2009 Ninth International Conference on Hybrid Intelligent Systems

Applying concept mapping on the influent learning in virtual classroom

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Abstract—**The diversity of learning abilities between learners in the virtual classroom is wider than those in traditional classroom. It is difficult to prepare a suitable teaching material for the needs of all learners in virtual classroom. Particularly, for online learning in real time, the learners with higher abilities will have lower learning efficiency but the learners with lower abilities could not catch progress of the course. So, in this research, we propose an influent learning model to improve learning efficiency of learners in virtual classroom. In this model, teacher prepares a set of examination questions which include all pre-concepts of the course. The concept map of each learner could be built from his (or her) answers of the questions and the relations between pre-concepts. We distribute all learners to different influents based on the concept maps of learners. Thus, the teacher could adjust his (or her) teaching materials to fit the characteristics of learners in the variety of influents to improve the learners' learning efficiency.**

Keywords- virtual classroom; learning ability; online learning in real time; influent learning; concept mapping

I. INTRODUCTION

In virtual classroom, all learners could discuss with each other by discussion board, video conference, message passing, etc. They need not gather together with each other in specific space for discussion. So, the learning environment could satisfy the varieties of characteristics of all learners. But, the diversity of learning abilities between learners in the virtual classroom is wider than those in traditional classroom [7]. Thus, it is difficult to prepare teaching materials to fit all the varieties of characteristics of learners.

The learners with varieties of learning abilities could have all kinds of learning styles when they are not learning in real time. For example, they could study the pre-concepts before studying the course or to study them on demand. The learners with weaker learning ability could study a course for a longer period of time, etc. But, it is a big problem for the varieties of learners when the learning program is in real time. The learners with weaker learning ability may lose the learning interests when they could not catch the progress of the course [13]. Thus, in this research, we propose an influent learning model which divides the learners into some influents to fit the learners' characteristics.

The division is based on concept mapping [1]. The concept map of each learner could be obtained from the results of pre-examination which evaluates the cognition ability of the learner on the pre-concepts of the course. Then, all the learners are divided into some influents based on their concept maps. The learners in the same influents will have similar concept maps so that they will have similar cognition abilities. Thus, the teacher could modify the teaching contents and teaching styles based on the characteristics of the influent. The dividing results based on concept mapping are likely to fit the characteristics of learners better than the dividing results based on the overall ability index. So, the influent learning based on concept mapping is likely to reach the goal of teaching students in accordance with their aptitudes.

The concept of influent learning is similar to influent education [2]. They are both likely to reach the goal of teaching students in accordance with their aptitudes. But, influent education distributes the learners to different groups according to their abilities. After the distributing, it needs a long period of time for a learner to change the track. Thus, there exists unfairness in the influent education [18]. There also exists unfairness in the mechanism that divides classes based on ability index. The students in the same class may have similar ability just after the division. But, after a period of learning time, the diversity of abilities between learners will become larger. The proposed influent learning model just temporally divides the learners for learning a course. So, it could suit the characteristics of the variety of learners as well as avoid the unfairness existed in influent education.

II. RELATED WORKS

A. Virtual classroom

Virtual classroom is built on the network environment. The teacher and the learners interact with each other over the computers [15][17]. Virtual classroom has more multimedia contents, functions of queries, transmissions and data integrations when compared with traditional classroom [6]. Except for the asynchronous discussion board and announcement board, it offers synchronous tools for the activities of teaching, discussing, reading and testing [5][12]. By-passing temporal and spatial constrains, learning over the network environment becomes a new learning style. So, network universities become more popular [8]. For example, both Tamkang University and Taiwan University have begun to use virtual classroom as real time and synchronous learning environment [19][20][21].

Synchronous learning is a real time and interactive learning environment over the Internet [16]. Teachers and learners need to connect to network at the same time. They could discuss to each other as well as answer questions in real time. Thus, the learners are able to learning with adaptability [3]. In the other way, the learners in asynchronous learning just respectively study the teaching

978-0-7695-3745-0/09 $25.00 © 2009 IEEE
DOI 10.1109/HIS.2009.60

materials prepared by the teachers. They could not discuss to each other simultaneously.

