AN ATTEMPT TO DIAGNOSE LEARNERS’ UNDERSTANDING LEVELS
CONSIDERING CONFIDENCE

Michihiro Namba
Department of Humanities
Yamanashi Eiwa College
888 Yokone Kofu,
Yamanashi, Japan
E-mail: namba@yamanashi-eiwa.ac.jp

ABSTRACT
Intelligent Tutoring Systems require a high diagnosis capability of learners’ understanding levels. “Confidence” which is subjective and fuzzy data can be expected for improvement of the diagnosis ability, but the utilization is not easy. This paper describes a diagnosis method with confidence, which uses Self Organization Map(SOM). The demonstration results showed usefulness of using confidence in estimating understanding level.

KEY WORDS
Understanding levels, Confidence, Self Organization Map, Diagnosis

1 Introduction
We often use objective materials such as correctness or answer time in order to judge learners’ understanding levels. Then, several Intelligent Tutoring Systems (ITSs)[1] which provide tutorial services that support learning have been developed. Artificial Intelligence (AI) contributes to research of ITSs because it has advanced techniques in both computer and cognitive science. Some studies build learner models by using analytical or AI methods[2, 3].

ITSs with AI models such as fuzzy rule or Bayesian network have been proposed[4, 5, 6], and have demonstrated highly precise estimation ability. However, they need a great number of learners’ data in order to use expressive fuzzy rule or statistical analysis.

Estimation system using Cellular Neural Networks(CNNs) for associative memory[7] has also been presented[8, 9]. CNNs have remarkable features of its easy implementation and a high association ability. The experimental results have shown a high capability of the system. But, we have a big task to design representative patterns which indicate center of cluster since the diagnosis performance depends on the adequacy of the designed patterns. Hence, we should design with sufficient consideration.

In order to improve the accuracy of ITSs, introducing learner’s confidence level which is one of subjective evaluation is expected. But, it is not easy to deal with it. This study attempts to diagnose understanding levels by using the confidence and other information, and uses Self-Organization Map(SOM)[10] as diagnosing tool.

SOM is a kind of artificial neural network based on competitive learning. It has input and competitive layers.

In addition, it is able to reduce high dimensions of data vectors by its efficient behavior. We can discriminate high dimensional data sets with the feature. This is remarkable function of SOM. Hence, SOM is very widely used in medical science, architectonics, economics, engineering, and so forth. In education field, a learning support system by using self organized feature map has been presented[11]. We have already reported SOM diagnosis system based on objective data, and demonstrated its capability[12].

This paper describes the method for diagnosing learner’s understanding level by using subjective/objective data and SOM, and demonstrates the usefulness of the system in diagnosis experiments for 29 learners.

2 Self Organization Map
SOM has two layers named ‘Input Layer’ and ‘Competition Layer’ (See Figure 1.). The competition layer has some array of nodes in a two dimensional plane. N—dimensional vector which each node has is named ‘Reference Vector’. Let the reference vector of i-th node and an input vector be \( w_i = (\omega_{i1}, \omega_{i2}, \cdots, \omega_{iN}) \), and \( x = (\xi_1, \xi_2, \cdots, \xi_N) \), respectively. And then, SOM determines \( w_i \) with maximum similarity to \( x \) by

\[
k = \text{argmin}_i \{||x - w_i||\}. \tag{1}
\]

The subscript \( k \) signifies the winner node. SOM performs training by revising the reference vector of the winner node. The updating function is

\[
w_i(t + 1) = w_i(t) + h_{ki}(t)(x(t) - w_i(t)), \tag{2}
\]

where \( t = 0, 1, 2, \cdots \) denotes the discrete time. Note that updating reference vectors is also performed around the winner node. \( h_{ki} \) defined as neighborhood function represents topological closeness of their nodes, and is defined as
Figure 1. Self Organization Map

\( h_{ki}(t) = \alpha(t) \exp \left\{ - \frac{||r_i - r_k||^2}{2\sigma^2(t)} \right\}, \quad (3) \)

where \( r_i \) and \( r_k \) are location vector of nodes \( i \) and \( k \) respectively. The learning rate \( \alpha(t) \) represents strength of learning, and \( \sigma(t) \) is the range of the neighborhood. They monotonically decrease according to time.

Training procedure of basic SOM is summarized below.

1. Every reference vector \( w_i(0) \) is randomized.
2. An input vector \( x \) is given for SOM.
3. SOM determines the winner node by Eq.(1).
4. Training is performed by Eq.(2).
5. The steps 2-4 are iterated.

SOM is a typical unsupervised learning model, and can map high dimensional input data into the two dimensional plane (non-linear projection).

3 Diagnosing Understanding Levels by using SOM

3.1 Outline

The outline of diagnosis system by using SOM is shown in Figure 2. We express the detail below.

1. All learner’s test data are extracted from results of test.
2. The learner’s vector is obtained from the raw data.

3. The learner’s vector is classified by SOM.
4. Learner’s understanding level is determined by the classification result.
5. The system provides appropriate feedback to the learner.

3.2 State Definition

Attribute values used in our study is described. “Accuracy” represents the correctness of the answer, and has three states (“High”, “Medium” and “Low”). “Time” shows time required for answer, and has three states (“Short”, “Medium” and “Long”). Furthermore, “Confidence” represents the learner has confidence about the answer, and has three states (“Weak”, “Medium” and “Strong”).

