APPLYING FUZZY LOGIC FOR LEARNER MODELING AND DECISION SUPPORT IN ONLINE LEARNING SYSTEMS

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ABSTRACT

Advances in computers and multimedia technology have changed traditional methods for learning and skills training. Online learning continues to play a major success of any academic program. Such learning can personalize learning needs for students, it can provide an environment where virtual reality techniques are used to create interactive interfaces and real-time software can monitor every response made by the user. This paper presents an attempt to introduce the concepts of fuzzy set theory the design of a an online educational module. Such a module can deal with uncertainties in the knowledge acquisition, representation and decision making. The fuzzy logic principles are used in creating the learner model and to provide the appropriate teaching material to each learner according to his/her learning level.

Keywords: Online learning, Virtual learning environment, Fuzzy logic, Learner modeling, Decision making.

Introduction:

With the advent of computer and communication technology, students in distance learning and online learning programs can receive learning materials online, join televised lectures, attend videoconference classes that link students and instructors from numerous geographic locations and participate in chat room discussions[Salmon,2002]. There is a big debate about effectiveness of online learning. One of the major issues is the lack of face-to-face interaction among students and faculty members. The second issue is dealing with real-sense learning and training especially for applied sciences education. Educational software products, such as WebCT, LearningSpace, or other internet-based courseware, are also used to enhance such interaction.

Computer-based education and training techniques are now well established, and provide an environment to create interactive interfaces, and real-time software can monitor every response made by the learner or the system. Our society is changing into knowledge and information society, there will be new opportunities and new challenges in all dimensions of our life. One of the challenges will be that we have to continue dealing with online learning systems. These systems are real-time, large scale, and complex [Al-Aubidy, 2003].

Several efforts have been made to develop computer animation-based learning and training systems [Fang, 1998; Francioni, 1998]. However, computer animation alone will not provide users with opportunities to obtain real-sense learning/training and develop their skills. For that reason, there is a need to explore more advanced technologies to improve learning and training. Virtual reality has found a number of applications in learning and skills training. For engineering education, virtual reality has been used for chemical reaction engineering at Michigan University [Bell,1996], for aerospace engineering at Syracuse University [Higuchi,1996], for teaching structural analysis at National Chiao University, Taiwan [Chou,1997], and for designing a set of experiments in physics at Houston University [Loftin,1993].

As the number of students entering the higher education increases along with the requirement for greater cost efficiency, the potential benefits of computer based learning and training are great. The diversification into distance learning, community education and industrial training which higher education is currently exploring can

also be enabled through the adoption computer based learning and training, especially if they can be delivered over networks which reach into homes, factories as well as educational institutions. The open university at UK uses new technologies to improve the quality of education for learners and to broaden their access to it. The university has invested about £30m in e-learning over the past seven years to provide high quality interactive educational materials that meet learner's need most effectively [Davis, 2002]. Recently, the UK eUniversities project aims to deliver online learning in the best of higher education. The project is being formed as a venture between UK universities and colleges and private sector parameters and other strategic allies.

On the other hand, real educational processes deal with uncertainty in human knowledge. However, most of available educational systems use classical methods to handle vague information in the knowledge representation and decision making. Furthermore, fuzzy set theory incorporates precise techniques for solving such problems [Turban and Aronson, 2001; Yen and Langari, 1999]. In fact, fuzzy logic concepts have been used in several expert systems for knowledge representation and reasoning [Al-Aubidy, 2003].

The purpose of this paper is to share the features of virtual reality technology and fuzzy set theory to design an interactive online learning system. The system software will check the learner's information and his/her knowledge levels to provide the appropriate teaching materials to each learner. The teaching materials are prepared to cope with various learners. Using such a system will enable users to move from one learning unit to the other according to his/her learning level and test score in each unit. This active system will enable users to see what happens rather than to imagine what should happen.

