MULTI-AGENT SIMULATION OF AN EDUCATIONAL COLLABORATIVE WEB SYSTEM

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ABSTRACT

This paper describes the simulation of the activities of a group of students who are using a simulated collaborative educational system, based on a real system (called *KnowCat*) used by real students in several courses in our department. The simulation has been implemented as a multi-agent system, where both the students and the work they perform are represented by interacting agents. The objective of the simulation is to provide a means to analyze different situations and to study global system behaviour and effects such as the quality of the most voted documents, or the overall learning progress and motivation of students.

1. INTRODUCTION

The Internet has become an essential tool for many kinds of service providers, which have adapted their business organization to benefit from this media. In particular, educational courses have evolved from traditional lessons in the classroom to on-line systems, which offer rich interaction possibilities (both synchronous and asynchronous) between learners, and between learners and teachers. These systems allow a more flexible learning process, by permitting the access to educational contents anywhere, anytime.

On-line educational systems are less guided than traditional learning, promoting exploration and a more active role of the student. In this way, in some systems the student is responsible on his own for choosing the learning path among the available contents. In an educational context, groupware [G94] and collaborative systems [AC99], promote team-work and problem solving, for example by making the students work together by creating parts of the educational materials, or supporting joint activities to evaluate, classify or modify such materials.

Evaluating and testing this kind of web based systems is difficult, as it requires many users interacting concurrently. In educational systems, sometimes it is beneficial to study and analyse the effects that can be produced due to the different kinds of interaction: user-system, and user-user (directly or through the system). A model of these interactions prior to implementation would enable to better design and organize the educational system so as to maximize its usefulness.

Thus, we propose in this paper the use of modelling and simulation for the study of educational web systems. In particular, we advocate the use of agent-based modelling and simulation [JSW98] for this purpose. This is a powerful and natural way to carry out complex simulation experiments where many autonomous and interacting entities take part. The key abstraction in this methodology is the autonomous agent. According to [JSW98], an agent is "*a computer system, situated in some environment, that is capable of flexible autonomous action in order to meet its design objectives*".

One of the most interesting things to study in this kind of systems is emergence [GT99]. This phenomenon occurs when interactions in a large population of objects at one level give rise to different types of phenomena at another level. In our case, we study the global system efficiency (e.g. student satisfaction, educational material quality, increase of motivation and learning retention) from local student interactions. In particular, in this paper we have built a model inspired by the KnowCat [AC99] system using the Swarm [MBLA96] libraries for multi-agent development. The work is aimed at providing a framework for experimenting different situations and assumptions about student behaviours. We believe that modelling and simulation can be a valuable means for decision support for this kind of systems, and may help in (re-)organizing the real system for maximizing the results.

The rest of the paper is organized as follows. Section 2 gives an overview of the KnowCat system. Section 3 presents the simulation model. Section 4 discusses the implementation and shows some experiments. Section 5 compares with related research and finally section 6 ends with the conclusions and future work.

2. THE *KNOWCAT* SYSTEM

KnowCat is a web-based collaborative system [AC99] which achieves the self-organisation of a set of documents, created and provided by a group of users, in such a way that the system is able to determine the quality of each document as a function of evaluations by the users themselves and their behaviour. The system uses these data to provide naive users with suggestions on the documents that they should study. This system has been used in practice in several courses offered in our department, where the students generate sets of documents about the subject matter of the course in such a way that those with the best quality can be used by the same students participating in the experiment, or those who come in subsequent terms.

In the following, we describe the most relevant features of the *KnowCat* system, of interest in the frame of the experiments described in this paper. They occur as three different phases, which correspond to different student interactions. In the first phase (***creation***), teachers divide the subject matter into a set of *themes* and assign each student one or several of them. The student must build a document for each assigned theme, describing the associated concepts and ideas, using notes taken in the classes, the recommended bibliography, or any other appropriate related source. In this phase, the only interaction of the students with the *KnowCat* system corresponds to the actual delivery of the documents.

In the second phase (***voting***), each student is assigned a number of votes and a different set of themes to be revised. They must then read the documents provided by other students and assign their votes to those documents considered to be the best.

Finally, in the third phase (***reading***), the system classifies the documents according to the votes they have received. The best ones are then recommended to students asking for information about a given theme as support material for the subject matter under study.

