Courseware Broadcasting Tree of Second Generation CAI
and Its Description Method with Fuzzy Genetic Technology

Fengxiang Zhang
School of Computer Science & Technology of
Huazhong University of Science & Technology
Wuhan, Hubei 430077, P.R.China

Yi Lan
Wuhan Star Sky Computer Co.,
Wuhan, Hubei 430077,P.R.China

Abstract: Based on our research results of many years, we presented the concepts and definitions of “differential and integral of courseware”, “differential points of knowledge”, “knowledge differential points database” and “degree of difficulty”, also a courseware broadcasting tree structure of second generation CAI—irregular X-tree network and its constructing rules. We described characteristics and problems of the broadcasting sequence as well as the features of its horizontal, vertical, and slant shifting. We took the lead on creating the description method with fuzzy genetic technology for second generation CAI by combining knowledge of fuzzy set theory, artificial intelligence, and genetic algorithm. Finally, one of our test courseware with some characteristics of second generation CAI was reported.

Key Words: Second Generation CAI, Differential and integral of courseware, Irregular X-tree, Fuzzy genetic algorithm

1. Problem Statement

The contemporary courseware is of first generation CAI, its lessons are given according to the contents (scenes) of linear sequence which are fixed so that it cannot be changed while the courseware are broadcasting. The courseware broadcasting in this manner likes the movie show. No matter audiences like this movie or not, it keeps showing. This is the manner as “pot pouring down” and never changed at any turn. This broadcasting style is only suitable for movie but not for teaching because there is no communication between the teachers and students. A teacher must give the lessons based on the knowledge level of students, otherwise its effect would not be very significant. The experiential teachers teach students in accordance with their aptitude.

The above problem is the radically problem of first generation CAI today. The contents of this kind of courseware are showing one by one according to the prearranged and unchanged path, so that the knowledge cannot be partitioned and reorganized. Because this courseware cannot store any knowledge outside the path, the stored knowledge is showing in linear sequence without taking care of the response from students. Obviously, this courseware cannot meet the requirements of distance teaching and internet-based education. In fact this courseware has already produced the side-effect in distance teaching.

For example, in the ‘programming language’ lessons of the first generation CAI courseware, in order to explain the multiple recursion, it shows some examples such as Simpson rule and N! . It is suitable for those students whose education levels are above undergraduate if this courseware uses Simpson rule to compute \( \int f(x) \, dx \) as an example, but it is not suitable for those students whose levels are not over undergraduate level. Because they have not learnt to calculus, the courseware has to choose computing N! as an example. Due to the lack of multiple teaching model, the first generation CAI can not satisfy the demands of those two kinds of students above.

In second generation CAI, in order to possess the capability of an excellent teacher, courseware has to show based on students’ education levels and their responses. When making the courseware, in order to make the courseware to possess the capability of multiple teaching model and intelligence, we have to store relative information of students into the courseware such as records of how effective of previous lectures, demands of current students including the degree of difficulty of lessons and so on. The courseware could play the segments according to what students could understand based on the previous information. For example, we use the same examples Simpson rule and N! for explaining the “multiple recursion”. Before giving the lecture, courseware automatically search information of the students, so that courseware can choose one of the two examples to teach them. If the student’s education level is above undergraduate level, then courseware can choose the Simpson rule as the example, otherwise courseware can choose N! as the example. Because in the first generation CAI, courseware cannot meet the basic teaching requirement that is to teach students in accordance of their aptitude, those courseware has already blocked the development of computer distance teaching.

2. Differential and integral of courseware and differential point of knowledge

We have been doing research work on the CAI courseware which possess mentioned functions above since 1997. And we presented the concepts of second generation CAI and the “differential of courseware” and “Integral of courseware”.

