Time-Quality Tradeoff of Waiting Strategies for Tutors to Retrieve Relevant Teaching Methods

Wen-Chung Shih, Shian-Shyong Tseng*, Che-Ching Yang and Tyne Liang

Abstract

As more and more undergraduate students act as voluntary tutors to rural pupils after school, there is a growing need for a supporting environment to facilitate adaptive instruction. Among others, a teaching method retrieval system is intended to help tutors find relevant teaching methods for teaching a particular concept. However, teaching methods demanded by tutors might not be in well-organized forms or even unwritten. Thus, the technology of conventional information retrieval cannot be simply applied to retrieve teaching methods. Therefore, we propose to invite experts (teachers) to join the support environment and provide ad hoc teaching methods. Nevertheless, it is difficult for tutors to decide how long they will wait for replies from remote teachers, which is called a due time setting problem. Furthermore, a trade-off inherent in the problem is that an early reply does not necessarily mean a good one. Our idea is to propose an interactive approach to deal with the uncertainty during retrieving teaching methods. In this study, we define this problem and evaluate several waiting strategies. A prototype has been designed and implemented, and experiments have been conducted to evaluate the performance of the four waiting strategies. The results show that waiting strategies have a significant impact on retrieval performance.

Keywords

Teaching method retrieval, Due time setting, Volunteer tutor, Availability, Trustworthiness

Introduction

Encouraged by the concept of Service Learning (Bringle & Hatcher, 1996), more and more undergraduate students are willing to serve as voluntary tutors. The e-Tutors Project (http://www.dsg.fju.edu.tw/) supported by the Ministry of Education, Taiwan, provides remote tutoring service for pupils in rural areas. The preliminary results show that the learning performance of students has been improved. However, for this service to further assist rural students, the goal of adaptive learning has to be considered in a tutoring process. In fact, most of voluntary tutors are freshmen or sophomores from universities, who might not be professional educators. Hence, a tutor supporting mechanism is needed to facilitate adaptive tutoring. Among others, a teaching method retrieval system can help tutors to find effective teaching methods for pupils.

Traditional information retrieval focuses on static text resources. Instead, teaching method retrieval focuses on ad hoc teaching method discovery. That is to say, the teaching method to be found might have not been represented in a well-organized form, and might need further processing by experts. Also, the default users of the teaching method retrieval system are tutors, instead of tutees. Specifically, a tutee is assigned a Contact Tutor and then this Contact Tutor can get assistance by finding experts in the supporting environment, such as a social network. As shown in Figure 1, when a tutor cannot successfully make the pupil understand a concept, the tutor can ask for help from a social network consisting of supporting experts and teachers.

The due time setting problem is one of the important issues for teaching method retrieval in social networks. The primary reason is that a criterion is required for decision making when a submitted query is not responded. Particularly if the query is not replied to in the expected time, which can be estimated by log mining, the user will be confused. There are two main difficulties in the Due Time Setting problem. First, it involves not only technical issues, but also subjective human factors. For example, the system can calculate the estimated due time according to the information of availability, and provide it to the user as a suggestion. This is fine when the requested peer answers in time. However, how should the user act if the requested peer does not respond in time? When unexpected situations happen, one flexible solution is to resort to users’ wills. Second, too little information about peers for decision making is available. A mechanism of peer information acquisition is needed for human decision makers.
Our idea is to interactively set due time during the teaching method retrieval process. On one hand, tutors can interactively communicate with the experts to evaluate the time needed for getting a teaching method. On the other hand, tutors can estimate the time needed for getting a teaching method according to the reputation of experts. For example, some user might want to wait longer for a quality peer, even with low availability. We have compared several waiting strategies in this scenario. To realize this idea, a two-phase framework is proposed, which consists of a construction phase and a search phase. First, due time is set to a default value estimated by the system. When the query is due, the system asks the user whether to extend the due time or not. Other information is also provided for decision making.

Experiments are conducted to evaluate the performance of these waiting strategies. A tutor supporting environment is established by this prototype system, and 100 elementary-school teachers join this experiment to serve as supporting experts. The experiments investigate the importance of due time setting, the impact of supporting experts on performance and the waiting behavior of tutors. The results show that due time setting has significant impact on teaching method retrieval performance. Also, participants’ opinions are reported.

