Animated Pedagogical Agent based on Decision Tree for e-Learning

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Abstract

This paper proposes a LMS (Learning Management System) with intelligent agent to provide effective adaptive messages to a learner. The unique features of this paper are shown as follows: The agent system proposed in this paper has a Learner Model, which is automatically and continually constructed by applying the decision tree model constructed from the learning histories data stored in the data-base. The constructed Leaner Model predicts a learner's future final status (1.Failed, 2. Abandon, 3. Successful, 4.Excellent) using his/her current learning history data. The constructed Leaner Model becomes more exact as the amount of data accumulated in the Data-Base increases .The agent system presents the optimal instructional message based on the learner's predicted future state. The agent provides some attention cues according to [1] *at the timing when a learner begins to be bored with his/her learning. In addition, this paper demonstrates the effectiveness of this system through actual e-Learning classes.*

1. Introduction

Motivation is essential to learning and performance, particularly in e-learning environments where learners must take an active role and be self-directed in their learning [2]. Despite the importance of motivation to learning, between 1988-2000, less than one percent of papers at the international conferences concerned with distance education focused on motivational issues. Keller[3] argues that although motivation is idiosyncratic, learner motivation can also be affected by external aspects. Visser reported that motivational messages could reduce rates of dropout learners[4]. Moreover, Visser intended to enhance the learners' motivation in e-learning situations using motivational messages[5]. Gabrielle applied technology-mediated instructional strategies to Gagnes events of instruction and showed the effects of the technology-mediated instructional strategies to motivation [6]. These studies emphasize the effects of the teacher's motivational messages adapted to a learner's status. However, if the number of learners is substantial, then it is difficult for a teacher to individualize and personalize messages to students. The main idea of this paper is to develop a system with an animated agent which substitutes for the teacher's role as a virtual mentor. That is, this paper proposes a LMS (Learning Management System) with an intelligent agent to provide effective adaptive messages to a learner using the learner model and the learners' learning histories data.

Many computer-based learning environments using agent technology have been proposed (For example, see [7]-[12]), but there is no study which employs Data-Mining technologies applied to learners' learning histories data.

The unique features of this paper are shown as follows:

- The agent system proposed in this paper has a Learner Model, which is automatically and continually constructed by applying a data mining tool, the decision tree model, to the learners' learning histories data-base.
- The constructed Leaner Model predicts a learner's final future state (1.Failed, 2. Abandon, 3. Successful, 4.Excellent) using his/her current learning histories data. The constructed Leaner Model becomes more exact as the amount of data accumulated in the Data-Base increases.
- The agent system has various instructional advice messages corresponding to the learner's predicted status.
- The agent provides some attention cues according to [1] at the timing a learner begins to be bored with his/her learning.

In addition, this paper compares the developed LMS with an LMS without the agent system through actual e-Learning classes for one semester. The results show that the number of the students who give up their classes is significantly less than the number in the case of the LMS without the agent system. In addition, the results show that the average score of the final test in the case of the developed LMS with the agent system are significantly higher than the average score of the final test in the case of the LMS without the agent system. Some questionnaires and interviews with the learners show that the agent system enhances the learners' motivation and it has the role which contributes to the learners maintaining a constant learning pace.

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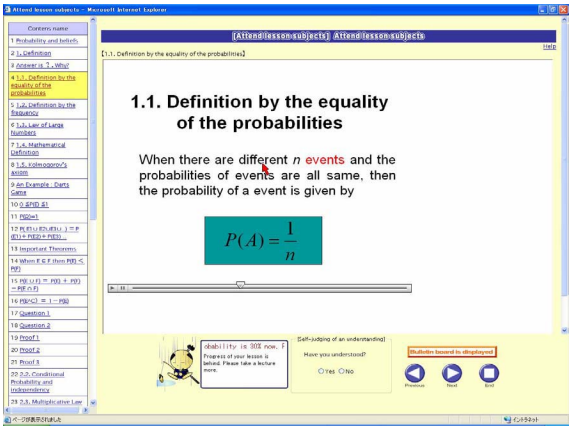


Figure 1. LMS "SAMURAI"

