning is decomposed in four phases. In our design methodology of the learning system, we propose the reuse of cases composed of :

- The description of the learner profile at a reference time in the navigation process.
- A list of pages recommend for this behaviour. (Fig 2)

5-2-2 The case representation

The case let to manipulate a pertinent associations deduct from the navigation between a comportment at a referenced time and a value pages.

Case = Initial Profile +Final Profile A set of pages recommended
[_____] [_____]
Problem Solution

5-2-3 design of the reasoning phase

The reckoning of the recommandation is done in four phases:

- Search
- Reuse
- Revision
- Apprenticeship

5-3 Adaptive collaboration space

Currently, learning environments based on the collaboration of learner's present new alternatives to the teaching-learning process in educational institutions as well as in organisations.
The goal of adaptive collaboration space is to use the system's knowledge about different users (stored in user models) to form a matching collaborating group. Existing examples include forming a group for collaborative problem solving [Hoppe, 1995];[IKEDA, Go & Mizoguchi, 1997] or finding the most competent peer to answer a question about a topic [Bishop, Creer and Cooke, 1997]; [McCalla et al, 1997].

In the adaptive collaboration space, we design the process by which users share their experiences, a group of learners who have shared goals for their learning process are identified by the system (from their student model). We develop then a virtual classroom on the WWW in which students study and work in-groups. (Fig3) The tutor system matches the group, and then the students of this group start the collaborative study process. Students learn by collaborating with their peers, the system must:

- Be aware of the participants who are working in a given moment.
- Be aware of the activities of each member of the learning group via an electronic agenda.
- Be aware of the tasks already concluded by the members of the learning group.
- Provide a synchronous communication tool between peers (chat) as well as asynchronous communication tool (e-mail).

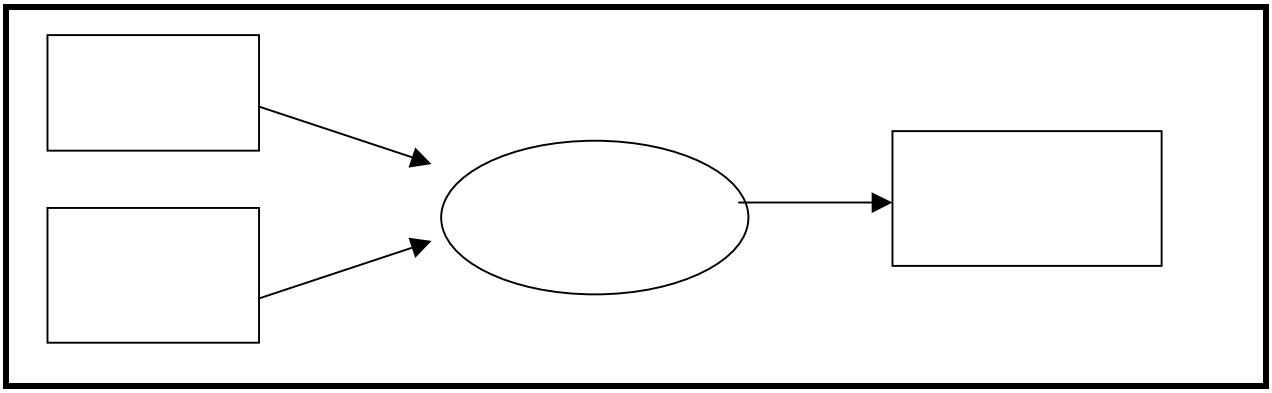

Fig 3 Functional Diagram of the adaptive collaboration

6- Architecture of the system

Taking in account the methodology of designing an educational environment presented above, each learner must have an own course, which is adapted to the aptitudes and the objectives of the learner. To resolve the famous "getting lost" problem, the learner who cannot hardly find

his own way in hyperspace can use the adaptive navigation space in which the system propose an optimal path according to the profile of the learner and the profile of some learner who have success in their educational process. Our system can propose to each learner a group of students to lead them to collaborate in learning process, when they are not satisfy or not reach their target learning with the generation of the course or the proposition of the "optimal path" of navigation deduct from the experience of other learners who had success.

6-1 Architectural elements

The adaptation of our system rests on the domain model and the student model.

