Applying Fuzzy Control in the Online Learning Systems

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Abstract: Current computer-assisted instructional systems are mostly oriented towards offering flexible, adaptive and personalized instruction solutions. Managing the learning process in a computer-assisted instructional system may be done manually, a case in which the instructional decisions belong to the learner, or automatically, when the decisions are made by the computer program. Literature designates the manual management of the online instructional process with the term *learner* control, whereas the one used for denominating the automatic management is *program control.*

Taking into consideration the characteristic of the online instruction process, defined by a virtual communication between the teacher/trainee and the learner, that may be realized by synchronic or asynchronic communication media, the issue of managing the instruction process poses two problems/aspects. The former refers to defining the management method, i.e. manual or automatic, and the latter relates to the way the automatic management of the instruction process may be fulfilled, considering the nontechnical aspect of the process.

This paper analyzes the terms *learner control* and *program control* in the context of the online instruction process and the factors that influence reaching the performance/proficiency objectives in the online instruction process *learner control* or *program control* approaches. It also proposes a fuzzy type regulator that is able to regulate the online instruction process working regime. Theoretical results presented in this paper are simulated by using MatLab program, FIS Module

Keywords: Elearning, fuzzy control, learner control, machine (program) control

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1. Introduction

The control of the learning process in a computer-assisted instructional system can be carried out manually, case in which the instructional decisions are to be taken by the instructors or automatically, case in which a software program is to control the instructional process. The term used to define the manual control of the online learning process is *learner control* and the term used to define the automatic control is *machine (program) control.*

The control mode of the online learning process has two aspects. The former aspect refers to the regime of control: manual or automatic. The latter aspect refers to the structure, components and implementation mode of an online learning automatic system, taking into consideration the nontechnical aspect of the process.

The term *metacognition* designates the knowledge of a person over the cognitive process itself and the ability of a person to optimize the functionality of his/her cognitive process. The concept of metacogniton is a fuzzy concept. [16] This concept has a determinant role in the regulation of the online instruction process. This aspect requires a fuzzy control to regulate the working regime of an instructional system.

The new paradigm of the computer-based instruction is directed to the flexible learning, adaptive learning and personalized learning. In a computer-based instruction system, the control over the learning process can be performed by the learner or by the machine. The literature in the field of education provides a lot of experiences about the control in the online learning process. The challenges of the control in the online learning have two sides: in the former, we report to who controls the process: the learner or the machine, and in the latter, we report to the manner to realize an automatic controller to the online learning process.

So, the major challenges are: to establish the degree of the learner control and the machine control, the moment when it is needed to transfer the control from learner to machine (software program), or from machine (software program) to learner and so forth and what components of the e-courses, seen as control objects have to be controlled by the learner or by the software program.

So, we can summarize these aspects in the following questions: who, how much, when, what controls the online learning process.

To manage these problems, we have to define the concepts of the learner control and the machine (or program control) control.

2. The Learner Control and Program Control Concepts in the Context of Online Instruction

The control of the online instructional process can be a manual control (the regulator element is the learner), the term used being *learner control*, or an automatic control, case in which we use *program control* or *machine control*.

interests and the preferences of the instructors.

Learner control refers to the possibility of the learners to choose the topics and sequencing of topics and exercises, to choose instructional and communication strategies according to their motivations, interests and preferences. Chung and Reigeluth [1] provided six methods of learner control: control over content, sequence of the instructional materials, speed of learning, control over display (screen design), advisory strategies and internal processing of learning.

