國立交通大學

資訊科學與工程研究所

博士論文

自我組織式行為塑模應用於程式學習之研究

A Self-Organizing Behavior Modeling on Programming e-Learning

研 究 生：翁瑞鋒

指導教授：曾憲雄 博士

中華民國九十九年十二月

自我組織式行為塑模應用於程式學習之研究

A Self-Organizing Behavior Modeling on Programming e-Learning

研 究 生：翁瑞鋒　　Student：Jui-Feng Weng

指導教授：曾憲雄 博士　　Advisor：Dr. Shian-Shyong Tseng

國 立 交 通 大 學

資 訊 科 學 與 工 程 研 究 所

博 士 論 文

A Dissertation

Submitted to Department of Computer Science and Engineering

College of Computer Science

National Chiao Tung University

in partial Fulfillment of the Requirements

for the Degree of

Doctor of Philosophy

in

Computer Science

December 2010

Hsinchu, Taiwan, Republic of China

中華民國九十九年十二月

自我組織式行為塑模應用於程式學習之研究

學生：翁瑞鋒　　指導教授：曾憲雄 博士

國立交通大學資訊學院

資訊科學與工程研究所

摘要

資訊科學與工程領域的學生在學習程式語言的過程中，問題解決能力的訓練一直是很重要的課題。給一個問題時，學生要可以分析問題的屬性，判斷並選擇最適當的問題解決策略來設計程式演算法並實作。問題解決的教學一般來說是不容易的，因為不同學生即使在學習同一個問題解決策略時，常會有不同的思考錯誤徵狀發生，而不同的徵狀背後也往往是由於不同的邏輯錯誤或迷失概念造成的，也因此造成學習診斷上的困難。為了能確切診斷並提供適性化的學習導引，因此需要定義出學習行為模型來描述學習狀態。隨著 Web 2.0 式數位學習的蓬勃發展，學生的學習歷程，有機會透過社群網絡網站、討論版網站、社群標籤分享網站、維基百科與線上遊戲等平台，能更完整的紀錄下來以提供更精確的行為模式之分析，然而 Web 2.0 平台上相較於傳統課堂上單純只有老師與同學的學習環境，由於學習情境的多變性(如:社交關係)，因此不容易透過靜態分析就能一次預定出學生完整的行為模型。因此 Web 2.0 式數位學習的學習行為模型的設計有三個技術上的問題，分別是如何提供延伸性以反映行為模式的變化、如何保有穩定性以避免受到雜訊影響分析、如何保有可讀性來提供學習評量上的使用。為了解決上述這些問題，在本論文中使用知識工程技術，提出了使用本體論來定義後設資料註記之結構的方式，來標註記錄下來的學習歷程。將學生的行為模型透過本體論的概念與結構來敘述，因此可以將動態環境中學習模型之設計問題，轉成本體論建構與維護之問題。因此提出了知識本體論結晶化的概念來塑模學習行為。透過素民式知識擷取與歷程資料探勘來延伸本體論，透過群體驗證與後設資料驗證來確保本體論的穩定性，透過本體論之邏輯結構定義，搭配規則式評量系統來提供行為模型的可讀性。在實驗驗證方面，實際應用在大專生遞迴解題策略之線上學習平台上，以及國中生布林邏輯的學習上，實驗結果發現透過行為塑模提供的學習導引，能有效的提升學生的學習效果。

關鍵字: 本體論、自我組織式行為模型、程式學習、知識工程、適性化學習、社群網路服務、庶民分類、群體智慧

A Self-Organizing Behavior Modeling on Programming e-Learning

Student: Jui-Feng Weng Advisor: Dr. Shian-Shyong Tseng

Department of Computer Science and Engineering

National Chiao Tung University

Abstract

The problem solving capability is important for students in the Programming course of Computer Science. While given the problem, students need to firstly analyze the problem and select an appropriate problem solving strategy for further flow chart design and code implementation. Problem solving in programming is generally considered to be difficult because different students usually have different error symptoms and the symptoms usually have different root causes. Therefore, to provide the adaptive learning guidance, a behavior model is needed to describe the students' learning status. In Web 2.0-based e-Learning environment, the students' portfolio on the platforms of social network service, web forum, social bookmark, Wikipedia, web games, etc. can be used as the potential resources to build the students' behavior model precisely. However, the changing of learning context such as social networks on the Web 2.0 platforms make it more difficult to predefine the students' behavior model using one shot approach. Therefore in Web 2.0-based e-Learning, there are three technical issues for behavior modeling which are the extensibility for modeling the evolving behaviors, the stability for noise handling, and the understandability for learning behavior assessment. How to provide a learning behavior model which can be self-organized to maintain and discover the evolving behaviors becomes an important and challenging issue.

In this dissertation, the learning behavior modeling problem is defined as that *given the learning content and context of learning activity, how to model the students' behaviors to provide adaptive learning guidance*. Under different learning contexts,

the behavior modeling problem can be reduced to the *problem solving strategy formulation and realization problem* for self programming learning, the *trustworthy experts modeling problem* for inquiry learning, and the *consensus building problem* for folksonomy-based knowledge sharing activity.

With our observations, students could have meaningful learning actions when the purposes of the actions in specific learning context are obtained. Accordingly, to build the students' behavior model, the Purpose-based Ontology is built to model the purpose of the actions. Next, the ontology-based learner behavior modeling approach is proposed to analyze the frequent action patterns and organize the obtained patterns with the structure of ontology as learning behaviors. Therefore, the learning guidance issues under different contexts can be resolved by the following behavior modeling approaches to provide the adaptive learning guidance based on the built behaviors. Under the context of intelligent tutoring system, the *Generalized Model Tracing* approach is proposed to organize the diagnosis results of different program model tracing with *Problem Solving Strategy Ontology*. The diagnosis result can be used to provide the learning guidance for problem solving strategy. Under the context of learning forum, the *Cascading Topic Clustering Algorithm* and *Self-organized Ontology Maintenance Scheme* are proposed to organize the forum experts' inquiry activities with the *Purpose-based Ontology*. Building the forum experts' behavior model can provide trustworthy expert finding service for inquiry-based learning. Under the context of collaborative constructed sharable content repository, the *IRT-Based Metadata Reengineering Scheme* is proposed to evaluate the effectiveness of folksonomy tags and resolve the synonym, redundancy and incompleteness problem of metadata by the domain taxonomy. Accordingly, the tag effectiveness value can detect the conflict and provide the tagging guidance to resolve the consensus building problem to obtain the well-tagged metadata. To evaluate the proposed behavior modeling approach, the applications with different learning contexts are investigated including *adaptive programming misconception diagnosis, game rule tuning learning activity, trustworthy expert finding service for inquiry learning on the programming learning forum,* and *intelligent solution retrieval system.* The experiments for students' learning effectiveness have been done. The experimental results show the applications with behavior models have higher learning effects.

Keywords: ontology, self-organizing behavior model, programming learning, metadata reengineering, adaptive learning, social network service, folksonomy, collective intelligence

誌謝

本論文能完成，首先要感謝的是我的指導教授 曾憲雄博士。跟隨 曾教授一路從碩士班到博士班這將近十年的研究歲月裡，親自感受到 曾教授不論在教學研究或為人處事，都為學生樹立典範。常常透過日常的對話，將學術研究中許多抽象層次、哲理的思考，透過獨到的創意思考方式，循循善誘並激發我們對問題的解析，讓學生體會領會研究的奧妙與樂趣。因此本論文的誕生，以及學生各方面能力的成長，主要感謝 曾教授對我的指導與鼓勵。

此外特別要感謝從論文研究計畫書口試、校內口試到最後口試一路給予我許多論文修改建議的 孫春在教授與袁賢銘教授，讓我重新檢視本論文的研究核心貢獻。感謝在校內口試中，彭文志教授對成果整理與呈現方式的提點；也感謝在最後口試中，給予我寶貴意見的 黃國禎教授、 楊鎮華教授、蘇豐文教授以及 陳孟彰老師，對於論文方法與結果呈現，給於精闢的見解與指導。由於他們的指正，讓此論文最後的呈現能夠更加強一致性與連貫性，讓整體論文能更加的完整。

感謝交大知識工程實驗室的夥伴們，特別是蘇俊銘學長在計畫與研究上許多經驗的指導，時文中學長與李威勳學長們的鼓勵，跟我一起在參當勞奮鬥的兄弟們楊哲青、李宗儒、董元昕與曲衍旭，以及許多屆實驗室的學弟妹們，大家的革命情感是永久的。也感謝蓮芳給我的支援與幫助。同時也感謝系辦的俞美珠、馮詠喬與楊耀萱協助口試與畢業相關事宜，以及給我的支援、包容與鼓勵。

要感謝的人太多，謹將本篇論文的完成，獻給我親愛的爸爸、媽媽，以及一路照顧支持我的老婆雅惠。博士畢業，是另一段研究生涯的開始，期望在未來的人生中，我能不忘初衷，持續在自己喜歡的學術研究中保有熱誠，並進一步貢獻給世界。

翁瑞鋒

2010 年，新竹交通大學

Table of Contents

List of Figures

List of Tables

Chapter 1 Introduction

The problem solving capability is important for students in the Programming course of Computer Science. While given the problem, students need to firstly analyze the problem and select an appropriate problem solving strategy for further flow chart design and code implementation. Problem solving in programming is generally considered to be difficult because different students usually have different error symptoms and the symptoms usually have different root causes. Therefore, to provide the adaptive learning guidance, a behavior model is needed to describe the students' learning status.

With the growth of Web 2.0 technology, students use lots of Web applications such as social network service, web forum, social bookmark, Wikipedia, etc. during learning or homework time and thus several practitioners start the new research field of *Web 2.0-based e-Learning*. As Shown in Figure 1.1, current students' programming learning activities such as online testing, social network service, Web forum, social bookmark, Wikipedia, sharing technical articles, etc. are getting more and more popular.

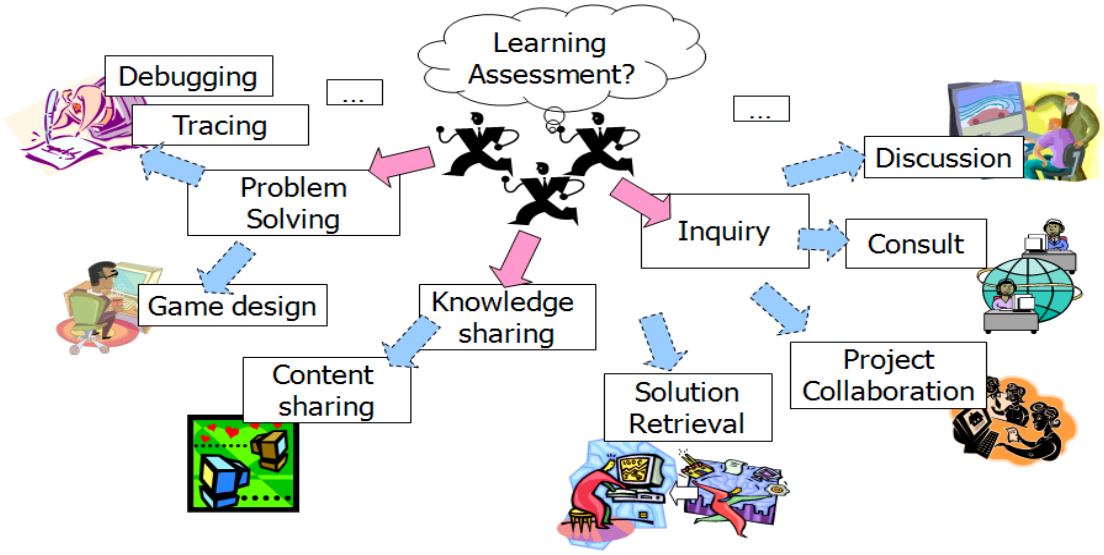


Figure 1.1 Web 2.0-based programming e-Learning

In Web 2.0-based e-Learning environment, the learning contexts such as computer adaptive testing, learning companions on the social network platforms, technical documents on the forum, etc. can be used as the potential resources to build the students' behavior model precisely to provide the adaptive learning guidance.

However, the multidisciplinary knowledge and the changing of learning community on the Web 2.0 platforms make the students' behaviors more complex. In addition, the new Web 2.0 applications and technologies of learning environment emerge rapidly. The learner's behavior models evolve as well. Therefore in Web 2.0-based e-Learning, there are three technical issues for behavior modeling which are the extensibility for modeling the evolving behaviors, the stability for noise handling, and the understandability for learning behavior assessment. How to provide a learning behavior model which can be self-organized to maintain and discover the evolving behaviors becomes an important and challenging issue.

In this dissertation, the learning behavior modeling problem is defined as *given the learning content and context of learning activity, how to model the students' behaviors to provide adaptive learning guidance*. Under different learning contexts,

the behavior modeling problem can be reduced to the *problem solving strategy formulation and realization problem* for self programming learning, the *trustworthy experts modeling problem* for inquiry learning, and the *consensus building problem* for folksonomy-based knowledge sharing activity.

With our observations, students may have meaningful learning actions when the purposes of the actions in specific learning context can be obtained. Accordingly, to build the students' behavior model, the Purpose-based Ontology is built to model the purpose of the actions. Next, the ontology-based learner behavior modeling approach is proposed to analyze the frequent action patterns and organize the obtained patterns with the structure of Purpose-based Ontology as learning behaviors. Therefore, the adaptive learning guidance can be provided based on the built behavior models.

The behavior modeling approaches for adaptive learning guidance are proposed in three learning contexts which are the *self-assessment activity on the online tutoring system, programming inquiry activity on the learning forum, and knowledge sharing activity on the content repository*.

For the self-assessment activity on the online tutoring system, the *Generalized Model Tracing* approach is proposed to organize the diagnosis results of different program model tracing with *Problem Solving Strategy Ontology*. The diagnosis result can be used to provide the learning guidance for problem solving strategy.

For the programming inquiry activity on the learning forum, the *Cascading Topic Clustering Algorithm* and *Self-organized Ontology Maintenance Scheme* are proposed to organize the forum experts' inquiry activities with the *Purpose-based Ontology*. Building the forum experts' behavior model can provide trustworthy expert finding service for inquiry-based learning.

For the knowledge sharing activity on the content repository, the *IRT-Based*

Metadata Reengineering Scheme is proposed to evaluate the effectiveness of folksonomy tags and resolve the synonym, redundancy and incompleteness problem of metadata by the domain taxonomy. Accordingly, the tag effectiveness value can detect the conflict and provide the tagging guidance to resolve the consensus building problem to obtain the well-tagged metadata.

To evaluate the effectiveness of proposed behavior modeling approach, the learning guidance applications with different learning contexts are investigated including *adaptive programming misconception diagnosis*, *game rule tuning learning activity, trustworthy expert finding service for inquiry learning on the programming learning forum*, and *intelligent solution retrieval system.* The effectiveness evaluation of behavior modeling is based on the comparison between learning effects of the applications with and without the behavior model. The experimental results show that the applications with behavior models have higher learning achievements.

The rest of this dissertation is organized as follows. In Chapter 2, we review the previous work on related research. Then, the overview of the proposed framework is presented in Chapter 3. Next, the behavior modeling approaches of three learning activities are introduced in Chapters 4, 5 and 6, respectively. Finally, a discussion of the main contribution and the concluding remarks are shown in Chapter 7.

Chapter 2 Related works

In this chapter, the literature reviews of ontology-based modeling approaches and programming learning behavior modeling are provided.

2.1 Ontology-based modeling approaches

- **Ontology-based intelligent tutoring system**

In e-Learning domain, the ontology is widely used to denote the representative concepts and associated relations among learning materials. To manage a large number of learning materials, many Learning Content Management Systems (LCMS) have been proposed by means of the ontology-based approach [1][25][32][33][42][48][66]. The e-learning was considered as the "learning of organizational memory"; thus the ontology and semantic web technology were used to capitalize the learning knowledge and index the learning resources. In [31][53], the concept map was applied to visualize the learner's thought and then connect the concepts to the learning contents in LCMS. Thus, the students were able to browse and explore the relevant leaning contents to extend their understanding via the concept maps. In QBLS [24], the ontology with domain model and pedagogical model was proposed to support the design and annotation of the learning resources. Thus, the QBLS can provide the efficient concept information and reasoning mechanisms for the adaptive learning system. It was mentioned that the reusing of existing ontology was a quite conclusive approach. However it also outlined the difficulty of finding acceptable match between different visions of a domain while using the ontology.

Besides the annotation of the learning contents for adaptive learning, in [36][37] the ontology was used as the intelligent assessment model. After the exam, each learner can have a personal assessment result to indicate the misconception and possible

remedial suggestions by referring the structure of concept map. The Salisbury [65] indicated that to achieve efficient performance in a higher level skill, it was required to have some basic perquisite concepts. Thus, the concept effect relationship was applied to annotate the concepts of test items and remedial learning information.

In summary, the effectiveness of the surveyed adaptive e-learning systems and assessment systems were highly dependent on the well defined domain ontology. However, how to construct an acceptable ontology for more complex or larger domain is still a challenging issue.

- **Taxonomy-based Ontology Construction and Folksonomy-based Ontology Construction**

In order to assist the experts constructing ontology, traditional taxonomy-based ontology authoring tools such as Protégé [78], OilEd[8], JOE [45], and SWOOP [38] with Graphical User Interface have been developed to visualize the concepts and their associated relations. These tools are designed for individual user ontology construction with top-down domain analysis process. However, in some dynamic or complex domain, it is costly and time-consuming for individuals to construct an acceptable ontology. Therefore, the collaborative ontology construction approaches are proposed with different incremental ontology learning strategies.

With rapid growth of Web 2.0, one of the emerging visions is the “collective intelligence” of a community of users to contribute their knowledge. The folksonomies mean the user-generated classification keywords, emerging through bottom-up consensus [80]. In this dissertation, we regard folksonomies as an ontology constructed by community. According to Wikipedia experience, we know that communities can provide knowledge more quickly and widely than small group of

experts. Therefore recent researches tended to propose the collaborative folksonomy-based ontology construction approaches. Researches such as Ontolingua [30], Collaborative Ontology Building (COB) [7], and OntoWiki [4] construct a web space where members of the ontology developers community can access, browse, edit, and modify ontologies. Each member of community can contribute to ontology with their background knowledge. Although various knowledge can be rapidly collected from the community members, the system administrator still has to manage the ontology manually. Furthermore, the growth of the amount of data brings more conflicts and noises. The lack of a convergence methodology may result in ontology distortion.

2.2 Programming learning behavior modeling

- **Model tracing**

To support the programming learning, previous studies [22][61] proposed the algorithm animation to demonstrate the execution process of program. With the progress of the program development kit, most of the debugging tools allow the program to be traced step by step and assist the programmer discover the bugs with less effort. However, these tools are basically designed for programmers who can trace the program by themselves, since the provided messages are too difficult for novice learners to understand.

To support the programming learning, the Intelligent Tutoring Systems such as LISP Tutor [3] or DISCOVER [60] are proposed with the interactive practice system using model tracing approach. In the debugging test, the designed buggy patterns are placed in the program and the novice learner is asked to discover them. In [40], a tutoring system with program debugging interface was proposed. However, for the

novice learners who can't write the correct program, how to assess their possible misconception from mistake symptoms and provide the appropriate remedial learning is also an interesting and challenging issue.

• Programming learning with context of game design

To motivate the students' learning interest, the game design is widely accepted as an effective way [47][52]. The researches about game design with learning models such as the learning through project-based learning [20] or problem-based learning [64] with innovative programming laboratories were proposed. These researches show that the interesting game design as learning scenario can effectively engage the students' learning. With our observation, the common attractive point of these learning models is that the game design learning content provides interesting scenario instead of abstract concepts provided by traditional lecturing approach.

The narrative and storytelling has a long history of use in structuring, organizing and communicating human. The benefits of using cases and stories for instruction have been demonstrated in many studies. In [77], the narrative-based interactive learning environment generates the cases from knowledge base to support the training of novice in decision making. In [39], the Case-Based Reasoning approach has been applied to support the construction of cognitive model of simulation-based learning system and serious games. These studies used the knowledge base system to support the generation of learning cases with meaningful scenario for the students.

• Social network assisted programming learning

Besides the syntactic level learning, the training of problem solving skills such as the learning through project-based learning [11][17][20][65] or problem-based

learning [35][64] with innovative programming laboratories were investigated. The interesting learning context such as game design was adopted to motivate the learners' engagement. As even small projects are usually implemented in teamwork, the collaboration among members becomes a new issue. Thus, researches based on the social-culture constructivism were proposed to provide the collaborative programming environments [14][15][17][51][56][58][60][70] or the peer assessment activities [9][44][69]. The collective, collaborative learning tools such as discussion board, e-mail, etc are integrated in the learning platform. The assessment through portfolio analysis usually applied to model the behaviors of students [16][18][41][50][63][67].

Chapter 3
Self-organizing Behavior Modeling

Problem solving is the most important capability for learners in Programming Language subject. While given the problem, students need to firstly analyze the problem and select an appropriate problem solving strategy for further flow chart design and code implementation. Therefore, how to provide the adaptive learning guidance for problem analysis is our concern.

3.1 Behavior modeling problem

Current students' programming learning activities such as programming forum discussion, online testing, reading online technical articles, download sample codes, content sharing, etc. are getting more and more popular. To provide the adaptive learning guidance for problem analysis, the learning contexts such as visualization tools, inquiry learning companions, technical documents, etc. are important resources in Web 2.0-based e-Learning environment. The platforms of social network service, web forum, social bookmark, Wikipedia, web games, etc. can act as the potential activity resources to build the students' behavior model. As Shown in Figure 3.1, the students' behaviors of learning diagnosis, project-based game creation, inquiry learning, and knowledge sharing activities can be obtained from the accessing of resource contexts and interaction or collaboration with social contexts.

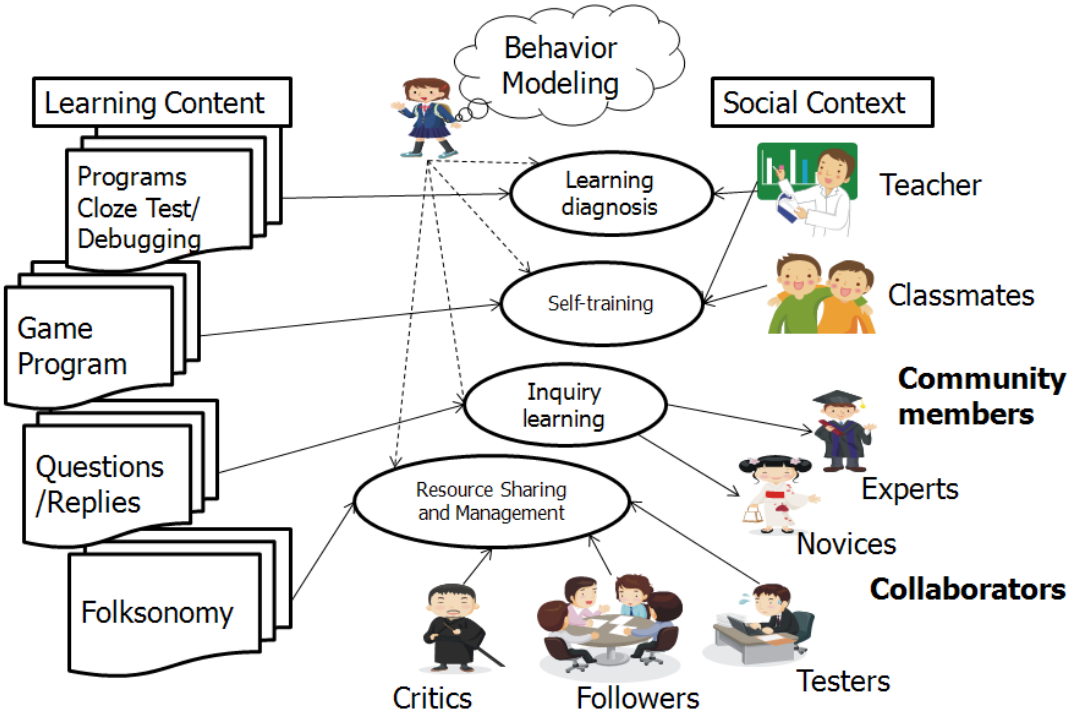


Figure 3.1 The e-learning activities with different contents and contexts

However, the multidisciplinary knowledge and the changing of learning community on the Web 2.0 platforms make the students' behaviors more complex. Therefore, how to acquire and update the learning behavior models becomes an important and challenging issue. In this dissertation, the learning behavior modeling problem is defined as followings.

Definition 3.1 The Learner Behavior Modeling Problem (LBMP)

Given the learning content and context of learning activity, LBMP is how to model the students' behaviors to provide adaptive learning guidance.

To simplify the discussion, the inquiry-based programming learning scenario is proposed with three learning activities as shown in Figure 3.2 and the behavior modeling are discussed in Chapter 4, Chapter 5 and Chapter 6, respectively. While

students participate in the inquiry-based programming e-learning, they firstly participate in the self-assessment activity on the online testing system to discover the possible misconceptions. While the misconception for specific programming topic is discovered, the learner can inquire the solution with other community members on the Web forum by posting questions. After several iterations of discussions, while the students figure out the misconception, they can share the learned knowledge on the Web content repository by uploading the learning reports or extending the concept ontology to annotate the new discovery. Besides, the students can retrieve the contents related to the learned concepts and adds their comments for the contents.