When the system is used according to the preceding phases, a lot of information is generated in the form of documents whose quality is not tested by experts in the subject matter, but by the students themselves through the assignment of their votes. However, the votes may not be objective, because the students tend to give their votes to documents written by their acquaintances and friends, or to those easier to read (or shorter ones) but which may not provide a general review of the theme. It may well happen that the most voted documents are not really the best, and the objectives of the use of the system would not be reached.

The application described in this paper simulates the *KnowCat* system and its use by the students, so as to obtain information and perform experiments on the effects of the behaviour of the students on the quality of the generated documents, and the knowledge the students would be able to get from their use as support material.

3. SIMULATION MODEL

First, we start describing the structure of the model. Figure 1 shows a class diagram of the simulation model. Three classes of agents are defined in the simulated system: students, documents, and the *KnowCat* system itself, which envelopes all the others. Documents are purely reactive agents, since they do not perform any action on the other agents. On the other hand, both students and the simulated *KnowCat* system are active agents, as they perform actions on other agents by their own initiative, although they are also capable of receiving external influences.

The *KnowCat* agent marks the start and the end of each of the three phases described in the preceding section, and assigns tasks to the students. The simulation is performed in a time frame where the unit is the week. During each week, the students will try to solve the tasks they have been assigned by the system. Depending on the phase of the work, they can also perform voluntary activities by their own initiative.

The student dynamics is inspired in part in a similar system built by [K05], where the students are assigned a level of motivation which increases when they successfully perform the assigned tasks and decreases when they fail. If their motivation reaches zero, the students stop using the system. In addition to this, each student is provided with a list of knowledge which changes while they use the system. The set of knowledge reached by the students at the end of the simulation is a good indicator of the success or failure of the system.

Compared to the real system, the model applies a certain number of simplifications. During the creation phase, to allow the students finding information about the themes they have been assigned, several documents are initially provided by the teacher. The student should read them before creating the documents assigned to them. After the first phase is finished, these starting documents are removed from the system. Also, during the voting phase, no themes are assigned to the students, who must chose by themselves the documents they want to read and vote.

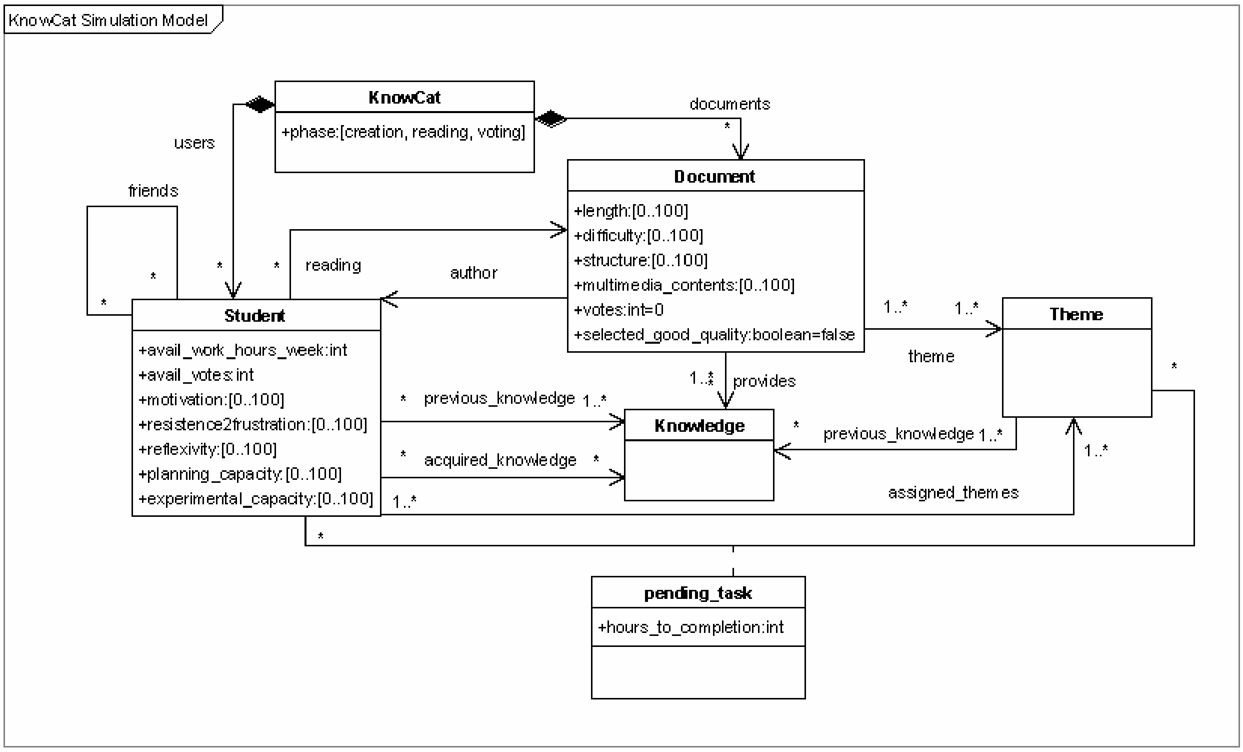

Figure 1: Class diagram of the simulation model.

