Simulation of University Education Process

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Abstract: The article deals with one possible usage of agent based simulation. This method is advantageous for tasks that can be modeled through a set of basic building elements - agents and their interaction. This contribution shows an application of this approach for the simulation of university education. Conceptual model of university education based on AB modeling of the students was developed for this purpose. The aim was to develop a tool which could help to improve the quality of higher education processes through better knowledge about them obtained from their simulations.

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1 INTRODUCTION

Solving problems using simulation techniques has become a very popular method particularly in recent years. Three main approaches to simulation are available to us. The first one which is based on system dynamics (SD) has been used since the 1960s, and it was first introduced by Jay Forrester (Forrester, 1961). This is the macro view of problem to be solved.

The second one is based on the occurrence of specific events (DE - Discrete Event). The modeled system is described using activities that affect states of the system.

Building the model consisting of similar, relatively simple objects is the third option. Their behavior and mutual interactions create global characteristics of the system, which we call agent based (AB) approach.

This paper will show an application of AB simulation in the area of higher education with a conceptual model and its implementation presented. The aim of the work was to create a model of a university study process based on the credit system, which would be usable for simulations related to the preparation of teaching methodology and subsequent improvement of its quality.

Section 2 of this article presents related work, and the solution to this problem is described in section 3. Section 4 is the core of the paper and here the conceptual model of university education is presented. Chapter 5 is focused on the implementation of the model and conclusions are presented in section 6.

2 CURRENT STATE

Creating AB simulations is a hot topic, mainly because of availability of tools applicable to this area, with some of them being e.g. NetLogo (Wilensky, 1999), REPAST (Argonne National Laboratory, 2012) and Swarm (Swarm Development Group, 2012). These systems are freely available on the Internet. Commercially available, AnyLogic (AnyLogic Company, 1992-2012) allows to combine several above mentioned approaches to create heterogeneous models. The Izumi's paper (Izumi, et al., 2007) is suitable introduction to the AB approach. Information about AB approach can also be found in Siebers (Siebers & Aickelin, 2008).

The use of AB approach for university study modeling has not been specifically published in scientific literature and therefore we can conclude that it is a little explored area.

Problems of coordination and behavior of agents in the socio-technical systems are discussed by Eccles et.al. (Eccles & Groth, 2006). The Tang's article (Tang, et al., 2006) also touches on this theme, but its content is primarily focused on modeling human capital hidden in education. Additional materials are focused on exploring interactions in social networks, such as (Komis, et al., 2002). Modeling of certain student properties (namely loyalty) is described in an article (Helgesen & Nesset, 2009). Exploration of collective behavior

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is explored, for instance, in (Xiang-Min & Ming-Yong, 2010). An interesting approach is presented in (Ayala, 2009), where the student model is based on the definition of appropriate ontology. Modeling a particularly mental capacity of a student is discussed in (Dimitrova, 2003). Ammar (Ammar, et al., 2010) comments the incorporating emotional stimuli and on inputs into the educational system.

3 THE UNIVERSITY STUDY PROCESS

For simulation the study process was modeled in 4 steps.

The admission process, being an important information source for setting up the model is first.

The second step is the student’s enrollment in courses each semester. The key is the process of selecting a course and fulfilling the necessary prerequisites as stated by the requirements of the particular major.

The course study process is not important for the modeling purposes. Only the third step is essential - study results and how they are determined.

After the study period, certain administrative tasks have to be completed and these have a direct bearing on the student’s progress. Afterwards the student can enroll in other courses in the next study period or terminate (successfully or unsuccessfully) his/her study. This is the fourth step.

The proposed study process is based on the credit system and assumes the existence of three groups of courses: required, compulsory elective and optional. The student must obtain a specified number of credits from each of these groups. Minimum number of credits that the student must acquire in the study period is also a certain motivation for him/her.