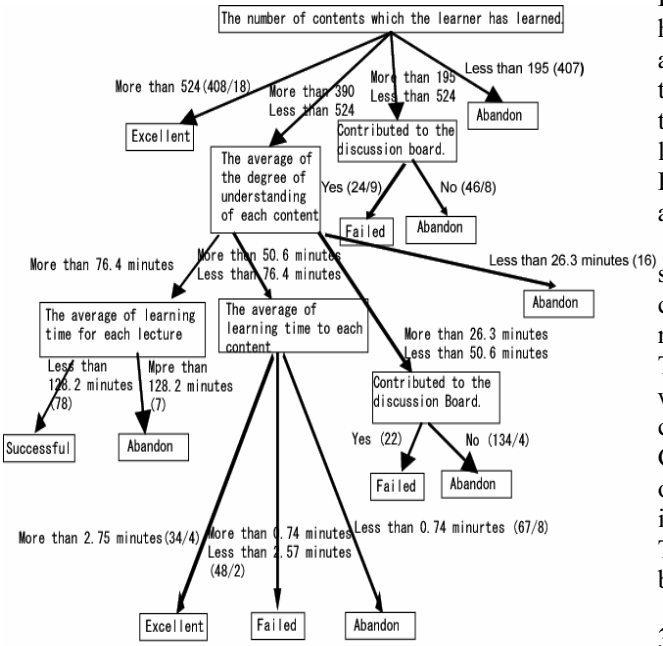


Figure 2. An example of constructed decision tree

2. Outline of LMS "Samurai"

The author has developed a LMS (Learning Management System), which is called "Samurai"(for example, see [13]), and has provided many e-learning courses. The LMS consists of 1.Contents Presentation System (CPS), 2.Contents Database (CD), 3.Learning Histories Database (LHD), and 4.Data Mining System (DMS). The CPS integrates various kinds of contents and presents the integrated information on the web page.

Figure 1 is an example of our typical e-leaning content presentation by the LMS "SAMURAI". The system presents the contents by clicking on the menu button. The sound track of the teacher's narration is also presented according to Mayer and Anderson [14], and the red pointer simultaneously moves. This lesson corresponds to a 90 minute lecture at university and includes 42 contents. Although the content in figure 1 is text content, there are four kinds of contents 1. Text contents, 2. Illustration contents, 3.Animation or CG contents, and 4.Video clip contents. In this lesson, there are eleven text contents, eleven illustration contents, ten animation contents, and ten video clip contents. The system also presents some test items which confirm the learners' degree of comprehension as soon as the contents have been completed.

The CD is a database which consists of various kinds of media, text, jpeg, mpeg, and so on. The proposed platform monitors learners' learning processes and saves them as a log data in the LHD. First, the teacher makes the contents concerned with his lecture, and saves them on the CD. Then, the CPS automatically integrates the contents, and presents them to the learners. The learners can learn them through the internet. The learners' learning histories log data is saved in the LHD, and it is analyzed in the DMS. The DMS presents the feedbacks for the learners and the teacher respectively.

The LMS monitors learners' learning processes and stores them as a log data in the LHD. The stored data consists of A) Contents ID, B) Learner ID, C) The number of topics which the learner has completed, D) Test Item ID, E) Operation order ID, F) Operation ID which indicates what operation was done in the content,
G) Date and Time ID which indicates the time and date of starting the operation, and H) Time ID which indicates the time that it takes to complete operation. This data enables the system to reproduce the learner's behavior in e-learning.

3. Learner model using Decision Tree for e-learning histories data

The main idea of this paper is to apply a data-mining method to the huge amount of stored data and construct a learner model to predict each learner's final state of his/her learning. Here, the states are considered as follows: 1. Failed (The learner fails the final examination. His/her final examination mark is less than 60.), 2. Abandon (The learner gave up the learning before he/she takes the examination), 3. Successful (His/her final examination mark is more than 60 and less than 80.), and 4. Excellent (His/her final examination mark is more than 80.) In order to predict the learner's final status, a well known data-mining method, Decision Tree[15], is employed using the following variables corresponding to each learner's status every week is used:

1. The number of contents which the learner has learned.

2. The times which the learner has accessed the e-Learning system.
3. The average number of times which the learner has completed each content
4. The average learning time to each lecture which consists of several contents and is corresponding to 90 minutes lecture)
5. The average of the degree of understanding of each content (This is measured by the response to the question which is corresponding to each content in the e-Learning)
6. The average learning time for each course which consists of fifteen lectures
7. The average number of times which the learner has changed his/her answer to the questions in the e-Learning
8. The number of times which the learner has contributed his/her opinion to the discussion board.
9. The average learning time of each content

Because all courses are designed to be learned for 15 weeks, fifteen decision trees are estimated corresponding to learners' learning histories data for the fifteen weeks. We use C4.5 algorithm [9] as a learning algorithm for the decision trees. The program is developed using Java and is installed to the LMS "Samurai". These decision trees are always estimated using updated learning histories data. Therefore, the decision trees structures to predict the learner's final status always change. In this algorithm, all variables are always to be used. An example of actually constructed decision tree, which is learned by 1,344