Two additional entities are defined: knowledge, and themes. Knowledge is divided in two kinds: previous knowledge, which the student possesses as the consequence of previous studies, and acquired knowledge, which corresponds to the current course. The course is assumed to be divided into themes, each of which requires a set of previous knowledge to be understood. A student acquires knowledge about a theme by reading one of its associated documents. The assignment of knowledge to themes is automatically performed by the *KnowCat* agent.

A *document* is an agent containing the following attributes: its length (an integer between 1 and 100), difficulty (a percentage), degree of structure (a percentage), multimedia contents (a percentage), the number of votes obtained by the document (initially 0), and a switch indicating whether the document has been selected by the system as a good quality document. A document is related to the assigned theme, to the required previous knowledge (which is the same for all the documents associated with the same theme) and to the list of knowledge which can be gained by studying the document, a subset of the knowledge associated to the theme. A good quality document should ideally provide all the knowledge associated to its theme. A document is also related to the student who authored the document.

A *student* is an agent with three types of attributes:

- Character definition: resistance to frustration, degree of reflexivity, experimental and planning capabilities.
- Dynamic properties: motivation, affected by the resistance to frustration; number of hours available per week, which varies as a function of the student motivation and can increase or decrease as a consequence of the student behaviour during the current week.
- Accounting information: number of votes which the student can assign during the voting phase (a maximum value, the students may assign a smaller number of votes depending on their motivation); their pending tasks and the number of hours needed to complete them (relation *pending_task*).

A relation links students to their previous knowledge, which assumedly has been acquired in previous courses. Its value varies between one third and one hundred percent of the maximum knowledge which the student can have in the system. This includes the newly acquired knowledge, which the student gets during the simulation, which has an association to the document being read, the assigned themes, and his friends.

Next we describe the dynamics of the model, by presenting the inter-agent interactions and the student behaviour.

Student-document interaction. When the students read a document, the system quantifies their *degree of understanding* as a function of the following data:

- A comparison between the current knowledge of the student versus the list of required knowledge associated to the document. This factor has as much weight as the next two together.
- A function of the student reflexivity, planning capacity and motivation versus the length, difficulty and structure of the document.
- A comparison of the experimental capability of the student versus the multimedia contents of the document.

Every time a student reads one document, a part of the available hours for the current week is expended. The motivation of the student is also adjusted as a function of the understanding obtained from every document read.

Student-KnowCat interaction. The student interacts with the *KnowCat* system in the following ways:

By being assigned themes and the documents which must be read in the first phase.

By uploading documents to the system when they have been created.

By reading and voting documents created by other students.

By reading (optionally, if they have sufficient motivation) additional system documents.

Student behaviour. Student behaviour depends on the phase the system is:

Creation phase: the students read the initial documents associated to the themes they have been assigned by the *KnowCat* system and create new documents related to those themes. Each task in this phase may take several weeks, as a function of the degree of understanding obtained by the students from the initial documents and their motivation.

Voting phase: The students read documents generated by other students. If a minimum degree of understanding is obtained, the document receives one vote. Otherwise, the document is voted with a certain probability if the author belongs to the list of friends of the voting student.

Reading phase: The students may read additional documents in the system, to get extra knowledge. If the students are sufficiently motivated, they will participate in this phase, otherwise they will do it with a 50% probability. If a document has been marked with good quality, it is always read, otherwise it will be read with a 50% probability.

4. IMPLEMENTATION AND EXPERIMENTS

To simulate the *Knowcat* system, we used the Swarm multi-agent simulation library [MBLA96], which is based on ObjectiveC and Java and provides facilities to simulate sets of agents, each of which may recursively contain other agents. The simulation can be dynamically controlled, in such a way that the state of the agents can be modified or tested at any point, making it possible to extract measurements in real time. The three kinds of agents (student, Knowcat and Document) are classes that inherit from the swarm class *SwarmImpl*. As classes student and Knowcat are *active* agents, they have an associated action table (swarm class *Schedule*), so that they can autonomously perform these actions.