“Differential of courseware” is a concept that to partition the contents of courseware into smallest units which is called “differential point of knowledge”. We call it “differential point” in the following for short. The size of one “differential point of knowledge” unit is due to its volume of knowledge contents and its complexity, which is defined that it cannot express perfectly the knowledge field of the corresponding special field if it further partitioned. The teachers, who edit the courseware, can decide the unit size of courseware based on the requirements of this courseware. In general, the size of “knowledge point” in the first generation CAI is much bigger than of “differential point of courseware” here. “Knowledge point” refers to a whole knowledge of a special field, is
correspond with the sub-points under the section in a textbook or contains the contents in 3rd or 4th level of a book catalog, and is the smallest unit of teaching contents specified by the outline education, which is determined by scholars in the special field. Such as “CC2001” had been established by IEEE/CS and ACM. One class hour is refers only to one or several “knowledge points”. The “differential point of knowledge” of second generation CAI is much smaller than the “knowledge point” of first generation CAI. In general, the courseware knowledge point of the first generation CAI is equivalent to a group of “courseware differential points”. For example, in the actual courseware “computer network” which possesses the characteristics of second generation CAI, the mean broadcasting time of one differential point is about 1-2 minutes.

The purpose of partitioning courseware into the differential points is to split and reorganize the course so that students can choose contents, do intelligent search and broadcast the courseware based on their demands. This purpose cannot be reached in first generation CAI because the courseware contents broadcast according to the linear sequence, and there is no intelligence in first generation CAI. But in second generation CAI, all the courseware contents (all the “differential point of knowledge”) are stored in “knowledge differential point database”, each differential point has its unique name. Those unique names of all differential points are taken as names of nodes, and those nodes (a set of mapping nodes) are constructed to a broadcasting network that courseware can be partitioned and reorganized arbitrarily along the path consisting of connecting lines of any two nodes while broadcasting.

Above courseware broadcasting model is based on the concept of “integral of courseware” which is the reverse process of “differential of courseware”, and this concept is to broadcast the courseware according to connecting points selected from “differential points of courseware”.

3. Structure of broadcasting sequence and degree of difficulty

In order to do “integral of courseware” and choose to broadcast a series of “differential points” from numerous “differential points databases”, we must construct the “structure of broadcasting sequence” in advance. This structure must be constructed according to the rules below:

1. Independent of the “knowledge differential point database”.
2. Denominating the nodes of this structure according to the name of corresponding differential points (or denominating according to the name of mapping name of differential point), so that it can search the corresponding knowledge differential point by the name of node from “knowledge differential point database”.
3. The relationship of connection between nodes must measures up to the requirements of the second generation CAI. The most important requirement is that courseware can automatically choose the path according to the previous stored students’ information and the degree of difficulty that students inputted on line.

The purpose of setting up the teaching path is to simulate the capability of teachers who give lectures in different ways for different students. Most of the experienced teachers can teach one class in lots of different ways that means they can store the relative knowledge in their brain “knowledge database”. While teaching, they can choose one certain path from their brain “knowledge database” according to students’ responses, call a series of “knowledge points” on the path.

In our courseware of second generation CAI a “teaching path” would be chosen with some intelligent simulation algorithm, and also this certain path could be dynamically changed according to listener’ situation. Therefore, the multiform teaching methods that we have to store into the database in second generation CAI are much more then in first generation CAI.

“The degree of difficulty” is a parameter that is used to control the depth of courseware knowledge while courseware broadcasting, which is inputted by students. In developing our courseware “computer network” which possesses the characteristics of second generation CAI, we used to set up the maximum probability of this parameter (degree of difficulty) to “moderate”, so that it can match normal distribution.

The degree of difficulty can be real-timely inputted by students. This parameter should be changed “stepless”, but the LOM which established by LTSC of America regulated the standard of this parameter to five levels, namely “very hard”, “hard”, “medium”, “easy”, and “very easy”. Actually this standard already rated this parameter to five levels, so that it changed the consecutive degree of difficulty to inconsecutive five levels. According to this standard, we can construct the “courseware broadcasting sequence model” based on the 5-branch tree structure (see figure 1).

In this model, there is a 5-branch sub-tree under every node (differential point) which contains the corresponding five difficulty levels. This five differential points are called “next one generation differential point”, and the next second generation points is of $5^2 = 25$, the rest may be deduced by analogy, the N generation contains $5^N$ points. From here we saw that “courseware broadcasting sequence” is based on the 5-branch tree model.