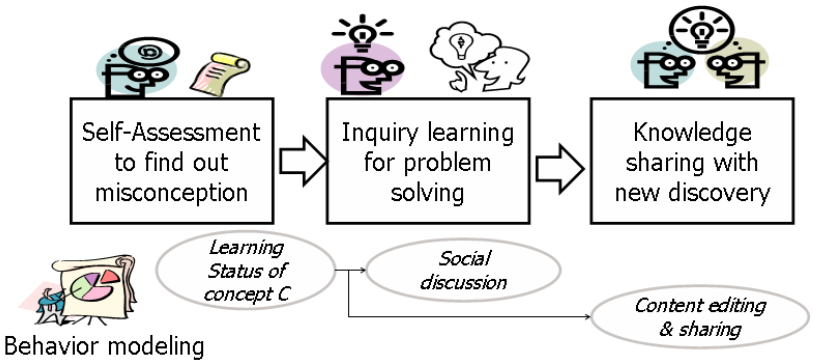


Figure 3.2 The inquiry-based programming e-learning

Students on different platforms usually have different behaviors due to different contexts. Therefore, under different learning contexts, the behavior modeling problem can be reduced to the *problem solving strategy formulation and realization problem* for self programming learning, the *trustworthy experts modeling problem* for inquiry learning, and the *consensus building problem* for folksonomy-based knowledge sharing activity.

3.2 The idea

With our observations, students could have meaningful learning actions when the purposes of the actions in specific learning context are obtained. To model this property in the learning platform, the knowledge-based programming learning platform is proposed to provide learning guidance based on the high level knowledge structure as shown in Figure 3.3. The learning content ontology is used to construct the metadata and assessment rule for the learning status of students. From the obtained portfolio, the guidance rules of learning platform can be extended by the ontology evolving process called ontology crystallization.

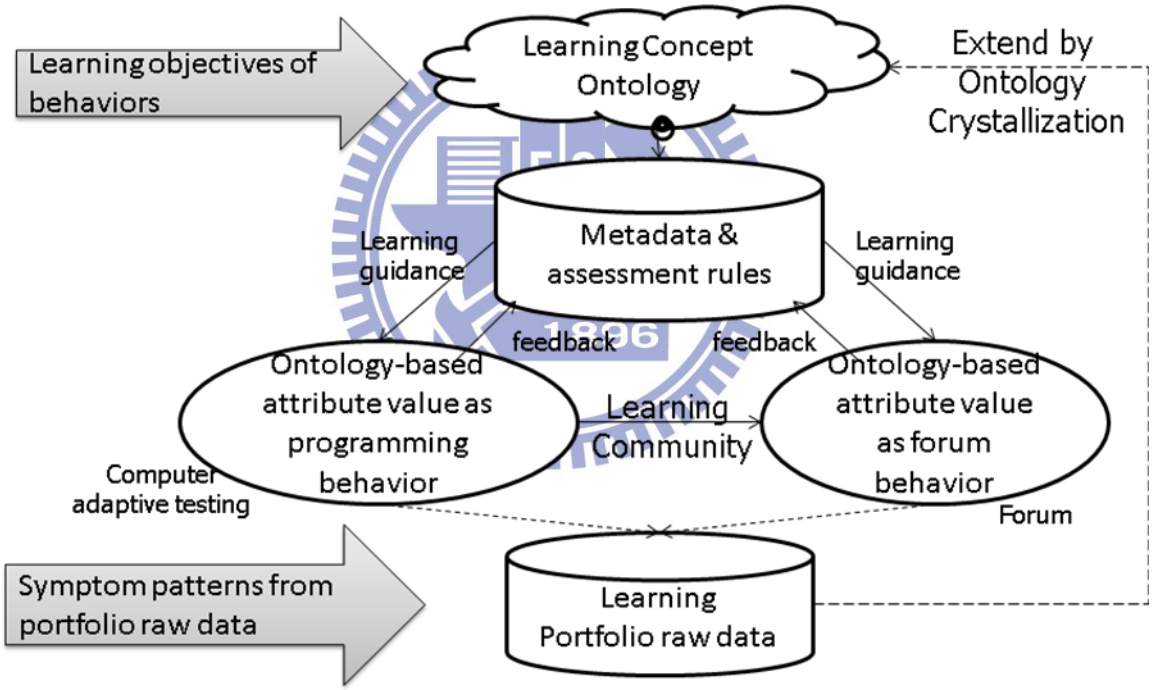


Figure 3.3 The knowledge-based programming learning platform

With the knowledge-based learning platform, the knowledge engineering approach is applied to obtain the self-organizing behavior model as shown in Figure 3.4. There are four steps in the self-organizing model which are the knowledge representation to define the extensible ontology structure, the knowledge acquisition

to extend the knowledge from folksonomy and maintain the stability using the proposed *Folksonomy-based Delphi method*, the knowledge reasoning to provide learning guidance using the assessment rules generated from constructed Ontology and the knowledge retaining to discover new behaviors and maintain the stability by proposed *cascading data mining*.

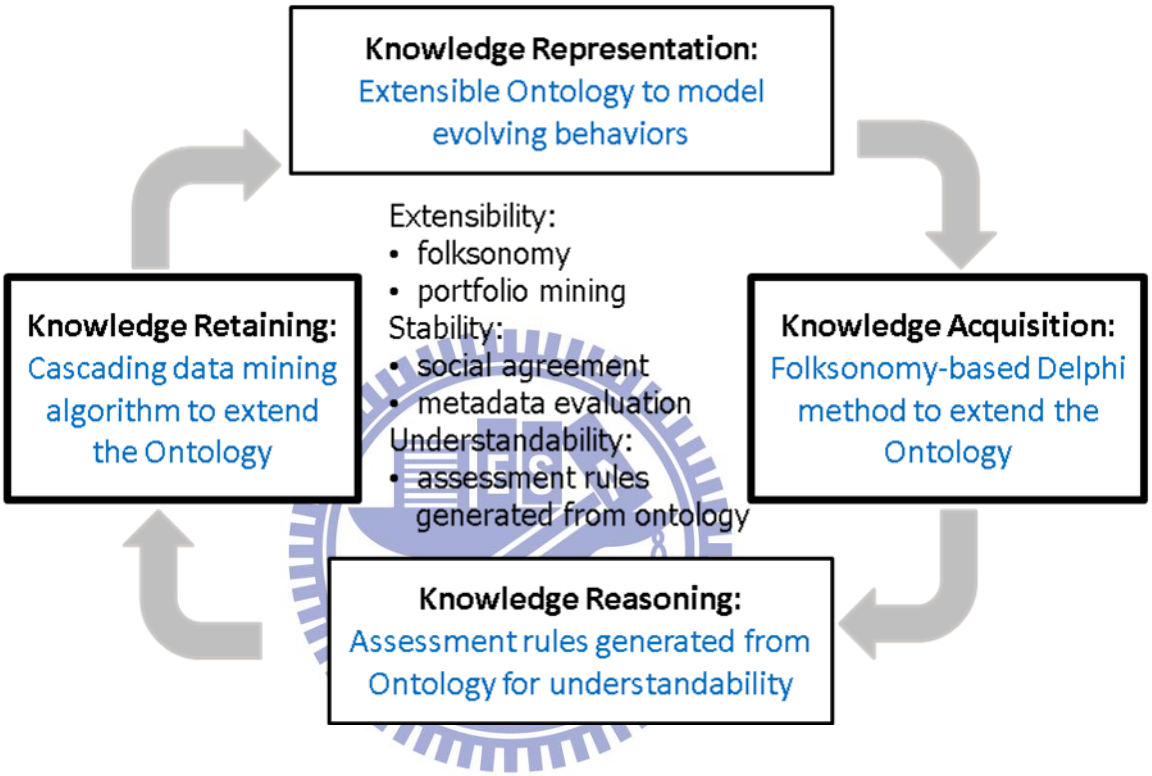


Figure 3.4 The knowledge engineering for self-organizing behavior modeling

Accordingly, to build the students' behavior model, the Purpose-based Ontology is built to model the purpose of the actions. The definition of Purpose-based Ontology is as followings.

Definition 3.2 The Purpose-based Ontology (O) is defined as O = (P, C, A, R), where

- $P=\{p_1, p_2, \ldots, p_n\}$ is a finite set of purpose nodes in the *Purpose Layer* to represent predefined purposes in the domain.

- For each purpose p_i, the concepts $C_i=\{p_i.c_1, p_i.c_2, \ldots\}$ is a finite set of topic nodes in the *Concept Layer* to represent different topics discussed in the forum. Topic nodes are linked to the corresponding purpose node by the "*A Part OF*" relations.
- For each purpose p_i and concept c_j, the action $A_{ijk}=\{ p_i.c_j.a_1, p_i.c_j.a_2, \ldots\}$ is a finite set of nodes in the *Action Layer* to represent the linkages associated to the original action log. The action nodes are linked to the corresponding concept node by the "*Instance Of*" relations.

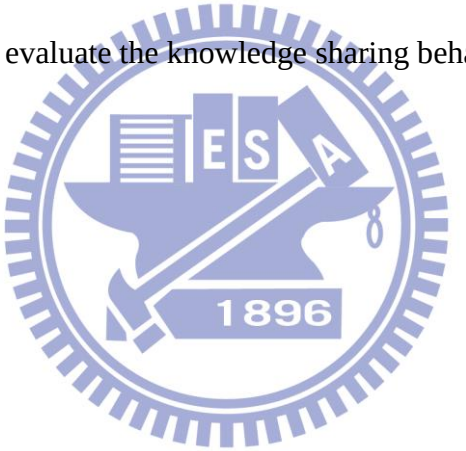
The Purpose-based Ontology can be instantiated to different concepts definition in different learning contexts. Next, the ontology-based learner behavior modeling approach is proposed to analyze the frequent action patterns and organize the obtained patterns with the structure of ontology as learning behaviors. Therefore, the learning guidance issues under different contexts can be resolved by the following behavior modeling approaches to provide the adaptive learning guidance based on the built behavior models.

Under the context of intelligent tutoring system, the *Generalized Model Tracing* approach is proposed to organize the diagnosis results of different program model tracing with *Problem Solving Strategy Ontology*. The diagnosis result can be used to provide the learning guidance for problem solving strategy. The learning guidance applications of *adaptive programming misconception diagnosis* and *game rule tuning learning activity* are investigated to evaluate the self-assessment behavior model.

Under the context of learning forum, the *Cascading Topic Clustering Algorithm* and *Self-organized Ontology Maintenance Scheme* are proposed to organize the forum experts' inquiry activities with the *Purpose-based Ontology*. Building the forum experts' behavior model can provide trustworthy expert finding service for

inquiry-based learning. The learning guidance application of *trustworthy expert finding service for inquiry learning on the programming learning forum* is investigated to evaluate the inquiry behavior model.

Under the context of collaborative constructed sharable content repository, the *IRT-Based Metadata Reengineering Scheme* is proposed to evaluate the effectiveness of folksonomy tags and resolve the synonym, redundancy and incompleteness problem of metadata by the domain taxonomy. Accordingly, the tag effectiveness value can detect the conflict and provide the tagging guidance to resolve the consensus building problem to obtain the well-tagged metadata. The learning guidance applications of *metadata reengineering* and *intelligent solution retrieval system* are investigated to evaluate the knowledge sharing behavior model.



Chapter 4
Behavior modeling of self-assessment activity on online testing system

Comprehending the program examples is important for students in the course of Introductory to Programming to develop their problem solving capability. With our observation, well-trained programmers usually have the capability to explain the problem solving strategic concept of program examples. For example, the *linear recurrence strategy* is used in the *Selection Sort Program* to reduce the original sorting problem of n elements into the sub-problem of sorting n-1 elements. The recurrence strategy can be used in a series of programming designs such as *quick sort*, *binary search*, *printing multiplication table*, etc. In this chapter, the behavior modeling to provide adaptive learning guidance for problem analysis is discussed.

4.1 Programming behavior modeling to provide adaptive testing and learning guidance

To model the programming learning behavior, the Bloom's taxonomy [10] can be used to classify the programming learning achievement into different capability levels. The first is knowledge level in which the students can recognize the syntax and statement of program. The second is comprehension level in which the students can understand the semantic flow chart of program. The third is application level in which the students can understand the problem solving strategy used in the algorithm [21]. The fourth is problem analysis level in which the learner can analyze the properties of problem and select suitable problem solving strategy. However, most students can

only understand the knowledge level of the program examples. Thus, students are usually frustrated by the high barrier of program designing in the advanced programming course.

In the researches of behavior modeling on programming testing, the model tracing approach [3][40][60] is the most well-known. The traditional model tracing approach is based on a sample program of specific problem. Before testing, the student's possible coding actions should be modeled already. Thus, the testing process would interactively ask student to write down the code step by step. During the model tracing process, once the student encounters troubles in some step, the corresponding remedial instructions can be triggered to assist the student to finish the program coding. However, traditional model tracing approach can only support the intra-program behavior assessment e.g., it can only provide the syntax and semantic level instructions of single program statement.

To solve the problem, this chapter applied the pedagogical theory of Vygotsky's Zone of Proximal Development to support students learning the problem solving strategy with the metacognitive scaffolding. The *Problem Solving Strategy Ontology* is constructed to connect the relationship between low level programming statements and high level problem solving strategic concept.

Definition 4.1 Problem Solving Strategy Ontology (PSSO)

There are three layers in PSSO:

- Problem Strategic Layer: the algorithms of specific problem for students want to learn.
- Semantic Layer: the pragmatic semantic concepts that may be the misconceptions in comprehension level for students.

- Compound Statement Layer: the primitive semantic concepts that students can understand if learn diligently.

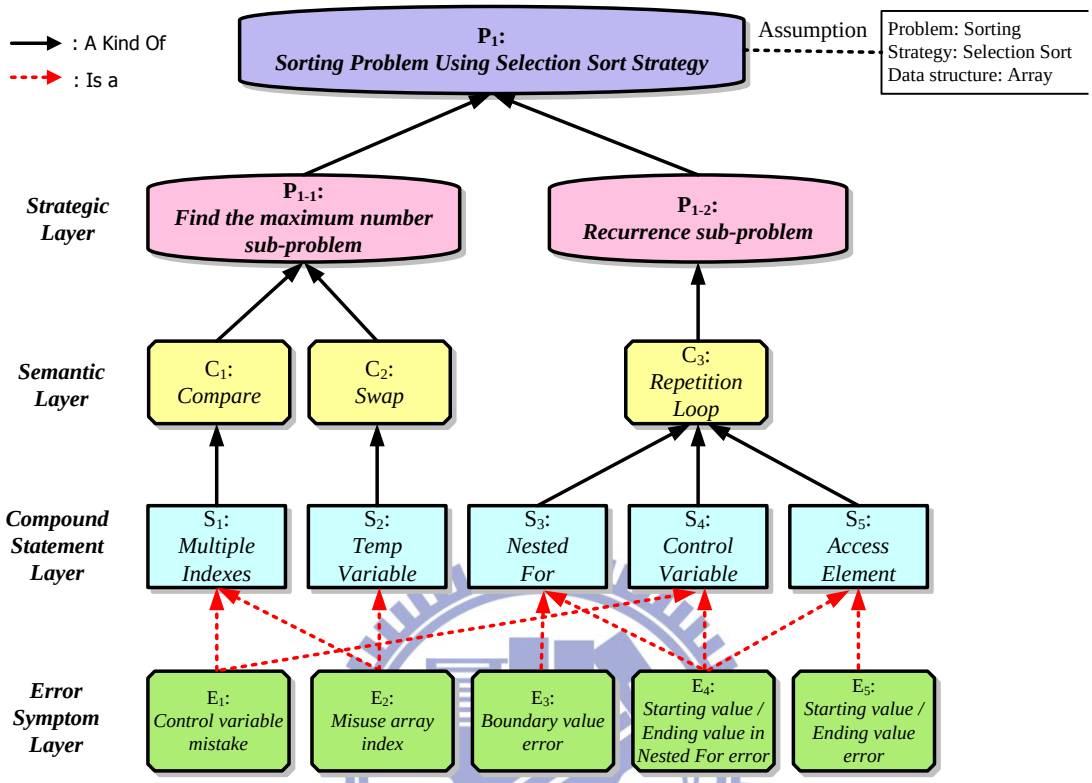


Figure 4.1 Problem Solving Strategy Ontology (PSSO)

Lev Vygotsky's theory of Zone of Proximal Development (ZPD) is a core of the theory of cognitive development which explores the development of the psychological function by analyzing the relationship between actual development level learning and developing. That is to say, we want to know the students' current status and their potential capabilities in the learning.

Students often have the primitive semantic knowledge, but they mostly do not have the pragmatic semantic knowledge. To refer to the ZPD theory, we thought that the students have the misconceptions in program understanding, because there is the *knowledge boundary* in the comprehension level of programming learning, as shown in Figure 4.2.

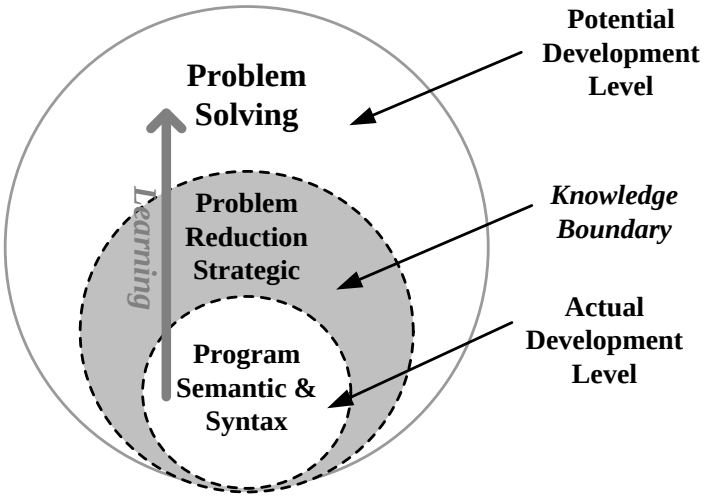


Figure 4.2 Knowledge Boundary in programming learning domain

Therefore, based on the Problem Solving Strategy Ontology, the classical program examples such as *selection sort*, *bubble sort*, *binary search*, *etc* are collected as learning scaffolding for training the recurrence strategy. In addition, the primitive program examples of the textbook are collected to provide the diagnosis of students' actual development level. The collected program examples are tagged with concepts of the Problem Solving Strategy Ontology.

According to the tagged program examples, the students' programming behaviors including frequent used pattern and error patterns can be built from mining the programming testing log. Once the behavior is built, the adaptive learning guidance service can be provided to assist students during the training of problem solving.

4.2 The behavior mining to discover error patterns

In this section, the debugging testing activity is proposed to assess the students' debugging capability. There are predefined buggy patterns as followings.

1). **The detection of syntax error that violates the grammar of programming language.**

- **Missing token**: student can detect the token omitted in the statement such as the missing token ";" omitted in the end of the statement "*printf("hello world!")*".
- **Extra token**: student can detect the redundant token which should be removed such as extra token ";" in statement "*for(….); printf("*");*".
- **Illegal delimiter**: student can understand that delimiter is a sequence of one or more characters used to specify the start and end boundary between separate regions of program expressions such as the curly brackets "{" and "}".

2). **The detection of misuse token error that happened in the mapping of pseudo code to program.**

- **Misuse operator:** student can detect the wrong usage of comparison operator "==" with assignment expression "=" in the statement "*if(a=1)*".
- **Misuse operand data type:** student can detect the incorrect operand usage with wrong data type or constraint such as integer variable "*a*" is mismatched with the wrong data type in the statement "*int a = 'c';* ".

3). **The detection of logical error that happened in the design of pseudo code for solving a given problem.**

- **Unawareness of operator precedence:** student can detect the computational priority of operators such as the programming for formula "*(a+b)*h/2*" may be written as "*Area_Trapzium = a+b*h/2;*" where the unawareness of operator precedence may cause the wrong result.
- **Absence of boundary condition of some variable:** student can detect the boundary condition of variables such as the "divided by zero" error in statement "*b=0; a=1000/b;*".
- **Unawareness of infinite loop:** student can detect if the stopping criterion of "for/while" or "if" the branching condition of expression is unreachable such as the infinite loop in statement "for(i=1, i<10, i--)" or "i=1; while(i>1){ i++; }".

Accordingly, the buggy patterns database can be constructed and indexed by the

taxonomy of the *Problem Solving Strategy Ontology*. Buggy patterns can be embedded in the selected programs and the students are asked to detect those buggy patterns by tracing the program to facilitate the error detection assessment. Two examples of "*selection sort*" and "*factorial number generation*" programs with embedded buggy patterns are shown in Example 4.1.

Example 4.1 Examples of program with embedded buggy patterns

With the constructed buggy patterns database, the buggy programs needed for error detection assessment can be provided. As shown in Figure 2, the example of *selection sort* with Program No. *Q001* is embedded with buggy patterns *"misuse token" in line 5, the "infinite loop" in line 8, and the "missing token" in line 15*; the example of *factorial number generation* with Program No. *Q002* is embedded with buggy patterns *"Misuse operand data type" in line 7, the "Misuse operator" in line 10 and line 12*.

```
// Program No.: Q001
// Problem Description: selection sort
//      Please write a program to sort the numbers in the input array.
//      Input:   numerical array, array size
//      Output: the sorted array
1.  void selectionSort(int numbers[], int array_size)
2.  {
3.  int i, j;
4.  int min, temp;
5.  for (i = 0; i = array_size-1; i++)       //bug: Misuse operator
6.  {
7.     min = i;
8.     for (j = i+1; j < array_size; j--)     //bug: Infinite loop
9.     {
10.      if (numbers[j] < numbers[min])
11.      min = j;
12.    }
13.    temp = numbers[i];
14.    numbers[i] = numbers[min];
15.    numbers[min] = temp                    //bug: Missing token
16. }
17. }
```

```
// Program No.: Q002
// Problem Description
//      Please write a program to show the factorial number
//      Input:   numerical number n
//      Output: the factorial number from 1 to n
1.#include <stdio.h>
2.#include <stdlib.h>
3.int main ()
4.{
5.   int i,n,sum=1
6.   printf("Input a integer, which will be used to calculate factorial\n");
7.   scanf("%d",n);                  //bug: Misuse operand data type
8.   for(i=1;i<=n;i++)
9.    {
10.          sum*i=sum;              //bug: Misuse operator
11.   }
12.   printf("%d!=%d\n",n,sum); //bug: Misuse operator
13.   system("pause");
14.   return 0;
15.}
```

Figure 4.3. Buggy programs of "selection sort" and "factorial number generation"

Definition 4.2 The student's portfolio

The portfolio of a student is composed of a set of testing results: $P = \{s_1, s_2, s_3, \ldots\}$ where symptom s_i=*(Program_no, line_no, position_no, symptom_id)* represents the novice student's mistake on program detection. The *Program_no*, *line_no* and *position_no* denote the position information of the occurred symptoms. The *symptom_id* denotes the identification of buggy pattern.

Example 4.2 The portfolio

Assume that the student failed to detect the "*misused operator*" or "*infinite loop*" buggy patterns in program Q001, then the portfolio is {(Q001, 5, 10, Bug_*misused_token*), (Q001, 8, 1, Bug_*infinite_loop*)}.

Thus, the assessments of different symptoms are as follows.

- **Assessment based on symptoms of syntax error:** the symptoms of syntax error are including "missing token", "extra token", and "illegal delimiter". The root causes for these symptoms can be most likely identified as misconception in "program structure" if the student only has symptoms in illegal delimiter; "unfamiliar with the statement" if the student fails in most of the symptoms; and "incautious" if the student only has symptom in partial program.
- **Assessment based on symptoms of misuse token:** the symptoms of misuse token are including "misuse operator" and "misuse operand data type". The root cause can be mostly identified as misconception in the **"**operator" if the student only has symptom in program operator; "the operand data type" if the student only has the corresponding symptoms; "fail in the mapping of pseudo code to program" if the learner has both symptoms.
- **Assessment based on symptoms of logical error:** the symptoms of logical error

are including “unawareness of operator precedence”, “absence of boundary condition of variable”, and “unawareness of infinite loop”. The root cause can be mostly identified as the corresponding misconception only when learner passes the syntax assessment but has the logical error symptoms.

Therefore, if the major symptoms in novice’s portfolio matched the symptoms of repertory grid, it can be identified as major root cause misconception. Besides, cooperating with other minor symptoms, the possible misconceptions can also be provided to the learner for further remedial learning.

To build the students’ behaviors, 20 students who participated in “*Introduction to programming language*” in the Asia University of Taiwan are involved. In the assessment, 11 programs are collected including 37 buggy patterns.

Next, the association rule mining is applied to generate the Concept effect relationship (CER) to demonstrate how the learning status of certain error patterns can be influenced by the other error patterns.

With the students’ portfolio, we use the software WEKA 3.4.10 to mine the relation between the misconceptions of the students by *Apriori Association Algorithm*. This algorithm is used to mine the relation between the misconceptions of the student. There are fifty records and fifty-five attributes proceed in the WEKA. The result we have found is shown in tables below.