2. Online Learning:

The internet has developed into one of the most revolutionary technologies ever. It has revolutionized business, commerce, communications, and high education[Davis, 2002]. The aim is to develop a system

that will truly change the development of human and social capital and the way individuals learn in a knowledge-based economy. Some of the common uses of the web include:

- enriching access to course materials.
- documenting course discussions.
- providing tutorials and drills.
- facilitating group work,
- providing remedial support and enrichment,

ability to plan and evaluate learning strategies and capability to monitor progress and adjust learning behaviors to accommodate needs.

Web-based learning is an interactive net-based learning system in which the world wide web(www) technology is used as a learning environment. It provides people with instant access to online courses wither they are at home or at work. The web can be used as both a digital library and a virtual classroom. Web-based learning making intelligent use of media such as computer conferencing, email, CD-ROMs, DVD, and the internet. Currently, most of learners are expected to have access to the internet.

The on-line courses adopt e-learning techniques where their use will enhance the learner experience. Media are chosen according to how best they meet the learning objective. The range of web-based learning materials and services available on courses include;

- e-conferencing,
- on-line alternative learning experiences for learners,
- electronic marking of assignments,

- CD-ROMs, DVD and web-based interactive simulations.

3. Virtual Learning Environments:

Virtual learning environments are increasingly becoming an important part of the education strategy for online delivery and flexible learning and training. Many universities and training centers already have learning environment based on virtual reality technology [BECTA, 2005]. Training means the transfer of skills, it is very important part of modern education. Some training aspects can be acquired from a book, or in a classroom, but there is no substitute for training with the real thing. Students may not have opportunities to acquire practical knowledge, which are very important in many courses. Today, it is very difficult to offer such costly courses, for a number of reasons, such as;

- Limited funds for running such programs,
- limitations on laboratory facilities,
- insufficient support of technicians,
- number of students, and
- safety considerations.

Learning and training through simulation provides significant benefits over other methods. Simulating the actual behavior of a certain process requires accurate modeling of each part in the process and integration of real-time 3-D graphics. In this case, each instrument is electronically driven by real-time signals based on a software model describing the instrument behavior. A computer-based flight simulator, for example, is a training system where pilots can acquire flying skills without involving a real airplane or airport [Higuchi and Henning,1996].

The development of computers and multimedia technology has opened up new possibilities for training based on virtual reality. Virtual reality is the most powerful extension of simulation based systems. In virtual reality there is a move to three-dimensional, multi-sensory using it.Virtual reality provides an environment where multimedia tools can be used to create interactive interfaces and real-time software can monitor every response made by the user. Virtual reality can be used to evaluate how a user can achieve new experience in training without the support of physical environment. Such training systems use a virtual environment as a substitute for a real environment [Perrie, 2003].

Virtual reality is a type of simulation in which a computer graphics are used to create a virtual world [Pantelidis, 1997]. It enables users to deal with a virtual (realistic-looking) world through the use of computer simulation and special devices. The virtual world is a real-time and interactive system that responds to the user's physical inputs and modifies the virtual world according to the user's inputs. Virtual reality has the potential to change and improve the ways in which students are educated [Whittington and Sclater, 1998]. In fact, future trends in learning and training will use virtual reality based education laboratories to support every type of education program.

A special hardware and software requirements are necessary to construct an online learning and training system based on virtual reality. Figure (1) illustrates a typical virtual reality system consists of four basic components, these are:

(1). Virtual Environment: A user can view and interact with entities through a stereo display monitor and stereo glasses.

(2). Virtual Reality Devices: These include;

- Stereo Glasses; which allows the user to view computer-generated images in true 3-D stereo depth.
- Gloves; which allow the user to communicate with Virtual environment through finger control.
- Position Sensors; which are used for tracking the position and orientation of the user's head and hands in 3-D space.
- Data Acquisition and Distribution unit (card) for computer interfacing with virtual devices.

(3). Virtual Reality Modeling: real-time modeling, which includes;

- Mathematical models of real (actual) world environments.
- Algorithms for on-line 3-D graphic generation.

Figure 1: A Typical Virtual Reality System

- Algorithms for creating virtual environments.