The previous interface allows configuring the initial parameters of the student population (i.e. its number and characteristics), the Knowcat system (e.g. the number of themes, the initial documents) and the environment (e.g. influence of friendship in the voting process).

Four different simulation experiments have been performed. Figures 2, 3 and 4 show the result of the *first set of experiments*, where the default values were used for all parameters. Motivation starts slightly above 45 and increases along the simulation until reaching a value of about 60. The number of documents generated per student is below 1, even though 2 had been requested (84 vs. 200). The number of votes assigned was also very small (156 vs. 500 requested, 5 per student). The amount of knowledge acquired by the students was slightly better than 20% (40 pieces of knowledge). This experiment confirms that students starting with a low motivation level do not reach satisfactory results.

The *second set of experiments* was performed increasing the student motivation. When the initial motivation average is set to 70 with a deviation equal to 10, better results are obtained. During the simulation, the average motivation increases to 90. 93% of expected documents are generated (186 vs. 200), and 70% of the expected votes are assigned (350 vs. 500). The average number of pieces of knowledge acquired by the students increases to near 60.

In the *third set of experiments*, the motivation of the students is the same as in the second experiment, but the average difficulty of the initial documents is increased to 90, with a 10 deviation. In this case, the motivation does not increase during the creation phase, although it improves during the voting and reading phases. The number of generated documents decreases by 17 (9%) while the votes assigned by the students also get below the 350 of the preceding experiment.

The *fourth set of experiments* maintained the same parameter values as the third, except that the average frustration resistance is set to 10 (rather than 50, which is the default) with a 10 deviation. In this case, the students cannot increase their motivation, which gives rise to significantly smaller numbers of generated documents and votes.

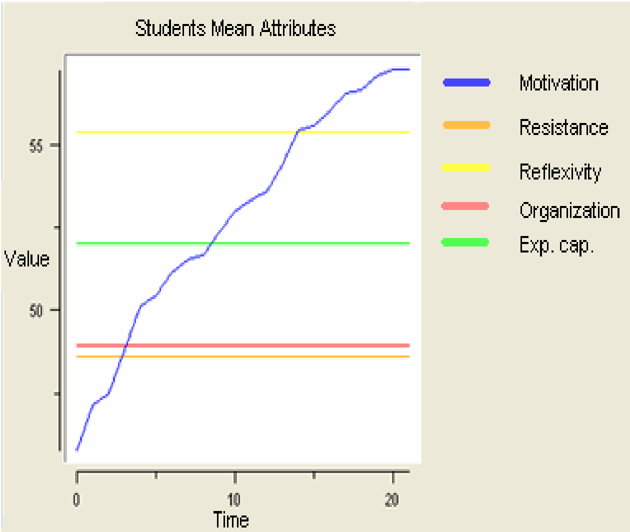

Figure 2: Average student attributes (1st experiment). Colors respectively represent average motivation, resistance to frustration, reflexivity, organization and experimental capability.

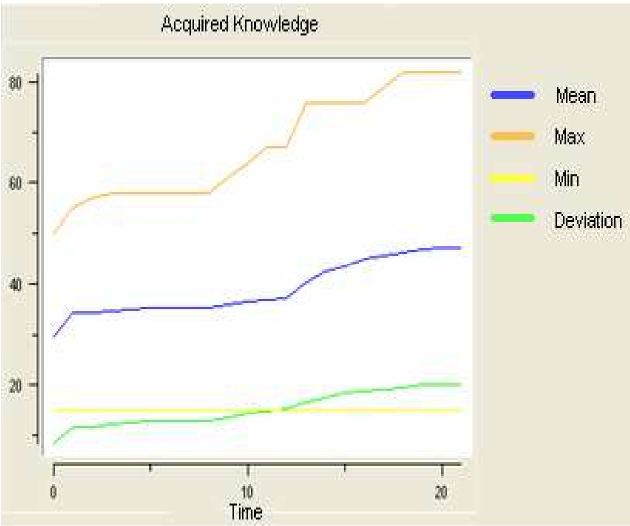

Figure 3: Acquired knowledge (1st experiment).