B. Concept mapping

Concept mapping is an effective learning tool proposed by Novak [1][10][11][14]. By representing the learners' concepts with graph, it can be exposed that how concepts are organized by learners. Thus, it will be helpful for learning and recalling by the association of concept map. So, concept map could be used to evaluate a learner's mature degree of a concept [9][14]. The concept map is composited by propositions. Each proposition contains two concept nodes and relation links. The concepts are organized in hierarchical relation. The general concepts are located on upper layers while the specific concepts are located on the lower layers.

The concept map could be subjectively determined by teacher or objectively constructed from the examination results of learners [14]. We could accumulate the examination results of learners to find the error rate of a concept corresponding to each learner. If a learner's concept is more mature, the concept error rate will decrease. Thus, the learning condition of a concept could be represented by the concept error rate could [1].

The characteristics of learners could be reflected in concept map. So, we obtain the concept error rates of pre-concepts from the examination of learners. The concept error rate of concept C_i could be represented as

$$P(C_i) = \frac{E_{C_i}}{N_{C_i}} \quad (1)$$

Where E_{C_i} denotes the number of wrongly answered questions which include the concept C_i and N_{C_1} denotes the total number of questions which include the concept C_i.

III. INFLUENT LEARNING MODEL

We will discuss the influent learning model in detail. By tradition, the dividing method is to find the overall ability index of learners' ability, sort the learners by the index, and then divide them to some classes. But, with this method, the specific characteristics of learners could not be reserved. Also, we could not understand the alternative mature degrees of pre-concepts. So, in our research, we divide the learners based on their concept maps. The alternative mature degrees of all pre-concepts are contained in concept map. The learners in the same influent will have similar mature degrees. Thus, the teacher could prepare the teaching materials based on the concept maps of the influent to fit the characteristics of learners.

The influent learning model is shown in Figure 1. It includes five processing steps.

1) Preparing for teaching

Except for main contents of the course, the teachers need to find the pre-concepts $C = \{ C_1, C_2, \ldots, C_r \}$ of the course. In advance, they need to prepare a examination mechanism to understand the mature degrees of pre-concepts for the learners. So, a set of questions $Q = \{ Q_1, Q_2, \ldots, Q_S \}$ must be prepared. The relations of questions Q and pre-concepts C could be recorded in the relation matrix $R = [R_{ij}]_{sr}$. Suppose that there are s questions and r pre-concepts. And, if the i-th question contains the j-th pre-concept, R_{ij} =1. Otherwise, Rij =0.

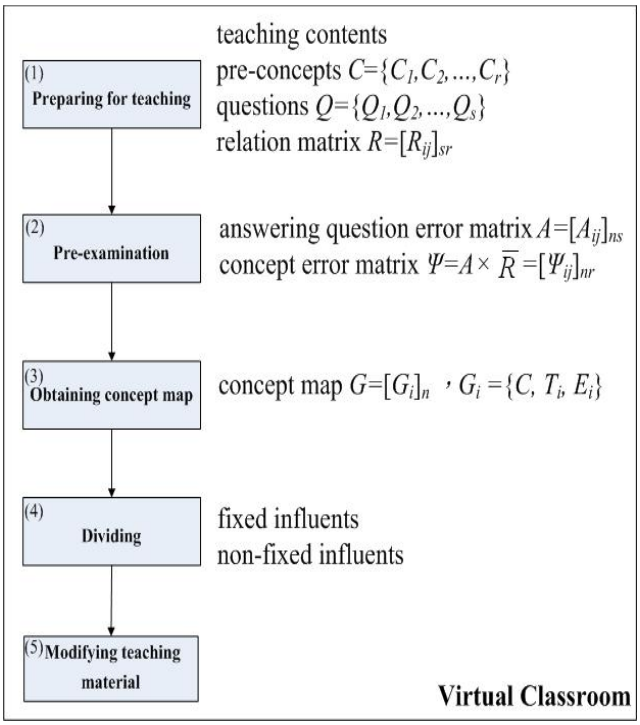

Figure 1. the influent learning model

2) Pre-examination

The pre-examination is the simplest way to find the mature degrees of pre-concepts for learners. After pre-examination, the *answering question error matrix* $A = [A_{ij}]_{ns}$ could be found. Suppose that there are n learners and s questions. And, if the *i-th* learner make wrong answer on the j-th question then A_{ij} =1. Otherwise, A_{ij} =0. The answering question error matrix A records all the answering conditions of learners. So, we could find the concept error matrix from the answering question error matrix A and the relation matrix R. That is, *concept error matrix*

$$\Psi = A \times \overline{R}, \quad (2)$$

Where $\overline{R} = [\overline{R}_{ij}]_{sr}$ is obtained from the normalization of column vectors of the relation matrix R. The normalization of column vectors makes the error effect of each pre-concept to be dispatched to each question which contains the pre-concept. So, Ψ represents the concept error rate of each pre-concept for all learners.