(4). Virtual Reality Control Software; which represents the main part of the virtual reality system. The functions of this software include;

- Signal processing on the real-time information from the virtual world.
- Real-time control of the changing virtual reality.
- Real-time communication between different virtual reality components.

4. Instructional Design:

Instructional design is both a systematic process for preparing a program of instruction and an organized collection of scientific principles about how people learn. Both process and principles are important to guarantee success. The basic trial and error methodology is a time consuming way to identify effective online learning. Instructors really need well-known teaching strategies that have demonstrate that they have effectively worked in a Computer-mediated environment.

The process of instructional design is essentially an engineering development process. It consists of four main activities as given in Fig.(2). It is clear that no course is

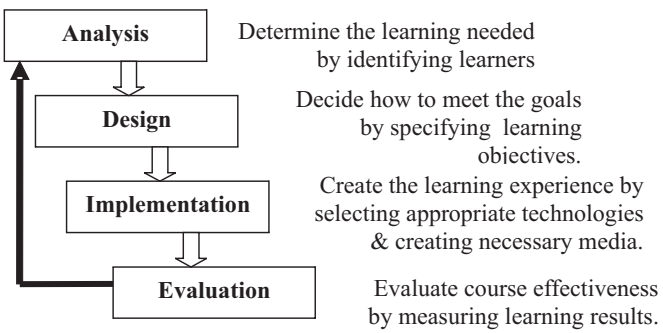

Figure 2: Instructional design cycle

perfect, and it can be improved. As soon as you build a course, you should evaluate its behavior and effectiveness. Such an evaluation cycle will guide you to continuously improve the course.

Online learning provides people with instant access to courses whether they are at home or at work. The world wide web (www) technology is very suitable for building online learning systems. The system software is established on a web server, see Fig.(3). The web is used for both a library and a virtual classroom.

The learners can access the server from a personal computer (client) connected to the server. In the proposed system, only text and images are used, therefore any web browser can meet the system

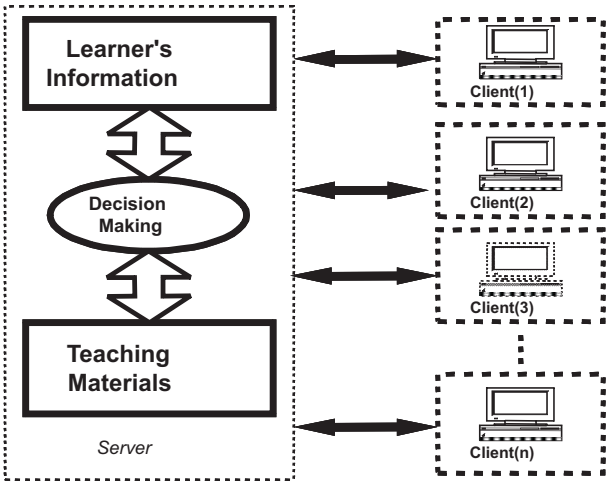

Figure 3: System Design Layout

requirements. The system software at the server side has three main parts, as given in Fig.3. These parts are, teaching materials, learners' information, and a decision-making module.

Teaching materials:

The teaching materials used in the system are related to the course "intelligent systems design" given in Philadelphia University-Jordan. The teaching materials have three contents; brief, normal and details. Each educational unit consists of several pages of HTML text

and JPEG images. As shown in Fig.(4), each page consists buttons such as;

NEXT: a request to view the next page.

BACK: a request to view the previous page.

DETAILS: a request for more details about the given materials.

SEARCH: a request for searching words and phrases in the teaching materials.

E-MAIL: authorized learner is automatically listed in the mailing list related to this course. Then, learner can communicate with the instructor and learners.

TEST: either self test or unit test.

EXIT: a request to stop learning.

The teaching materials are prepared to cope with various learners attending the course. During the editing process of the teaching materials thee following points must be considered:

- Syllabus is easily located, it includes course objectives, completion requirements, faculty members, textbook, reference books, and course schedule.
- Links to other parts of the course or external sources.