The novelty of this paper lies in investigating the trade-off between the waiting time and quality of search results when retrieving teaching methods in social networks. The main idea is that users can interactively extend the waiting time to receive potentially desirable results. The main contribution of this work is the definition of the Due Time Setting problem for a tutor supporting environment, which addresses the trade-off between waiting time and performance of teaching method retrieval. The uniqueness of this problem lies in the integrated considerations of availability, trust and expert interests for teaching method retrieval. Furthermore, several due time setting strategies are proposed and the results of an evaluation are presented.

**Purposes of the Study**

The primary purpose of this study is to address the Due Time Setting problem which is one of the important issues for teaching method retrieval in social networks. Also, other purposes include designing and implementing a prototype for performance evaluation, and conducting experiments to evaluate the performance of the waiting strategies in the study.

An empirical study was conducted to investigate the potential of this approach as a teaching methods retrieval tool. Three research questions were posed in this empirical study.

i. What are the impacts of using different waiting strategies (Trustworthiness, Average Wait Time, Specialty and Static)?

ii. What are waiting behaviors of tutors?

iii. What are students’ opinions on using this system?
Related Work

This work addresses the trade-off occurring in “indirect information retrieval”, which means retrieving ad hoc information (teaching methods) from experts, as shown in Figure 2.

![Figure 2. Indirect Information Retrieval](image)

Information Retrieval

General information retrieval methods are mainly designed for web pages. Nevertheless, documents in specific domains may need tailor-made methods to improve their retrieval performance. For example, FAQ (Frequently Asked Questions) search (Kim et al., 2007; Kim & Seo, 2006; Wu et al., 2006) and patent retrieval (Fujita, 2007; Kang et al., 2007; Li & Shawe-Taylor, 2007) are widely investigated to find more efficient methods.

Search in peer-to-peer networks has been a flourishing research topic in recent years. A number of solutions to peer-to-peer search have been proposed (Nottelmann & Fischer, 2007; Parreira et al., 2007; Zhu et al., 2006). Zhu et al. (2006) indicated that one of the difficulties in peer-to-peer search is the lack of global statistical information, thus impeding the straightforward application of the well-known vector space model approach to peer-to-peer networks. Content search has been addressed in Shen et al. (2004) and Zeinalipour-Yazti et al. (2007). Nottelmann & Fischer (2007), Parreira et al. (2007) and Zhu et al. (2006) conducted information retrieval methodologies in peer-to-peer networks, while Yang & Chen (2008) studied social network.

Expert Finding

In recent years expert finding has been widely addressed in the field of information retrieval (Balog et al., 2009; Petkova & Croft, 2008; Zhu et al., 2009). A typical need for expert finding is as follows. An employee new to a company needs to know background knowledge on a project. An efficient and effective solution for the employee is to find an expert specializing in this project in the company. Existing models of expert finding assume that there is a large repository of documents. Then the task of expert finding is to identify experts specializing in a particular topic by analyzing the documents in the repository. Our work investigates finding experts from social networks, rather than from a large repository of documents. In the field of social networks, issues such as trustworthiness and availability are also important. The main reason for this is that: it is difficult to obtain useful expertise an expert who is not trustworthy or not available. Therefore, a feasible solution to retrieving teaching methods in a social network should consider these issues.
Wait Time Management

Issues related to waiting time setting have not been widely discussed in the literature. In Khan & Haque (2008), wait time management strategies are investigated in the context of P2P computing. In Stutzbach et al. (2006), the problem of sampling peer properties in peer-to-peer networks was addressed. They adopted an adaptive random walk approach to deal with departing peers. If a query times out, they try another peer from a stack. Tsui (2001) has reviewed techniques for peer-to-peer knowledge management. His e-learning applications have focused on the technologies of file sharing, distributed content networks and collaboration. To sum up, while related research tends to discover factors which affect the response time, we propose an interactive information retrieval environment where users can decide whether to wait for results, or not. With respect to conventional information retrieval, the waiting time has little impact on precision and recall of the retrieved results. However, in the proposed Tutor Supporting Environment it is possible for a tutor to wait longer for a teaching method, which otherwise could not be generated by the remote expert due to insufficient development time.