4 THE CONCEPTUAL MODEL

The task described in chapter 3 is an ideal problem for the AB approach because many very autonomous and (in principle) similar objects participate in it.

An obvious candidate for modeling with the AB approach is the student himself. But the question is whether such an autonomous unit is also the course (including its teacher) itself. The introduced model does not assume that, with the courses being treated as passive objects with given properties and methods.

4.1 Model Environment

Environment that will define the basic simulation parameters is given by rules and regulations of the school. Its data structures must therefore store a rating scale, setting of the assessment grades, as well as recommended schedules (plans) of study. The basic time unit is one semester (one study period).

A list of subject matters T used as coordinates in descriptive vectors for the students and courses is essential for the model. Number of subject matters is not fixed and depends on the desired degree of detail and the ability to identify coordinate values. For simplicity and testing, the whole course can be replaced by one subject matter.

A very important parameter for assessing the quality of the learning process is the ideal graduate profile vector Q.

The main method associated with the model environment is, without doubt, model time control and the related management of actions in the process of simulation. The DE approach is used.

4.2 Simulation of the Student

Each student is modeled by his/her attributes and behavior. The basic idea is to represent the student in the model with four vectors with dimensions defined by T which describe a student person each from a different view (Eq.1). Coordinates of these descriptive vectors are normalized in the range < 0, 1 > (1 means highest or best).

The vector of knowledge K, which stores the actual level of student knowledge of the subject matter, is first. The second vector deals with personal preconditions A (study skills**)**. It is assumed that the student has different dispositions to study various subjects which do not change in time. The third vector is the motivation vector M. Again, different values of motivation for different subjects are assumed. The last is the goals vector G. This reflects the student's preference for knowledge he/she wants to acquire in school, in other words his/her professional focus.

Basic characteristics of the student can also be written in a matrix (Eq.1).

$$\begin{matrix} K \\ A \\ M \\ G \end{matrix} \left\{ \begin{matrix} k_1 & \dots & \dots & \dots & k_T \\ a_1 & \dots & \dots & \dots & a_T \\ m_1 & \dots & \dots & \dots & m_T \\ g_1 & \dots & \dots & \dots & g_T \end{matrix} \right\} \qquad (1)$$

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The initial values of the vectors *K* and *A* should be taken from the results of the admission tests. The coordinates of the vector *K* will increase monotonously. On the other hand values of vector *M* may change in both directions. The values of vector *G* may vary during the study according to the changing preferences of the student affected by both internal and external factors.

In addition to these basic data structures, each student is assigned a list of courses *S,* which he/she is attending during the current semester and an archive of finished courses.

In addition to the above attributes, it is necessary to equip the student with procedural knowledge and skills, i.e. definition of his/her behavior (methods).

One of the basic methods is undoubtedly the selection of student courses for the entire semester. The selection depends on the values of vectors *G, A, K* and *M*, on course credits and completed courses, which may constitute the prerequisites or must be repeated. Other aspects that influence the selection are: the requirement factor of the course, number of credits obtained from groups of courses and available space in the course.

The second group of methods is focused on the evaluation of the course and on the changes of the knowledge vector *K* and motivation vector *M*. These methods are usually utilized after the completion of the entire semester. Because of the interaction with the course description, more detail is given below.

4.3 The Course Model

The course is modeled by vectors with the same dimensions as the vectors describing the student. Input vector *I,* which expresses the level of required skill for entering and completing the course, is the first vector. The second vector *O,* the output vector*,* defines the maximum level of knowledge the student can achieve by studying the course. The course description could be written as an Eq. 2.

$$\begin{matrix} I \\ O \end{matrix}\begin{Bmatrix} i_1 & \dots & \dots & \dots & i_T \\ o_1 & \dots & \dots & \dots & i_T \end{Bmatrix} \tag{2}$$

The course model also contains additional data structures (e.g. the list of preconditions, the definition of duty or number of credits). An important limiting factor is the capacity of the course and its related actual occupancy.