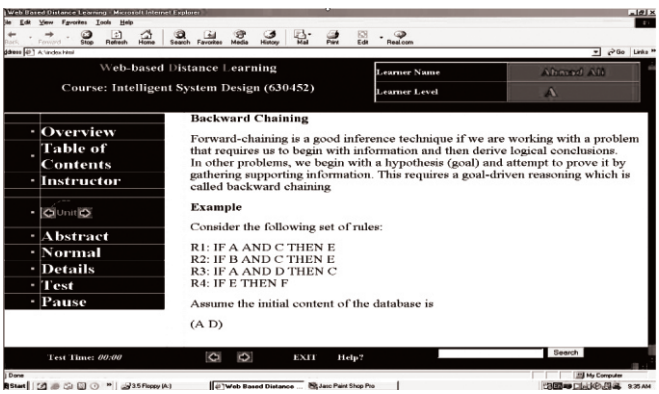

Figure 4: System Screen

Instructional materials required are easily located.

- Course content is organized in a logical format.
- Topics are clearly identified and subtopics are related to topics.
- Resources are separated into required and optional categories.
- Keep course pages to a comfortable length and easy to read.
- Images are optimised for speedy displayed include the necessary text.

Decision Making Module

One of the most important requirements that precede the design of an attractive distance learning system is to adopt software deal with all tasks in the system, which include;

- check if the learner is authorized to access the

learning system or not.

- check the learner information, to provide appropriate teaching materials to each learner.
- manage the teaching materials.
- check the learner's degree of understanding.
- analyses the collected information about each learner to update his/her knowledge level.

Learners information

It is necessary to update the learner model by the system in order to provide appropriate teaching material to each learner according to his/her knowledge level.

5. Learner and Instructor modeling:

One of the most important requirements that precede the design of the educational system is to adopt suitable methods for knowledge acquisition and real-time modeling of the actual world. In fact, human thinking and reasoning involve vague information, therefore, educational systems should be able to cope with such vagueness. The aforementioned vagueness is related to the following source [Al-Aubidy, 2003]:

- Information provided by the learner.
- The current knowledge level of the learner.
- The leaner level evaluation.
- The instructor experience.
- The objective behind the course materials.

Knowledge Representation:

The knowledge representation used for decisions learning management has a great importance in designing virtual reality based educational systems. The sequence of the educational events that is based on the instructor's experience is the core of such educational systems. Therefore, it is important to model the experience of the instructor in such away that the educational system should be flexible, easy, and at the same time enables the learner to deal with the course materials which are suitable to his knowledge level.

The modeling process of the instructor experience and course related physical world is not an easy task. Due to the knowledge acquisition vagueness, it is essential to use an efficient tool that is capable enough to model this knowledge in order to build a flexible decision rules.

Fuzzy Logic:

The fuzzy logic is the most suitable tool to deal with vague knowledge and the process of decision making in the educational system. It can deals with the kind of uncertainty that is inherently human in nature [Yen & Langari, 1999]. Decision making is not always a matter of true and false or black and white, it often involves gray areas. Fuzzy logic can be used in dealing with learner knowledge and instructor experience. It is an effective and accurate way to describe human perceptions of decision making problems[Turban and Aronson, 2001]. In online learning systems, the fuzzy set theory concepts can be used for solving problems related to the:

- Modeling of the learner.
- Modeling of the instructor experience.
- Identification of the learner knowledge level during each educational unit.
- Modeling of real world environments.
- Algorithms for on-line 3-D graphic generation.
- Algorithms for creating virtual environments.
- Real-time control of the changing virtual reality.

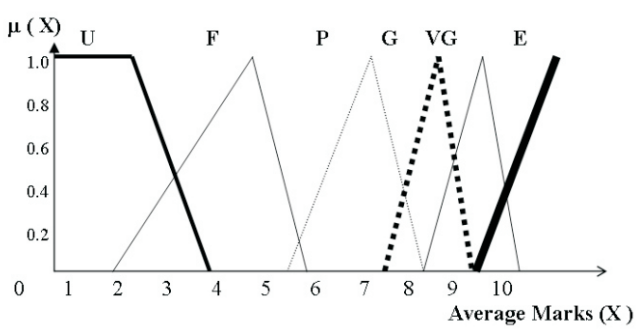

Figure 5: The fuzzy notation of the variable 'test result'

- Decision making for learning path selection.
- Overall evaluation of the learner.