We observe that the average motivation of the students tends to increase with the use of the system. This increase depends on the initial attributes of the students and the difficulty of the assigned tasks. In the case of high levels of motivation and resistance to frustration, combined with a low level of task difficulty, the results obtained by the students interacting with the system are satisfactory.

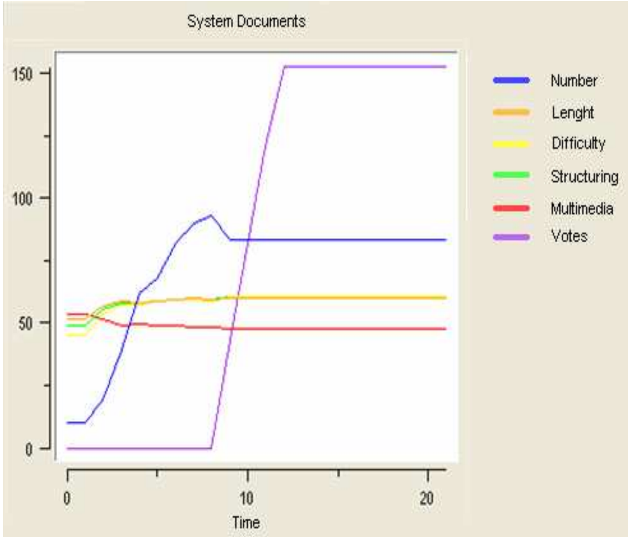

Figure 4: Characterization of documents in the system (1st experiment). Colors represent number of documents, their average length, difficulty, structuring and multimedia, plus the number of votes.

With a lower initial motivation, the evolution of this attribute is slower, affecting the knowledge acquired by the students. With a lower initial frustration resistance, the levels of motivation and knowledge acquired are also affected, but a little less. This may indicate that, even when the student experiences a high level of frustration using the system, if the initial motivation is high, the final results are only slightly affected.

An interesting fact is observed when the initial documents assigned to the students have a high degree of difficulty (third sets of experiments). In the creation phase, the initial motivation does not increase. This is because the majority of the students are not able to understand the reference documents, and thus the documents generated by the students have poor quality. However, in the following phases of the simulation, the motivation and knowledge increase. We assume that this happens because students in a small group, with attributes above the average, are able to understand the initial documents despite their difficulty. This group generates high quality documents, less difficult to understand by the rest of the students. In this way, the average motivation and knowledge increase. From this result we can remark that the cooperation between the agents in the system is positive, because the actions of the agents with better attributes influence the other agents, making them learn more. For the community of learners, this collaboration scheme is beneficial, as the results are better compared with the students working in isolation: they can take advantage of the findings of other students. Thus, the way in which the system works forces an altruistic behaviour of the participants, in the sense that the documents produced by each student are shared by the others.

5. RELATED WORK

Part of this model was inspired by the work in [K05], which proposes a model of an educational web-system for the study of indirect social interaction, where students can leave recommendations for good learning materials to other students. Our model is targeted to collaborative educational systems, in particular to *KnowCat*. We also use a much more complex model for the students.

Although agent-based simulation is increasingly used for the study of social phenomena, there are not many works in the literature dealing with simulation of web-based educational systems. For example, in [W07] a model is proposed to study the allocation of peer tutors in a community of learners using web-based systems. [YC02] investigates the performance of benevolent behaviour in a web based learning environment (as when individual learners actively provide help to their peers).

There are other works implementing simulated students for their interaction with a real system. For example, in [V02] a simulated student was used to detect "passive students" (students which do not collaborate) and off-topic conversations in a collaborative educational system called *Habipro*. Starting from the student model, we also intend to generate code to test the real web application.

6. CONCLUSIONS AND FUTURE WORK

A simulation model has been developed to study the impact of several parameters on the behaviour of the students using the *KnowCat* educational system. The parameters define student personalities, their friendship relationships, the quality of documents provided by the teachers and the time and tasks assigned in the course. The tool has been tested by means of simple simulations whose results correspond to the expected behaviour.

However, to perform a better analysis of the tool, we intend to compare the results of the simulation tool with those of the actual *KnowCat* system, when used by real students. This study must still be done, although at this point there is a certain amount of raw data available, from which conclusions can be obtained about student preferences and the appropriate values for the parameters we are considering. Another line for future work is the improvement of the tool to represent educational systems which follow paradigms different from those used by *KnowCat*. Finally, we intend to generate code from the models (in particular from the students model) in order to test the real system with different student behaviours.

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