There are a lot of studies about learner control. The freedom of the learner to configure the screen, to select the topic that will be studied, to select the learning strategy, to select the mode of evaluation represent options of the learner control. In [4], Kay asserted that we can improve learning effectiveness by giving the learner control over, and responsibility for their own learning. Clark and Mayer [2] offer three guidelines for the best use of learner control to optimize learning:

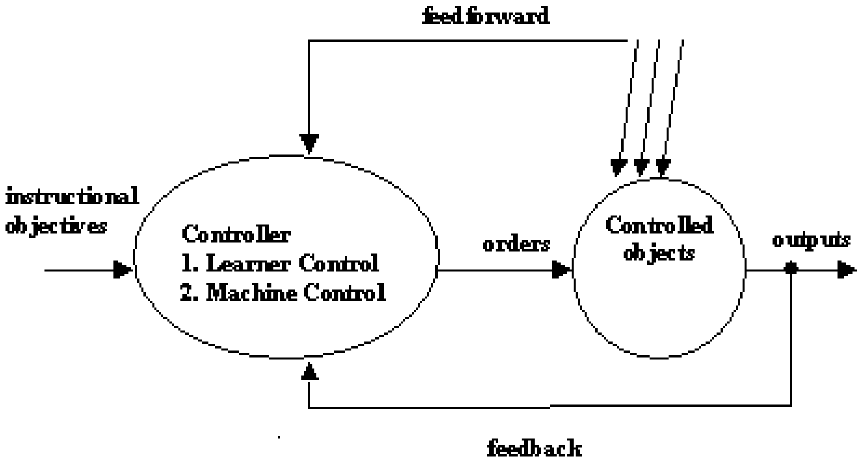

Figure 1. Automatic system to control online instructional process

The learner control concept was described in the papers [5], [7] as the opportunity of the students to order the instructional objectives to study, generating a customized pedagogical path. The idea the students control the instructional process means that the students can select the topics to study, the sequencing of the pedagogical materials, the exercises related to them, the possibility to select instructional and communication strategies, according to their motivations,

"- use learner control for learners with high prior knowledge or metacognitive skills and /or in lessons or courses that are advanced rather than introductory.

- when learner control is used, design the default navigation options to lead to important instructional course elements.

- include advice based on valid test questions to help learners make effective instructional decisions."

According to Milheim [9][8] the term learner control refers to learner control in an individualized lesson. The learner has to control pace, sequence and content or feedback. The problem issued in all researches on learner control in the online learning is not that if the learner has to control the instructional process, but the problem is to establish the degree of learner control: how much may the learner control the instructional process.

Sims and Hedberg [13] identified seven dimensions of learner control: control over content, control over sequence, control over pacing, control over the context, control over method of presentation, control over optional content, locus of control.

Friend and Cole [3] define the term learner control as follows: "allowing the learner some control in an individualized lesson" They stated that the learners may, control lesson pace, sequence, content, or feedback. Learner control depends on the age of the users, student's prior knowledge, the type of pedagogical material being used, the complexity of the course.

In a computer based instruction, learner control means that the students guide the process of instruction. So, students will have a bigger responsibility, independence and autonomy. They will be more motivated and the degree of their interest in the learning process will be increased.

The major problems of this aspect are how much the learner controls the instructional process, when the control has to be transferred to the learner and who are the students that can control the process. In [2], the authors conclude that the learner control is more likely to be successful in the following situations: "when learners have prior knowledge of the content and skills involved in the training; when the subject is a more advanced lesson in a course or more advanced course in a curriculum; when learners have good metacognitive skills; when the course is of low complexity."

The machine (program) control in the online instructional process refers to the automation of the learning process: the learners have to follow pedagogical strategies without the freedom to choose any content, screen, items evaluation, etc.

Young examined the use of learner control and program control in the computer-based instruction. He compared outcomes of the learning process considering the students with high metacognitive skills and the students with low metacognitive skills. The result obtained was that program control is best. The results showed that the students with low metacognitive skills learned less in an instructional environment, which used learner control than the students in an instructional environment, which used machine (program) control. The learners with high metacognitive sills learned better in both types of instructional environments.

3. Fuzzy System to Control the Online Instructional Process

Considering the information showed above, one can establish the structure of an online learning system according the figure no. 1.

The instructional objectives are defined through the intentional instructional models. These models are described using statement about the demonstrated behavior of the students at the end of the course.

The controller can be manual (learner control) or automatic (machine or program control).

The controlled objects are:

1. content: lessons, sections to be studied;
2. display: styles of presenting e-lessons, no. of screens of a courses, levels of presentation / rules, procedures, examples, practical applications;
3. mental activities: internal processing strategies, mnemonics techniques, information reformulation;
4. time of study;
5. the order of study units;
6. styles of evaluation, exams units;
7. metacognition.