In fuzzy sets, a linguistic variable takes on words or sentences as values. For example, let the variable x be the linguist variable "learner average result", then the following term {Excellent, Very Good, Good, Pass, Fail, Unsatisfied}can be constructed as shown in Fig.(5) . Each term in the set is a fuzzy variable. Now, if x in an element of a fuzzy set, then the associated grade of x with it's fuzzy set is described by a membership function(x), which takes values between zero and one.

6. Fuzzy Decision Support:

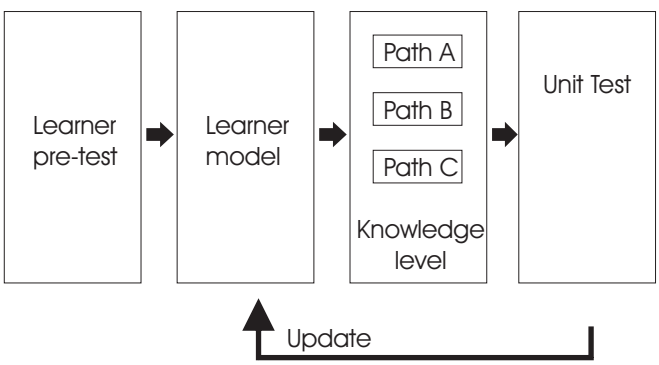

Figure 6: Block diagram of the proposed educational system

The flexible educational system provides an easy way to make possible the transformation from one learning level to another according to the learner background. In this case, three educational paths can be used;

- Learning path (A); includes a summary of the educational unit, which is quite enough for high quality learners.
- Learning path (B); includes the usual information as that given by the instructor for normal learners.
- Learning path (C); includes a detailed information that facilitates the learning process for beginners.

The above educational paths allow the high quality learner to go through the educational units so easily with minimum time while slow-witted learners take more time with high effort to pass each educational unit. Figure (6) shows a block diagram of the proposed educational system. The course material should be distributed for several educational units according to the syllabus adopted by the institute and the instructor's experience. The operation of this system can be summarized as the follows;

- A pre-test must be taken by the system to specify the knowledge level of the learner which enables him to enter the first educational unit.
- Feedforward learning according to the current educational level of the learner.
- The system will test the ability of the learner at each educational unit to update his/her model and to specify the new learning path for the next educational unit.
- According to his/her test in the current educational unit, the learner with grade (Good) or (Very Good) can transform from knowledge level (B) to (A) or from (C) to (B) in the next educational unit, as shown in Fig.(7).
- The learner with grade (Fail) will transform from the current learning path (A or B) to learning path (C) and remain at the same educational unit.
- If the test result at a certain educational unit is (Unsatisfied) then the learner at knowledge level (A) or (B) will remain at the same educational unit and at learning path (C) regardless of his/her learning path.

If the test result of the learner at knowledge level (C) is (Fail) then the system will advise the learner to leave this educational package.