Problem Formulation

In this section, we formulate the Interactive Due Time Setting Problem for tutors to retrieve effective teaching methods in a social network. In a tutor supporting social network, a tutor issues a request for Teaching Methods (TM) about some Learning Concept. The problem is how the tutor can interactively set the due time to acquire an effective TM from a supporting teacher within a time constraint. The terms appearing in the problem formulation are defined as follows.

Notation and Assumption

This paper focuses on the teaching and learning “concepts” of a subject area. A “concept” is the basic unit for learning in a subject area. As shown in Figure 3, the concepts of the subject “Mathematics” are divided into four categories: Numbers, Geometry, Algebra and Probabilities. We assume that an ontology has been constructed to represent all concepts needed in this work. An ontology of learning concepts can be constructed by the method in Shih & Tseng (2009) and Shih et al. (2008a). Therefore, the task of a tutor is to make a pupil understand a “concept”.

A Teaching Method (TM) is a sequence of operations, which can be followed by the tutor to help pupils understand the meaning of a concept. For example, a tutor finds that a pupil can not understand the concept of “the perimeter of a rectangle”. One Teaching Method offered by an experienced teacher might be “the demonstration method”, in which a building block is used by the tutor to indicate its perimeter. An Effective Teaching Method is a TM which can help the pupil to understand a concept.

In the interactive Tutor Support Environment, the feedback from remote experts plays an important role in due time setting. The due time estimated by the expert herself/himself is useful information for tutors’ reference. However, tutors need other objective information to evaluate the effectiveness of this estimate. Hence, the Expert Profile is

Figure 3. Ontology of Mathematics concepts
constructed and maintained to serve as the auxiliary information for decision making. In this paper, three of the main attributes of the supporting experts are characterized to analyze their impact on the performance of waiting strategies. In the following, the term Transaction is used to mean a communication session for a tutor to consult with an expert.

- This work addresses the trade-off between the waiting time and the quality (relevance) of a retrieved teaching method. However, there is another important attribute, trustworthiness, to be considered when retrieving teaching methods in social networks. For example, when a tutor asks an on-line expert to provide a teaching method, the tutor hopes that the expert can return a relevant teaching method as soon as possible. It is highly probable that the tutor’s wish would come true if the expert is the tutor’s “good friend” in the social network. That is to say, if the expert is a trustworthy friend of the tutor, the expert will make her/his best to provide a good teaching method as soon as possible. In this study trustworthiness (Trust) means the degree of friendliness, which is measured according to their historical transactions. When the expert promises to provide a teaching method and finally fails to reply, the Trust value is set to zero for this transaction. Otherwise, the Trust value of every transaction is set to one for this transaction. The Trust value of some expert is the average of Trust values in her/his historical transactions.

Policies for initializing the trustworthiness value of an expert depend on tutors. The optimistic policy can have 1 as the initial value, which means that the tutor assumes the expert a good friend. The pessimistic policy sets the initial value to 0, which means the tutor does not trust the expert. With a neutral policy, the initial value is 0.5. Updating of trust information occurs after each retrieval transaction. Therefore, the trustworthiness value of an expert will constantly evolve.

- Actual Waiting Time (AWT): The AWT value means the actual waiting time made by the expert in some transaction. When the expert promises to provide a TM and finally fails to reply, this transaction is not adopted for calculating the average AWT value. Therefore, the average AWT value is defined based on those transactions where the tutor provided a TM within the time limit.

- Specialty (Specialty): The Specialty value measures the proportion of providing relative teaching methods in each concept for some expert (supporting teacher). The relevance of a teaching method is judged by domain experts. The Specialty value in each concept for some expert is defined as follows.

\[
\text{Specialty} = \frac{\# \text{relevant}}{\# \text{provided}} \tag{1}
\]

Based on the three attributes, corresponding waiting strategies are designed and evaluated.

Problem Definition

In a common scenario of information retrieval, such as using a search engine, users input keywords as queries to search engines for retrieving relevant web pages. Search engines then evaluate the similarity between the keywords and web pages. Next, web pages relevant to the query are retrieved and ranked according to similarity computation. On the other hand, retrieving teaching methods in social networks is conducted in a peer-to-peer manner. For example, tutors identify experts in the social network, try to access the experts and then ask the on-line experts to provide their teaching methods.