Table 4.1 Large 1 Itemsets of buggy pattern

Large Itemsets L(1):	
Minimum support: 0.6	
Minimum metric <confidence>: 0.9	
Number of cycles performed: 8	
The Buggy Pattern	Support(%)
$printf_1$	60%
$printf_6$	65%

$printf_{10}$	70%
$scanf_2$	85%
$Scanf_5$	70%
if_1	80%
if_4	80%
if_5	60%
for_2	60%
$while_1$	75%
$doWhile_1$	75%

Table 4.2 Large 2 Itemsets of buggy pattern

Large Itemsets L(2):	
Minimum support: 0.6	
Minimum metric <confidence>: 0.9	
Number of cycles performed: 8	
The Buggy Pattern	Support(%)
$printf_{10}$、$scanf_2$	65%
$printf_{10}$、if_1	60%
$printf_{10}$、if_4	65%
$printf_{10}$、$doWhile_1$	60%
$Scanf_2$、$Scanf_5$	60%
$Scanf_2$、if_1	70%
$Scanf_2$、if_4	65%
$Scanf_2$、$while_1$	65%
$Scanf_2$、$doWhile_1$	65%
$Scanf_5$、if_4	65%
$Scanf_5$、$doWhile_1$	60%
if_1、if_4	65%
if_1、for_2	60%
if_1、$while_1$	70%
if_1、$doWhile_1$	65%
if_4、$while_1$	60%
if_4、$doWhile_1$	70%
If_5、$doWhile_1$	60%
for_2、$while_1$	60%
$while_1$、$doWhile_1$	65%

Table 4.3 Large 3 Itemsets of buggy pattern

Large Itemsets L(3):	
Minimum support: 0.6	
Minimum metric <confidence>: 0.9	
Number of cycles performed: 8	
The Buggy Pattern	Support(%)
$printf_{10}$、$scanf_2$、if_4	60%
$printf_{10}$、if_4、$doWhile_1$	60%
$scanf_2$、if_1、$while_1$	60%
$scanf_2$、if_4、$doWhile_1$	60%
$scanf_5$、if_4、$doWhile_1$	60%
if_1、if_4、$doWhile_1$	60%
if_1、for_2、$while_1$	60%
if_1、$while_1$、$doWhile_1$	60%
If_4、$while_1$、$doWhile_1$	60%

Table 4.4 Best rules found from large itemsets

Best rules found:	
Minimum support: 0.6	
Minimum metric <confidence>: 0.9	
Number of cycles performed: 8	
Best Rules Found	Confidence(%)
$if_4 \rightarrow while_1 \rightarrow doWhile_1$	100%
$for_2 \rightarrow if_1 \rightarrow while_1$	100%
$if_1 \rightarrow for_2 \rightarrow while_1$	100%
$for_2 \rightarrow while_1 \rightarrow if_1$	100%
$scanf_5 \rightarrow doWhile_1 \rightarrow if_4$	100%
$printf_{10} \rightarrow doWhile_1 \rightarrow if_4$	100%
$for_2 \rightarrow while_1$	100%
$if_4 \rightarrow doWhile_1 \rightarrow$	100%
$for_2 \rightarrow if_1$	100%
$doWhile_1 \rightarrow if_4$	93%
$while_1 if_1$	93%
$scanf_5 \rightarrow if_4$	93%
$printf_{10} \rightarrow if_4$	93%
$printf_{10} \rightarrow scanf_2$	93%
$while_1 \rightarrow doWhile_1 \rightarrow if_4$	92%
$if_1 \rightarrow doWhile_1 \rightarrow while_1$	92%
$while_1 \rightarrow doWhile_1 \rightarrow if_1$	92%
$if_1 \rightarrow if_4 \rightarrow doWhile_1$	92%

$if_1 \rightarrow doWhile_1 \rightarrow if_4$	92%
$scanf_5 \rightarrow if_4 \rightarrow doWhile_1$	92%

With the discovered behavior patterns, the relations of behavior patterns are shown in Figure 4.3. If the students made the mistake with *misuse token* of the statement "*if*", then the students most likely made the mistake with *misuse declaration* to the statement "*printf*" as well. Furthermore, we can point out the misconception of the student who made several mistakes at the same time. For example, if the students misuse token in the statement "*if*", then the students may have logical error in the statement "*do-while*" and misuse token in the statement "*while* " at the same time.

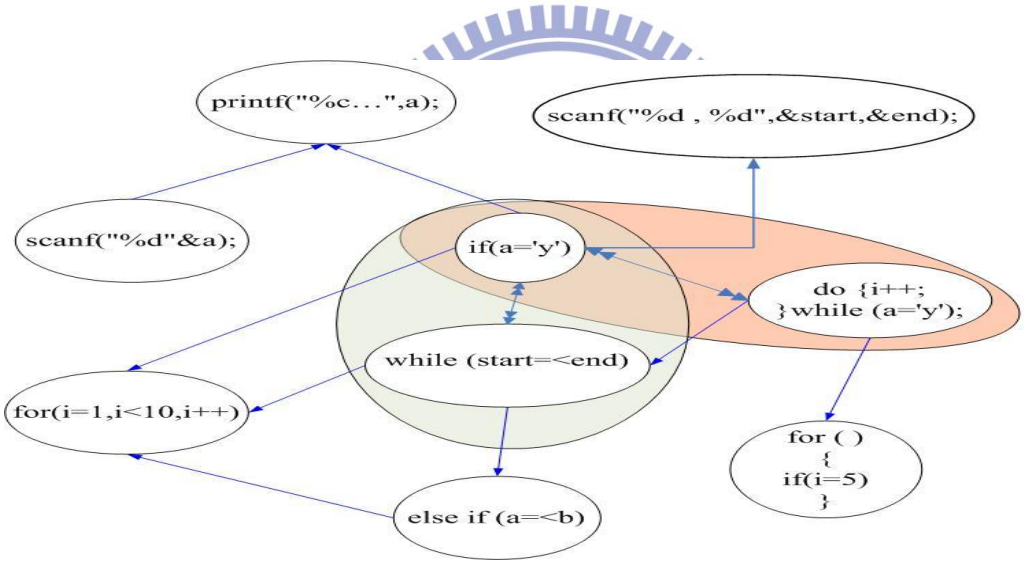


Figure 4.4 The relations of behavior patterns

After analyzing students' symptom portfolio, there are different error patterns discovered as followings.

- Assessment for statement "printf": There are 55% students with symptom on the detection of "printf". With the consideration of more symptoms, 15% students failed to detect almost all bugs. Therefore, their misconception can be judged as *unfamiliar with the statement "printf"*. The other 40% students only failed in the

misuse operator buggy pattern of “printf”. Therefore, their misconception can be judged as *misuse operator with the statement “printf”*.

- Assessment for statement “scanf”: There are 80% students with symptom on the detection of “scanf”. With the consideration of more symptoms, 25% students failed to detect almost all bugs. Therefore, their misconception can be judged as *unfamiliar with the statement “scanf”*. The other 55% students only failed in the misuse operand data type of “scanf”. Therefore, their misconception can be judged as *misuse operand data type with the statement “*scanf*”*.
- Assessment for the statement “if”: There are 85% students with symptom on the misuse operator of “if”. With the consideration of more symptoms, 45% students failed to detect almost all bugs of the misuse operator. Therefore, their misconception can be judged as *misuse operator with the “if”*. The other 40% students also failed in the bugs of operator precedence, therefore, their misconception can be judged as “*unawareness of operator precedence*”.
- Assessment for the statement “for”: There are 65% students with symptom on the missing token of “for”. Since they only failed in this bug; therefore their misconception can be judged as *unfamiliar with the “for” statement* .

4.3 Evaluation

With the discovered programming error patterns, scaffolding-based assessment which is the adaptive learning guidance service can be provided. Our learning activity is implemented by using cloze testing to obtain student's knowledge boundary and guide students to comprehend the problem solving strategy.

As shown in Figure 4.4, there are four processes for the scaffolding-based learning by example process. The first is to collect classical sample programs as the example database. The second, the programming comprehension starts from providing a target program for the learner to learn. While learner has misconception on the target program, instead of give the answer directly, the third process provides more sample programs for learner to practice by decomposition the program structure of original sample program. Thus, for each concept of program structure, it retrieves several programs from the program database which are similar to the provided sub-structure of the target program as the remedial sample program. Since the remedial sample programs are easier than the original one, the learner may easier to comprehend. Next in the forth process, once the provided remedial sample programs are learned, the scaffolding-based learning by example process applies the remedial learning using these programs as the scaffolding examples to hint the learner. Thus, with the sample programs as learning scaffolding, the learner can easier comprehend the target program.

During the scaffolding-based learning by example process, when a program is provided for leaner to learn, we still want to know if she can really understand the program or not. Therefore, our idea is to apply the cloze test on program structure to facilitate the assessment during the programming comprehension learning. Since the assessment using cloze test is open-ended for the learner to provide her answer, it

motivates the learner to comprehend context and structure of the sample program in order to answer the cloze test item. Moreover, since the cloze box can be set in the program structure level, block statement level and statement element level, for one sample program, it can further detect the learner's misconception is happened in what kind of comprehension level. Thus, it can provide more informative feedbacks.

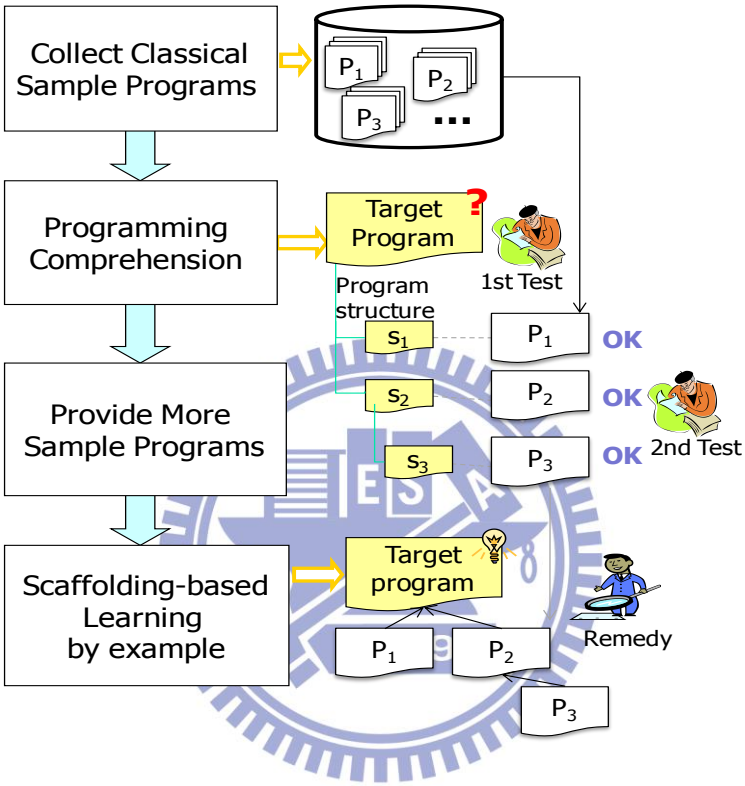


Figure 4.5. The scaffolding-based learning by example process

- **Scaffolding-based cloze item generation**

With the retrieved sample programs, the learning of programming comprehension is based on the structured programming model. The cloze test is provided for the learner level by level based on the program structure. As shown in Figure 4.5, the cloze test item of the sample program is generated by replacing the program statements of each level by empty sign. Thus, the learner can follow the assessment process to learn the programming comprehension.

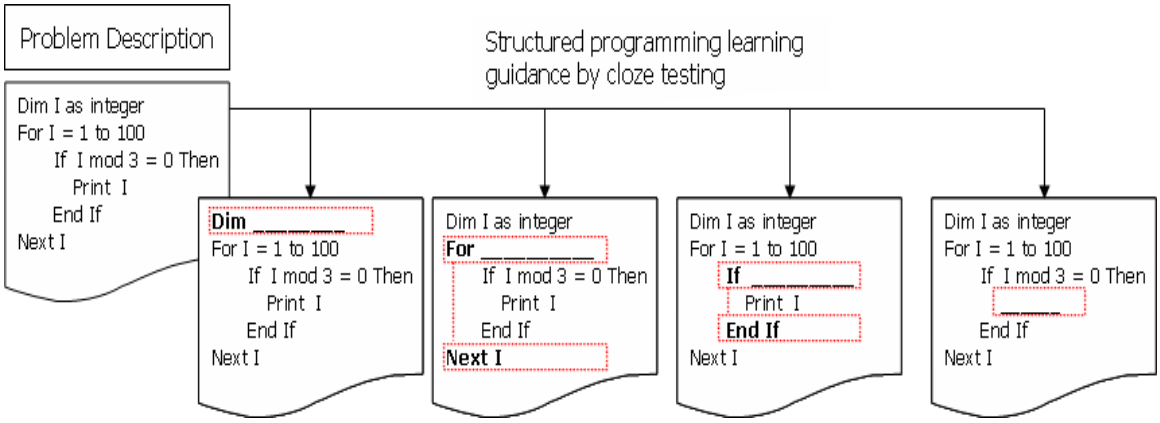


Figure 4.6 Structured programming learning using cloze test

- **Remedial scaffolding-based cloze test generation**

Once the sample program has been learned by the learner, it can be used as the learning scaffolding example to learn the derived problems. As shown in Figure 4.6, remedial cloze test is shown with sample program as referred example that the learner answered before. Furthermore, to inform the similar and difference between referred example and derived problem, the scripts of the hint can be derived by comparing the metadata of two programs.

Referred Example	Derived Problem	Hint
Print the natural numbers from 1 to 100 which are multiplies of 3.	Print the number sequence from 1 to 100 where the n-th value is "An = 7n+2".	
10 Dim I as integer 20 For I = 1 to 100 30 If I mod 3 = 0 Then 40 Print I 50 End If 60 Next I	10 Dim I, A as integer 20 For I = 1 to 100 30 A = [ ] 40 if [ ] then 50 Print A 60 End If 70 Next I	Similar concepts: 1. Declaration 2. Repetition Different concepts: 1. assignment statement 2. if statement

Figure 4.7 Remedial cloze test with sample program as learning scaffolding

To evaluate the application, the system is implemented in environment APACHE, PHP and MYSQL. The system screen shots are shown in Figures 4.7 and 4.8.

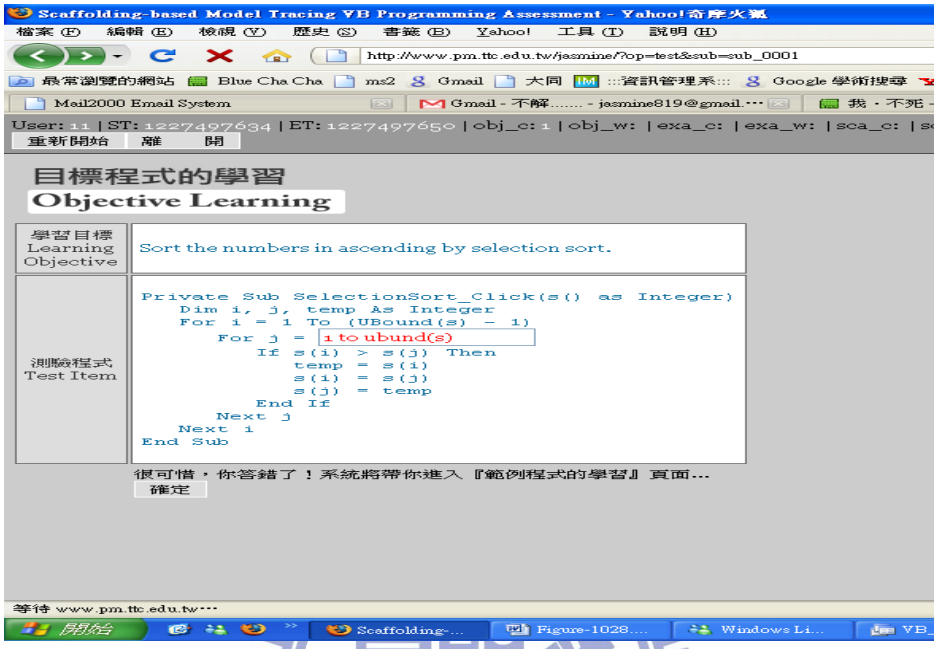


Figure 4.8 Cloze testing with error pattern detection

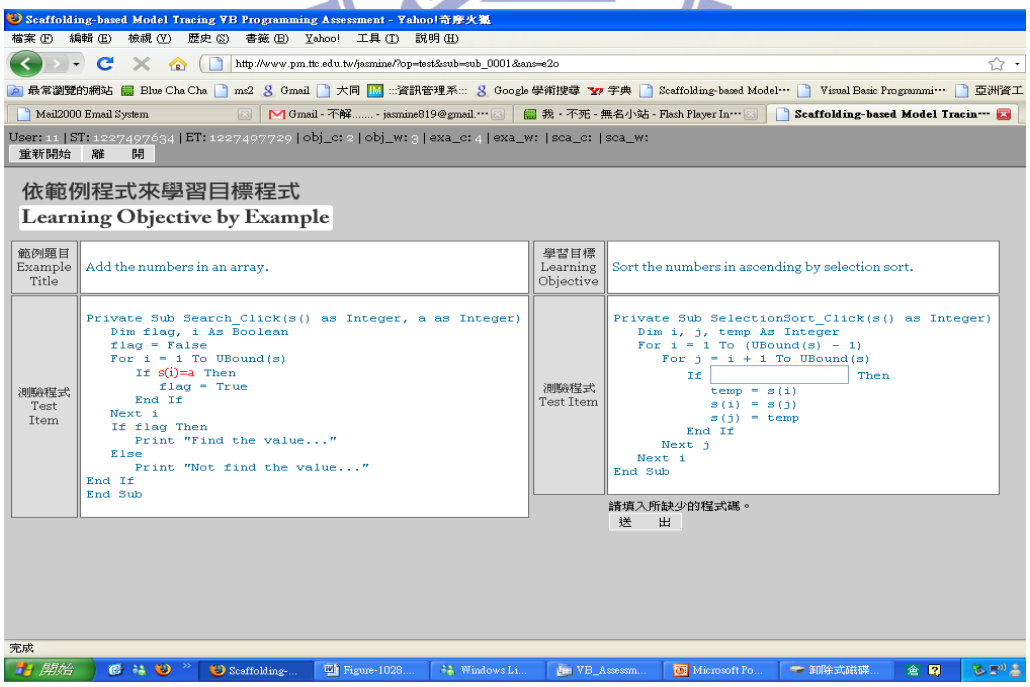


Figure 4.9 Cloze tests with similar pragmatic concept where one as the remedial sample code

There are 55 students of college school were participated in our two experiments and randomly divided into 21 students in control group and 34 students in experimental group. The experiments of comparison of learning improvements and comparison of learning outcomes for two groups are as followings.

- Comparison of learning improvements

The testing score of the learning achievement is shown in Table 4.5. To evaluate the difference between two groups, the paired two-sample T-test for means of scores is applied. Consequently, the t-test results of the experimental groups suggest significant differences but the control group has no significant differences. Finally, we may conclude that the experimental group has higher learning improvement.

Table 4.5 The score for each group (total score=100)

		Pretest		**Posttest**		
		Mean	**Std. Div.**	**Mean**	**Std. Div.**	Paired t-test
Control (size=21)	**group**	17.38	17.86	21.90	17.57	t(26)=0.0997, p=0.9214
Experimental (size=34)	**group**	19.26	13.31	32.94	16.57	t(39)=3.9141, p=0.0004*

*p<.05

- Comparison of learning outcomes

The testing score of the learning achievement is shown in Table 4.6. To evaluate the difference between two groups, the un-paired two-sample T-test for means of scores is applied. The null hypothesis H_0 assumes that population variances are equal. The t-test results show that F-value is 1.12488 and p-value is 0.026. Consequently, the t-test results of the two groups suggest significant differences at a confidence interval

of 95%. Finally, we may conclude that the experimental group has higher learning achievement than control group.

Table 4.6 The score for each group (total score=100)

	Size	**Mean**	**Std. Dev.**
Control group	21	21.90	17.57
Experimental group	34	32.94	16.57
F=1.12488, p-value=0.026*			
*p<.05			

From the experiments, we find that the service can motivate students to actively study the relations of different problems. It can also motivate students to rethink the program examples of the textbook. Some students thought that our system did aid them for programming understanding. Based on the scaffolding-based assessment, the problem solving strategy can be easier learned from program examples as learning guidance.

Chapter 5
Behavior modeling of programming inquiry activity on the learning forum

In the course of Programming Language subject, the inquiry-based learning [12] which is usually applied to train learners' practical problem-solving capability is an effective strategy that helps learners to link the theory to the practice and develop teamwork collaborative learning skills [69].

In the programming learning forum, the inquiry-based learning begins when learners identifying the encountered problem. Next, the learner can logon the programming learning forum to start the inquiry by posting his/her question of problem. The senior programmers (i.e., the experts) or other learners with similar topic interest will feedback by replying the learner's question. The inquiry and feedback cycle is repeatedly executed until the learner is satisfied with the solution.

5.1 Inquiry Behavior modeling on the learning forum

In the C++ learning forum, a hot topic is usually formed by a specific issue with several inquiry aspects. Our basic assumption is that there are purposes behind inquiry activities stored as forum documents. Therefore, the forum inquiry behavior analysis can be reduced to the knowledge structure mining problem. As we know, the clustering of similar documents cannot be easily done without keyword vectors clustering analysis. However, the synonyms and high dimension nature of keyword-based model may cause the clustering results to be sparse and useless.

With our observation, the inquiry can be presented with *purpose* and *topic*. Thus, the idea of divide and conquer strategy is applied to classify the forum documents into several purposes and then apply the clustering analysis for each purpose separately. Accordingly, to support divide and conquer strategy, the Purpose-based Ontology is defined to maintain the purposes and topics of the forum documents. As shown in Figure 5.1, the forum documents are analyzed and transformed to the Purpose-based Ontology. Thus, the ontology can support the analysis of inquiry topic and inquiry process for teacher to conclude the inquiries of learners.

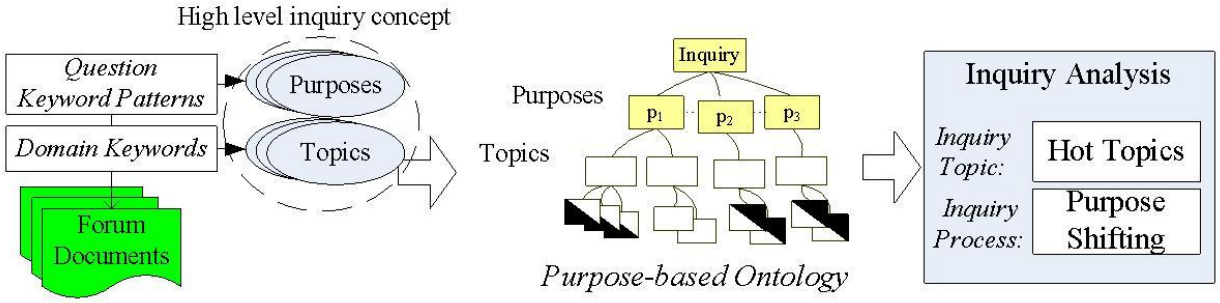


Figure 5.1 Purpose-based Ontology to support inquiry analysis

In a C++ learning forum, it is composed of a group of documents. To represent the documents, the domain keywords dictionary is constructed. Thus the input document keywords sets can be obtained using the statistical and syntactic processing tools with the existing dictionary [19]. The definition of forum document is as follows.

Definition 5.1 The Forum keywords set

Given a dictionary, the forum keywords set $\sum$ is defined as the set of keywords that used in the forum.

Definition 5.2 The Inquiry Document

In the forum , the x-th inquiry document is represented as the keyword vector $Doc_x=<v_1, v_2,\ldots, v_{|\sum|}>$, $v_j=1$ if keyword k_j appears in the Doc_x.

Example 5.1 The Inquiry Document example

With vector set $\sum=\{k_1, k_2, k_3, k_4, k_5, k_6, k_7, k_8, k_9, k_{10}\}$, assume that the keywords used in document Doc_a is $\{k_1, k_2, k_3, k_4\}$, and Doc_b is $\{k_1, k_3, k_4, k_5, k_8\}$. Thus, Doc_a = <1, 1, 1, 1, 0, 0, 0, 0, 0, 0> and Doc_b = <1, 0, 1, 1, 1, 0, 0, 1, 0, 0>.

In the C++ learning forum, there are different inquiry types. Based on the common inquiry words such as what, why, how, etc. and the frequently asked questions in C++ domain, most of the C++ learning forum inquiries can be categorized into the purposes shown in Table 5.1.

Table 5.1 Inquiry purposes of C++ forum

Question Types	Description	Example Issues
What's the meaning	Questions about the definition of function library.	*Concept about template and data member revision; Concept about static object, etc.*
What's wrong	Questions about what's wrong with the bug or specific programming error.	*Problem about free and delete from memory; Why can't it pass-by-reference, etc.*
What's different	Questions about what's the difference between two or more domain concepts	*Conflict about dynamic class creation and overloading; Differences between structure in C and Class in C++, etc.*
How to do	Questions about how to implement the required	*How to use constructer in Class; How to initiate the*

	functionality.	*array in construct, etc.*
How to use	Questions about how to use the function library or program statements.	*How to compile the class in another directory; How to use winsock.h in dev c++, etc.*
Other experience sharing	Other discussion topics such as quiz, experience sharing, etc.	*Best practices of OOP; bibles of C++, etc.*

5.2 The Purpose-based Ontology for behavior modeling

In the various inquiry processes in C++ forum, the semantic meanings of documents are usually implicitly defined in their contents. Therefore the Purpose-based Ontology (PO) is proposed to model the relations of the purposes, topics, issues and documents of the forum by explicitly representing the structure of topics to support the hot topic classification. There are four layers in PO which are the *Purpose Layer, Topic Layer, Issue Layer and Document Layer*. The relations among the root to the purposes and the purposes to the topics are represented by the "Part of" relations to divide the domain into sub-categories. The relations among topics to the issues are represented by the "A Kind of" relations to show the general and specific issues of each topic. Finally the relations among the raw data and the keyword vector models of documents are represented by the "Instance of" relations. Assume there are n predefined purposes; the definition of Purpose-based Ontology is given as follows.