6-1-1 The domain model

The simplest form of the domain is a set of domain concept. By concepts we mean elementary pieces of knowledge for the given domain. Dependings on the domain and the application area, concepts can represent as bigger or smaller pieces of domain knowledge. The domain model is a semantic network with nodes corresponding to domain concepts and with links reflecting several kinds of relationships between concepts. Each concept can be either an outcome concept or a prerequisite concept. A concept is included in the spectrum as an outcome concept if some part of this page presents the piece of knowledge designed by the concept.

A concept is included in the spectrum as a prerequisite concept if a user has to know this concept to understand the content of the page.

Indexing is a simple but powerful mechanism, because it provides the system with knowledge about the content of its pages: the system knows which concepts are presented on each page and which concepts have to be learned before starting to learn each page. The learning objectives represent the knowledge which the learner must have. Each objective is represented with a set of concepts.(Fig 4)

The learning objectives are used by the tutor system to select the next activity to suggest for the learner. A learning objective is reached, if all the concept of this objective are reached.

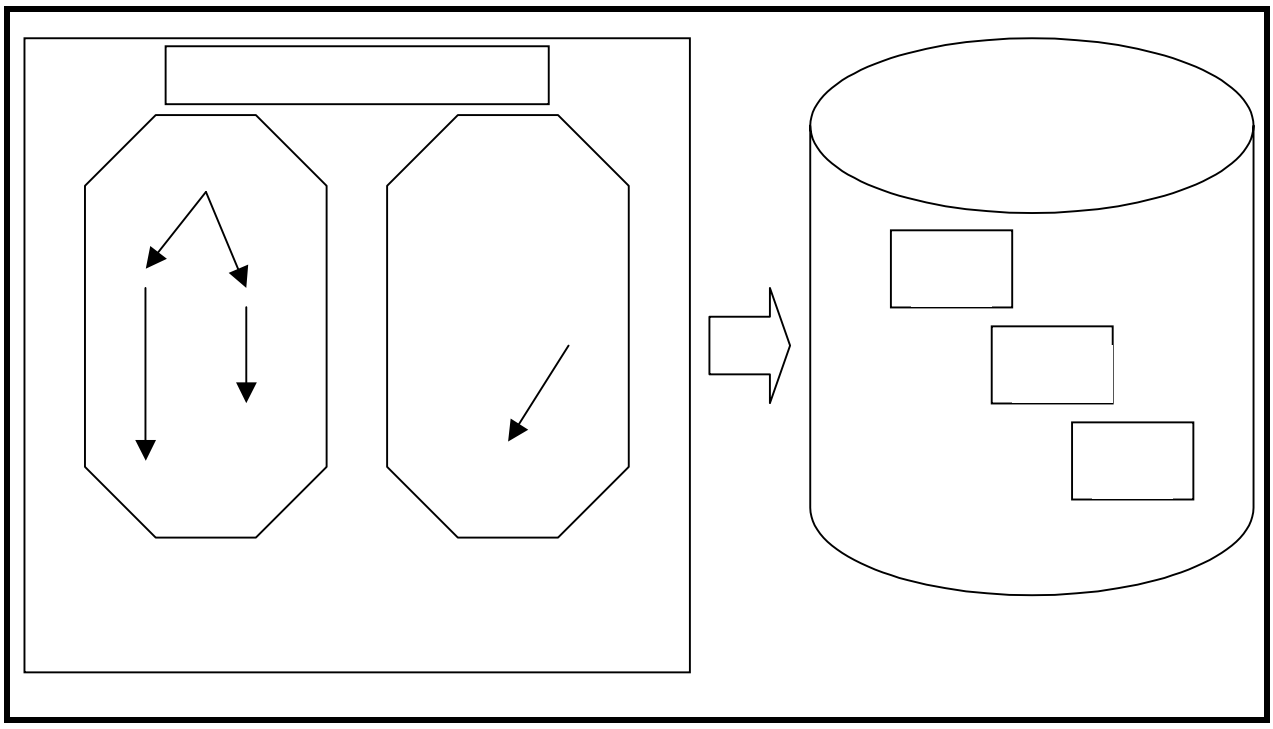

Fig4-Representation of the domain model

6-1-2 The student model

In this model, the system stores some value which is an estimation of the user's knowledge level of the concepts. It can measure the user's knowledge of different concepts.
In this model, we characterizes a learner by:

- static general information, which may change rarely during the process of training. It is the identification and the final profile of the learner (a set of objectives).
- Dynamic information, which may change with the evolution of the learner in the learning process, it corresponds to the progression in the formation: the objectives prerequisite (dynamic, because the system is able to decide, if the objective was not really reach), the evaluation of the objective (by the evaluation of the answer to exercices), the level of the learner and the ability to collaborate in a collaborative learning process.