4. The characteristics and problems of “courseware broadcasting sequence”

1. Structure of 5-branch tree indefinitely growth

Because the structure of 5-branch tree grows on $5^N$, it grows very fast. For example, in our actual “computer network” courseware, the mean time for broadcasting one point is around 1-2 minutes, and one lesson which is through 30 generations is going to broadcast about 45 minutes. Based on the theory above, the last generation should contain $5^{30}$ differential points, this is a huge astronomical figure for only one lesson, what about one course which has more then 10 or 20 lessons? So, it is a serious problem.

2. Courseware is a irregular 5-branch tree
According to the LOM, there are five levels that contain five corresponding sub-levels. But in fact, we cannot be up to this standard. In real application of this model, it is possible to contain corresponding 0 to several knowledge differential points under one knowledge differential point, so the probability of “5-branch” emerging is different for different courses and different levels, and is not always the peak of the normal distribution. There would be less 5 branches. In this situation, it displays “merge edge” (see figure 1). For example, the next “easy” node and “very easy” node are connecting to same parent differential point. Conversely, there were more than 5 sub-differential points under a differential point. There are two methods to solve this problem, one is to discard the extra points exceed 5 points. Another solution is to construct the irregular “dynamic X-tree” by adding branches.

5. Three Dimensional Search Path

A 5-branch tree search algorithm can be used to search a normal 5-branch tree. But students would “suddenly realize the truth” in learning. For example, a student may not be able to follow the class at the beginning, so he would turn the degree of difficulty to the “easiest”, then the courseware broadcasting system would adjust itself automatically to go through the left-most path in Figure 1. After a while, the student would find out the broadcasting contents related to some of knowledge, which he had known. So at once he understood and followed the class completely. Then he might not continue to use the “easiest” path to learn. The course were be still broadcasting. The student would probably change the degree of difficulty from “easiest” to “difficult”. It should cause a jump from low left “easiest” branch to “difficult” branch in the broadcasting tree. It might be a jump at same level or a jump between different levels. Where should the search point jump to and how to jump? There is no 5-branch tree search algorithm to solve the problem. It all depends on student’s individual intelligence and the degree of familiarity with the class materials. So we found out that “5-branch tree CAI broadcasting network” of second generation CAI is no longer a pure 5-branch tree but a new type of network called “second generation CAI broadcasting network”, which never seen before. The shape of this network is that: top is small, going down large; there is irregular 5-branch tree structure (or other tree structure depended on the standard) in vertical direction; it allows the jump intelligently in horizontal direction. The jump path can not be predefined, it can only be modeled using dynamic algorithm. The search point can jump to any branch, jump to any node of another “generation”. So this kind of structure makes the “tree” no longer a two dimensional but three dimensional.

In Figure 2, the root is regarded as 0 generation. Under the root, there are total 5 differential points of first generation: 1, 2, 3, 4, 5. Each differential point also has next generation nodes such as 11,12, 13, 14, 15, 21, 22, 23, 24, 25, ... . Number of digits for each differential point represents the number of generations. For example, differential point “1342” has 4 digits, so it is of fifth generation. The position of differential point “1342” is on the second node under the 4th branch under the 3rd branch under the first node under root.

There are three “horizontal” jump paths in Figure 2 as follows.

(1) The jump from differential point “13” to point “41” is the jump within same generation. The meaning of courseware broadcasting for this jump is that the degree of difficulty has been changed from “easy” to “difficult” while the broadcasting is still going on without interrupt. The reason for this jump is that the students feel the class is too easy that they want to increase the degree of difficulty.

(2) The jump from differential point “12” to “422” is the jump down to next generation. That means not only the degree of difficulty has been changed but also several contents has been passed without going through detail.

(3) The jump from differential point “14” to “5” is the jump backward. That means students find out the class much easier than they expected. They want to increase the degree of difficulty and go on from preceding contents.