Definition 5.5 The Purpose-based Ontology (PO) is defined as PO = (P, T, V, D, R), where

- $P=\{p_1, p_2, \ldots, p_n\}$ is a finite set of purpose nodes in the *Purpose Layer* to represent predefined discussion purposes of the programming forum.
- For each purpose p_i, the topics $T_i=\{p_i.t_1, p_i.t_2, \ldots\}$ is a finite set of topic nodes in the *Topic Layer* to represent different topics discussed in the forum. Topic nodes are linked to the corresponding purpose node by the "*A Part OF*" relations.
- For each purpose p_i and topic t_j, the issues $V_{ij}=\{p_i.t_j.v_1, p_i.t_j.v_2, \ldots\}$ is a finite set of issue nodes in the *Issue Layer* to represent the discussion keyword features of forum documents. Issue nodes are linked to the corresponding topic node by the "*A Kind Of*" relations.
- For each purpose p_i, topic t_j and issue v_k, the documents $D_{ijk}=\{ p_i.t_j.v_k.d_1, p_i.t_j.v_k.d_2, \ldots\}$ is a finite set of document nodes in the *Document Layer* to represent the linkages associated to the original forum documents. The document nodes are linked to the corresponding issue node by the "*Instance Of*" relations.

In the Purpose-based Ontology, the purpose concepts are predefined manually to classify the inquiry topics of C++ learning forum into purposes. The topic concepts are obtained from the clustering analysis of the issues concepts which are the keyword vectors of the forum documents. An example structure of Purpose-based Ontology is shown in Figure 5.2.

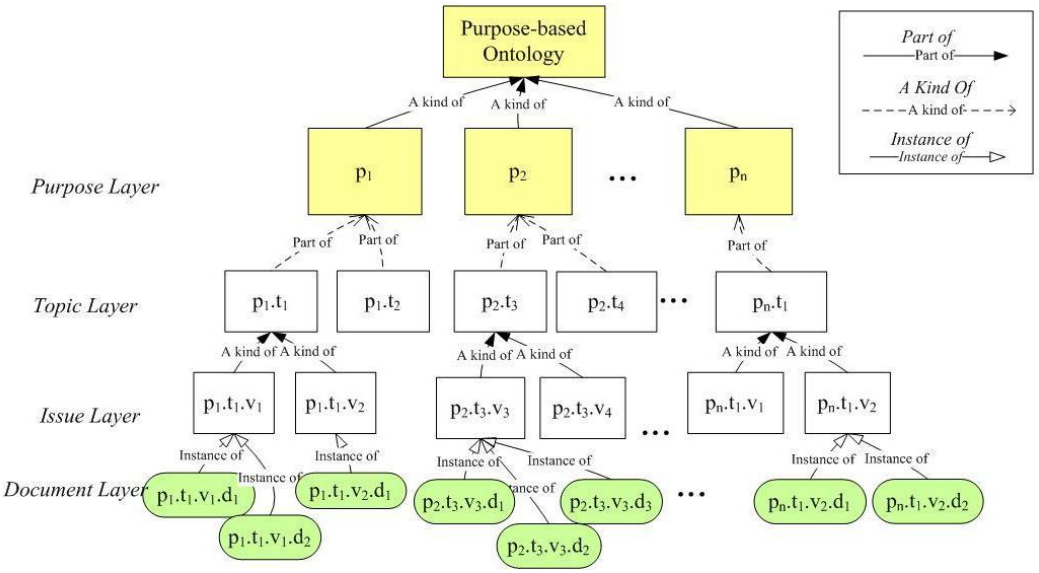


Figure 5.2. The four-layer Purpose-based Ontology

With the defined Purposed-based Ontology, the domain knowledge structure of the topics in the forum can be represented clearly. In order to represent the discussion contents of topics, the Topic Coverage, Topic Focus and Topic Quantity are defined. The topic coverage is defined as the union of the keywords vector Doc_x that belongs to the topic t.

Definition 5.6 The Topic Coverage

$$Coverage(t) = \bigcup_{i,j} \{Doc_x \mid \forall x, Doc_x \in t.v_i.d_j \}$$

The topic focus is defined as the intersection of the keywords vector Doc_x that belongs to the topic t.

Definition 5.7 The Topic Focus

$$Focus(t) = \bigcap_{i,j} \{Doc_x \mid \forall x, \quad Doc_x \in t.v_i.d_j \}$$

To evaluate the discussion divergence of each topic, the existing keyword number of a topic t is represented as | t |. Thus, the topic density is defined as the division of topic focus and topic coverage in Definition 5.8.

Definition 5.8 The Topic Density

Density(t) = |Focus(t)| / |Coverage(t)|

Example 5.2 TC, TF and TD of topics

Given a topic t, there are two documents in t which are Doc_a = <1, 1, 1, 1, 0, 0, 0, 0, 0, 0> and Doc_b = <1, 0, 1, 1, 1, 0, 0, 1, 0, 0>. Thus Coverage (t) = <1, 1, 1, 1, 1, 0, 0, 1, 0, 0> , TF= <1, 0, 1, 1, 0, 0, 0, 0, 0, 0>, and TD = 3/6 = 0.5.

5.3 The Cascading Forum Topic Mining Algorithm for Self-Organized Ontology Maintenance

With the initial version of Purpose-based Ontology which is given by domain experts, it can be used to conduct the topics discovery in the forum. Since the forum documents are incrementally inserted, the Self-Organized Ontology Maintenance Scheme is proposed. As shown in Figure 5.3, there are five processes which are Initialized purpose editing, purpose classification, topic clustering, Ontology updating, and new documents inserting.

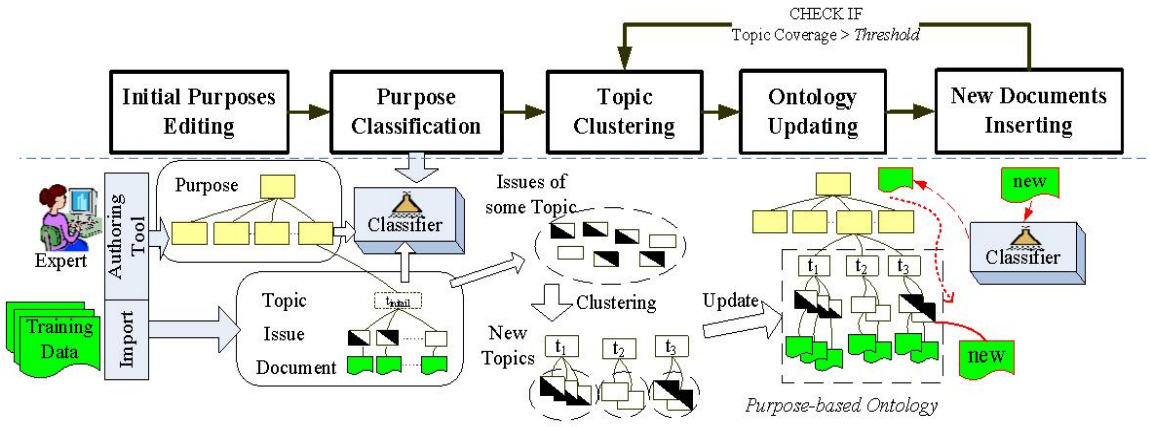


Figure 5.3 The self-organized ontology maintenance scheme

Firstly, in the initial purpose defining process, the domain expert is required to edit how many purposes s/he wants to analyze in purpose layer of the ontology. Secondly, the training data can support the construction of classifier for purpose classification. Thirdly, in the topic clustering process, if the Topic Density of some topic is lower than the threshold, the documents number associated with the topic is too large. Thus, the clustering process is applied to reorganize the original topic into sub-topics. Fourthly, the ontology updating process revises the original ontology to new version. Finally, the new documents inserting process keep creating new node and associating to the ontology for the inserted form documents. It periodically checks the Topic Density of ontology and applies the topic clustering to self-organize the topics of the ontology after a number of documents are inserted. Thus, the Purpose-based Ontology can be periodically enhanced and maintained. The Self-Organized Ontology Maintenance Algorithm is shown in following algorithm.

Algorithm : The Self-Organized Ontology Maintenance Algorithm

Step 1. In the initial Purpose Editing process, the domain experts provide the initial inquiry purposes of learning domain to classify the documents.

Step 2. The classified documents as initial training set to perform the purpose classification analysis.

Step 3. For each topic, if the Topic Density (TD) value is larger than the threshold which means that there are too many documents classified in one topic, the Topic Clustering process is triggered to cluster the documents into groups of sub-topics.

Step 4. In the Ontology Updating process, the original ontology is updated with the new clustered sub-topics.

Step 5. While a new document is inserted, classify the document into the specific purpose and

insert into the most similar topic in the Purpose-Ontology. If the Topic Density of the inserted topic node is acceptable then stop, else go to Step 3 and update the ontology.

In this section, the cascading forum topic mining algorithm is proposed to discover the hot topics.

1) Purpose Classification

Generally speaking, the forum documents are composed of the title and the content body. The title may consist of the question words represent the purpose of question; the content body may consist of either detailed question descriptions or the answer phrases corresponding to the purpose of question. According to researches about question analysis [75], most of the question patterns can be represented as "question word + domain keywords", where the question word is one of the interrogatives (What, How, Why, etc.) and the domain keywords represents the keywords in the subsequent chunks that tend to reflect the intended answer more precisely. Therefore, with the manually constructed initial Purpose-based ontology and the training data, the question patterns are extracted for purpose classification with the question analysis and document structure information.

- **Question pattern**

For different purposes of documents, there are usually different question patterns such as different interrogatives and various adjective terms. The interrogatives and adjectives can be formed as the question patterns.

- **Answer pattern**

Besides the question pattern, the different purposes of the documents may be predicted from the answer patterns.

To classify the forum documents into purposes, the lexical pattern matching approach in different structure level is used. For example, the title keywords set can explicitly express the document purpose with question phrases starting with interrogatives such as “what”, “how”, “why”, etc. There are some example patterns of purposes “what’s the meaning”, “what’s wrong”, “how to do” and “how to use” as shown in Table 5.2.

Table 5.2 The question and answer keyword-pattern examples of different purposes

Structure Level	Purpose	Keyword-pattern
Question-pattern example	What’s the meaning	*what is, meaning, definition, …*
	What’s wrong	*bug, error, problem, help, correct, why, can’t,…*
	What’s Difference	*comparison, difference, the relation of, …*
	How to do	*how to, how to implement, functionality, can use,…*
	How to use	*use, call function, …*
Answer-pattern example	What’s the meaning	*define as, used for, refer to,…,*
	What’s wrong	*because, maybe, …*
	How to do	*can use, call function,…*
	How to use	*parameter is, for example,…*

Therefore, in each level, the defined patterns are represented as the Boolean features vector for the classification algorithms [49][55][57][62]. If the defined pattern appears in the document, then the feature value is set as 1. Therefore, with the defined features

and training set, the purpose classifier can be constructed as shown in Figure 5.4. Since there are usually a group of discussions posted in the forum documents by following the same title, the Purpose Classifier by Content is applied firstly to identify the question or answer patterns in the content. It stops if the document can be classified; otherwise the Purpose Classifier by Title is applied for further classification by the terms in the title part.

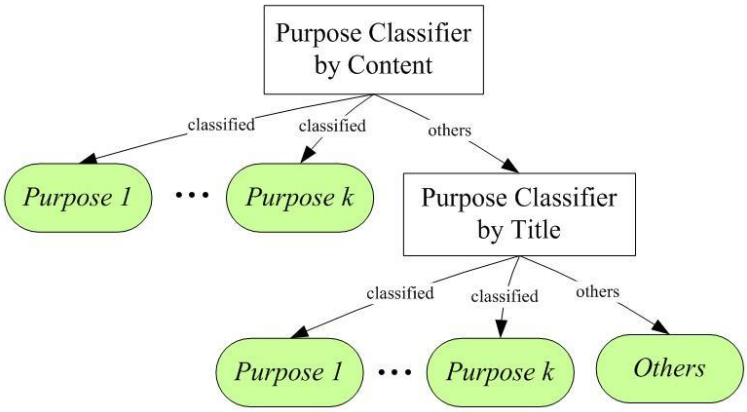


Figure 5.4. The structure-based purpose classifier

2) The Multi-Level Document Distance

In this dissertation, we apply the *Term Frequency - Inverse Document Frequency* (**TF-IDF**) weighting scheme [4][26][68][76] to represent the topics of documents. Each document can be represented by a vector $<tf_1 \times idf_1, tf_2 \times idf_2, \ldots, tf_n \times idf_n>$, where tf_i is the frequency of the *i-th* term, $idf_i = \log(n/df(t))$ is the *Inverse Document Frequency* (*IDF*) of the *i-th* term in the document, *n* is total number of documents and *df(t)* is the number of documents that contains the term.

To calculate the semantic distance of document issues, the C++ Domain Keyword Ontology is used. The keywords can be collected from the index of textbooks and online documents. The categories of the domain keywords include "*platform*", "*algorithm*", "*Program Statement*", "*Bug description*", "*GUI*", etc. The leaves of the

concepts are the keyword sets to describe the concept. For example, the concept "*API*" has the sub concepts "*DLL*", "*LIB*", etc. as shown in Figure 5.5.

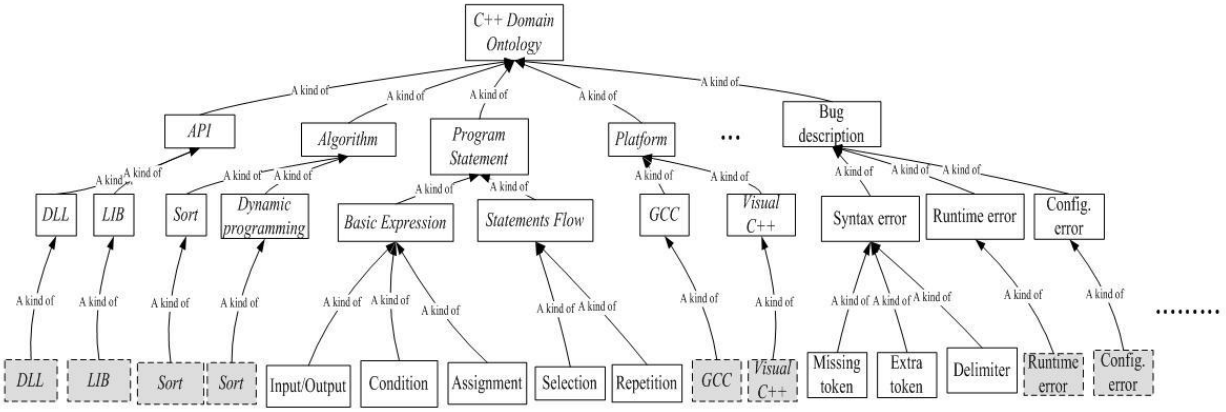


Figure 5.5. C++ domain ontology

For conveniently creating the relationships among concepts according to the ontology structure, we assume that each sub class of C++ Domain ontology will have the same depth. However, in general, the depths of concept structures are different. Therefore, in C++ Domain ontology, if the depth of a leaf concept is too short, the ***Virtual Node*** (**VN**) will be repeatedly inserted as its child node until the difference of the desired depth has been filled.

Accordingly, the semantic distance between two documents can be calculated by the weighted sum of the ontology distance from bottom level to root level. The bottom level has the highest weight and the higher the levels, the lower the weights.

With the ontology structure described above, let the depth of domain ontology be h, the i-th element of document in level ℓ are represented as $U_i^{(\ell)}$. Assume that the element $U_i^{(\ell)}$ has k children which are $U_1^{(\ell+1)}$,…, $U_k^{(\ell+1)}$, the values of $U_i^{(\ell)} = \sum_{j=1}^{b} w_j \times U_j^{(\ell+1)}$. Thus, the semantic distance of two documents U and V calculated by weighted sum of multi-level distance can be defined as follows.

Definition 5.9 The weighted sum of Multi-Level Document Distance (MLDD)

The Euclidean Distance of two keyword vectors in level ℓ is represented as $U^{(\partial}$ and $V^{(\partial}$.

$$Dist(U^{(\ell)}, V^{(\ell)}) = \sqrt{\sum_{i=1}^{n} (U_i^{(\ell)} - V_i^{(\ell)})^2}$$

The weighted sum of Multi-Level Document Distance from level 1 to level h is defined as:

$$\text{MLDD(U, V)} = \sum_{\ell=1}^{h} W_\ell \times Dist(U^{(\ell)}, V^{(\ell)})$$

Example 5.3 document distance measurement

There are three documents with original keyword vectors Doc_a=<1, 0, 0>, Doc_b=<0, 1, 0> and Doc_c=<0, 0, 1>. With the definition of weighted sum of multiple levels document distance, the distance measurements among documents are MLDD(Doc_a, Doc_b) = $\sqrt{2}$ and MLDD(Doc_a, Doc_c) = $\sqrt{2} + 0.8*\sqrt{2}$. As shown in Figure 5.6, although the distance among them in the original keyword vectors are the same, the documents within the same class of concepts tend to be more similar.

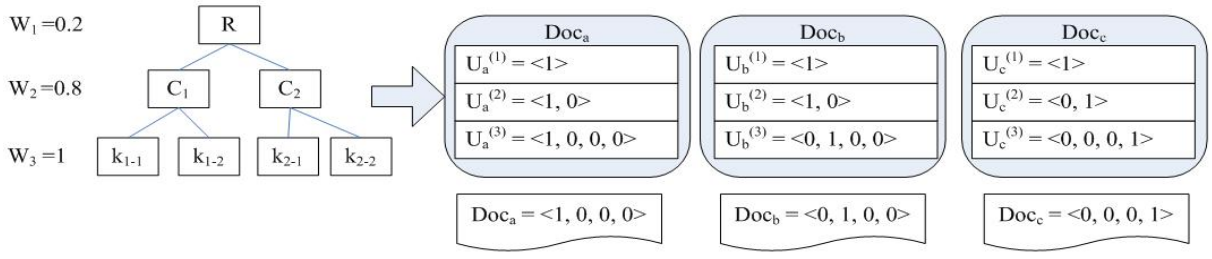


Figure 5.6 The example of documents distance

3) Cascading Topic Clustering Algorithm

With the defined Purposes-based Ontology, the cascading clustering algorithm is applied for the topic discovery. Firstly, the Purposes-based Ontology is referred to

classify the documents into the predefined purposes by the interrogatives patterns. Secondly, for each purpose, the topics can be discovered by clustering analysis using the MLDD distance measurement for the issue vectors. Since the number of topics is unknown so far, only the criterion of the required average documents' distances of each topic can be set, the ISODATA clustering algorithm [6] which can adaptively divide and merge the clusters to find the most suitable cluster number for the data distribution is applied. The cascading topic clustering algorithm is proposed as follows.

Algorithm: The cascading topic clustering

Input: Keyword vectors of forum documents, Purpose-based ontology

Output: Clustering results

Step 1. Predict the purposes of forum documents as *what, how, why, others, etc,*.

Step 2. For each purpose, retrieve the concerned concepts set of this purpose from the Purpose-based Ontology.

Step 3. For all documents in this purpose, apply the ISODATA clustering algorithm with the weighted sum of multi-level document similarity.

Step 5. Store the clustering results into the associated purpose subclass of Purpose-based Ontology.

Step 6. If there still exists an un-clustered purpose, then go to Step 2 for next purpose.

Step 7. Output and save the clustering result as topics.

Example 5.3 Example of the cascading data mining for topic clustering

Assume that there are 10 Docs with keywords $\sum=\{k_1, k_2, k_3, k_4, k_5, k_6, k_7, k_8, k_9, k_{10},$

k_{11}, k_{12}, k_{13}}.

Table 5.3 The keyword vector of documents

	k_1	k_2	k_3	k_4	k_5	k_6	k_7	k_8	k_9	k_{10}	k_{11}	k_{12}	k_{13}
Doc_1	1	1	1	1	1	1	1	1	1	0	0	0	1
Doc_2	1	1	0	1	1	1	1	1	1	1	0	1	0
Doc_3	1	1	0	1	1	1	0	0	0	0	0	1	0
Doc_4	1	1	1	1	1	1	1	1	1	1	1	0	1
Doc_5	1	1	1	1	1	1	1	0	1	1	1	0	1
Doc_6	1	0	0	1	1	1	1	1	1	1	0	1	0
Doc_7	0	1	1	0	1	1	0	1	0	0	0	0	0
Doc_8	0	1	1	0	1	1	0	1	0	0	0	0	0
Doc_9	1	1	0	1	1	1	0	0	0	0	0	1	0
Doc_{10}	1	1	1	1	1	1	0	1	0	1	1	0	1

These documents are classified first, and the classification results can be stored in Table 5.4.

Table 5.4 The result of applying structure-based classification

Purpose Label	**Doc**
What's the meaning	{Doc_1, Doc_4, Doc_5, Doc_7, Doc_8, Doc_{10}}
What's wrong	{Doc_2, Doc_3, Doc_6, Doc_9}

Next, for each purpose, the clustering analysis is applied and the clustering results can be stored as the data fields as Table 5.5.

Table 5.5 The Result of Applying ISODATA Clustering Algorithm

Purpose Label	Cluster	DOC	Cluster Centers
What's the meaning	C_{1-1}	{Doc_1, Doc_4, Doc_5, Doc_{10}}	<1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1>
	C_{1-2}	{Doc_7, Doc_8}	<0, 1, 1, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0>
What's wrong	C_{2-1}	{ Doc_3, Doc_9}	<1, 1, 0, 1, 1, 1, 0, 0, 0, 0, 0, 1, 0>
	C_{2-2}	{Doc_2, Doc_6}	<1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 0>

Here we introduce the hot topics about "Object-Oriented Programming (OOP)". As shown in Figure 5.7, the number of documents of different purposes in topic "OOP" is presented. As we can see, the purpose of "How to do" is the frequently discussed purpose in forum documents. The "What's the difference" is the second one.

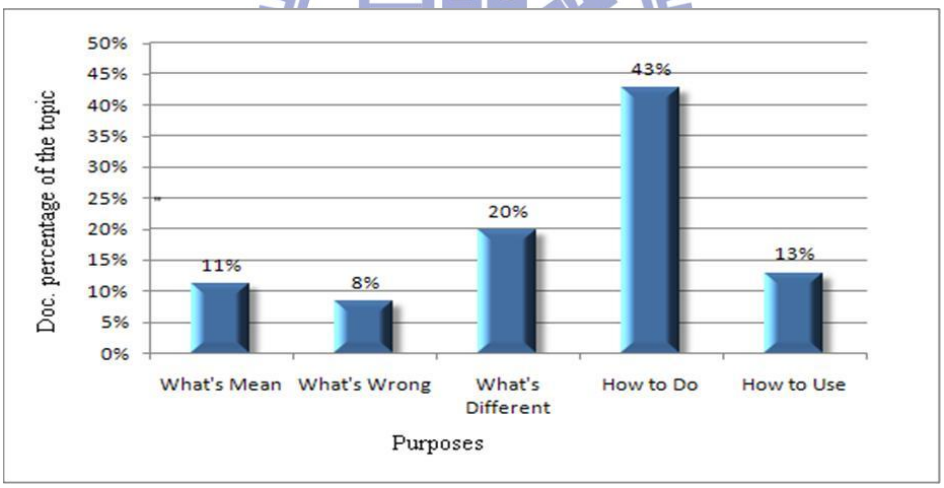


Figure 5.7 The purposes of the hot topic about "OOP"

With the further analysis of the purpose "*How to do*", the issues about "constructer", "the initiate and release of the object", etc. are discussed frequently. In the purpose "*What's Difference*", the issues about "*C and C++*", "*structure and class*", etc. are discussed frequently. The rest of main issues discussed in each purpose are shown in Table 5.6. With the wide purpose hot topic analysis, the inquiry topics of

learners can be shown.

Table 5.6 The issues of different purposes discussed in the hot topic "OOP"

Hot Topic: Object-Oriented Programming (OOP)	
Purpose	**Issues**
What's Mean	*Concept about template and data member revision;* *Concept about static object*
What's Wrong	*Problem about free and delete from memory;* *Why can't it pass-by-reference*
What's Difference	*Conflict about dynamic class creation and overloading;* *Differences between structure in C and Class in C++;* *Difference between define and typedef;* *Difference between WaitEvent and SignalEvent;* *Difference between iterator and [] of STL*
How to Do	*How to use constructer in Class;* *How to initiate the array in construct;* *How to delete the object created from overloading*
How to Use	*How to connect mysql DB with C++;* *How to compile the class in another directory;* *How to use winsock.h in dev c++;* *Can I use API in C*

5.4 Evaluation

To stimulate the problem solving activities in the community, the social network service of Web 2.0 with trustworthy experts finding is proposed. As shown in Figure 5.8, while questioner posts a question, the main keywords of the question is firstly identified with the interaction to the questioner. The expert finding service will find trustworthy experts based on their topic interest with respect to the posted question. Next, the questioner can configure the parameters to change the priority of the recommendation to fit their required trustworthiness and availability. The trustworthiness means that the experts may have topic interests to the posted question and have good reputation based on their portfolio on the forum. The availability means that the experts are still present and keep visiting the forum in recent months. Thus, with the recommended experts list, the system can actively organize the social network from questioner to these experts by inviting them to help solving the posted question on the forum.