3) Obtaining concept map

The concept map could be represented as $G=[G_i]_n$ when there are n learners. Where $G_i = \{C, T_i, E_i\}$ records the mature degrees of the pre-concepts for the i-th learner. The terms C is the set of all pre-concepts of the course, T_i is the mature degree of pre-concepts for the i-th learner and Ei is the relations between pre-concepts in concept map of the i-th

learner. The term T_i could roughly calculated from the *i*-th row of the concept error matrix Ψ, that is, T_i=[T_{ij}]$_r$. Where

$$T_{ij}=1-\Psi_{ij}. \quad (3)$$

But, with more exactly calculation, it needs to include the effects of the neighboring concepts. That is,

$$T_{ij} = \frac{\sum_{k=1}^{r} E_{kj}(1-\Psi_{ik})}{\sum_{k=1}^{r} E_{kj}} \quad (4)$$

Where E_{jj}=1. If other pre-concepts do not related to the *i*-th pre-concept, that is, $\sum_{k=1}^{r} E_{kj} - E_{jj} = 0$, equation (4) will be simplified to equation (3). It is easier to get the concept error matrix. But the term E_i for each learner could not be easily obtained. Thus, the term E_i may be simplified to be the relation of concepts for all the learners but not the specific view of learners.

4) Dividing

The dividing step is based on the concept maps. The simplest way of division is dividing all learners into fixed influents. Suppose that there are *m* teachers (or time periods). The division is to distribute all learners $S = \{S_1, S_2, \ldots, S_n\}$ to *m* influents which are corresponding to *m* distinct concepts $G = \{G_1, G_2, \ldots, G_m\}$. We compare the concept maps of all learners with the *m* distinct concept maps. If the Euclidean distance between the concept map of S_i and G_j is the smallest one compared with the distance of other *m*-1 distinct concept maps, then S_i is distributed to the influent of G_j.

This dividing method is simple while reserving the characteristics of learners. For example, suppose that {(2,2,2), (3,3,3), (4,4,4), (1,1,4), (1,2,3), (5,2,1), (4,2,2),(5,2,3)} represents the mature degrees of 8 learners with 3 pre-concepts. If these 8 learners will be divided based on the overall ability index, the dividing results may be {{(4,4,4), (5,2,3)}, {(3,3,3), (5,2,1), (2,2,4)}, {(2,2,2), (1,1,4), (1,2,3)}}. The overall ability index make no difference of (2,2,2) and (1,1,4) for both of them are summed to be 6. The teacher could only prepare the teaching materials for high, median and low ability. On the other hand, if these 8 learners will be divided based on concept maps, the results may be {{(2,2,2), (3,3,3), (4,4,4)}, {(1,1,4), (1,2,3)}, {(5,2,1), (4,2,2), (5,2,3)}}. Thus, the teacher could prepare the teaching materials for learners corresponding to (3,3,3), (1,2,3) and (4,2,2). This dividing result could fit the characteristics of most of learners.

But, if we need to take more care on the specific characteristics of learners, it is better to be divided from the learners' point of view. It does not have the decision of the number of influents before dividing. The number of influents is depended on the distribution of the concept maps of learners. When the number of learners gets larger, this style of dividing will be more important.

5) Modifying teaching material

After dividing, the concept maps of learners in the same influent will be closer. So, the teacher could modify the teaching materials to fit the characteristics of learners.

IV. ILLUSTRATIVE EXAMPLE

In this section, we will use an illustrative example to explain the steps of the proposed influent learning model.