The system applys all learners’ vectors to these attribute values, and determines their understanding levels.

3.3 Expression of Learner Vector

A question has three attributes mentioned above. Let averages of accuracy, time and confidence of \( i \)-th unit be \( a_i, t_i \) and \( c_i (i = 1, \cdots, Q) \), respectively. Learner vector can be represented as

\[ x = (a_1, t_1, c_1, \cdots, a_i, t_i, c_i, \cdots, a_Q, t_Q, c_Q). \quad (4) \]

\( Q \) means number of units. Hence, \( x \) is \( 3Q \) dimensional vector.

4 Experimental Results

The aim of experiments is to demonstrate usefulness of confidence in diagnosing learner’s understanding level. Experiment conditions are expressed as:

1. CBT (Computer Based Testing) is adopted.
2. All 30 questions are four multiple choices.
3. Basic questions are 16, and advanced ones are 14.
4. 29 learners take part in the experiments.
5. Tests of four units ("Mathematics : Calculation, Function, Equation, Probability") are used.

4.1 Parameters of SOM

We next describe SOM parameters used in the experiment.

1. $5 \times 5$ SOM is used according to the number of participants.
2. Parameters of SOM are not optimized (General values are used).
3. Every value of learner vectors is normalized in the range of $0 \sim 1$.

4.2 Classification Results

The classification result of all the participants is shown in Figure 3. Each label in the figure denotes participant's ID. Data arranged at the same node belongs to the same cluster by property of SOM. Hence, for instance, the learners '17' and '18' located at the upper right node belongs to the same cluster. Data arranged at adjacent nodes basically belongs to the same cluster. However, boundary may exist between adjacent nodes, which means they belong to different clusters. We can’t judge learner distribution from the only figure.

Then, we use code information which shows data feature assigned in each node. It is shown in Figure 4, and consists of six fan-shaped pieces.

The size of pieces corresponds to average of classified learners. For example, see the learners '17' and '18' assigned in upper right in Figure 3, and focus on the upper right node in Figure 4. The fan-shaped pieces which correspond to “Confidence I”,”Accuracy I”,”Confidence II” and “Accuracy II” are relatively large. The symbols I and II show level of questions, and correspond to “Basic” and “Standard”, respectively. Moreover, the pieces of ”Time I” and ”Time II” is small. This result shows they have high understanding levels and answer with confidence in both levels.

We can similarly estimate understanding levels of all learners. The fan-shaped pieces indicates that all learners are classified into five clusters shown in Figure 3. We next estimate by calculating accuracy, time and confidence in each cluster. The averages in each cluster are shown in Table 2. We here focus on the clusters 'A' and 'B'. Both of them have high accuracy and short time. However, 'B' has strong confidence, and 'A' is weak. This implies the learners in 'B' can analyze their understanding levels, and the learners in 'A' can't. We can discriminate them by considering confidence. The learner in 'E' has low accuracy and strong confidence, which implies analyzing his behavior of answer and proper instruction are required.

Different instruction corresponding to the confidence will be required in order to improve quality of learning. It is not easy to effectively use the confidence which is uncertain. However, self-evaluation is very important information for evaluation and instruction. This experimental results will contribute to progressing ITSs research.

Table 1. Features of the learners '17' and '18'

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Time</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>High</td>
<td>Short</td>
<td>Strong</td>
</tr>
<tr>
<td>II</td>
<td>High</td>
<td>Short</td>
<td>Strong</td>
</tr>
</tbody>
</table>

5 Conclusion

This paper tried to diagnose understanding level considering learner’s confidence. The learner vector which represents learner’s characteristic had three attributes(correctness, time, and confidence). We next diagnosed understanding levels of 29 participants by using typical SOM. As a result, all participants could be classified into five clusters by using the visualized map and code information. Discriminating learners based on the confidence is very meaningful because we can provide more appropri-
Table 2. Analysis of classification results (Accuracy:%, Time:s)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learners</td>
<td>5</td>
<td>13</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>29</td>
</tr>
<tr>
<td>I Accuracy</td>
<td>83.8</td>
<td>89.9</td>
<td>75.0</td>
<td>59.0</td>
<td>56.3</td>
<td>78.0</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>44.7</td>
<td>43.6</td>
<td>52.4</td>
<td>79.7</td>
<td>33.1</td>
</tr>
<tr>
<td></td>
<td>Confidence</td>
<td>4.74</td>
<td>8.41</td>
<td>6.28</td>
<td>3.98</td>
<td>8.06</td>
</tr>
<tr>
<td>II Accuracy</td>
<td>47.7</td>
<td>63.3</td>
<td>19.2</td>
<td>31.7</td>
<td>15.4</td>
<td>47.2</td>
</tr>
<tr>
<td></td>
<td>Time</td>
<td>62.8</td>
<td>82.9</td>
<td>64.5</td>
<td>106.4</td>
<td>33.5</td>
</tr>
<tr>
<td></td>
<td>Confidence</td>
<td>3.58</td>
<td>6.87</td>
<td>2.08</td>
<td>2.59</td>
<td>5.54</td>
</tr>
</tbody>
</table>

Figure 4. Code information

A innovate instruction for each learner. The results contribute to ITSs research. Our future tasks are to quantify the confidence and optimize SOM parameters in order to improve diagnosis system of understanding level.

Acknowledgement

Part of this research was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science and Technology.

References