7. Rule-based Decision Making:

	CLA	CLB	CLC
TE	NLA	NLA	NLB
TVG	NLA	NLA	NLB
TG	NLA	NLB	NLC
TP	NLB	NLC	NLC
TF	NLB*	NLC*	NLC*
TU	NLC*	NLC*	OUT

NOTE :
(*) Stay in the same unit
(C) Current
(T) Test
(N) Next
(L) Learning Path

Table 1: Rules for fuzzy decision making

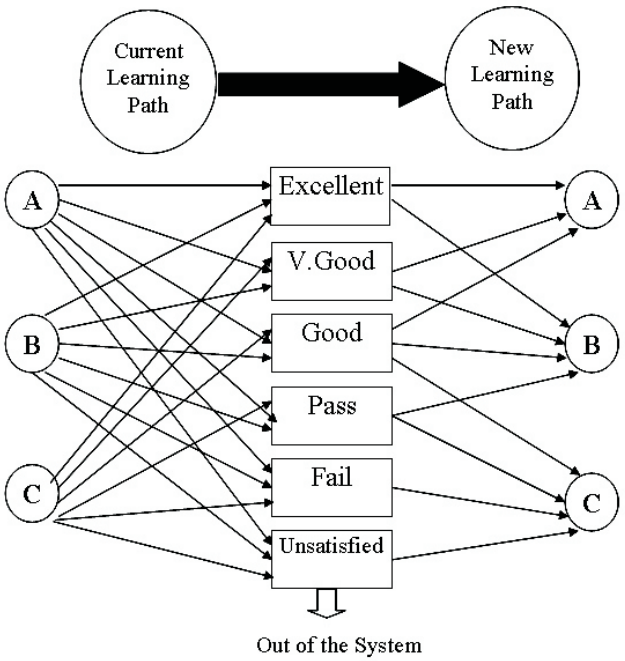

Figure 7: Layout of the decision making process

The knowledge related to the decision making process can be represented by a set of rules. In general, a rule is an implication statement expressing the learning level, test result and learning path in the next educational unit. For example, the rule;

IF CLB AND TVG THEN NLA

This means that if the current learning path (CL) is path (B) and the test (T) is very good (VG) then the next learning path (NL) is path (A). In this system, a set of 18 fuzzy rules, that combine the current learning path and test result are used, as given in table (I).

8. System Evaluation:

In order to verify the performance of the proposed fuzzy-based decision making module, the learning system has been implemented and tested. In this test the learners were 3rd year undergraduate students with different learning knowledge levels. After the learning sessions of the educational unit a self test can be performed by the learner, before the unit test, to check the learner's degree of understanding. The unit test consisted of 33 questions representing topics both general and specific and covers the educational unit material.

- Learner contact time with given educational unit (unit # 4) ranged from 3.5 hours to about 10 hours, see Table II. Five students (2,3,4,5 & 8) were remained in the same learning levels, while the learning levels of the others were changed.
- Learners scores ranged from 35% to 92%.

Learner Number	Current Learning Level	Educational Unit Test	Total Contact Time (min)	Next Learning Level
1	A	Pass	210	B
2	A	Good	255	A
3	A	Good	240	A
4	B	Good	405	B
5	B	Good	390	B
6	B	Pass	375	C
7	B	V.Good	425	A
8	C	Good	455	C
9	C	VGood	520	B
10	C	Excellent	590	B

Table 2 : Rules for fuzzy decision making

- Learners with high learning level (CLA) were able to understand the teaching material given in the unit by using learning path (A) together with on-line discussion with the instructor. Learners with low learning level (CLC) were able to make good progress using learning path (C) with other materials gathered from other resources. In this case more time is required to accomplish the educational unit.

According to the current learning level of the learner and his/her score in the unit test, the next learning level will be modified.

Conclusions :

This paper focuses the importance of using fuzzy logic in learner modeling and decision making process in online learning systems. Online learning systems provide learners with the flexibility to balance study, work and

personal commitments. In such a system, the teaching material (theories and related knowledge) can be integrated with on-line display through virtual environments. Moreover, modeling and decision-making based on fuzzy logic effectively contribute in dealing with vague information. The decision making process in this system is taken place according to the actual knowledge level of the learner. The system can provide the learner appropriate teaching materials according to his/her knowledge level. Learners can ask the course instructor questions about the topic.

The fuzzy decision making of the proposed learning system has been implemented and tested to demonstrate its effectiveness. Students and graduates through a questionnaire have evaluated the system. The result shows that such a system is effective for both students and graduates for continuous learning. On the other hand, learners must be disciplined and well organized, and must have effective time scheduling.

Future trends in education will use virtual reality environments to support every type of educational program. The virtual reality system provides a powerful education tool that can assist users in learning and training through a computer system and some special devices. Such a system is flexible, cost effective and safe. These systems are designed and implemented by a team of engineers.

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