Step 1. Preparing for teaching

Except for main contents of the course, the teacher must list the pre-concepts *C* of the course (as shown in TABLE I), prepare a set of questions *Q* and construct the relation matrix *R* (as shown in TABLE II) corresponding to *C* and *Q*

TABLE I. THE LISTED PRE-CONCEPTS OF THE COURSE (*C*).

code	Pre-concept
C_1	Category of network protocols
C_2	Concept of network security
C_3	Domain name
C_4	Network connection
C_5	e-mail
C_6	Network connection equipments
C_7	Functions of browser
C_8	Software of communication
C_9	Category of internet
C_{10}	Functions of searching engines

TABLE II. THE RELATION MATRIX *R* CORRESPONDING TO *C* AND *Q*.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Q_1	1									
Q_2	1	1		1			1	1	1	
Q_3	1		1					1		
Q_4	1		1			1				
Q_5	1					1				
Q_6	1		1	1						
Q_7			1		1	1				
Q_8	1									
Q_9	1		1							
Q_{10}	1	1	1			1	1			1

Step 2. Pre-examination

After pre-examination, the answering question error matrix A (as shown in TABLE III) could be constructed from the answering results of learners. In advance, the concept error matrix Ψ(as shown in TABLE V) is obtained. The *normalized relation matrix* $\overline{R}$ (as shown in TABLE IV) is obtained from the normalization of column vectors of the *relation matrix R*.

TABLE III. THE ANSWERING QUESTION ERROR MATRIX A.

	Q_1	Q_2	Q_3	Q_4	Q_5	Q_6	Q_7	Q_9	Q_9	Q_{10}
S_1	1			1			1			1
S_2		1		1	1	1		1	1	1
S_3		1				1		1		
S_4	1			1						1
S_5		1				1				
S_6		1				1		1		
S_7								1	1	1
S_8										
S_9	1		1					1		
S_{10}		1				1				1

TABLE IV. THE NORMALIZED RELATION MATRIX $\overline{R}$ IS OBTAINED FROM THE NORMALIZATION OF COLUMN VECTORS OF THE RELATION MATRIX R.

TABLE V. THE CONCEPT ERROR MATRIX Ψ

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Q_1	1/9	0	0	0	0	0	0	0	0	0
Q_2	1/9	1/2	0	1/2	0	0	1/2	1/2	1	0
Q_3	1/9	0	1/6	0	0	0	0	1/2	0	0
Q_4	1/9	0	1/6	0	0	1/4	0	0	0	0
Q_5	1/9	0	0	0	0	1/4	0	0	0	0
Q_6	1/9	0	1/6	1/2	0	0	0	0	0	0
Q_7	0	0	1/6	0	1	1/4	0	0	0	0
Q_8	1/9	0	0	0	0	0	0	0	0	0
Q_9	1/9	0	1/6	0	0	0	0	0	0	0
Q_{10}	1/9	1/2	1/6	0	0	1/4	1/2	0	0	1

Step 3. Obtaining concept map

From our previous definition of concept map, $G = [G_i]_n$ when there are n learners. Where $G_i = \{C, T_i, E_i\}$ records the mature degrees of pre-concepts for the i-th learner. The terms C is the set of all the pre-concepts of the course, T_i is the mature degrees of pre-concepts for the i-th learner and Ei is the relations between the pre-concepts in concept map of the i-th learner. But, for simplicity, we just adopt the term T_i to represent the concept map of the i-th learner. We use Equation (3) to roughly calculate the mature degrees of pre-concepts of all learners (matrix T) and amplify them by 100 to form TABLE VI.

There are 10 pre-concepts in our illustrative example. Since the concept maps are represented by the mature degrees of pre-concepts, the concept maps could be represented as 10 dimensional vectors. For example, the concept of learner S_1 is represented as G_{S_1}= (67, 50, 50, 100, 0, 25, 50, 100, 100, 0), those are the elements of the first row in TABLE IV.

TABLE VI. REPRESENTING THE CONCEPT MAPS BY THE MATURE DEGREES OF PRE-CONCEPTS OF ALL LEARNERS (G=100T)

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
S_1	67	50	50	100	0	25	50	100	100	0
S_2	22	0	33	0	100	25	0	50	0	0
S_3	67	50	83	0	100	100	50	50	0	100
S_4	67	50	67	100	100	50	50	100	100	0
S_5	78	50	83	0	100	100	50	50	0	100
S_6	67	50	83	0	100	100	50	50	0	100
S_7	67	50	67	100	100	75	50	100	100	0
S_8	100	100	100	100	100	100	100	100	100	100
S_9	67	100	83	100	100	100	100	50	100	100
S_{10}	67	0	67	0	100	75	0	50	0	0