The orders consist in selecting orders. In the case of learner control – the orders are internal and the students have the role of regulator. In the case of machine (program) control – the orders are external and they are emitted by software.

To decide the type of controller in an online instructional system, it is proposed a fuzzy controller. Fuzzy controllers are based on fuzzy theory. The field of fuzzy sets and fuzzy logic was first introduced by Lotfi Zadeh [15]. Mamdani introduced fuzzy control in [6].

A fuzzy controller is a rule-based controller. The strategy to generate the control used in a fuzzy control is implemented using an inference mechanism and it uses a more or less natural language. A standard controller can replace a fuzzy controller. The inputs and outputs of a fuzzy control have numerical or fuzzy values. The components of a fuzzy controller are: a pre-processing block, a crisp-fuzzy conversion block, a knowledge base, a decisional block based on fuzzy reasoning, an inference engine, a fuzzy-crisp conversion block, a post-processing block. [14]

In this paper, it is proposed an extension of the system from [10]. The structure is represented in figure no. 2.

values of the selector. If the variable SEL receives a crisp value smaller than 0.5, then value 1 is transmitted to the output – program control, else it is transmitted to the output - learner control.

IIS is an intelligent instructional system with reaction; it is an expensive system, a complex system, really hard to be realized, but more efficient. [11] In this case, the software program regulates the whole instructional process.

IS is an instructional system in which students assume the instructional decisions. It is a simple system, with low costs to realize and implement.

The output vector Y has the following components: the number of students that have promoted the course, the time necessary to study.

The error ε vector has the following components: the number of students that have not promoted the courses, the difference

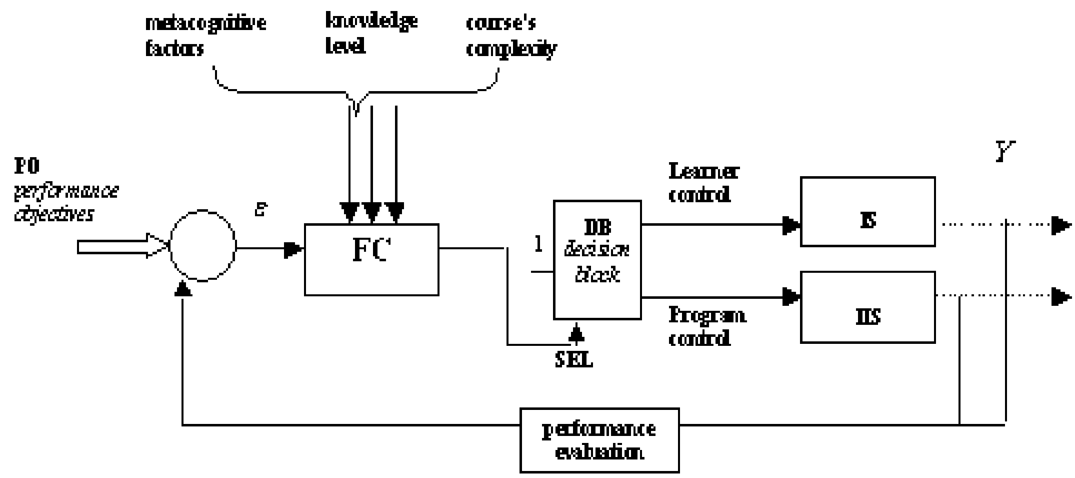

Figure 2. Fuzzy system to control the working regime of an online instructional system

PO - the performance objectives refer to the financial objectives, time objectives, number of students that are promoted an electronical course, etc.

FC - fuzzy controller regulates the control input (learner control or program control) of the online instructional process.

DB – decision block works as demultiplexor and transmits value 1 in accordance with the

between the real cost and the planned cost of the instructional system, the difference between the time reserved for the course and the time consumed to study.

The fuzzy controller is a Mamdani controller; the accumulation of the conclusions activated uses the max operator.