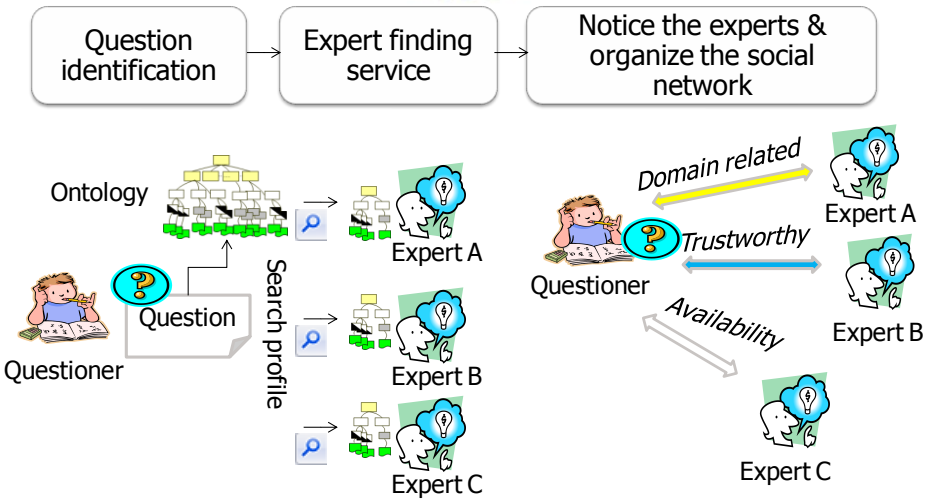


Figure 5.8 The trustworthy expert finding service to bridge the social network for problem solving

Since the trustworthiness of the service is based on the posted forum documents, it

may result in the phenomenon of "the more discussions you post, the more your social network can be explored". Thus, the service on the forum can facilitate the collective intelligence and the social network of Web 2.0 to enrich the programming problem solving in the learning community.

The expert's profile including topic interest, trustworthy and presence is defined. An example is shown in Figure 5.9.

- Topic interest: referred to the number of concepts in the issue layer of PCO, the topic interest is a vector of Boolean values where *k*-th element is assigned to 1 if the expert has posted the documents related to the *k*-th issue before.
- Trustworthy value: it is also a vector with the same length as that of topic interest to represent the reputation of the expert in the specific topic. The *k*-th element of trustworthy value is represented by the ratio of the number of satisfied questioners to the number of all questioners with respect to the expert's historical replies. The larger the value, the more trustworthy the expert is.
- Presence value: it is a list of array which records the ratio of the number of online days to the number of all days in each month. The M_1 is the ratio of that in the last month; M_2 is the ratio of that in two months ago, etc.

Topic Interest

Issue	V_1	V_2	V_3	...	V_n
Is_Interest	1	1	0	...	1
Deg_Trust	0.5	0.9	0	...	0.3

Presence

Month	M_1	M_2	M_3	...
Avg_Online	0.5	0.3	0.6	...

Figure 5.9 An example of expert's profile representation

With the defined expert profile, the aim of the expert finding service is to retrieve the relevant experts whose profiles are related to the posted question. It can be formulated as the objective indicators as follows.

A *Question Q* is inputted by a questioner to express his/her programming problem

with the concept weight vector. When a learner inputs a sentence of question description, the predefined thesaurus is applied to extract the frequently used keywords. Thus, the question is transformed into the keyword vector where the length of the *Q* is limited to the number of issues in PCO. Next, the weight values, from 0 (not related), 0.5 (partially related), to 1 (highly related), can be adjusted by questioner to represent the relation degree of his/her question to the issues. In general, the keywords of similar meaning are recognized as the same concept. Since the documents in the forum are short sentences, the length of concept weight according to our experiment can be limited to the vector with less than 50 keywords.

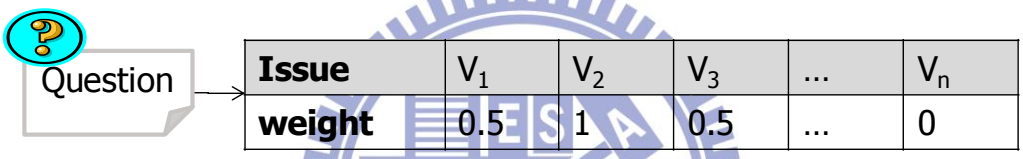


Figure 5.10 Keyword vector of posted question

1) The trustworthy expert finding

In order to determine the degree of relevance of a query and experts, the indicators of objective function are defined. Assume that we are given a query *Q* and an expert *E*. Let *E.Interest* represent the interest vector and let *E.Trust* represent the trustworthy vector of expert's profile. Here, an objective function *Obj* for measuring the correlation between query and expert is proposed by combining the objective functions of Obj_{Trust} and $Obj_{\text{Available}}$.

- **Trustworthiness:** The correlations of query vector Q with vectors *E.Interest* and *E.Trust* respectively are firstly calculated by the inner product represented as $Q \bullet E.Interest$ and $Q \bullet E.Trust$ each of which represents the similarity of two vectors. Thus, the trustworthiness value is measured by the weighted sum of two

inner products with the α factor to control the importance weighting between trustworthy or topic interest. The objective function of trustworthiness is defined in Equation 1.

$$Obj_{\text{Trust}}(Q, E) = \alpha \times (Q \bullet E.Interest) + (1-\alpha) \times (Q \bullet E.Trust) \quad (1)$$

where the factor α, $0 < \alpha < 1$, is used to control the importance weighting between trustworthy or topic interest.

- **Availability:** To reduce the problem of asynchronous, the existing experts can be invited to join the problem solving discussion with higher priority. Thus, the availability parameter is included in the objective function. The objective function of availability is measured by the weighted average of presence records in expert's profile. Assume there are N records in the presence array and the $E.M_i$ represents the i-th element in the array, the objective function is defined in Equation 2. The availability is judged by the number of login records within a period of time. Accordingly, the factor τ is proposed to annotate the fading of the behavior influence based on the probability pheromone update of Ant algorithm [28].

$$Obj_{\text{Available}}(E) = \sum_{i=1}^{N} \tau^i \text{E.M}_i \Big/ \sum_{i=1}^{N} \tau^i \quad (2)$$

where the τ, $0<\tau<1$, is the factor to reflect the fading of expert's behavior influence.

Therefore, the range of these two objective terms, Obj_{Trust} and $Obj_{\text{Available}}$, are both in [0, 1]. The objective measurement Obj for question Q and Expert E which is a linear combination of Obj_{Trust} and $Obj_{\text{Available}}$ is defined in Equation 3.

$$Obj(Q, E) = \beta \times Obj_{\text{Trust}}(Q, E) + (1-\beta) \times Obj_{\text{Available}}(E) \quad (3)$$

where the factor β, $0 \leq \beta \leq 1$, is used to control the weight between trustworthiness and presence.

Based on the definition of objective measurement function, there are several heuristic strategies for the questioner to choose.

- **Trustworthy experts first** (e.g. set $\alpha=0.2, \beta=1$): Recommend the experts who are highly related to the question and have high reputation to help solving the posted question. It can be used for the difficult problem solving topics, such as the program debugging, how to implement new application, etc.
- **Similar topic interest experts first** (e.g. set $\alpha=1, \beta=0.5$): Recommend the experts who actively reply the related questions to help solving the posted question. It can be used for finding learning partners to discuss the topic, such as how to configure the developing platform, how to use the specific function or modules, etc.
- **Expert's availability first** *(e.g. set $\alpha=0.8, \beta=0.2$)*: Recommend the active users to reply their opinions. It can be used for the need of quick feedback, such as the comparison of different SDK, opinion sharing for new technology, etc.

2) The feasibility evaluation

- Training set for ontology construction

  The data of programming learning forum "Programmer-Club" consisting of 14,000 forum documents and 1734 user accounts are collected from year 2001 to 2007 as the test data. The characteristics of the forum test collection are listed in Table 5.7.

Table 5.7 Characteristics of the test forum documents database

Forum Name	No. of postings	No. of community members	Subject
Programmer-Club	14,183	1734	C/C++ programming

- Sample questions

  To compute the precision of the proposed approach in different questions, four frequently asked hot topics which are issues of "Q_1: the object-oriented programming", "Q_2: the string processing", "Q_3: the array processing", and "Q_4: the loop statements" are collected as sample questions.

- Expert finding service configurations

  Three expert finding strategies with different configurations of parameter values are listed in Table 5.8.

Table 5.8 Parameter values of the three experts finding strategies

Experts finding Strategy	Topic interest: α	Trustworthy: β
S_1. Trustworthy experts first	Low ($\alpha=0.2$)	High ($\beta=1$)
S_2. Similar topic interest experts first	High ($\alpha=1$)	Median ($\beta=0.5$)
S_3. Experts availability first	High ($\alpha=0.8$)	Low ($\beta=0.2$)

For each question proposed above, the precision of retrieved top-*k* experts is evaluated. In this way, the *precision* measure is judged by the human experts who are instructors of programming language course in universities. The precision is defined in Equation 4.

Precision = N_Acceptable_Expert / N_Retrieved (4)

where N_Retrieved is the number of recommended experts and N_Acceptable_Expert is the number of acceptable experts judged by the human experts.

Therefore, with the test data mentioned above, the objective values of different experts are ranked and top 20 of them are retrieved. The precision measures are shown in Figure 5.11. The Q1 to Q4 in x-axis represents different questions, and the data in y-axis represent the precision value. For each question, the measurements of three different expert finding strategies are shown.

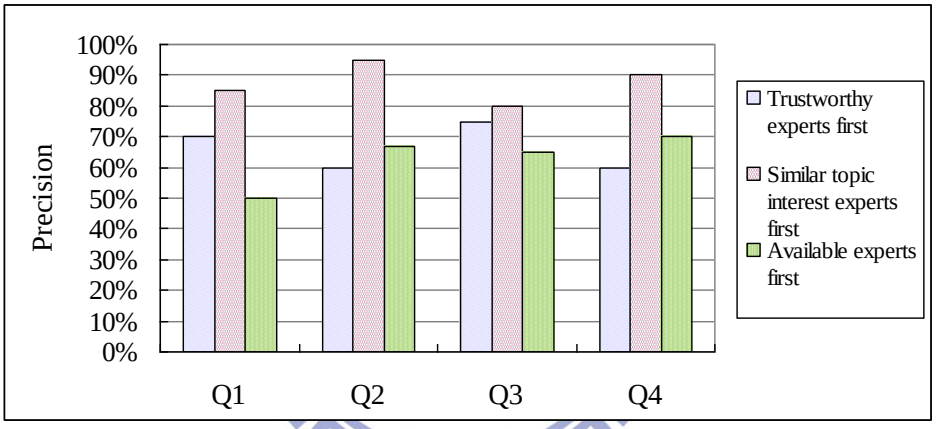


Figure 5.11 Precision measure for the three expert finding strategies

As shown in Figure 5.11, we found that the precision values obtained by "*Trustworthy experts first*" strategy and "*Experts presence first*" are relatively low. With further observation held later on, the documents of Q2 and Q4 are lack of sufficient number of trustworthy values in our training data. Even though, the average precision values are higher than 50%. In summary, we may conclude that the proposed expert finding service are feasible in general where the similar topic interest experts first strategy can have highest feasibility.

3) The effectiveness evaluation

In addition to the feasibility evaluation, the effectiveness of the proposed social network services is investigated. The inquiry-based learning process is based on the existing web forum and learning community treated as learning context. The prototype of the social network service is provided as the add-on functionality to recommend the trustworthy experts based on learner's question. The experiment held by involving 21 university students who are majored in computer science all with programming experience participated in the evaluation. The questionnaire analysis is applied to evaluate the students' satisfaction degree of the provided services in different inquiry problems and in different expert finding strategies as shown in Table 5.9 and Table 5.10 respectively. The items are measured by the five-point Likert scale ranging from 5, "strongly agree" to 1, 'strongly disagree". The mean and standard deviation (SD) of the questionnaire statistical results are shown as follows.

Table 5.9 Questionnaire of learners' satisfaction in different inquiry problems

Questionnaire Item	Mean	SD
Q_1. I think the inquiry-based learning with experts on the forum is helpful for the programming problem solving.	4.05	0.80
Q_2. I think the inquiry is especially helpful in the problems of "what's the meaning" or "what's the different".	4.10	1.00
Q_3. I think the inquiry is especially helpful in the problems of "what's wrong".	4.19	0.98
Q_4. I think the inquiry is especially helpful in the problems of "how to use" or "how to do".	3.95	0.86
Q_5. I think the inquiry is especially helpful in the discussions of "new experience sharing".	4.33	0.66

As shown in Table 5.9, the mean of Q_1 item is larger than 4.0. Thus, the expert finding service is helpful in general. The items from Q_2 to Q_5 show the satisfaction

value of different inquiry problems discussed on the forum. The highest mean value occurred in Q_5. It shows that the inquiry with experts is most helpful in "new experience sharing". The mean value of Q_4 is relatively lower than others. With the further feedbacks from learners for the problems of "how to use", some of them would like to read the technical documents by themselves rather than asking from social interactions. The mean values of items Q2 and Q3 are higher than 4.0 which represent the helpfulness of the services.

Table 5.10 Questionnaire of learners' satisfaction in different expert finding strategies

Questionnaire Item	Mean	SD
Q_6. I think the "trustworthy experts finding service" is helpful for my learning.	3.95	0.80
Q_7. I think the "availability experts finding service" is helpful for my learning.	4.05	0.74
Q_8. I think the "similar topic interest experts finding service" is helpful for my learning.	4.24	0.70
Q_9. I think the "automatic social networking service" is helpful for my learning.	3.62	0.67
Q_{10}. The "automatic discussion invitation services" of problems from other learners do disturb me.	2.67	0.86

As shown in Table 5.10, questionnaire items of learners' satisfaction in different expert finding services have been investigated. The item Q_{10} was asked in opposite ways compared to others. In average, from the mean value of Q_6, Q_7, Q_8, and Q_9, the satisfaction evaluations of proposed services are larger than 3.0 which means acceptable. Among them, the item Q_8: "similar topic interest experts finding service" got the highest value. In addition, the feedback of how to further improve the service was provided. One of the learner's feedback said that the categories and topics can be more customized for their learning subjects. Thus it can be easier for students to ask

the right question to find the right experts.

In summary, the experiment result shows the effectiveness of inquiry behavior modeling to provide the learning guidance by trustworthy experts finding service. Most of students agreed that the proposed social network service is helpful for their learning.

Chapter 6
Behavior modeling of content tagging for learning resource management

With rapid growth of Web 2.0, one of the emerging visions is the “collective intelligence” of the community of members to contribute their knowledge. The collaborative content sharing platforms such as the Wikipedia, YouTube, Flicker, etc. are getting more popular. With the online knowledge sharing platforms, learners can easily contribute their learning contents and share the resources contributed by others. However, users in the community may have multidiscipline background. How to efficiently categorize the contents and effectively provide the solution retrieval service becomes a challenging issue.

In this chapter, the behavior modeling for students in the knowledge sharing community is proposed for adaptive solution retrieval for problem solving.

6.1 Knowledge sharing behavior modeling on content repository

The Web application technology referring to Web 2.0 facilitates mass collaborating and sharing on the online platform. The folksonomy approach which means users providing tags to categorize the users’ generated contents has been proved useful in many Web applications such as the *Delicious*, *Flickr* or *YouTube*. The folksonomy is currently one of the most popular contents organizing methods. As shown in Figure 6.1, the item bank of programming problems as an example, students can act as contributors who upload their programming test items or solutions to the learning content management system and share their learning experiences. Students annotate the contents by folksonomy tags which are the user-generated classification

keywords. Students can act as consumers or followers who download and reuse the items by searching the tag. Students can also act as critic who update or revise the items or folksonomy tags in the content repository.

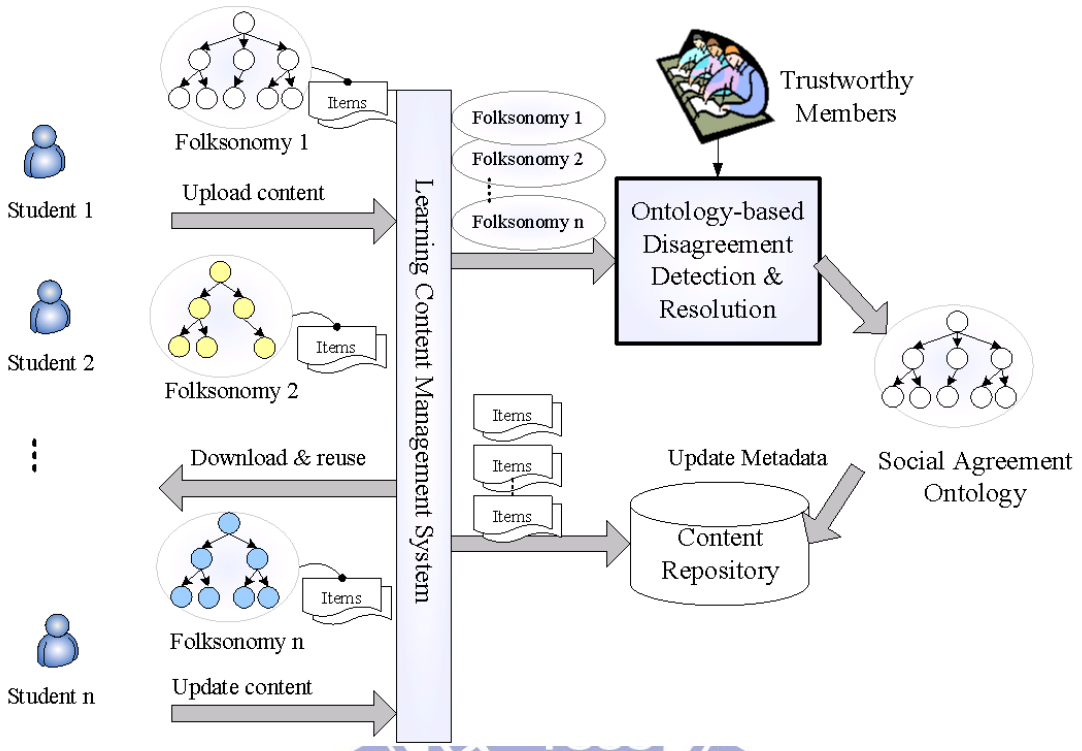


Figure 6.1 The behaviors of knowledge sharing activity on content repository

To provide adaptive content retrieval service, the taxonomy [5][27] is important information for retrieving the test items to meet the concepts to be tested. If the test items of the item bank are tagged with taxonomy, then the test items can be easily retrieved by fix length keyword vector model as shown in Figure 6.2. For example, the terminal nodes of taxonomy can be represented as fixed length vector <$C_{1\text{-}1}$, $C_{1\text{-}2}$, $C_{2\text{-}1}$, $C_{3\text{-}1}$, $C_{3\text{-}2}$>. Therefore, the user's query of the concepts "$C_{1\text{-}1}$ *OR* $C_{3\text{-}1}$" can be represented as vectors <1, 0, 0, 0, 0> and <0, 0, 0, 1, 0> where the 1s represent the required concepts based on the vector model. While the similarity between the test item keyword vectors and the query keyword vectors are larger than the predefined

threshold, the test items will be retrieved for the test sheet composition algorithm.

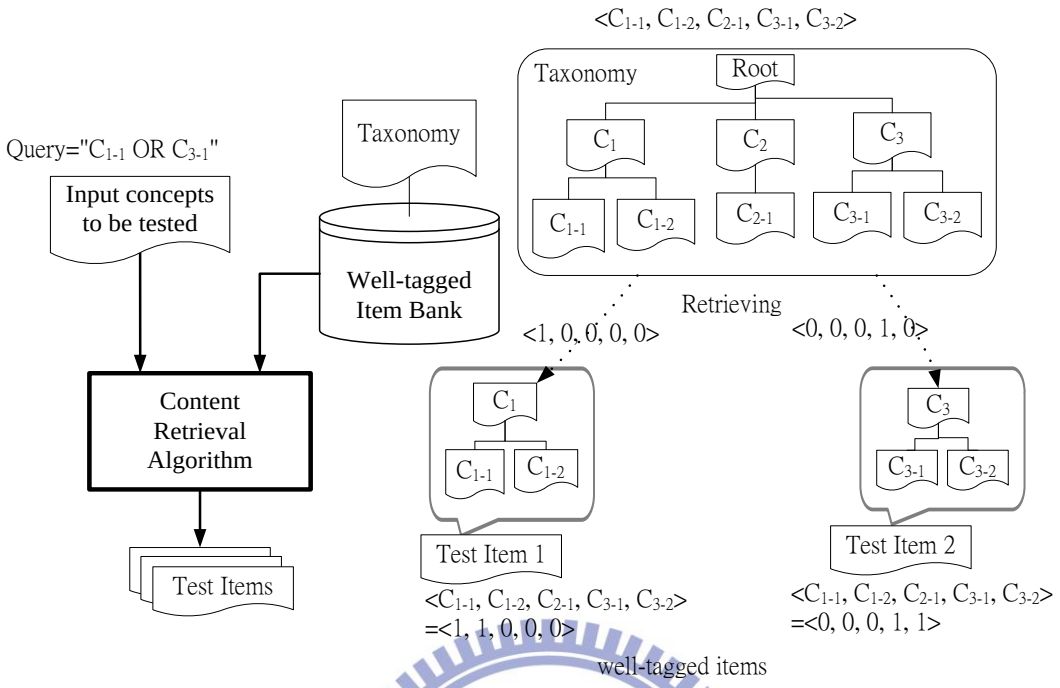


Figure 6.2 The test sheet composition supported by the well-tagged item bank

The test items tagged with the taxonomy can be the well-tagged test item. The definition of well-tagged test item is as follows.

Definition 6.1 The well-tagged test item

A test item is well-tagged only when the tagged concepts of a test item are not overlapped with each other and no more tags can be added to describe the tested concepts.

In contrast to the taxonomy, the benefit of the folksonomy approach is that the tags can be quickly collected and the tags make sense to users. However, the main drawback of the folksonomy is that the uncontrolled tagging process is apt to cause the synonym, redundancies and incompleteness of tags. With our observation, this is

because different folks may have different disciplines for contents categorization. Therefore, the problem of how to converge the diversified social tags into consensus taxonomy which is defined as tags consensus building problem arises with the growth of users and contents.

In order to build the consensus taxonomy for content retrieval, the users' behavior model needs to be built for disagreement detection. Therefore, the knowledge sharing activity can be obtained by the combination of content access actions and the tag refinement with respect to the existing taxonomy structure. Accordingly, the users' behavior modeling for knowledge sharing is defined as followings.

Definition 6.2 The knowledge sharing behavior model

B=(C, A) where

- C: the contributed or modified folksonomy tags.
- A={New | Support | Against } represents the knowledge sharing actions of New: user adds a new content and tag, Support: user reuses current content without modification, and Against: user deletes or modifies the existing content and tag.

Since users provide knowledge based on different disciplines, the conflicts of tags as followings need to be resolved.

- The tag synonym and hyponym means that the concepts of two tags are overlapped.
- The tag redundancy means that some tagged concept is not highly related to the test item.
- The tag incompleteness means that the existing tags are insufficient to describe the test item.

If the defects of tags can be reorganized to complement each others, then the self-tagged content repository can be refined and integrated into well-tagged content repository as shown in Figure 6.3.

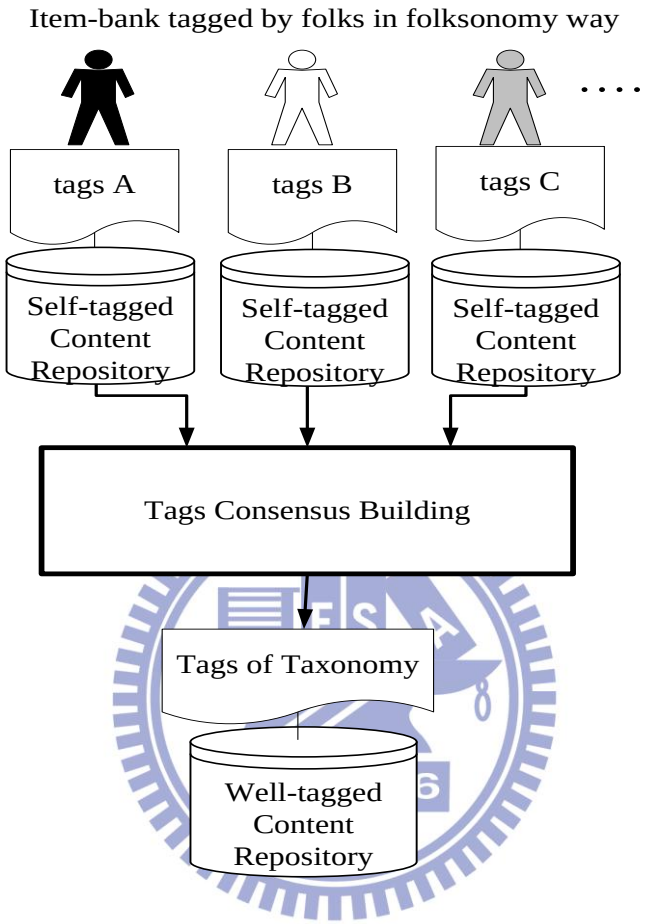


Figure 6.3 Tags consensus building problem

We define this metadata reengineering process as the tags consensus building problem as follows. Solving the problem can avoid retrieving the unexpected test items during the test sheet composition.

Definition 6.3 Tags Consensus Building Problem

Given self-tagged item bank, the problem is how to resolve the synonym, redundancies and incompleteness of tags in each test item to build the well-tagged item bank.

6.2 The Iterative, Collaborative Ontology Crystallization scheme for Consensus building

To solve the Tags Consensus Building Problem, the different disciplines of concept hierarchy about tags need to be resolved first. In this section, the ontology [3] is applied to model the concept hierarchy about tags. To obtain the consensus of concept hierarchy, an Iterative, Collaborative scheme called Ontology Crystallization is proposed based on the idea of modified Delphi method [2][23][43][46][54][59][71]. The modified Delphi method is an iterative, group decision support methodology for the convergence process usually having several rounds of brainstorming stage and conflict resolution stage using the digitized questionnaire. Accordingly, as shown in Figure 6.4, when tags with new concept hierarchy are added, the new contributed assertions of concept hierarchy are regarded as the candidate assertions. After there are a number of candidate assertions, the ontology crystallization process is triggered and assertions can be appended to the new converged ontology, e.g., the version k+1 and k+2 in Figure 6.4.