Step 4. Dividing

In this step, we divide the learners into 3 fixed influents, named A_1, A_2 and A_3. Suppose that the teaching materials are designed for 3 types of concept maps including G_{A_1} = (100, 100, 100, 100, 100, 100, 100, 100, 100, 100), G_{A_2}= (67, 50, 72, 50, 90, 75, 50, 70, 50, 50) and G_{A_3}= (0,0,0,0,0,0,0,0,0,0). The learners of concept map G_{A_1} have the characteristics of full mature pre-concepts of the course. So, the progress of the course could directly go to the main topics. The concept map G_{A_2} is the geometrical center of concept maps of all learners. The mature degree of the first pre-concept is 67% and the mature degree of the 5th pre-concept is 90%. So, the teacher could modify the teaching materials to fit the characteristics of learners in this influent. The learners of concept map G_{A_3} have the characteristics that they do not know anything. So, the teacher must teach them from the beginning.

Since each learner has his (her) specific concept map, the distributing is based on the distance between the concept maps of both the teaching material and the learner. That is to say, is the concept map of a learner closer to G_{A_1}, G_{A_2}or G_{A_3}? For example, the concept of learner S_1 is G_{S_1}= (67, 50, 50, 100, 0, 25, 50, 100, 100, 0). The distances between G_{S_1}= (67, 50, 50, 100, 0, 25, 50, 100, 100, 0) and G_{A_1}= (100, 100, 100, 100, 100, 100, 100, 100, 100, 100), G_{A_2}= (67, 50, 72, 50, 90,

75, 50, 70, 50, 50) and G_{A_3}= (0,0,0,0,0,0,0,0,0,0) are calculated as follows.

$$D_{S_1A_1}=\sqrt{(67-100)^2+(50-100)^2+(100-100)^2+...+(0-100)^2}=184.97$$

$$D_{S_1A_2}=\sqrt{(67-67)^2+(50-50)^2+(50-72)^2+...+(0-50)^2}=139.59$$

$$D_{S_1A_3}=\sqrt{(67-0)^2+(50-0)^2+(50-0)^2+...+(0-0)^2}=20643$$

Trivially, S_1 belongs to the influent of A_2. TABLE VII shows the distances between the concept maps of A_3 distinct teaching materials and all learners. We could find that both S_8 and S_9 belong to the influent of A_2 and S_2 belongs to the influent of A_3, respectively.

TABLE VII. THE DISTANCES BETWEEN THE CONCEPT MAPS OF 3 DISTINCT TEACHING MATERIALS AND ALL LEARNERS

	S_1	S_2	S_3	S_4	S_5
A_1	184.97	262.10	169.94	140.28	168.15
A_2	139.59	138.01	93.52	95.66	94.16
A_3	206.43	121.24	221.08	237.65	224.66
	S_6	S_7	S_8	S_9	S_{10}
A_1	169.94	133.43	0.00	62.27	235.17
A_2	93.52	92.33	126.48	117.24	114.13
A_3	221.08	244.14	316.23	289.62	164.63

Step 5. Modifying teaching material

Since the learners in each influent are known, all we have to do is to find the geometrical centers of the concept maps of learners in all influents. Thus, the teaching materials are modified for the concept maps G'_{A_1} = (84, 100, 92, 100, 100, 100, 100, 75, 100, 100), G'_{A_2} = (69, 43, 71, 43, 86, 75, 43, 71, 43, 43) and G'_{A_3} = (22, 0, 33, 0, 100, 25, 0, 50, 0, 0).

V. CONCLUSION AND FUTURE RESEARCH

In this research, we propose an influent learning model in virtual classroom. The concept mapping techniques are applied to dividing the learners in the influent learning model. Except for fitting the characteristics of learners, it effectively reserves the characteristics of learners for teacher to prepare the teaching materials. We construct the concept maps of learners from the results of pre-examination. And then, divide all learners into some influents based on their concept maps. Since the learners of each influent have similar mature degrees of pre-concepts of the course, the teacher could prepare the teaching materials which fit the characteristics of the learners of the influent. So, the goal of teaching students in accordance with their aptitudes could be reached.

For the future works, we will study the non-fixed dividing. By studying more about the characteristics of learners, we hope that they could improve the performance of dividing algorithm and the preparing of the teaching materials. On the other hand, we will make an evaluation model to evaluate the performance of the influent learning model.

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