For the same training objectives, each learner will have an own course according to the pedagogical factors and learning objectives. It makes it possible to obtain a target and better adapted learning.

6-2 Architecture of the educational system

The author of a course must obviously respect the model of the domain defined before. He will be able to produce a well-structured generic course based on this model and the learning materiel to be given to learners according to their profiles.
When the student begins the session, he has to type his name and a password, to create and recover his student model. Students may choose in what order they wish to explore the objectives, enabling them to develop their comprehension of the course at their own rate, but the system tutor flow the progression of the learner according to his final objectives, declared before by the learner and stored in his student model with his prerequisite objectives, and when he ask for a help, the tutor is able to generate to him the courses according to his student model, or proposing to him a path of navigation according to the experience of other learners or the expert, if he is not interested by the guided mode, and finally, proposing to him a matching group to collaborate with his members and had an efficient learning. For this, the architecture presented (Fig 5) let us to distinguish three modules: Navigational, collaborative and informational modules.

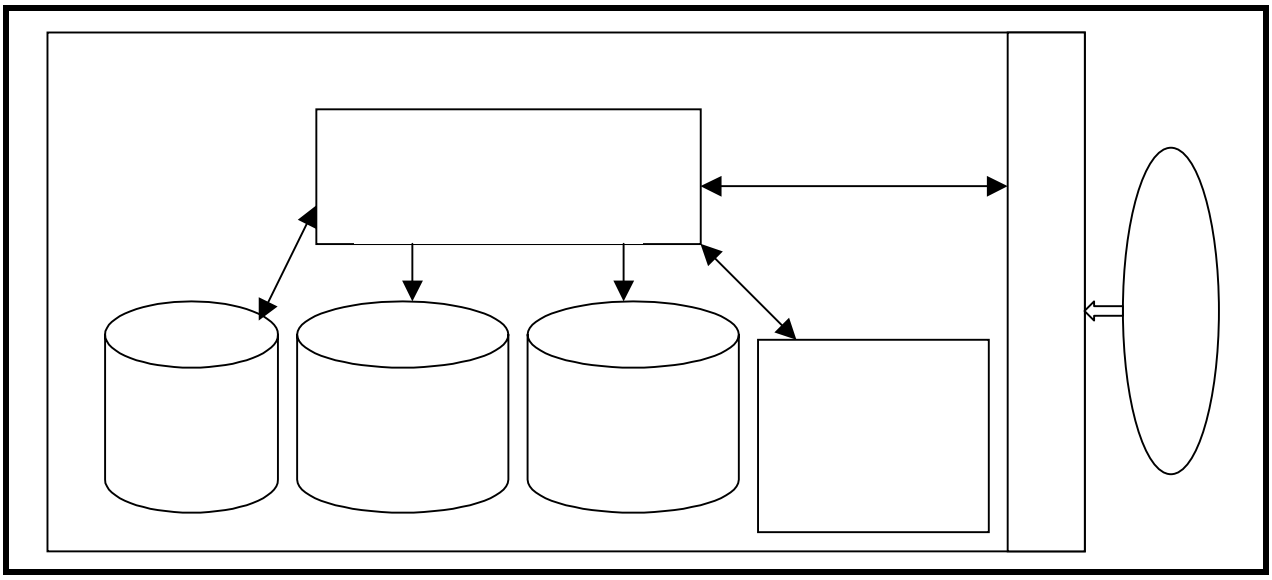

Fig5-Architecture of the educational system

7-Conclusion

To validate our design and evaluate our model, we created a prototype. The communication between the learner and the server is based on the http protocol. The Java language is used.

The Java language is used. To access a course, the learner sends a request which containts personnel information, curriculum vitae (prerequises) and the final objectives. The system generates the student model based on this information. Adaptive technologies can contribute to several directions of research and development on Web-based educational systems. In our system, we present a methodology for design of an intelligent tutoring system supporting interactive learning. The intelligent tutor tries to adapt the course according to the profile of the learners, adapt an "optimal path" to the learner to help him in his navigational process and form a matching group to let the collaborative process.

In the next version of our paper, we will describe the implementation of this architecture, using the XML language to provide adaptable courses.

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