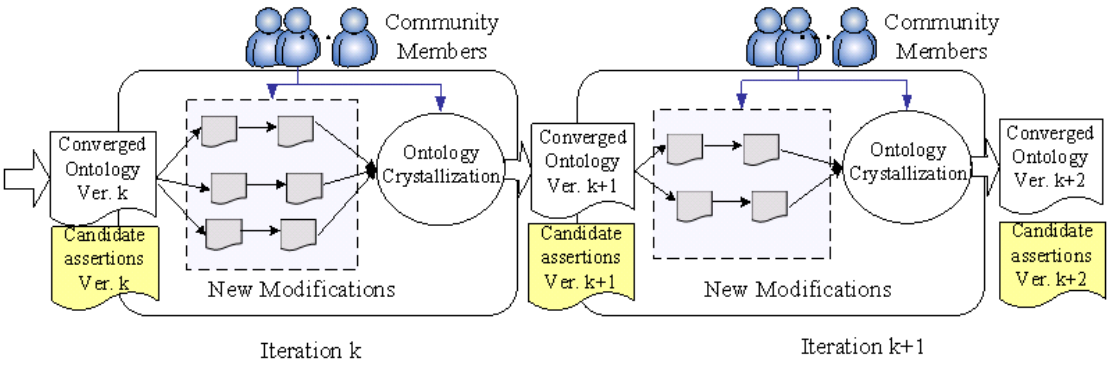


Figure 6.4 The Iterative, Collaborative Ontology Crystallization scheme

In the ontology crystallization process, the questionnaire approach is used to

efficiently gather information and acquire users' opinions of tags with conflict concept hierarchies. To achieve the social agreement, the Folksonomy-based Delphi Method is proposed to resolve the disagreements through the voting by questionnaire.

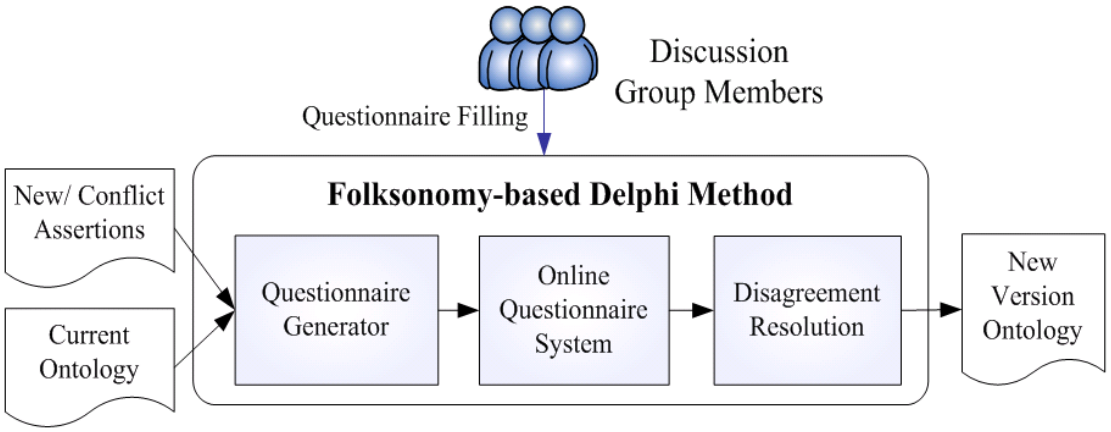


Figure 6.5 Folksonomy-based Delphi Method

As Shown in Figure 6.5, the Questionnaire Generator process detects conflict assertions and generates appropriate questionnaire by constructed questionnaire item templates. In the Online Questionnaire System, the disagreement resolution can be done by voting from community members. Since the conflict resolution using original Delphi method tends to become onerous task. To ease the task, the dynamic users are involved in the Delphi group. To compensate the loss of consistency, the users are classified into groups based on their proficiency and expertise. Thus, the users in the Delphi group can be substituted by the different users in the same group. The questionnaire system of Folksonomy-based Delphi Method is shown in Figure 6.6.

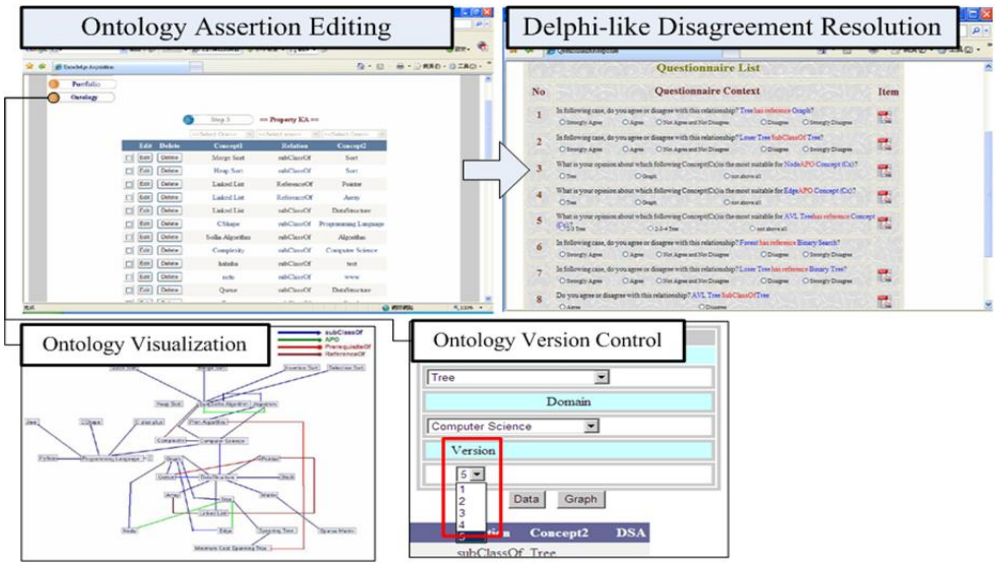


Figure 6.6 Questionnaire system of Folksonomy-based Delphi Method

6.3 The metadata effectiveness evaluation

With the consensus domain concept hierarchy, the defects of tags still need to be resolved. Accordingly, tag effectiveness criterion is proposed to resolve the defects of tags. Assume there are tags T_1 and T_2 collected in folksonomy way. The tags can be mapped to the concepts in the given concept hierarchy with nodes C_1, $C_{1\text{-}1}$, $C_{1\text{-}2}$, and $C_{1\text{-}3}$. The tag effectiveness criterion of tags can be obtained such as T_1.effectiveness, T_2.effectiveness. The *Threshold* represents the minimum value of required tag effectiveness. Three heuristic rules for the tag effectiveness refinement are as follows.

The first situation is shown in Figure 6.7. If the associated concepts C_1 and $C_{1\text{-}3}$ of two tags T_1 and T_2 have the *consist_of* relation, then the tags are synonym or hyponym. The synonym and hyponym can be resolved by selecting the tag with highest effectiveness value.

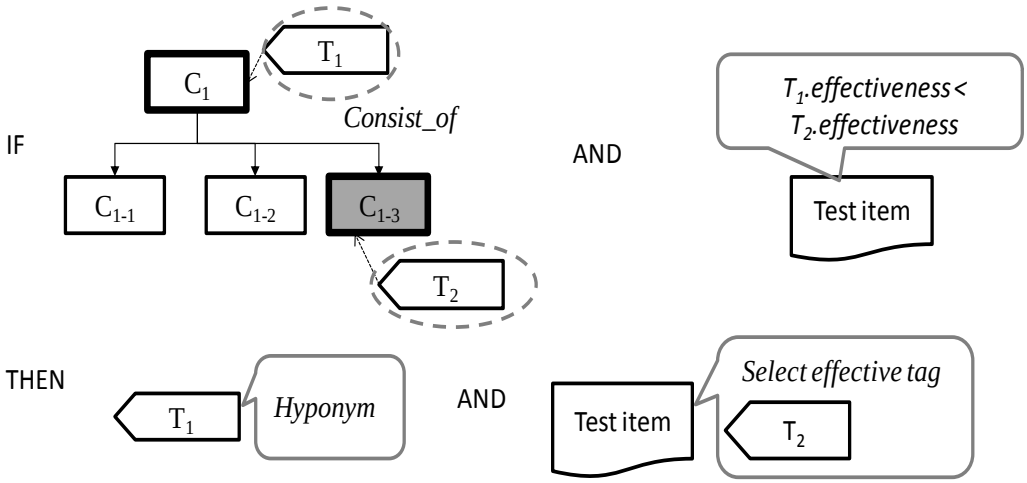


Figure 6.7 The synonym resolution heuristic rule

The second situation is shown in Figure 6.8. If the tags T_1 and T_2 are in the same sub-tree of the concept hierarchy, and the effectiveness value of tag T_1 is lower than the required threshold, then the tag T_1 might be the redundant tag. The redundant tag can be eliminated.

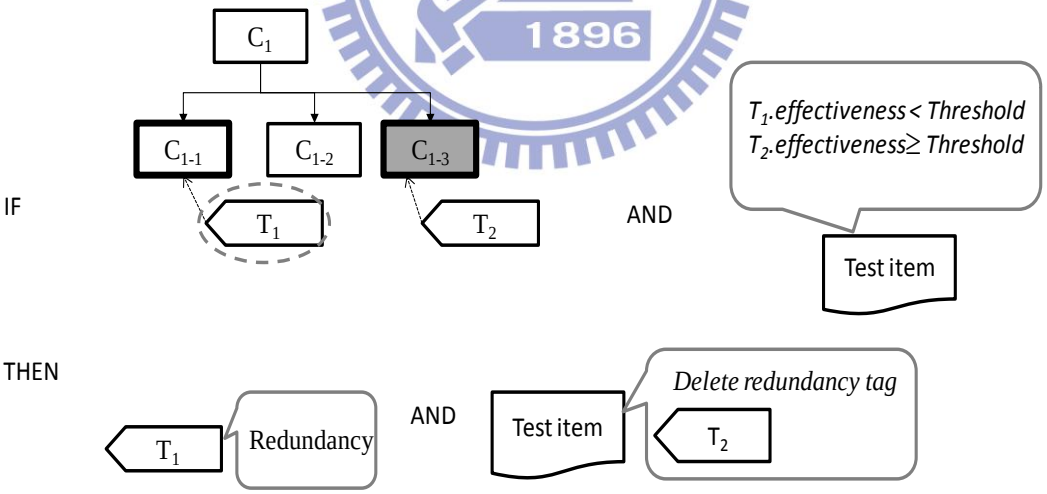


Figure 6.8 The redundancy resolution heuristic rule

The third situation is shown in Figure 6.9 If there is a course-grained tag and its effectiveness vale is lower than the required threshold, then the tags of the test item is incomplete. The incompleteness can be handled by drilling down the concept

hierarchy and suggest the fine-grained tags to evaluate the effectiveness again. If the candidate fine-grained tags are effective then the incompleteness is resolved. Else we should ask the users to add more tags to improve the metadata of test item.

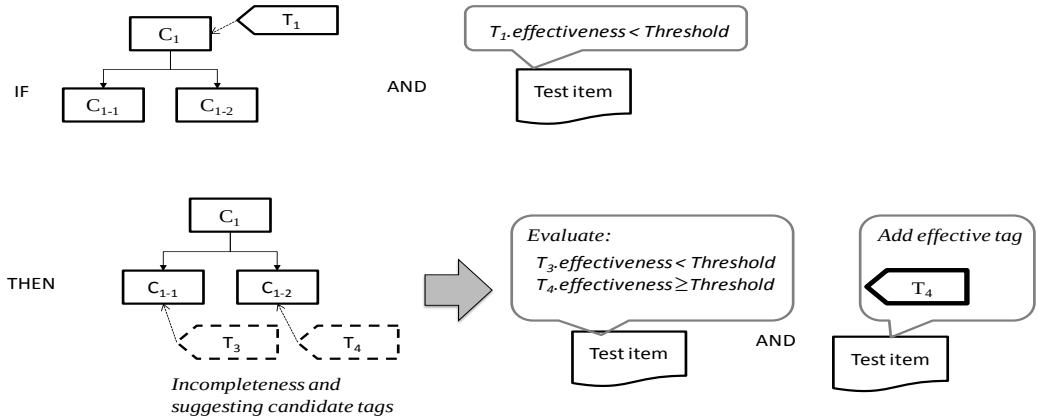


Figure 6.9 The incompleteness resolution heuristic rule

Based on the ideas above, the tag effectiveness refinement heuristic rules are proposed to resolve different defects as follows.

- **R_1: Synonym resolution heuristic rule**

  If (T_1 and T_2 have *consist_of* relation) AND (T_2. effectiveness > T_1. effectiveness) then select the tag T_2 Else select tag T_1.

- **R_2: Redundancy resolution heuristic rule**

  If (T_1.effectiveness < *Threshold*) then delete the tag T_1.

- **R_3: Incompleteness resolution heuristic rules**

  If (concept of tag T_1 has children concepts) then suggest tags of children concepts as candidate tags (assume T_3 and T_4). While (T_4.effectiveness ≥ *Threshold*) then add tag T_4.

In the proposed tag effectiveness refinement heuristic rules, the effectiveness of tags is an important factor to decide which tags should be selected or eliminated. In

our approach, the tag effectiveness evaluation can be obtained from the pretesting result of students. For each test item, if the students have high achievements for the tagged concepts and correctly answer the item, then the tags are effective. Else, the tags have lower effectiveness value and need to be refined or eliminated. Thus, the Item Response Theory (IRT) [34][79] is applied to evaluate the effectiveness of tags based on students' learning achievements, discrimination of test items and difficulty degree of test items. The IRT-based Tag Effectiveness Criterion is defined as followings.

Definition 6.4 The IRT-based Tag Effectiveness Criterion

For the item j, the value P_j indicates the difficulty degree and the value D_j indicates the discrimination degree. For the student i, the learning ability value $\tilde{x}_i$ ranging from -3.5 to 3.5 indicate the weighted learning degree from low to high. Thus, the S_{ij}, the tags effectiveness of the test item j via score of student i, can be evaluated by the modified logistic model of Item Response Theory equation,

$$S_{ij} = \frac{1}{1+e^{-1.7D_j(\tilde{x}_i+P_j)}}, \; e = 2.719 \tag{1}$$

Next, for tag k, let R_k be the sum of S_{ij} scores of correct items and W_k be the sum of S_{ij} scores of incorrect items. The factor τ is an arbitrary small positive real number to make sure that the nature logarithm function is well defined. Thus, the C_k, the IRT-based Tag Effectiveness Criterion of the tag k, is defined as follows.

$$C_k = ln\ ((R_k+\tau)\ /\ (W_k+\tau)) \tag{2}$$

With our experience, the criterion value ranges from -4 to 4. The larger value indicates higher effectiveness and negative value indicates no effectiveness.

With the defined IRT-based tag effectiveness criterion and the heuristic rules proposed above, the algorithm of the IRT-Based Metadata Reengineering Scheme is proposed as follows.

Algorithm 6.1. The IRT-Based Metadata Reengineering Scheme (IRT-RES)

Input: tags of self-tagged test items, domain concept hierarchy, students' pretesting results on test items.

Output: consensus tags.

//Phase 1. Construct the concept hierarchy of tags:

Step 1. Map the tags of the metadata to the concept hierarchy.

Step 2. For each concept node, if there are multiple tags on the same concept node, then resolve the ambiguity by keeping one unique tag.

//Phase 2. Tag refinement based on IRT-based tag effectiveness:

Step 3. For all tags, execute the *Tag effectiveness evaluation algorithm (defined in Section 4.1)* to obtain the tag effectiveness criterion using students' pretesting results on test items.

Step 4. For tags of each test item, apply the tag effectiveness refinement heuristic rules to obtain the tags defects. Suggest the inference results to the users to support the tags consensus building. Repeating the tag refinement process of Phase 2 until all defects of tags are resolved and then output the consensus tags.

6.4 Evaluation

To evaluate the effectiveness of the tag, an experiment has been done. The experiment results showed the tag refinement results and users' satisfaction for our approach.

1) Experiment of Social tags versus IRT-MRS

In the experiment, our goal aims to prove that the IRT-MRS can effectvely refine the social tags collected in folksonomy way. The item bank metadata reengineering experiment selected the scope of *Trigonometric Function* in 11th grade Mathematics as the experiment domain. The test items were selectd from the term examination to make sure the quality and teachers were asked to provide the tags in folksonomy way as the test item metadata. There were 21 senior high school teachers participated as folks in the social tagging process. Two domain experts who have ten years experiences in the 11th grade Mathematics for test sheet composition and taxonomy construction were participated to evaluate the effectiveness of tags constructed by our approach.

The concptual view of the experiment procedures is shown in Figure 6.10. For the same test items, the *tags A* constructed by 21 teachers in folksonomy way were compared to the *tags B* constructed by our approach. The 18 classes of high school students' pretesting scores of those test items were input to the metadata reengineering process. Afterward, the effectiveness of tags A and tags B were evaluated by two experts. Two experts were asked to provide their tags as the evaluation test cases. If the tags B are closer to the experts' tags than tags A, then we can conclude that our approach can effectively refine the tags.

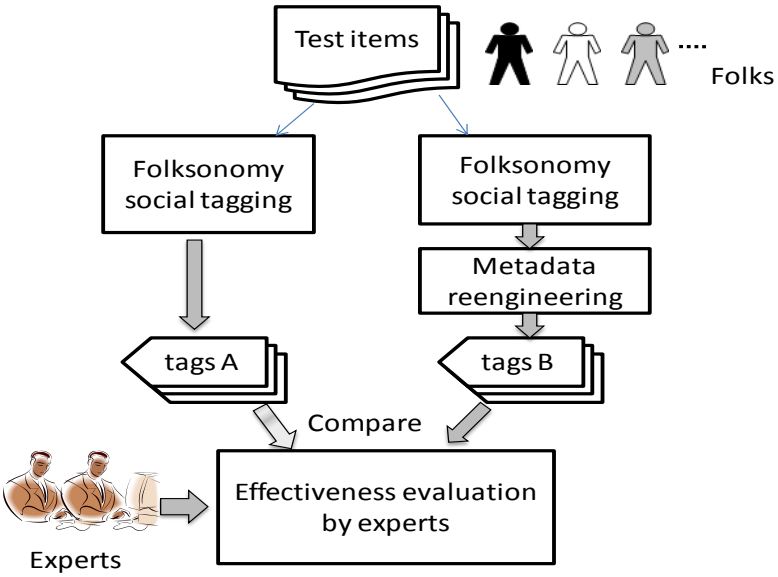


Figure 6.10 The experiment of tag evaluation by experts

2) Experiment results

The Figure 6.11 shows the collected social tags in the experiment. The tags were mapped to the concept hierarchy and assigned with the unique identification.

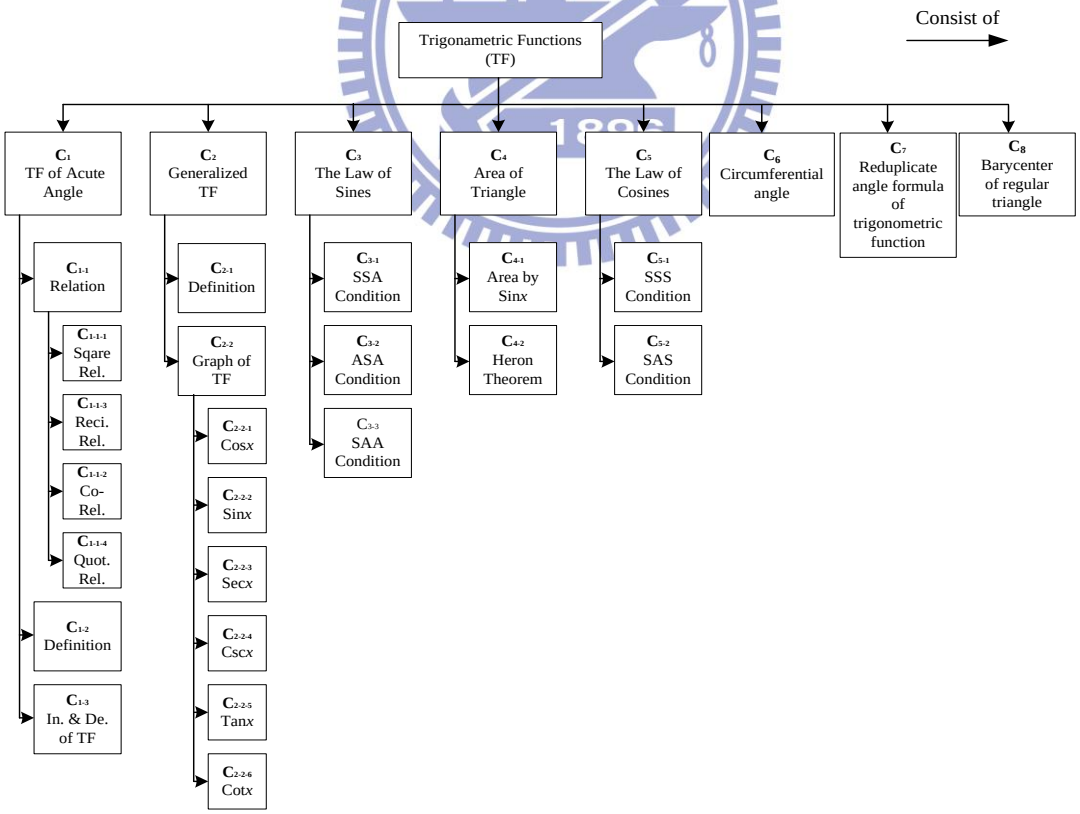


Figure 6.11 The tags of the trigonometric function domain

The tags of test items obtained from traditional folksonomy, IRT-MRS, expert 1 and expert 2 are shown in Table 6.1. The test items are sorted by tag size of traditional folksonomy. The tags given by expert 1 and expert 2 are test cases.

Table 6.1 Tags of test items collected from folksonomy, IRT-MRS, and experts

Test item	Tag size	Social Tags of traditional folksonomy	Tags of IRT-MRS	Tags given by Expert 1	Tags given by Expert 2
T_1	1	$C_{2\text{-}1}$	$C_{2\text{-}1}$	$C_{2\text{-}1}$	$C_{2\text{-}1}$
T_2	1	C_5	C_1, $C_{2\text{-}1}$, C_3, C_5	C_5	C_5
T_3	2	$C_{2\text{-}1}$, C_5	C_5	C_5	C_5
T_4	2	C_3, C_8	C_3, C_6	C_3	C_3
T_5	2	$C_{2\text{-}1}$, C_5	$C_{2\text{-}1}$,C_5	C_5	C_5
T_6	2	$C_{2\text{-}1}$, C_5	C_1, C_5	C_5	C_1, C_5
T_7	3	C_1, $C_{1\text{-}3}$, $C_{2\text{-}2}$	C_1	$C_{1\text{-}3}$	$C_{1\text{-}3}$
T_8	3	C_1, $C_{1\text{-}2}$, $C_{2\text{-}1}$	C_1, $C_{2\text{-}1}$	$C_{2\text{-}1}$	C_1, $C_{2\text{-}1}$
T_9	3	C_1, $C_{1\text{-}1}$, $C_{1\text{-}1\text{-}1}$	C_1	$C_{1\text{-}1}$	$C_{1\text{-}1\text{-}1}$
T_{10}	3	C_4, C_5, C_7	C_5	C_5	C_5
T_{11}	4	C_1, $C_{1\text{-}1}$, $C_{1\text{-}1\text{-}1}$, $C_{1\text{-}3}$	C_1	C_1	$C_{1\text{-}3}$, $C_{1\text{-}1\text{-}1}$
T_{12}	4	C_3, C_5, C_6, C_8	C_6, C_8	C_3, C_6	C_6
T_{13}	4	C_1, $C_{1\text{-}1}$, C_2, $C_{2\text{-}1}$	$C_{2\text{-}1}$	$C_{2\text{-}1}$	$C_{2\text{-}1}$
T_{14}	5	C_1, C_4, $C_{4\text{-}1}$, $C_{4\text{-}2}$, C_5	$C_{4\text{-}2}$	$C_{4\text{-}1}$, $C_{4\text{-}2}$, C_5	$C_{4\text{-}1}$, $C_{4\text{-}2}$, C_5, $C_{1\text{-}1\text{-}1}$
T_{15}	5	$C_{1\text{-}2}$, C_4, $C_{4\text{-}1}$, $C_{4\text{-}2}$, C_5	C_1, $C_{4\text{-}1}$, C_5	$C_{4\text{-}1}$, $C_{4\text{-}2}$, C_4, C_5	C_4, C_5
T_{16}	6	$C_{1\text{-}3}$, C_3, $C_{4\text{-}2}$, C_5, C_6, C_7	C_3, $C_{4\text{-}2}$	C_3, $C_{4\text{-}2}$, C_5,	C_3, C_5

In IRT-MRS, the calibration software for the three parameter logistic IRT model

is used to obtain the IRT-based tag effectiveness criterion. The average number of altered tags for test items with different tag sizes is shown in Figure 6.12. The test items with larger tag size are more diversified and thus the IRT-MRS refines more number of tags.