There are defined four linguistic input variables: a metacognitve factor (metacognitive skills), knowledge level, the complexity of the e-course and error ε (to exemplify the error there is considered the number of students that have not promoted the course)

The metacognitive skills variable has the range of discrete values from 0 to 52.

The output variable, SEL, defines the type of working regime (learner control or program control) and it can take a value from the range $[0,1]$.

The fuzzification transforms input data to degree of membership. The defuzzification method is a COG (center of gravity) method.

The linguistic variables and terms are presented in the table no. 1.

Table no. 1 List of variables used in fuzzy system

Linguistic variables	Type of variable	Linguistic terms
Metacognitive skills (AM)	Input	B M S
Level of knowledge (NC)	Output	B M S
Error (ε)	Input	ZE PS PM PB
SEL	Output	B M S

Simplification, it is used a SISO rules base.
If AM is B then SEL is S.
//metacognitive skills are big – SEL is small//
If AM is M, then SEL is M.
// metacognitive skills are medium – SEL is medium//
If AM is S, then SEL is B.
// metacognitive skills small – SEL is big//
If ε is ZE, then SEL is B.
//the error is zero – SEL is big//
If ε is PS, then SEL is B.
//error is positive small – SEL is big //
If ε is PM, then SEL is M.
//error is positive medium – SEL is medium//
If ε is PB, then SEL is S.
//error is positive big – SEL is small//
If NC is B, then SEL is B.
//knowledge level is high – SEL is big //
If NC is M, then SEL is M.
//knowledge level is medium – SEL is medium //
If NC is S, then SEL is S.
//knowledge level is low– SEL is small //

The universe of discourse of AM variable is given by the integers from the range $[0,51]$.
The measurement system uses the questionnaire from [12].
The range $[0,1]$ gives the universe of discourse of SEL variable.
The universe of discourse of error is the range $[0,30]$.
The universe of discourse of NC is the range $[0,10]$.

The memberships functions are triangular and they have the following form:

$$\varphi_{m,d}(x)=\begin{cases}1-\left|\frac{m-x}{d}\right|, m-d\le x\le m+d\\ 0, otherwise\end{cases}$$

$m\in R$, $d>0$

To simulate the functioning of the fuzzy system, it is used the software MATLAB 7.1.

To define fuzzy set of input variable AM, it is used a simple covering with three triangular fuzzy sets, two asymmetric sets and one symmetric set. Those sets form a fuzzy partition. The fuzzy covering of AM variable is showed in the figure no 3.

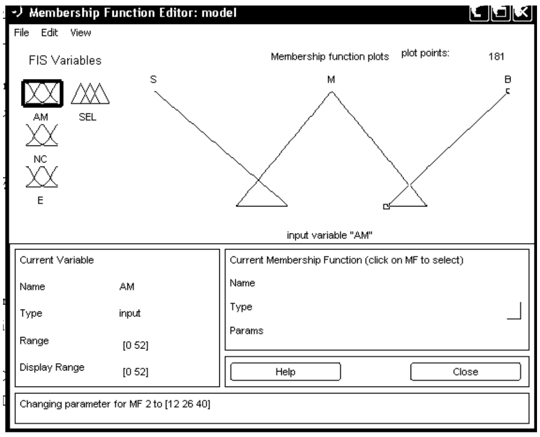

Figure 3. The fuzzy covering of AM variable

The fuzzy covering of NC variable is realized using three fuzzy sets that are triangular and symmetric (figure no. 4).