In interactive tutor supporting environments, due time setting plays an important role in retrieving teaching methods. Therefore, this work is devoted to investigating the impact of waiting strategies on the performance of teaching method retrieval, which means that a tutor issues a request for Teaching Methods (TM) about some Concept in a tutor supporting environment. The problem is, given the profile of supporting experts and the admission of interaction with supporting experts, what is the impact of different waiting strategies on the performance for Teaching Method Retrieval. Especially, we focus on three waiting strategies according to the expert profile.

We use two criteria to evaluate the performance of waiting strategies. While Reduced Recall (RR) extends the classical Recall measure by considering the waiting time, Reduced Precision (RP) extends the classical Precision measure by considering the waiting time. The two criteria are defined as follows.

\[
\text{Precision} = \frac{\# \text{relevant}}{\# \text{retrieved}} \tag{2}
\]
\[
Reduced\_Precision = \frac{Precision}{(T + T_0)}
\]
(3)

\[
Recall = \frac{\#retrieved}{\#responsive}
\]
(4)

\[
Reduced\_Recall = \frac{Recall}{(T + T_0)}
\]
(5)

where
- \#relevant is the number of relevant teaching methods;
- \#retrieved is the number of retrieved teaching methods;
- \#responsive is the number of experts who are willing to respond;
- \(T\) is the actual waiting time;
- \(T_0\) is a constant representing the time taken to initialize the transaction. In this paper, the \(T_0\) value is set 0 since we adopt relatively larger due time \(T\).

**Interactive Waiting Strategies**

The flow of Interactive Due Time Setting is an iterative process, as shown in Figure 4. Each of the iterations is composed of the following steps:
- Set Initial Due Time. When context information is not available, the initial due time can only be roughly set. However, in the interactive tutor supporting environment, the feedback from the remote expert is a good value for the initial due time.
- Set Waiting Strategy. According to available context information, such as Trustworthiness, various waiting strategies can be adopted to set a good value for the due time.
- Calculate Due Time. This step calculates the due time according to the initial due time and the waiting strategy derived in the previous steps.
- Wait for Response. When the due time is determined, the tutor waits for replies from remote experts. If the tutor duly receives teaching methods, the process ends. Otherwise, the tutor can reset the due time by initiating a new iteration.

![Flowchart](image)

*Figure 4. The flow of Interactive Due Time Setting*
We have proposed a preliminary classification of plausible waiting strategies for the purpose of evaluation, as shown in Figure 5. These waiting strategies can be classified into three categories according to available context information: Trustworthiness, Actual Waiting Time and Specialty. In general, the setting of due time can be represented by the following formula:

\[ T_{\text{Due}} = w(\text{Trust}, AWT, \text{Specialty}) \times T_{\text{Initial}} \]  

(6)

where

- \( T_{\text{Due}} \) is the due time derived from the waiting strategy;
- \( T_{\text{Initial}} \) is the initial value of the due time set by the tutor;
- \( w \) is the weighting function for adjusting the initial due time. This function has three parameters: \( \text{Trust} \), \( AWT \) and \( \text{Specialty} \). A waiting strategy can employ a combination of the three parameters to derive its due time.

![Interactive Waiting Strategies](image)

**Figure 5.** Classification of Interactive waiting strategies

The proposed waiting strategy of a tutor can be modeled by the weighting function in Formula (6) which is a combination of three parameters: \( \text{Trust} \), \( AWT \) and \( \text{Specialty} \). A tutor can work out her/his waiting strategy according to experts’ trustworthiness, average response time and specialty. In this preliminary study we address three basic and independent strategies. The meanings of these strategies are explained as follows.

**Trust-weighted Strategies**

With Trust-weighted strategies the due time is determined mainly according to experts’ trustworthiness. The more trustworthy the expert is, the longer waiting time will be derived. The physical meaning behind this strategy is to trade off additional time for possible quality content. Therefore, we expect to adjust the initial due time by the following formula:

\[ T_{\text{Due}} = \alpha_{\text{Trust}} \times \text{Trust} \times T_{\text{Initial}} \]  

(7)

where

- \( \text{Trust} \) is the historical trustworthiness value of the expert (0 \( \leq \) \( \text{Trust} \) \( \leq \) 1);
- \( \alpha_{\text{Trust}} \) is a constant larger than one, which controls the range of the derived due time.