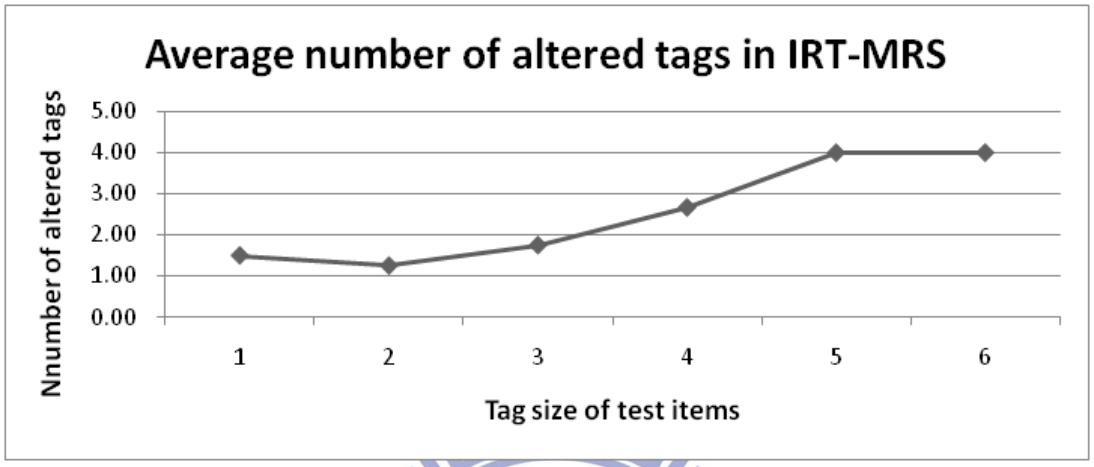


Figure 6.12 The average number of altered tags for test items with different social tag sizes

The tags were evaluated by the average number of differences from the tags given by two experts.

The smaller differences mean that the tags are more effective. The comparison of the social tags and tags of IRT-MRS based on two experts' tags are shown in Figure 6.13 and Figure 6.14. In general, the tags of IRT-MRS can improve the social tags with tag sizes larger than two.

Figure 6.13 Comparison of the social tags and IRT-MRS based on expert 1's tags

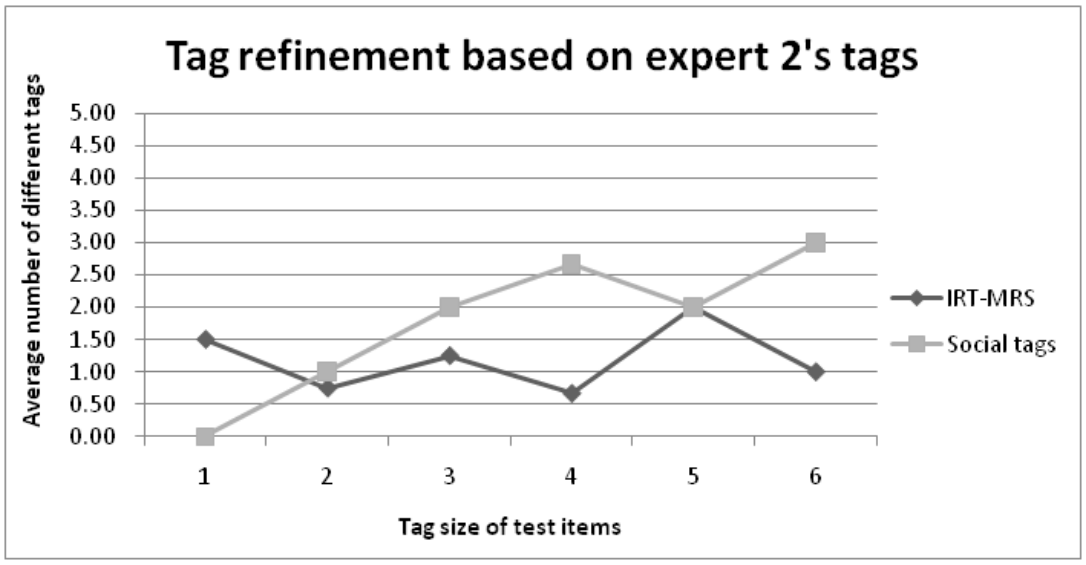


Figure 6.14 Comparison of the social tags and IRT-MRS based on expert 2's tags

Afterward, the correctness evaluation for the tags of IRT-MRS was conducted by the questionnaire analysis with the original 21 senior high school teachers. The typical five-level Likert scales item was used in the satisfaction questionnaire. The means of feedbacks in different levels had 14.3% general, 66.7% agreed and 19.0% strongly agreed for the correctness of the proposed approach. The feedbacks of open questionnaire from the teachers showed that they were amazing to the automatic tag refinement results. The IRT-MRS can effectively suggest them the tested concept of the test items from the students' pretesting reflection. Therefore, we may conclude that the IRT-MRS can successfully help teachers build the consensus and acceptable tags.

Chapter 7 Applications

In this chapter, the applications of behavior modeling using in game-based learning, enterprises system error solution retrieval and online adaptive learning content sequence services are investigated.

7.1 Application: teaching Boolean Logic through game rule tuning

The Boolean logic is the logical calculus with algebra of truth values 0 and 1 representing false and true. Numerous subjects studied in schools such as describing scientific theorem in Mathematics and Physics or causal statements in History and Literature use the Boolean logic as the formulation language. There are also many problems about decision making or rule designing in our daily life can use the skill of Boolean logic to help clarify the possible effects for different situations.

Since the Boolean logic is a tool for representing the cognitive principles or rules, the Truth table, Logic gate and Venn diagram approaches are usually used in traditional lecturing to visualize the behavior of different operators and the results of various logic expressions. However, these traditional approaches lack meaningful scenario to connect students' experiences, the mappings between Boolean logic and real world case spaces are usually difficult for students to imagine and comprehend. Teachers usually need to explain the concepts with real world cases including the formulation from the real world cases to Boolean logic space and the realization from the Boolean logic expressions to the real world space. It motivates this dissertation of applying the game-based learning approach to assist students in manipulating and observing the relationship of two spaces.

To support the teaching of Boolean logic and solve the issues above, the game-based learning with game rule tuning activity is proposed. The game rule tuning activity design process is shown in Figure 7.1. The initial process of selecting the suitable game is the most important process. For example, the logic learning should select the puzzle game focused on logic training, the management learning should select the strategy game focused on decision making, the clinical learning should select the simulation or action game focused on reaction training, etc. Next, the process of mapping learning objective to game property instantiates the abstract learning objective to the meaningful game scenarios or obvious scores. The process of modeling difficulty of learning activity allows the teachers to provide suitable tasks following the pedagogical need. In this dissertation, the classical game Pac-Man is chosen as the teaching material and the Scratch programming tool is used as the learning platform.

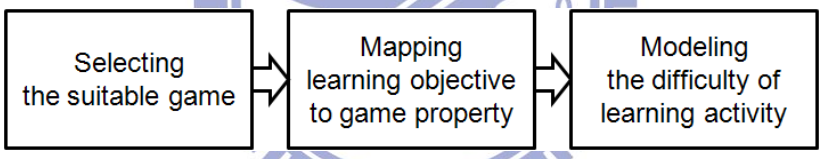


Figure 7.1 The Game rule tuning activity design process

With our observation, a game is composed of game rules, game script, and game roles. The popular game such as *Pac-Man* involves well-designed game rules, simple game scenario and characteristic game roles to interest players. In this dissertation, we define the grammar of game rules to represent the Boolean logic expressions space and the game scenarios to represent the real world case space. For example, the rule *"Ate_Pill AND Touched_Ghost →Score"* includes the conjunction and implication operators for one scoring scenario that "if the Pac-Man ate the pill and touched the ghost then the player gets one point of score". Thus, the students can practice the realization of Boolean logic from the game rules to the game scenario and vice versa.

Accordingly, our goal aims to provide several modified game scenarios from original Pac-Man game to stimulate students to comprehend the specific Boolean logic in game rules in terms of teacher's teaching objectives. Therefore, how to model and manipulate the rules of the game cases is our first concern.

The Scratch open source programming tool was developed by Resnick from MIT Media Lab in 2007 for students to easily create games and share their creations. The Scratch is used as the learning platform in the Boolean logic learning. The Scratch programming tool is based on the self-defined object-oriented programming language with the support of the logical operators including the conjunction, disjunction and negation. As shown in Figure 7.2, the WYSIWYG (what you see is what you get) interface of the Scratch programming tool allows students to easily compare the game scenario (the left part of Figure 7.2) and game rules (the right part of Figure 7.2).

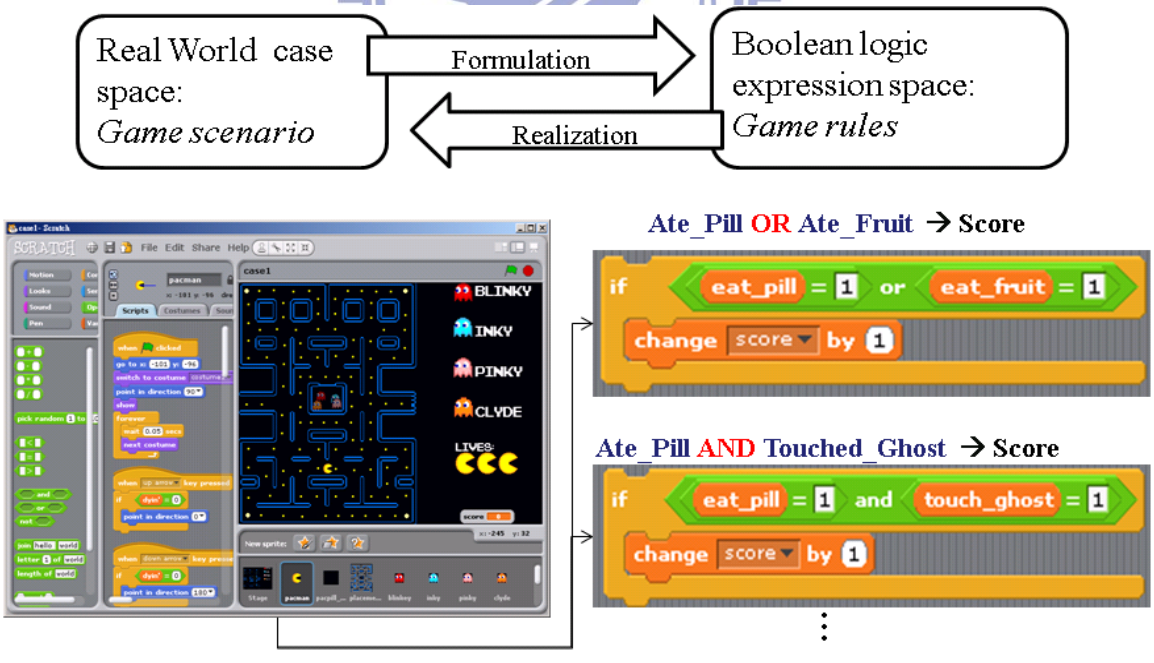


Figure 7.2 The Scratch programming tool

To evaluate the hypotheses we made, there are 67 random selected 9-th Grade students (14 to 15 years old) in Minzu Junior High School, Taipei, Taiwan

participated the experiment in semester 2009-2010. There are 27 students in control group and 40 students in experimental group and their background including semester grade of Mathematics and ratio of boys and girls are shown in Table 7.1.

Table 7.1 Students joined the experiment

Groups	size	Term	Math Score	Boys / Girls
Control group	27	2009-2010	66.33	12 / 15
Experimental group	40	2009-2010	62.6	19 / 21

The experiment tool of the learning achievement evaluation is the self-designed test sheet for Boolean logic realization.

- Comparison of learning improvements

The testing score of the learning achievement is shown in Table 7.2. To evaluate the difference between two groups, the paired two-sample T-test for means of scores is applied. Consequently, the t-test results of the experimental groups suggest significant differences but the control group has no significant differences. Finally, we may conclude that the experimental group has higher learning improvement.

Table 7.2 The score for each group (total score=100)

	Pretest		**Posttest**		
	Mean	**Std. Div.**	**Mean**	**Std. Div.**	Paired t-test
Control group (size=27)	54.44	20.82	54.81	20.64	t(26)=0.0997, p=0.9214
Experimental group	54.5	17.68	64	12.77	t(39)=3.9141,

(size=40)	p=0.0004*

*p<.05

- Comparison of learning outcomes

The testing score of the learning achievement is shown in Table 7.3. To evaluate the difference between two groups, the un-paired two-sample T-test for means of scores is applied. The null hypothesis H_0 assumes that population variances are equal. The t-test results show that F-value is 2.61181 and p-value is 0.0065. Consequently, the t-test results of the two groups suggest significant differences at a confidence interval of 95%. Finally, we may conclude that the experimental group has higher learning achievement than control group.

Table 7.3 The score for each group (total score=100)

	Size	**Mean**	**Std. Dev.**
Control group	27	54.81	20.63
Experimental group	40	64	12.77
F=2.61181, p-value=0.0065*			

*p<.05

From the experiment, our findings of applying the game tuning activity in the game-based learning can be concluded in following points:

- Although the game-based learning is interesting for students, the game is additive for students. Therefore, the teacher should control the progress of the teaching stages and provide clear and well-designed learning goal.
- Since teaching the realization of Boolean logic is our main objective, choosing the well-known game with simple game scenario is better for students to quickly

catch the point.

- The learning materials and learning platform should be prepared for students to avoid wasting time in getting familiar or installing the preliminarily used tools.
- Understanding the application of Boolean logic affecting the interesting games is surprisingly attractive for students to actively engage in the learning activities.

Though this works, we have some suggestions of applying game to learning. For the game platform selection, the game should be easy to manipulate and the factors of the game should be easy to observe. For the reinterpretation of the game, teachers should connect the game scenarios, roles and rules with the knowledge in order to apply the pedagogical theory to the game-based learning activity. For the activity control, the teacher should be able to control the learning progress by dividing the game playing into several rounds, and thus the explanation can be provided before each round. For the activity design, the learning objectives of each activity are better to be limited in one or two specific concepts.

The effectiveness of the game-based learning for realization of basic operations of Boolean logic has been shown in our experiment. Currently, the Pac-Man game rule tuning activity only supports the learning of simple Boolean logic expressions for junior high school students. In the nearly future, we will further apply the game rule tuning activity for the complex logic expressions or higher order logic with quantifiers (existential and universal). Since the key point of game-based learning is the selection of the suitable game type, the simulation games or strategy games which contain more criteria for decision making can be selected as the game context for the learning of complex logic expressions.

7.2 Application: the enterprise problem diagnosis and solution retrieval

To obtain the high reliability and availability of the information system in the enterprise environment, the multi-domain architecture has been applied to system design extensively to enhance performance, flexibility and scalability of the information system [29][81]. However, it increases both the complexity of the system and the difficulty of problem diagnosis. Moreover, once the complex information system goes wrong, domain experts usually get together to look for solutions to fix the problem as soon as possible. In the enterprise environment, the expert finding and problem diagnosis of complex system is mission critical.

The typical customer relationship management system (CRM system) shown in Figure 7.3, a typical multi-domain system for daily operation, connects several component applications to provide services of billing management system, human resource management and network maintenance system. To ensure the CRM system works well in daily operation, experts in different domain (e.g., DBAs, system maintainers, system administrators and developers etc.) should participate in maintaining the system. Therefore, how to utilize domain knowledge and the profiles of experts during problem diagnosis processes to find the right persons to fix the problem of the complex system (multi-domain) has become an important issue.

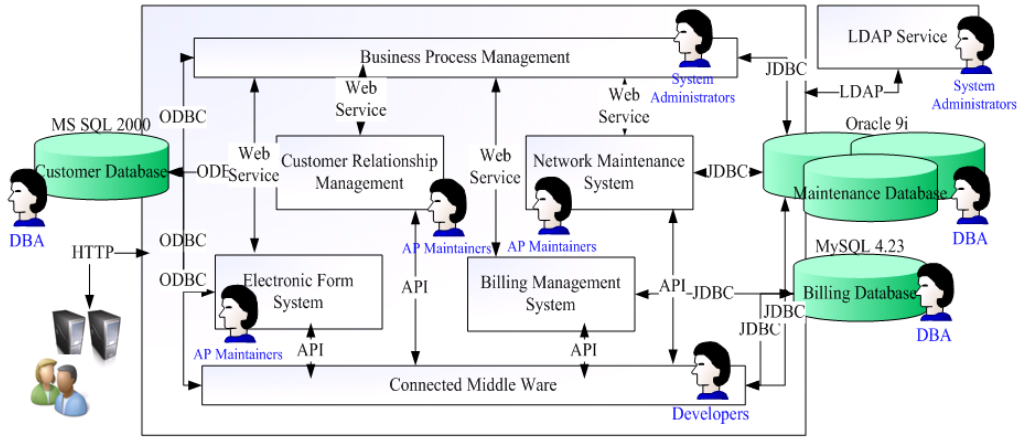


Figure 7.3 System architecture of CRM system.

As we have known, case-based reasoning (CBR) [13] is an approach that solves new problems by retrieving existing successful solutions of similar problems from a knowledge source of cases, the so-called “case-base”. CBR has been broadly applied in various areas such as problem diagnosis, solution retrieval, help desk, assessment, decision support, design, and planning [12][72]. However, the process of case-based reasoning is very time-consuming and the result might not be accurate when the case base is likely a large coarse-grained case base. Searching through the whole “case base” for a solution in a sequential way is rather inefficient. Moreover, it is important to recommend an appropriate expert to solve the problem based on her/his domain knowledge, technical skill, experiences, and so on. Since role-based access control model can be used to solve such requirements of problem diagnosis and solution retrieval, we combine it with a hybrid case-based reasoning approach, the rule-based case-base reasoning (RCBR) methodology, to apply to the high-level knowledge for problem diagnosis and the concrete-level knowledge for solution retrieval. The high-level knowledge which is extracted by rule-based reasoning (RBR) can locate the problem in a specific category, and the concrete-level knowledge can

retrieve solution from the specific case base with case-based reasoning (CBR).

Similar to the concept of object-oriented programming, we could treat all the entities in the real world as concepts and it is natural for us to model the world using concepts hierarchy. In knowledge acquisition phase, knowledge engineers acquire error type ontology with domain experts. The ontology is divided into two layers, the abstract layer ontology describes abstract categories of error types, and the concrete layer ontology describes error spaces of the specific domain. In Fig. 5, knowledge ontology of error spaces is excerpted from the oracle database that is designed by cooperation of the domain experts and knowledge engineers. The knowledge classes that include oval and rectangularity represent the concepts from domain experts. As shown in Figure 7.4, the knowledge class “oracle DB”, consists of two KCs (knowledge classes), “instance” and “database”, and the rectangle stands for knowledge class of the error type of cases. Two types of relationships are used in error type ontology to describe relationships of problems. The first one is the “trigger” relationship between concepts. Some rule class is triggered when some specific conditions are satisfied. It means that a problem may be transformed into another problem. For example, “system error” can transform to “databases error” when the root cause of error is identified in DB layer. The second one is “acquire” relationship, which could be used to describe the sub-problem may be solved by acquiring another rule class. For example, a “control file error” may acquire the expertise of “DB diagnosis”.

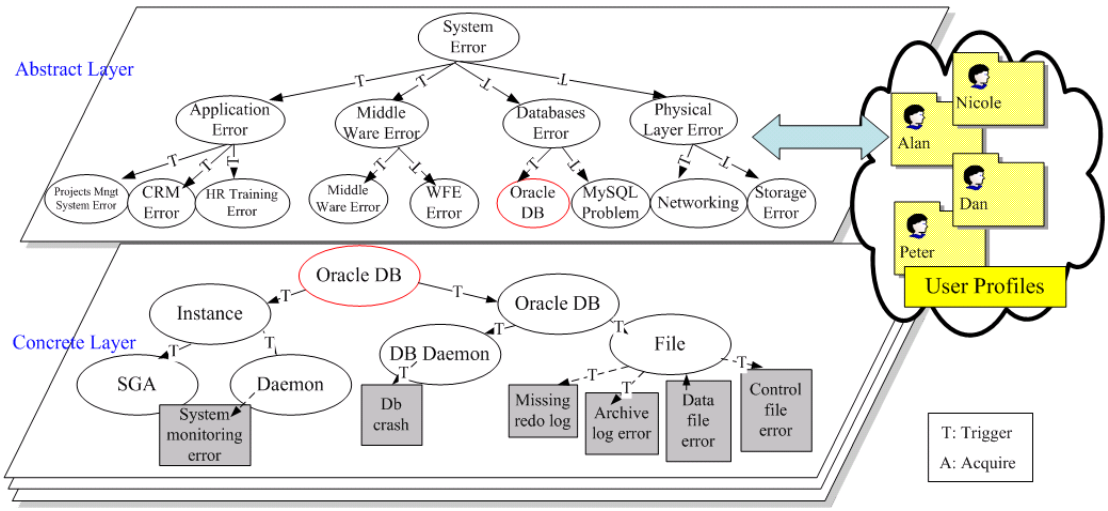


Figure 7.4 The error type ontology of oracle database

With the defined error type ontology, the Rule-based Error Type Inferring for Problem Diagnosis and the Case-based Reasoning for Solution Retrieval are proposed as followings.

1) Rule-based Error Type Inferring for Problem Diagnosis

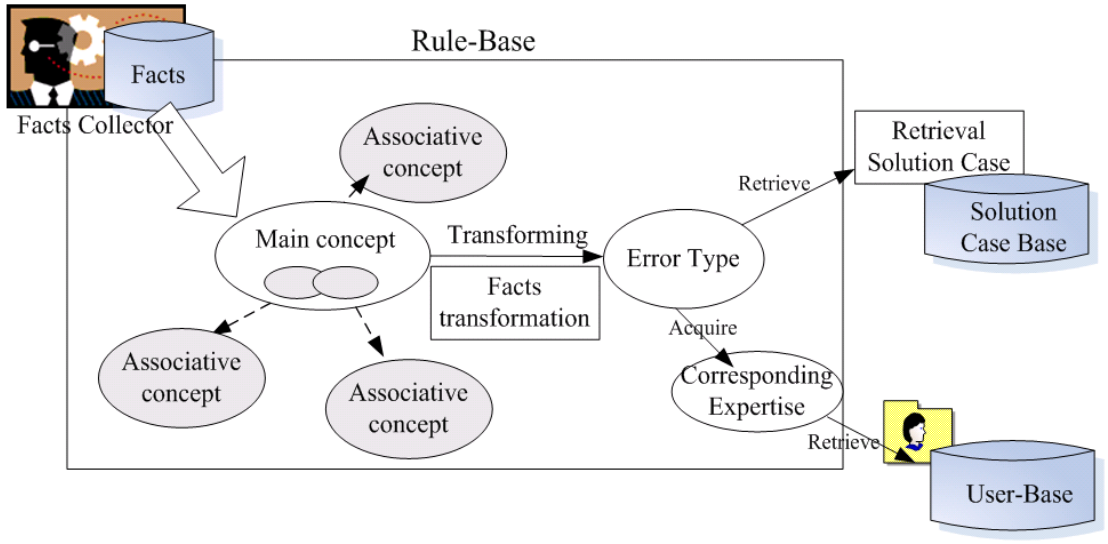
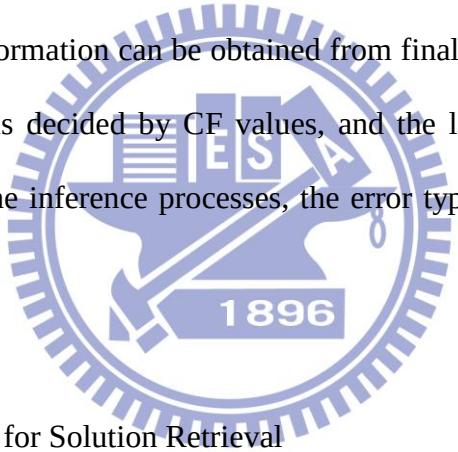


Figure 7.5 The behavior of pondering over known information in Rule-Base

As shown in Figure 7.5, when facts are collected through sensors or other input sources, the facts will be inferred from a specific concept in a domain and other three

concepts can be associated according to their relationships. Nevertheless, people may not consider all relevant knowledge at the same time since too much effort is required to solve the problem. Some inference skills are widely used in human thoughts to improve the performance of knowledge inference. The inference process for problem diagnosis is described as follows. The first step is to select a rule-base from multiple rule-bases. Because a knowledge system cannot contain all types of domain knowledge, it is necessary to specify a knowledge domain before inference. The second step is to collect the facts and specify a knowledge class (KC) containing the corresponding control knowledge for the problem to be solved. According to the specified KC, the inference engine will perform the reasoning process. Finally, interesting and useful information can be obtained from final fact value. Furthermore, the order of fired rules is decided by CF values, and the lower priority rules have weak CF values. After the inference processes, the error type of the problem can be identified.



2) Case-based Reasoning for Solution Retrieval

After the error type of the problem is diagnosed, we retrieve the solution from corresponding case base with Case-Based Reasoning approach. Case-Based Reasoning (CBR) is an approach that solves a new problem by recalling a previous similar situation and reusing information and knowledge of that situation. A process model of the CBR cycle may be described by the four processes: RETRIEVE the most similar case, REUSE the information and knowledge in that case to solve the problem, REVISE the proposed solution, and RETAIN the parts of this experience which it's likely to be useful for future problem solving.

Example 6.1

In the case bases, the original solution documents of error instances obtained from the experts and technical forums are retained as the attribute-based solution cases with attributes error type, subject, module, version, platform, publisher, date, and solution statement as described in Table 7.4. It is the example case of "Redo Log Error", and the case is represented as case vector by Local Solution Case Feature of error type "Redo Log Error".

Table 7.4 Example case of Dropping Redo Log Not Possible

Attributes	Description
Error Type	Redo Log Error
Subject	DROPPING REDO LOGS NOT POSSIBLE
Application	File
Version	8.1.7
Platform	Solaris
Description	Could not drop the redo logs which may be needed for instance recovery. The online redo logs could not be dropped if: 1.There are only two log groups. 2.The corrupt redo log file belongs to the current group.
Solution	The error ORA-1624 will be produced, since an online redo log file with status=CURRENT or status=ACTIVE in v$log could not be cleared. The command erases all data in the logfile. Please note that 'alter database clear logfile' should be used cautiously. If no archived log was produced, then it is impossible to conduct a complete recovery. Perform a backup immediately after completing this command.