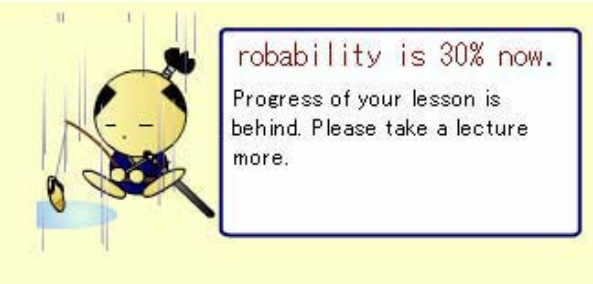


Figure 3. An intelligent agent system

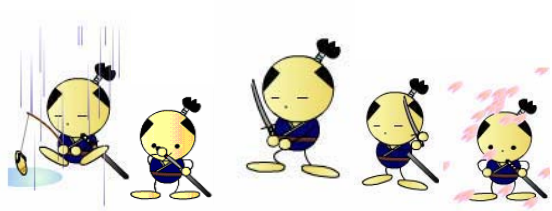


Figure 4. Various actions of the agent

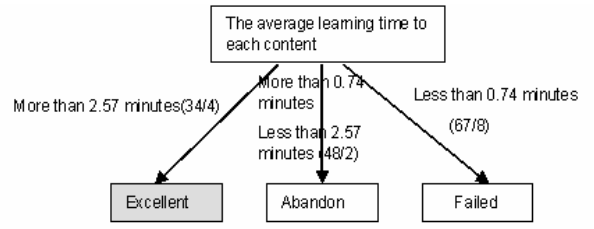


Figure 5 A part of the decision tree in Figure 2.

learners' data, is shown in Figure 2. This tree is estimated by 14th week learning histories data. (A / B) shown in the figure indicates as follows:, the number A indicates the number of cases which the inference is correct, and B indicates the number of cases which the inference is incorrect. For example, (408/18) indicates that the probability of the correct inference is 408/426. In this system, the decision trees corresponding to the weekly learner's status are always being constructed.

4. Intelligent Agent System

The main idea of this paper is to develop an intelligent agent system to provide optimum instructional messages to a learner using the previous decision tree as a learner model constructed automatically. The agent appears in the LMS as shown in Figure 3. The agent provides adaptive messages to the learner using the learner model. And the agent system also performs various actions based on the learner's current status as shown in Figure 4.The instructional messages to a learner are generated as follows:

1. The system predicts the target learner's future status and it's probability using the constructed decision tree.
2. If the predicted status is "Excellent", then the agent provides messages as follows: "Looking great!, Continually do your best. Probability of success is xx%". "If the predicted status is not "Excellent", the system searches the closest "excellent" node from the current predicted status node. For example, let us consider a part of Decision Tree in Figure 2 as Figure 5. If the predicted status is "Failed ", the nearest node "Excellent" is the gray node in the figure. The system searches the nearest node "Excellent" and detects the operations which change the learner's predicted status to "Excellent". In this case, "the average learning time of each content " is detected. The instructional messages are prepared corresponding to these variables shown in Table1. The system provides the messages with the predicted future status, his/her probability of success estimated by the decision tree, and the instructional messages according to table 1.

5. Attention cues to attract a learner's attention

Ueno[1] showed that the learner begin to feel some mental workload about every 18 minutes by measuring

learners' pupil sizes during learning. In addition, he proposed an animated agent to enhance learner's attention to learning in e-Learning. Here, the animated agent provides some kinds of attention cues, which are the agent's actions to attract learners' attention, when the learner begins to feel some mental workload. The actual experimental results demonstrated that the attention cue provided by an animated agent was an effective method for restoring learner's attention in e-learning situations. According to these results, the

Table 1. Instructional messages corresponding to the detected variables

Variables	Instructional messages
1.The number of contents which the learner has completed.	1. Progress of your lesson is behind. Please take a lecture more. 2. Progress of a lesson is liable to delay a little. Let's take a lecture more.
2.The times which the learner has accessed the e-Learning system.	3. You have not received the lesson well. Let's access the system more.
3.The average of the times which the learner has completed each content	4. Don't forget the previous contents? Let's confirm the previous contents again.
4.The average learning time of each lecture which consists of several contents and is corresponding to 90 minutes lecture)	5. It seems that there is little attendance time of your lesson a little. Please take a lecture over many hours more.
5.The average of the degree of understanding of each content (This is measured by the response to the question which is corresponding to each content in the e-Learning)	6. Were the contents of a lesson difficult? Let's take a lecture from the beginning once again. 7.When there are what you do not understand, let's ask a question in a discussion board.
6.The average of learning time of each course which consists of fifteen lectures	8. You have not received the lesson well. Let's access the system and study the contents slowly and carefully again.
7.The average of times which the learner has changed his/her answer to the questions in the e-Learning	9. You look your knowledge is not so robust. Let's take a lecture from the beginning once again.
8.The times which the learner has submitted his/her opinion to the discussion board.	10. Learning is done between learners. Lt's participate in and contribute on the discussion board.
9.The average of learning time to each content	11. Do you take a lecture on a lesson correctly? When you take a lecture on a lesson ordinarily, it should take time more.