6. Research on Description Method with Fuzzy Genetic Technology for Second Generation Courseware Broadcasting Tree

From above, we knew that the courseware broadcasting tree of second generation CAI is a net structure based on irregular x-tree. Its time complexity is O(X^n). Using ordinary tree search algorithm will be very expensive and difficult because of the irregular tree structure and net structure. Since 1997 we have been working on finding a solution. And we found that the combination of fuzzy math and artificial intelligence could solve this problem effectively. We come up an algorithm “x-tree fuzzy genetic search algorithm”. This algorithm will be described as follows.

(1) Definition of “x-tree fuzzy genetic search algorithm” for second generation CAI.

• X-tree fuzzy genetic search algorithm is the combination of fuzzy set theory and genetic algorithm from artificial intelligence.
• Using fuzzy data to define student’s understanding level for the class.
• Using genetic algorithm to simulate the whole process of automatic adjusting class progress according to student’s feedback information.
• The parent code in genetic algorithm is not a set of fix code. It is produced with current fuzzy values and student’s features, namely the parent code is based on fuzzy data and fuzzy states.

(2) Fuzzy set and degree of membership of student’s learning state

The response from students to class contents can be classified as “Easy”, “Medium” and “Difficult”. Thus three basic fuzzy set can be built, that is D (Difficult), E (Easy) and M (Medium) as follows:
\begin{align*}
D = \{ \text{Difficult, } \mu_{d0}, \text{Somewhat Difficult, } \mu_{d1}, \text{Relative Difficult, } \mu_{d2}, \text{Difficult, } \mu_{d3}, \text{Very Difficult, } \mu_{d4} \},
\end{align*}

Or described as follow vector:
\begin{align*}
\mathbf{D} = \{ \mu_{d0}, \mu_{d1}, \mu_{d2}, \mu_{d3}, \mu_{d4} \} &= \{0.8, 0.6, 0.7, 0.9, 1.0\}
\end{align*}

\begin{align*}
E &= \{ \text{Easy, } \mu_{e0}, \text{Somewhat Easy, } \mu_{e1}, \text{Relative Easy, } \mu_{e2}, \text{Easy, } \mu_{e3}, \text{Very Easy, } \mu_{e4} \},
\end{align*}

Or described as follow vector:
\begin{align*}
\mathbf{E} = \{ \mu_{e0}, \mu_{e1}, \mu_{e2}, \mu_{e3}, \mu_{e4} \} &= \{0.8, 0.6, 0.7, 0.9, 1.0\}
\end{align*}

\begin{align*}
M &= \{ \text{Medium, } \mu_{m0}, \text{Somewhat Medium, } \mu_{m1}, \text{Relative Medium, } \mu_{m2}, \text{Good, } \mu_{m3}, \text{Very Good, } \mu_{m4} \},
\end{align*}

Or described as follow vector:
\begin{align*}
\mathbf{M} = \{ \mu_{m0}, \mu_{m1}, \mu_{m2}, \mu_{m3}, \mu_{m4} \} &= \{0.8, 0.6, 0.7, 0.9, 1.0\}
\end{align*}

\begin{equation}
(3) \text{ Rules for how to use degree of membership}
\end{equation}

Five buttons will be set in the CAI system. Each button represents a fuzzy set such as “Very Difficult”, “Difficult”, “Medium”, “Easy” and “Very Easy”. Those buttons are used to reflect student’s learning states. Because “Medium” corresponds to ideal state, so it can be designed as “Default” state. When students are learning, the degree of difficulty corresponds to three fuzzy sets. Each fuzzy set also has five states. How to determine the degree of membership? It should conform to following rule:

When selecting current degree of difficult, the initial value for degree of membership is \{ \mu_{d0}, \mu_{d1}, \mu_{d2}, \mu_{d3}, \mu_{d4} \}. The degree of membership for last chosen state must be selected according to current chosen state. The rule is illustrated in Table 1, 2, 3.