**AWT-weighted Strategies**

The historical behavior of the expert can also be useful information for adjusting the initial due time. If the \( AWT \) (Actual Waiting Time) value of the expert is larger than the waiting time claimed by the expert, we expect to increase the initial due time by the following formula:

\[ T_{\text{Due}} = \alpha_{\text{AWT}} \times AWT \times T_{\text{Initial}} \]  

(8)

where

- \( AWT \) is the historical value of Actual Waiting Time of the expert;
- \( \alpha_{\text{AWT}} \) is a constant, which controls the range of the derived due time.

**Specialty-weighted Strategies**

With the goal of solving the question of pupils, the tutor expects to find a good teaching method, instead of a quick reply. Therefore, it is reasonable to extend the initial due time when the expert has a high Specialty value in the
learning concept. If the Specialty value of the expert is high (0 \leq Specialty \leq 1), the waiting time given by the expert would be extended to increase the possibility of obtaining a reply. Therefore, we adjust the initial due time by the following formula:

\[
T_{Due} = \alpha_{Specialty} \times Specialty \times T_{Initial}
\]  

(9)

where

- Specialty is the historical Specialty value of the expert;
- \(\alpha_{Specialty}\) is a constant, which controls the range of the derived due time.

Prototype: A Two-Phase Tutor Supporting System

To realize a Tutor Supporting Environment, a two-phase architecture is proposed, as shown in Figure 6. In the Search Phase, the tutor can retrieve teaching methods. The Interactive Teaching Method Retrieval Module enables the tutor to retrieve desirable teaching methods from the social network by submitting a query of some concept. In the Construction Phase, an Ontology is constructed and maintained to represent the concepts in the subject areas. In addition, an Expert Profile is constructed and maintained to collect and manage information about experts for decision making.
The flow of the aforementioned Interactive Teaching Method Retrieval Module is shown in Figure 7. The stage of Due Time Setting can be implemented with various waiting strategies. We have implemented the strategies for evaluation.

The initial ontology is constructed based on the Mathematics Ontology, as shown in Figure 3, by the 100 participating teachers. This ontology includes 100 concepts, which are equally divided into four categories: Numbers, Geometry, Algebra and Probabilities. With the built ontology, Expert Profile can be represented with respect to each of the concepts. In this implementation, the expert’s profile includes Trust, AWT and Specialty. An example is shown in Figure 8. For the concept “C₂”, this teacher has a high Trust value of 0.8. The average waiting time for “C₂” teaching method is 7 minutes. Also, the teacher has a middle degree of specialty, 0.5.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>...</th>
<th>Cₙ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trust</td>
<td>0</td>
<td>0.8</td>
<td>0.7</td>
<td>...</td>
<td>0.4</td>
</tr>
<tr>
<td>AWT</td>
<td>20</td>
<td>7</td>
<td>16</td>
<td>...</td>
<td>13</td>
</tr>
<tr>
<td>Specialty</td>
<td>0.1</td>
<td>0.5</td>
<td>0.3</td>
<td>...</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*Figure 8. An example of Expert Profile of some teacher*

**Experimental Results**

In this study, there are 100 pupils, 100 undergraduate tutors and 100 elementary-school teachers who volunteer to participate in this experiment and live in Taiwan. Each tutor is assigned a pupil. All teachers are involved in the three experiments. In the first experiment of Due time setting on static strategy, the participants are 4 pupils, 4 tutors and 100 teachers. In the experiment of waiting strategies evaluation, the participants are 10 pupils, 10 tutors and 100 teachers. In the last experiment of waiting behaviors of tutors, the participants are 100 pupils, 100 tutors and 100 teachers.

**Experimental Setup**

We have built a simulated Tutor Supporting Environment with the prototype system. A supporting community consisting of 100 elementary-school teachers was formed to help tutors via the Internet. To construct the profile of each supporting teacher, a training phase has been conducted for one month (from May 15 to June 15, 2009). On average, 25.5 supporting sessions have been collected for each teacher, and the distribution is shown in Figure 9.