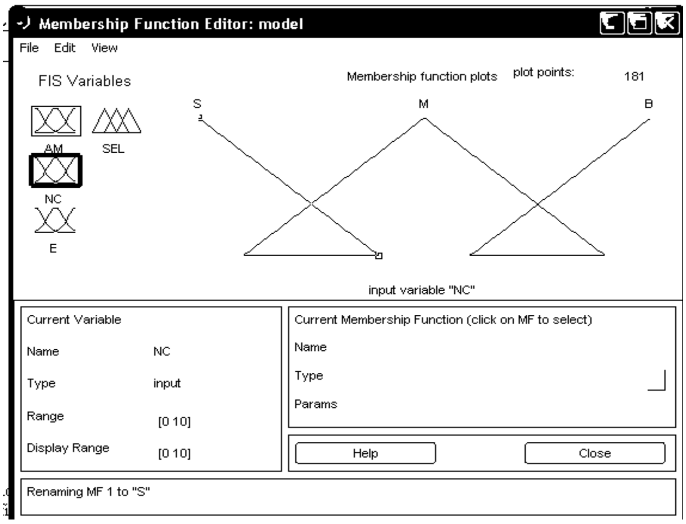

Figure 4. The fuzzy covering of NC variable

Four fuzzy asymmetric sets are used to cover the error (figure no. 5).

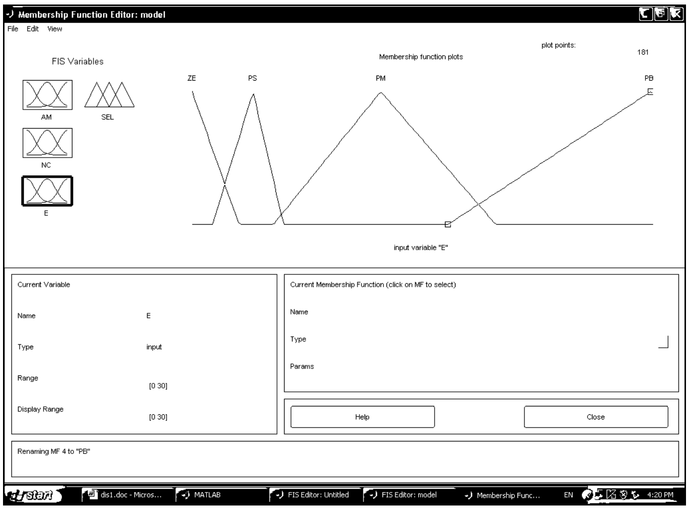

Figure 5. The fuzzy covering of error

Three fuzzy sets are used to cover SEL variable (figure no. 6).

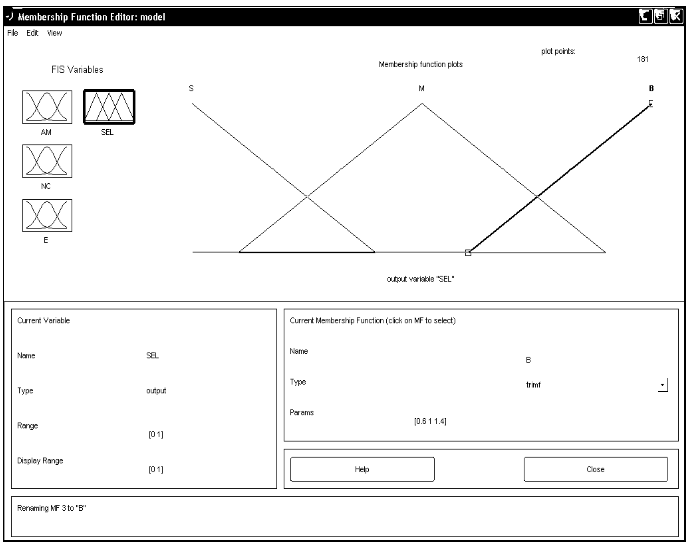

Figure 6. The fuzzy covering of SEL variable

The rules model is showed in figure no 7.

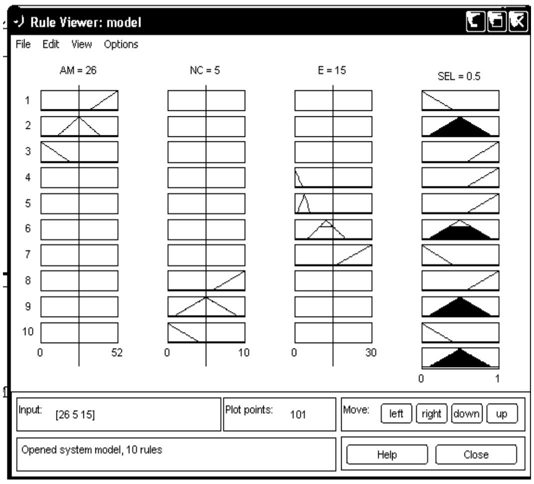

Figure 7. The inference rules model ($\varepsilon = 15$)

The interpretation of the results is: if 15 students do not achieve a minimal mark to promote the course, then SEL variable receives value 0.5 and the decision block transmits value 1 on the branch Program Control.