The amount of knowledge gained by the student is probably the most important method associated with the course.

$$\Delta k_{t\in T} = \begin{cases} \max_{s\in S}\left(g_t m_t a_t \left(o_{st} - k_t\right)\right), & o_{st} > k_t \\ 0, & o_{st} < k_t \end{cases} \tag{3}$$

As shown in Eq. 3, the change of coordinates of vector *K* is calculated as the maximum from expansion of knowledge across all courses studied during the entire semester *S* using the difference between the maximum possible output value of the course o_{st} and the original value k_t and the coordinates g_t, m_t and a_t of corresponding vectors and it reflects the influence of study goals, motivation and study skills relevant to the subject matter. This procedure takes into account the mutual influence of courses studied in the same period.

A related method to the above mentioned one is evaluation of the student. The evaluation c_s of the student in the course *s* is the measure of success of the student in the course according to Eq. 4 and the specific grade is derived from the study regulations (e.g. $c_s = 0.6$ to $c_s = 0.75$ means grade C).

$$c_s = \frac{\sqrt{\sum_{t\in T}\left(w_{st} - i_{st}\right)^2}}{\sqrt{\sum_{t\in T}\left(o_{st} - i_{st}\right)^2}}, w_{st} = \begin{cases} i_{st}, & k_t < i_{st} \\ k_t, & i_{st} < k_t < o_{st} \\ o_{st}, & k_t > o_{st} \end{cases} \tag{4}$$

The i_{st}, o_{st} and k_t are the coordinates of the corresponding vectors.

For the proper functionality of the model it is necessary to define the change of motivation vector *M* after the semester ends. The model assumes that the student is positively motivated by extreme study results, both positive and negative. In contrast, average results have a negative motivational effect. Motivation Δm_{st} increases if the resultant evaluation from the course *s* in selected subject matter *t* is far enough from the average results of the student, otherwise it declines. The final change Δm_t of the motivation vector coordinate is the maximum of all the changes Δm_{st} across all courses *s* studied in the entire semester *S*.

5 EXPERIMENTS AND FUTURE WORK

The above study model was implemented in AnyLogic and was verified by testing data regarding the study of approximately 200 students in 60 courses during 9 semesters. Courses included 11 subject matters. The model provides both online summary information, as well as storage of individual student data for offline use.

The model computes the quality q and also q_t of all subject matters (Eq. 5) for every student. Vector Q is the graduate profile vector, and K is the knowledge vector. The quality values are important for the evaluation of effectiveness and success of the study process and the quality of the graduates.

$$q = \frac{|K|}{|Q|}, \qquad q_t = \frac{k_t}{q_t} \qquad (5)$$

Experiments which were performed were designed to validate the model using real process of students' studies. Due to the structure of the admission procedure it was not possible to use data from it for setting the student parameters, and initial values of vectors K, A, G, and M were thus generated from estimated intervals with Gaussian probability distributions. The values of course vectors I and O were obtained from discussions with students. Initial results confirm the hypothesis, that especially preconditions together with capacity limits affect the structure of the student's study plans.

The main goal of future work is to specify parameters of the model from data in the faculty information system and from data contained in the admissions results.
Our first goal is to determine the parameters for the probability distributions used for setting of the student simulation vectors K, A, M a G. The model can then be used for exploring global study processes.

In the second step we would like to suggest mechanisms enabling the use of the proposed system for modeling real learning process of the students by utilizing regularly updated data. This would allow prediction of their study results and limit potentially problematic situations.

6 CONCLUSIONS

This paper describes the agent-based model for the simulation of the process of university studies. Its aim is to contribute to the effectiveness and setting of study plans and processes. The first experiments were conducted with the model to verify its applicability for solving practical problems. Further development will focus mainly on validating and fine-tuning the model for accurate simulation of real world situations and verifying its predictive capability.

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