*Figure 9. The distribution of supporting sessions*
Two criteria have been adopted to evaluate the performance of waiting strategy. Reduced Precision (RP) extends the classical Precision measure by considering the waiting time. To calculate RP, it is necessary to determine the relevance of teaching methods to concepts. In this evaluation, the work of determining the relevance was executed by human experts. Particularly, five professors, experts in e-Learning, were invited to judge whether a teaching method was relevant to a Mathematical concept or not, the relevance being decided by vote.

Impact of Due Time Setting on Static Strategy

The purpose of this first experiment was to determine the importance of Due Time Setting for retrieving teaching methods in a tutor supporting environment. A Static waiting strategy was implemented as a baseline for evaluation. The Static strategy waits for a fixed amount of time. The participants are 4 pupils, 4 tutors and 100 supporting teachers. Each tutor is assigned a pupil. Without loss of generality, we let the 4 pupils study the four subjects: Numbers, Geometry, Algebra and Probabilities. Tutors use the tutor supporting environment to retrieve teaching methods. Each pupil asks three questions about learning concepts, and the average Precision and Recall values are derived. Figure 10 shows the results with respect to classical recall and precision. First, we observe that the Recall value increases as Due Time increases for the four subjects. This means that an adaptive waiting strategy is demanded and a naïve static waiting strategy will not be suitable for this scenario. Similarly, the Precision value increases as Due Time increases for the four subjects, though not so significantly. Furthermore, we find that Due Time Setting is suitable for the scenario of Recall-oriented teaching method retrieval, which tries to find as many results as possible. For Precision-oriented teaching method retrieval, longer waiting might not significantly increase the performance.

Next, since the classic Recall and Precision measures are related to the Due Time, a new metric is needed to evaluate the performance of various waiting strategies. We use the Reduced Recall and the Reduced Precision measures to present the results of Figure 10, as shown in Figure 11. We found that the two reduced measures take Due Time into account.
consideration for the performance of teaching method retrieval. Consequently, the performance does not depend on Due Time. The range of Reduced Recall falls between 0.01 and 0.035; the range of Reduced Precision falls between 0.03 and 0.06 (excluding the values for “Due Time = 5 minutes”). Note that, although the variance looks obvious in this figure, the range of variance is really small and can nearly be neglected.

**Evaluation of Waiting Strategies**

The next experiment was to understand the impact of the expert profile on performance, with respect to Trustworthiness, Average Wait Time and Specialty. A Static waiting strategy was implemented as a baseline for evaluation. The Static strategy waits for a fixed amount of time, which is 10 minutes in this experiment. We chose the value of 10 minutes because this is the common waiting time for the participating tutors, as presented in the next section. The participants were 10 pupils, 10 tutors and 100 supporting teachers. Each tutor was assigned a pupil. The profiles of the 100 teachers are shown in Tables 2-4. Table 2 shows the teachers divided into three groups according to their Trust values. For example, the teachers of “High Trust” group are highly trustworthy, which means they used to provide useful support according historical transaction records. Tutors can trust the experts and wait for their support. However, tutors should not count on the “Low Trust” experts even though the experts have high Specialty values or short waiting time.

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Trustworthiness Range</th>
<th>Number of Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Trust</td>
<td>0.75 &lt; Trustworthiness ≤ 1</td>
<td>45</td>
</tr>
<tr>
<td>Mid. Trust</td>
<td>0.5 &lt; Trustworthiness ≤ 0.75</td>
<td>38</td>
</tr>
<tr>
<td>Low Trust</td>
<td>0 ≤ Trustworthiness ≤ 0.5</td>
<td>27</td>
</tr>
</tbody>
</table>

Table 3 shows the teachers divided into three groups according to their Average Wait Time values. For example, the teachers of “Long Wait” group let tutors wait more than 15 minutes on average. If the waiting time estimated by the teacher is far from the Average Wait Time, the Due Time might need to be adjusted to avoid unnecessary waiting.