If the error is 24, SEL receives the value 0.415 and the decision block transfers 1 to the Program Control (figure no.8).

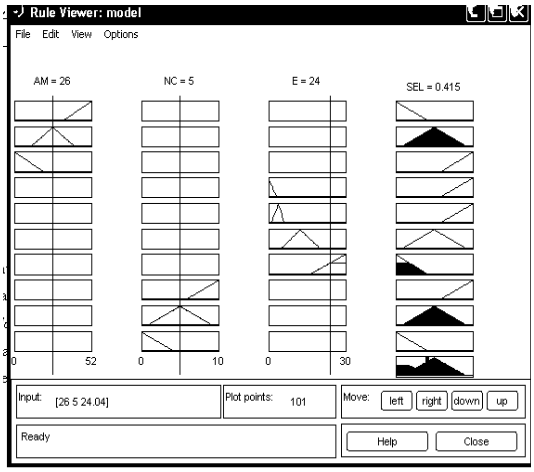

Figure 8. The inference rules model ($\varepsilon = 24$)

If the error is 0, the SEL variable receives the value 0.613 and the decision block transfers value 1 (figure no. 9).

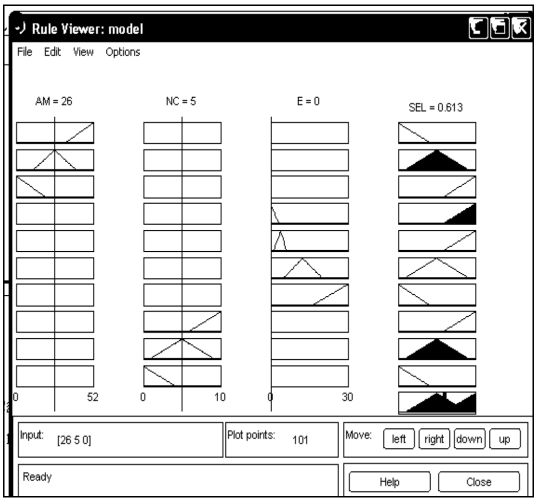

Figure 9. The inference rules model ($\varepsilon = 0$)

The error and metacognitive skills – SEL mapping is presented in figure no. 10.

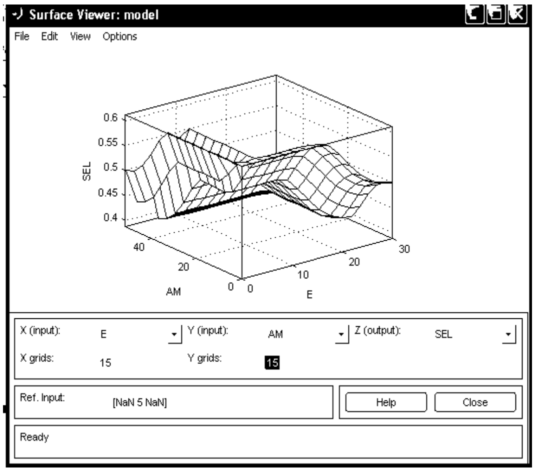

Figure 10. The control surface of the fuzzy instructional system

According to the results above, the conclusion is: if error increases, then the online instructional system needs to be controlled automatically.

4. Conclusions

The problem of the online instruction may be approached through different techniques from fields that are not apparently connected. Investigations and researches in the domain of the online instruction have revealed the possibility to use methodologies based on fuzzy inductive reasons. The fuzzy regulator that was presented in this paper mediates the working regime of the online instructional processes management. In case of automatic control, the online instructional process is controlled by a computer program, and orders are generated by using techniques of artificial intelligence, whereas in manual control, instructional decisions belong to the student/trainee that acts as his/her own instruction regulator.

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