\begin{table}[h]
\centering
\begin{tabular}{ |c|c|c|c|c| }
\hline
Last Chosen State & Difficult & Very Difficult & Difficult & Difficult \\
\hline
Current Chosen State & Difficult & Easy & Easy & Default & Difficult \\
\hline
Corresponding Fuzzy Set State & Difficult & Somewhat at Difficult & Relative at Difficult & Difficult & Very Difficult \\
\hline
Corresponding Degree of Membership & 0.8 & 0.6 & 0.7 & 0.9 & 1.0 \\
\hline
\end{tabular}
\caption{Table 2}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{ |c|c|c|c|c| }
\hline
Last Chosen State & Easy & Very Easy & Difficult & Difficult \\
\hline
Current Chosen State & Easy & Difficult & Difficult & Default & Easy \\
\hline
Corresponding Fuzzy Set State & Easy & Somewhat Easy & Relative Easy & Easy & Very Easy \\
\hline
Corresponding Degree of Membership & 0.8 & 0.6 & 0.7 & 0.9 & 1.0 \\
\hline
\end{tabular}
\caption{Table 1}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{ |c|c|c|c|c|c|c|c|c| }
\hline
Current Chosen State & \text{Default (Medium)} & \text{Default (Medium)} & \text{Default (Medium)} & \text{Default (Medium)} \\
\hline
Corresponding Fuzzy Set State & \text{Medum} & \text{Somewhat at Medium} & \text{Relative Medium} & \text{Good} & \text{Very Good} \\
\hline
Corresponding Degree of Membership & 0.8 & 0.6 & 0.7 & 0.9 & 1.0 \\
\hline
\end{tabular}
\caption{Table 3}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{ |c|c|c|c|c|c|c|c|c| }
\hline
Fuzzy Threshold Value & Difficult & Medium & Easy & Difficult & Medium & Easy & Difficult & Medium & Easy \\
\hline
\hline
\end{tabular}
\caption{Table 4}
\end{table}

\begin{equation}
(4) \text{ Calculation of fuzzy state data}
\end{equation}

The degree of membership of state selecting search path as well as other state information.
\begin{align*}
I &= f(\mu_{d0}[i], \mu_{m0}[j], A, T),
\end{align*}

Where, \( \mu_{d0}[i], \mu_{m0}[j], \mu_{e0}[j] \) is the degree of membership for this fuzzy set. \( i=0,1,2,3; j \) represents the generation number of selected path; \( T \) is the feedback value of measuring result; \( A \) is the feedback value to questions.

\begin{equation}
(5) \text{ Determination of parent code in genetic algorithm}
\end{equation}

Based on comparing current fuzzy prediction value with fuzzy threshold value, the parent code can be calculated. The best search path can be found out by genetic algorithm as following table 4.

\begin{table}[h]
\centering
\begin{tabular}{ |c|c|c|c|c|c|c|c|c| }
\hline
Student' s features & T1 & T2 & T3 \\
\hline
Fuzzy Threshold Value & Difficult & Medium & Easy & Difficult & Medium & Easy & Difficult & Medium & Easy \\
\hline
\hline
\end{tabular}
\caption{Table 4}
\end{table}

7. Conclusion

Distance teaching is developed rapidly with the popularization of computer network and Internet. On-line school is becoming more and more popular. But the first generation CAI still has insolvable problems. The research for second generation CAI must be brought up quickly. We must focus on its platform, automatic courseware making tools, on-line answering systems, exam systems and corresponding management systems, sample systems. Those systems would be developed with lots of computer technology including computer network, artificial intelligence, information management and so on.

This paper described a second generation CAI structure. We come up this structure in our focal project “SBF—An intelligent multimedia system for shooting, editing, showing in teaching activities” supported by Chinese Ministry of Science and Technology during 1997-1999. The structure can be implemented. We have successfully used this structure in the courseware of second generation CAI, and have successfully partly developed courseware “computer network” which has some features of second generation CAI. The achievement of the SBF has been audited and approved by the panel from Chinese Ministry of Science and Technology in 1999. The practice shows that the structure described in this paper is practicable and useful. We keep doing research on ways to improve this structure and call for further discussion over the topic in the academia.

Reference