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Average Wait Time Range</th>
<th>Number of Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Wait</td>
<td>15 min &lt; Average Wait Time</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>5 &lt; Average Wait Time ≤ 15 min</td>
<td>46</td>
</tr>
<tr>
<td>Mid. Wait</td>
<td>0 ≤ Average Wait Time ≤ 5 min</td>
<td>31</td>
</tr>
</tbody>
</table>

Similarly, Table 4 shows the teachers divided into three groups according to their Specialty values. For example, the teachers of “High Specialty” group provided relevant teaching methods, implying they are “experts” in those concepts. Therefore, we might be willing to wait longer for the “High Specialty” group to get useful teaching methods.

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Specialty Range</th>
<th>Number of Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Specialty</td>
<td>0.75 &lt; Specialty ≤ 1</td>
<td>26</td>
</tr>
<tr>
<td>Mid. Specialty</td>
<td>0.5 &lt; Specialty ≤ 0.75</td>
<td>53</td>
</tr>
<tr>
<td>Low Specialty</td>
<td>0 ≤ Specialty ≤ 0.5</td>
<td>21</td>
</tr>
</tbody>
</table>

Figure 12 shows the results with respect to Reduced Recall and Reduced Precision, which are the average values of the 10 tutoring results. In general, we observe that the three strategies had a better performance than the Static strategy. This is reasonable because a fixed due time is not suitable for the Tutor Supporting Environment, where longer waiting time will result in better precision and recall.
For Reduced Recall, as shown in Figure 12(a), the Trust strategy and the AWT strategy perform better than the Specialty strategy. The main reason might be that the tutors using the Specialty strategy tend to set longer due time than needed, which results in performance degradation. For Reduced Precision, as shown in Figure 12(b), the Trust strategy and the Specialty strategy had better performance. Based on this result, we find that the two strategies are helpful for finding relevant teaching methods.

Waiting Behavior of Tutors: Trade-off

The next experiment addressed the waiting behavior of the tutors. The participants were 100 pupils, 100 tutors and 100 supporting teachers. Each tutor was assigned a pupil. After usage training for one month, this prototype was used to form a tutor supporting environment and retrieve teaching methods. The waiting time of the 100 tutors are illustrated in Figure 13. We observed that most of the tutors set their due time to 10 minutes though larger due time results in better performance. Also, Figure 13 shows the results with respect to classic Precision and Recall, which is the average value of the 100 tutoring results.

Opinions of Students

To collect participants’ opinions on this approach, we have conducted an open-ended-question interview with ten tutor participants and ten student participants. The open-ended questions are listed as follows.

- What is your main problem while teaching/learning mathematics?
- What do you think of using this system as an auxiliary teaching mechanism?
Tutors’ opinions are summarized as follows.

- Certain mathematical concepts are difficult for students to understand. When students cannot fully understand after the instructions, one of the tutors said to students: “Practice more exercises and you will understand it someday.” The other tutors said, “Just memorize the formulas.” These tutors wanted to help students understand these concepts but they did not know the appropriate teaching methods. Oppositely, other tutors will look for useful teaching materials such as web searching or peer assistance.

- The tutors stated that the proposed approach can help them retrieve useful and valuable teaching methods. One of the tutors said, “Sometimes I do not know how to teach, this system can help me call for assistance.” Another tutor said, “Using this system can retrieve different teaching methods toward this same topic. By using those teaching methods, my student can actually understand mathematical concepts.” One tutor said, “The Trust strategy is more useful than the static strategy. With the aid of the Trust strategy, I can retrieve useful teaching materials within a time constraint.” In addition, the suggestions of tutors are that the speed of communication mechanism need to be improved especially the network bandwidth and computer performance.

Students’ opinions are summarized below, respectively.

- Some of the students stated mathematics is abstract and difficult to learn. When they could not understand mathematical concepts after they asked for help, one of the students said, “I will learn it by rote.” The other student said, “I will give up.” Consequently, it is difficult for them to finish their homework themselves.

- With the proposed approach tutors try alternative teaching methods to make them understand the meaning of mathematical concepts. Students will not hear such answers as “you will understand it someday” or “just memorize the formulas.”