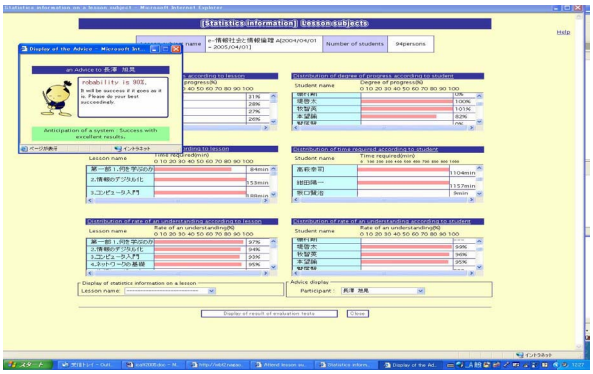


Figure 7. The feed-backs for a teacher

agent system proposed in this paper also provides some attention cues every 18 minutes.

6. Feed-Back for teachers

The proposed LMS also provides some feed-backs concerning all learners to a teacher as shown in Figure 7. The degree of learning progress for each learner, the learning time of each learner, and the rate of understanding the contents for each learner are presented in this system. In addition, this system also presents the current presented instructional messages from the agent to the learner whose message we want to know about, as shown in Figure 7. Thus, the teacher can know which kind of message was sent to each learner.

7. Evaluations of this system

This paper compares a class using the agent system with a class without the agent system for one semester. The decision tree for the agent system was learned using 1344 learners' learning histories data.

The details of the two e-learning classes are shown in table 2. The results show that the number of the students who gave up their class is significantly less than the number in the case of the LMS without the agent system. In addition, the he final test score results, learning time data, and progress of learning data also show that the proposed agent system enhanced learners.

The following two questionnaires were provided to the learners.

A. Does the agent system enhance your e-learning ?

1.Very poor, 2. poor, 3. Fair, 4.Excellent 5. Very Excellent

B. Were the instructional messages from the agent system adequate?

1.Very bad, 2. bad, 3. Fair, 4.good 5. Very good

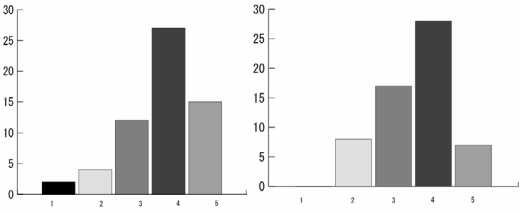
The results are shown in figure 8. The results show that the system is effective in enhancing the learners' learning and instructional messages from the system have a positive effect on the learner's status.

The presentation of the predictive learner's future status and the presentation of adaptive instructional message support learners to keep their required learning pace. As a result, the learner can learn until he/she satisfies his/her predicted future status.

8. Conclusions

This paper proposed a LMS (Learning Management System) with an intelligent agent to provide effective adaptive messages to learners using learners' learning histories data and data mining techniques. This paper compared the developed LMS with a LMS without the agent system through actual e-Learning classes for one semester. The results showed that the number of the students who gave up their classes were significantly

less than the number in the case of the LMS without the agent system. In addition, the results showed that average score of the final test in the case of the developed LMS with the agent system were



The Results for A The results for B

Figure 8. The results for the questionnaire

Table 2. The comparisons between a class with the system and a class without the system

	A Class using the agent system	A Class without the agent system
Subject	Information & Communication Technology	Information & Communication Technology
Students	Undergraduate Students at Nagaoka University of Technology (Third and Forth grade)	Undergraduate Students at Nagaoka University of Technology (Third and Forth grade
Learning Place	At each student's home	At each student's home
Credits	2	2
The number of students	74	92
The term	2003.April.10-July. 31	2004.April.10-July. 31
The number of students who gave up the class	14(18.9%)	49(53.2%)
The final test scores	Average: 93.26 Variance: 43.2 (n=60)	Average: 78.74 Variance: 215.24 (n=43)
The P- value of the statistical difference test of two averages	1.33E-07	
The total learning time	Average: 1045.13 Variance: 71721.8(n=60)	Average: 801.88 Variance: 65426.9(n=43)
The P- value of the statistical difference test of two averages	1.25E-05	
The average degree of progress of lesson	Average: 0.93 Variance: 0.64(n=60)	Average: 0.84 Variance: 2.03 (n=43)
The P- value of the statistical difference test of two averages	0.00031	
Total number of contributions in discussion board	714	928

significantly higher than the average score of the final test in the case of the LMS without the agent system. Some questionnaires and interviews with the learners showed that the agent system enhanced learning motivation and it was instrumental in learners maintaining required learning pace.

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