**Discussion**

As a consequence of these experiments we have several findings in response to the research questions. First, waiting strategies make a significant impact on the performance of teaching method retrieval in social networks. It is found in the first two experiments that the static waiting strategy results in poor performance. When the due time is set according to experts’ attributes, such as trustworthiness, the performance of teaching method retrieval can be improved obviously. Among these strategies, the trust-based strategy had the best performance in the interactive tutor supporting environment, especially for Recall-oriented scenarios. Second, we found that more than half of the tutors wait for ten to fifteen minutes. Their behavior does not result in optimal performance. In fact, setting suitable due time will improve the retrieval performance. Finally, we found that the opinions of tutors and students are in favor of using the system.

Shih et al. (2008b) pointed out the benefits of teaching material sharing, which can effectively reduce the teaching loads of teachers. However, with the rapid growth of information, it is difficult to find the target information on the Internet (Saito & Miwa, 2007). Furthermore, tutors may not be familiar with the skills of information seeking. To assist tutors in retrieving target information, time-quality tradeoff of waiting strategies is proposed in this study. The experimental results show that the proposed three waiting strategies got better performance than static strategy. Tutors not only retrieve relevant teaching methods easily but also shorten his/her waiting time. Besides, tutors can get runtime assistance to retrieve relevant teaching methods and save time for assisting weak pupils when coaching them. As for the students, different thinking styles affect learning preferences (Sternberg, 1997). Furthermore, research has shown that the sooner students receive feedback the more effective it is for their learning (Irons, 2008). Students can benefit from feedback if they receive it before they move onto their next assignment. Based on the students’ interview results, they have a positive attitude toward the proposed approach and their learning interests are aroused by using their preferred learning approach.

Trust computation mechanisms are important to P2P networks and social networks, which are used to update the degree to which a peer trusts other peers. The trust computation is similar to the weight learning appearing in many applications. For example, self-organizing maps of neural networks use similar, however more complex, methods to update neurons’ weighting vectors. Trust computation in P2P networks has received great attention in recent years (Li & Ling, 2004; Ming et al., 2005; Zhou & Hwang, 2007), and many existing methods can be used to support the proposed due time setting method, with minor modifications. To highlight the proposed idea, we have defined the Trustworthiness of experts and calculated the Trust value by straightforward statistical methods.
In this work, both recall-oriented and precision-oriented measures are used. On one hand, the teaching tasks of the participants can be recall-oriented, such as educational content review. On the other hand, precision-oriented measures are suitable for question answering, where one correct document is enough. Furthermore, the calculation of precision involves the decision of relevance. In this work, relevance is decided by vote among five experts. However, the concept of Web 2.0 can be applied to the determination of relevance. In other words, relevance can be decided by all members in the Tutor Supporting Environment, including tutors, teachers and pupils.

Conclusions and Future Work

In this study, a tutor supporting environment is proposed and shown as a promising platform for remote tutoring services for pupils in rural areas. To reduce response time without sacrificing the quality of retrieved teaching methods, we formulate the due time setting problem in tutor supporting scenarios, and evaluate the performance of different waiting strategies.

Experimental results show that the dynamic nature of a social network will degrade the performance of retrieval strategies if they do not take the expert profile into account. Advantages of the proposed approach can be summarized as follows. First, the due time setting mechanism improves response time without sacrificing much recall. Based on the effective management of trust, average wait time and specialty information, the dynamic status of experts can be estimated. Second, the due time setting in an interactive manner redeems the possible failure in statistical estimation, and provides a flexible way for human users to make decisions of due time extension.

From the discussion above we see some educational implications of using waiting strategies in social network-based teaching method retrieval. As indicated by Yang et al. (2007), one of the important elements to achieve knowledge sharing in a virtual learning community is mutual trust. It is possible that an expert refuses to offer a teaching method to a tutor. Our study complements Yang et al.’s work by addressing the trade-off of waiting time and content quality and indicating the importance of trustworthiness for retrieving teaching methods. According to our findings, tutors should consider suitable waiting strategies in order to enhance the quality of retrieved teaching methods. In addition, it is desirable for tutors to identify trustworthy experts through historical transactions and then to enhance their mutual trust constantly. Our findings suggest a two-stage retrieval mechanism: maintain your own community of experts for consultation, and then set suitable waiting time to retrieve quality teaching methods.

In the near future, we plan to extend this work to investigate interaction between humans and systems in the tutor supporting environment. Furthermore, we will try to integrate the tutoring platform with a Wiki-based teaching material design.

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