Based upon Local Solution Case Feature of "Redo Log Error", the solution case can be represented as case vector.

"DROPPING REDO LOGS NOT POSSIBLE" Vector = {"Redo Log Error", "dropping redo log", "8.1.7", "solaris", "online redo log", "corrupt redo log file", "ORA-1624", "status=CURRENT", "status=ACTIVE", "logfile", "alter

database clear logfile", ...}

To evaluate the performance of the novel approach, the Solution Retrieval System (SRS) is implemented based on RCBR approach to support problem diagnosis and solution retrieval for customer relationship management system of a telecom company as shown in Figure 7.6 and 7.7. We defined six error categories, and extracted about 10800 error inference rules, 360 real cases, and 27 expert profiles in SRS system. The experimental results of SRS system is compared to the KM Center which is original solution retrieval system implemented based upon keyword search approach.

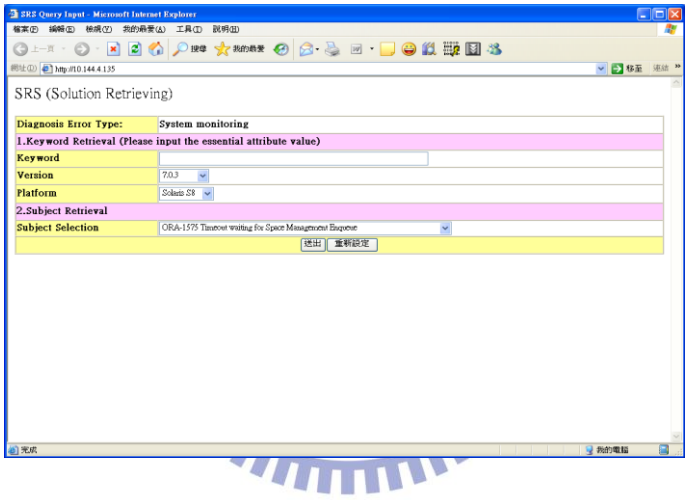


Figure 7.6 SRS User Interface in Query

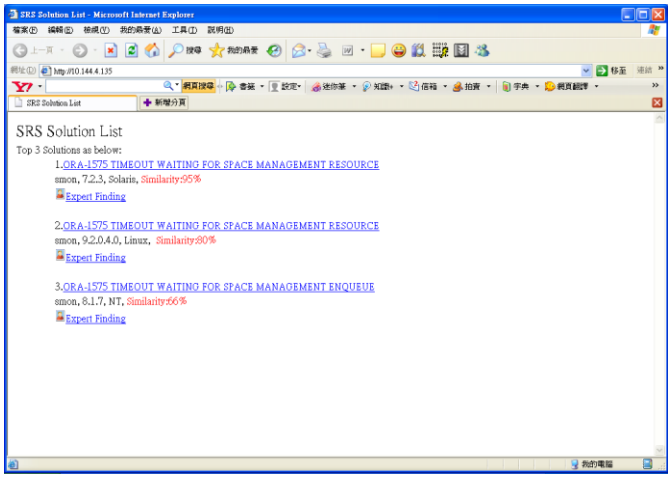


Figure 7.7 Solution List in SRS

Two experiments have been designed and implemented to evaluate the accuracy and efficiency of both Rule-Based CBR approach and Case-Based Reasoning approach, where five domain experts have participated in our experiments by inputting the query to both systems and then evaluating the results. In Experiment 6.1, we evaluated the accuracy in solutions and expert suggestion between the KC Center and the SRS. In the following experiment, we calculated the efficiency of system in average query times.

To evaluate the retrieval accuracy, 28 error problems have been dispatched to experts randomly for judging the correctness of suggested solutions from both systems, KC Center and SRS, and the evaluated results are shown in Table 7.5. In addition, the SRS system suggested appropriate expert to solve the problem. The experimental results showed that the average accuracy rate of RCBR (82.14%) is better than that of CBR (60.71%) as shown in Figure 7.8.

Table 7.5 Accuracy evaluation between RCBR and CBR

	Error Types						Average hitness
	Db crash	Redo log	Archive log	Data file	Control file	System monitoring	
Test Cases	5	4	6	4	4	5	28
Accuracy of KM Center (CBR)	3	3	4	2	2	3	17
Accuracy Rate of KM Center(CBR)	60%	75%	66%	50%	50%	60%	60.71%
Accuracy of SRS (RCBR)	4	4	5	3	3	4	23
Accuracy Rate of SRS (RCBR)	80%	100%	83%	75%	75%	80%	82.14%

Figure 7.8 Accuracy evaluation between SRS system and KM center

To evaluate the efficiency, the experiment of average query times in system diagnosis and solution retrieving was done. With predefined 28 questions of six categories, the average query times are listed in Table 7.6, where the query efficiency of SRS system is quicker than that of KC Center and the average query times of RCBR is 2.10, and CBR is 4.93. The diagram of Table 7.6 shown in Figure 7.9 describes the comparison result between SRS and KM Center for system diagnosis and solution retrieval in efficiency aspect.

Table 7.6 Efficiency evaluation between RCBR and CBR

	Average Times in Solution Retrieval						Average times
	Db crash	Redo log	Archive log	Data file	Control file	System monitoring	
SRS (RCBR)	1.60	2.20	2.00	1.20	2.40	3.20	2.10
KM Center (CBR)	4.40	5.40	4.20	5.00	4.60	6.00	4.93

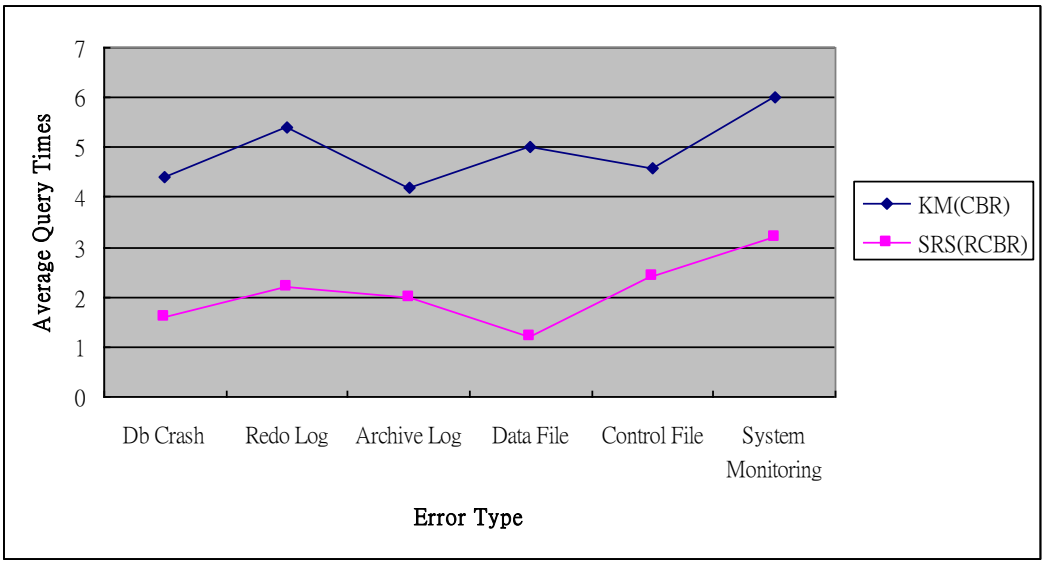


Figure 7.9. Efficiency evaluation between SRS system and KM center

According to the experimental results, the paradigm of using RCBR methodology and RBAC model to build SRS system works well and effective. RCBR will benefit the inference on problem diagnosis, and incorporate domain experts into retrieval system with RBAC model by constructing expertise ontology. It is assumed that the same approach could be adaptively modified to other problem domains for knowledge base and user database construction.

7.3 Application: the e-Learning system with adaptive content sequence

In this application, the adaptive learning guidance service for the contents in online sharable content repository is provided. The domain taxonomies are constructed for the adaptive learning system [44][72] and Ontology-based assessment system [74]. The descriptions of the applications and the effectiveness of the knowledge structure are as followings.

- Learning system with adaptive content sequence for 5th graders Natural Science

In the domain of natural science learning for 5th graders in an elementary school, there are lots of misconceptions in the subject of "*Three states of water*". Thus, the Concept Ontology of the domain is constructed to support the misconception diagnosis with the adaptive learning system called Object-Oriented Learning Activity (OOLA)[73]. The OOLA system can cooperate the learning content repository and testing item bank to perform the adaptive online learning activities. The Concept Ontology of subject "*Three states of water*" is constructed with "prerequisite relations" to represent the possible prerequisite misconception knowledge structure of students. The concepts of the ontology are annotated to the test items and the learning achievements of students are represented as the score of the concepts. Therefore, the OOLA system can be conducted by the Concept Ontology to provide the contents of the prerequisite concepts as remedial learning activity if the score of concept is lower than the threshold. The OOLA authoring tool and its associated learning systems such as content, test sheet, chat room application, etc. are shown in Figure 7.10.

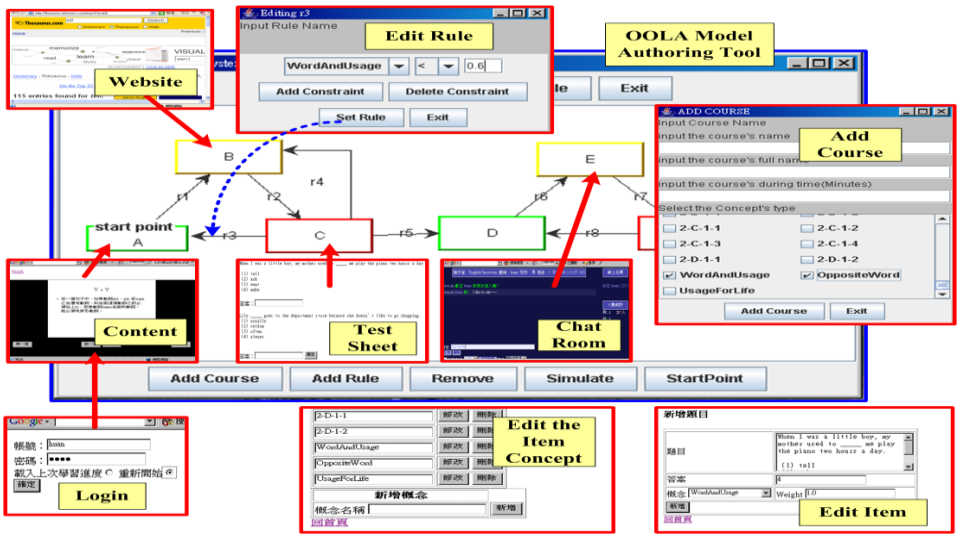


Figure 7.10 Adaptive learning system for 5th graders natural science

To evaluate the efficacy of adaptive learning systems, we apply the one-group pretest-posttest design for 62 students of 5th graders in an elementary school. After one month learning with adaptive learning system, the posttest examination score of the same scope is chosen as the dependent variable. The t-test of the score of all students is shown in Table 6.5. The N is the number of students, the Mean denotes the mean value of the score, and the Std. Dev. Denotes the standard deviation of the score. In Table 7.7, the value t = 4.797 and p-value is 0.000. Therefore, the t-test results of the pre-test and post-test are significant at a confidence interval of 95%. Finally, we may conclude that the designed adaptive learning system is effective for students.

Table 7.7 The pretest-posttest of adaptive learning system

	Pre-test	Post-test
N	62	62
Mean	25.74	28.13
Std. Dev.	3.15	4.14
t = 4.797 sig. = 0.000		

*P < .05

- Assessment system with adaptive test item sequence for 5th graders Mathematic

In the Mathematic learning of junior high school, there are several versions of textbooks or references learning contents. The Concept Ontology of the domain is constructed to support the test items categorization and maintenance with the Ontology-based assessment system called Probing Assessment System (PAS) as shown in Figure 7.11. The PAS is an assessment system which can maintain the test items from different resources to provide a comprehensive mathematics practicing. Thus, the Concept Ontology has been constructed to represent the content structure of different text-books. The "A-Kind-Of" and "A-Part-Of" relations are used to categorize the related concepts together from different learning resources. The student can select one familiar version of textbook to enter the testing. After the online testing, the test results show the score of the student and the learned concepts. To provide the extending learning, the testing results can be used to select the test sheets in different textbooks or resources to suggest the students for further practicing.

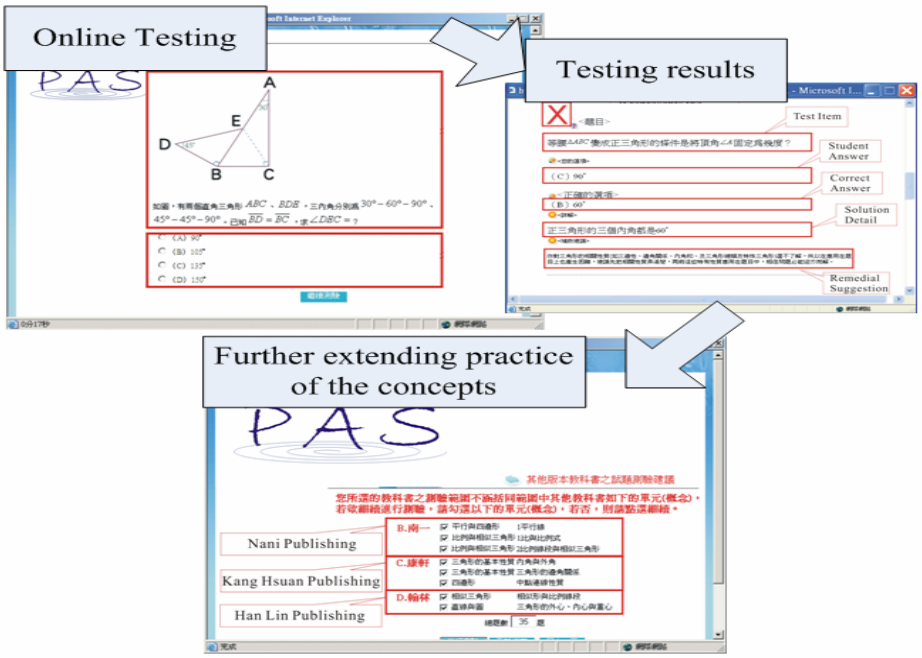


Figure 7.11 Adaptive assessment system for 5th graders mathematic

To evaluate the efficacy of the ontology constructed for the ontology-based

assessment system, an experiment has been conducted on a junior high school mathematics course from February 2006 to May 2006. One hundred and six students participated in the experiment. After three months, a post-test was performed to compare the learning performance of the students. The t-test for the test results of the pre-test and post-test is shown in Table 7.8. The N is the number of students, the Mean denotes the mean value of the score, and the Std. Dev. Denotes the standard deviation of the score. The t-value is 6.364 and p-value is 0.000. Therefore, the t-test results of the pre-test and post-test are significant at a confidence interval of 95%. Finally, we may conclude that the ontology-based assessment is useful in enhancing student learning efficacy.

Table 7.8 The pretest-posttest of ontology-based assessment system

	Pre-test	**Post-test**
N	106	106
Mean	57.76	76.04
Std. Dev.	21.52	20.26
t = 6.364 sig. = 0.000		

*P < .05

In summary, the experimental results presented above reveal that the adaptive learning system or assessment highly rely on high quality of ontology. Thus, the proposed folksonomy-based ontology construction and metadata reengineering approaches can facilitate the researches of ontology-based adaptive learning systems.

Chapter 8 Conclusion

In this dissertation, the extensibility, stability and understandability of behavior modeling issues are addressed on Web 2.0-based e-Learning environment. The self-organizing behavior modeling approaches are proposed to solve the *problem solving strategy formulation and realization problem* for self programming learning, the *trustworthy experts modeling problem* for inquiry learning, and the *consensus building problem* for folksonomy-based knowledge sharing activity.

Under the context of intelligent tutoring system, the *Generalized Model Tracing* approach is proposed to organize the diagnosis results of different program model tracing with *Problem Solving Strategy Ontology*. The diagnosis result can be used to provide the learning guidance for problem solving strategy. Under the context of learning forum, the *Cascading Topic Clustering Algorithm* and *Self-organized Ontology Maintenance Scheme* are proposed to organize the forum experts' inquiry activities with the *Purpose-based Ontology*. Building the forum experts' behavior model can provide trustworthy expert finding service for inquiry-based learning. Under the context of collaborative constructed sharable content repository, the *IRT-Based Metadata Reengineering Scheme* is proposed to evaluate the effectiveness of folksonomy tags and resolve the synonym, redundancy and incompleteness problem of metadata by the domain taxonomy.

In the experiment, the evaluations of the effectiveness of adaptive learning guidance based on the behavior models were done. The experimental results showed that the behavior models in different activities can support students to achieve higher learning achievements. In the near future, the behavior modeling approach will be further applied for the problem solving training in contexts of enterprise software testing and game creation project.

References

[1] M.H. Abel, A. Benayache, D. Lenne, C. Moulin "Ontology-based Organizational Memory for e-learning", *Journal of Education Technology & Society*, Vol. 7 no. 4, pp.98-111, 2004

[2] A.K. Ali, "Using the Delphi Technique to Search for Empirical Measures of Local Planning Agency Power", *The Qualitative Report*, Vol. 10 no.4, pp.718-714, 2005

[3] J.R., Anderson, A. T., Corbett, K. R., Koedinger, R., Pelletier, "Cognitive tutors: lessons learned", *Journal of the Learning Sciences*, Vol. 4 no. 2, pp.167-207., 1995

[4] S. Auer, S. Dietzold, and T. Riechert, "OntoWiki – A Tool for Social, Semantic Collaboration", 5th International Semantic Web Conference, Athens, GA, USA, November 5-9, 2006

[5] H. Avancini, A. Lavelli, B. Magnini, F. Sebastiani, R. Zanoli, "Expanding Domain-Specific Lexicons by Term Categorization," *Proceedings of ACM Symposium on Applied Computing*, pp. 793-797, 2003

[6] Ball & Hall, "ISODATA, a Novel Method of Data Analysis and Pattern Classification", *Stanford Research Institute, Menlo Park, Cal.*, 1965

[7] J. Bao, D. Caragea, V Honavar, "Towards Collaborative Environments for Ontology Construction and Sharing", International Symposium on Collaborative Technologies and Systems, 2006.

[8] S. Bechhofer, I. Horrocks, C. Goble, R. Stevens "OilEd: a Reason-able Ontology Editor for the Semantic Web", *Proceeding of the Joint German/Austrian Conference on Artificial Intelligence (KI 2001), no. 2174 in Lecture Notes in Artificial Intelligence.* Vienna: Springer, pp. 396-408, 2001.

[9] A. Bhalerao, A. Ward, "Towards Electronically Assisted Peer Assessment: A Case Study", *Association for Learning Technology journal*, Vol. 9 no.1, pp. 26-37, 2001

[10] B.S., Bloom, "Taxonomy of educational objectives: The classification of educational goals", *Handbook I, cognitive domain, New York, Toronto, Longmans, Green*, 1965

[11] T. Bratitsis, A. Dimitracopoulou, “Data recording and usage interaction analysis in asynchronous discussions: The D.I.A.S.System”, *AIED Workshops (AIED 05)*, 2005

[12] J. S. Bruner, “The act of discovery,” *Harvard Educational Review* , Vol. 31 no. 1, pp. 21-32, 1961

[13] J. D Carswell, D.C. Wilson, M. Bertolotto, “ Digital image similarity for geo-spatial knowledge management, advances in case-based reasoning,” *Proceedings of the sixth European conference*, ECCBR, Aberdeen, Scotland, United Kingdom, September 4 – 7, pp. 58 – 72, 2002

[14] A. Caspi, P. Gorsky, E. Chajut, “The influence of group size on non-mandatory asynchronous instructional discussion groups.” *The Internet and Higher Education*, Vol. 6 no.3, pp. 227-240, 2003

[15] C.B. Cazden, S.W. Beck, “Classroom discourse.” *Handbook of discourse processes*, pp. 165-197, 2003

[16] C.K. Chang, G.D. Chen, K.L. Ou, “Student portfolio analysis by data cube technology for decision Support of web based classroom teacher.” *Journal of Educational Computing Research*, Vol.19 no.3, pp. 307-328, 1998

[17] W. K. Chen, Y. C. Cheng, “Teaching Object-Oriented Programming Laboratory With Computer Game Programming”, *IEEE transactions on education*, Vol. 50 no. 3, 2007

[18] G.D. Chen, C.C. Liu, K.L. Ou, B.J. Liu, “Discovering decision knowledge from web log portfolio for managing classroom processes by applying decision tree and data cube technology. “ *Journal of Educational Computing Research*, Vol.23, No.3 pp.305-3*20*, 2000

[19] V. Christophides, G. Karvounarakis, D. Plexousakis, & S. Tourtounis, (2003), “Optimizing Taxonomic Semantic Web Queries Using Labeling Schemes,” *J. Web Semantics*, Vol. 1, no. 2, pp. 207-228, 2003

[20] B. Clark, J. Rosenberg, T. Smith, S. Steiner, S. Wallace, G. Orr, “Game development courses in the computer science curriculum”, *Journal of Computing Sciences in Colleges archive*, Vol. 23 no.2, pp. 65-66, 2007

[21] T. H. Cormen, C. E. Leiserson, R. L. Rivest, “Introduction to Algorithms”, *McGraw-Hill Book Company*, 1990

[22] T. Crews Jr., U. Ziegler, “The Flowchart Interpreter for Introductory Programming Courses”, *Frontiers in Education Conference*, FIE’98 28th Annual, 1998

[23] N. Dalkey, O. Helmer, “An experimental application of the Delphi method to the use of experts”, *Management Science*, Vol. 9 no. 3, pp.458-467, 1963

[24] S. Dehors, C. Faron-Zucker, R. Dieng-Kuntz, “QBLS:Semantic Web Technology for E-learning in Practice” ,*15th International Conference on Knowledge Engineering and Knowledge Management, Czech Republic,* 2nd-6th October, 2006.

[25] R. Denaux , V. Dimitrova, L. Aroyo, “Integrating Open User Modeling and Learning Content Management for the Semantic Web”, *Proceedings of UM2005*, 2005

[26] F. Debole, F. Sebastiani, “Supervised Term Weighting for Automated Text Categorization,” *Proceedings of ACM Symposium on Applied Computing*, pp. 784-788, 2003

[27] S. Deerwester, S. Dumais, G. Furnas, T. Landauer, R. Harshman, “Indexing by Latent Semantic Analysis,” *J. Am. Soc.Information Science*, Vol. 41, no. 6, pp. 391-407, 1990

[28] M. Dorigo, T. Stützle, “Ant Colony Optimization”, *MIT Press*. ISBN 0-262-04219-3, 2004

[29] W.W. Eckerson, “Three tier client/server architecture: Achieving scalability, performance, and efficiency in client server applications”. *Open Information Systems*, Vol. 10, 1, 1995

[30] A. Farquhar, R. Fikes, J. Rice, “The Ontolingua Server: a tool for collaborative ontology construction”, *International Journal of Human Computer Studies,* Vol. 49 no. 6, pp.707-727, 1997

[31] H. Funaoi, E. Yamaguchi, S. Inagaki, ”Collaborative concept mapping software to reconstruct learning processes”, *Proceedings of International Conference on Computers in Education* Vol. 1, pp.306-310, 2002.

[32] S. Gauch, J. Chaffee, & A. Pretschner, “Ontology-Based Personalized Search and Browsing,” *Web Intelligence and Agent Systems*, vol. 1, nos. 3-4, pp. 219-234, 2003

[33] J. Gonzalo, F. Verdejo, I. Chugur, & J. Cigarra´n, “Indexing with WordNet Synsets Can Improve Text Retrieval,” Proc. COLING/ ACL Workshop Usage of WordNet for Natural Language Processing, 1998

[34] R.K. Hambleton, S.H. Waminathan, “Item Response Theory”, *Kluwer-Nijhoff Publishing*, Boston, Massachusetts, 1985

[35] B.Y. Hu, J.Y. Yang, “Analyzing critical thinking and factors influencing

interactions in online discussion forum", Fifth IEEE International Conference on Advanced Learning Technologies (ICALT'05), 2005

[36] G.J. Hwang, "A Conceptual Map Model For Developing Intelligent Tutoring System." *Computers & Education*, Vol. 40 no. 3, pp. 217-235, 2003

[37] G.J. Hwang, C.L. Hsiao, C.R. Tseng, "A Computer-Assisted Approach to Diagnosing Student Learning Problem in Science Course," *Journal of Information Science & Engineering*, Vol. 19 no.2, pp.229-248, 2003.

[38] A. Kalyanpur, B. Parsia, E. Sirin, B. Cuenca-Grau, J, "SWOOP: A Web ontology editing browser", *Journal of Web Semantics*, Vol. 4 no. 2, pp.144-153, 2005.

[39] J.L. Kolodner, M.T. Cox, P.A. Gonzalez-Calero, "Case-based reasoning-inspired approaches to education", *The Knowledge Engineering Review*, Vol. 2 no. 3, pp.299-303, 2005.

[40] A.N., Kumar, "A Reified Interface for a Tutor on Program Debugging", *the 3rd IEEE International Conference on Advanced Learning Technologies (ICALT'03)*, 2003

[41] P.D. Laurie & T. Ellis, "Using data mining as a strategy for assessing asynchronous discussion forums", *Computers & Education*, Vol. 45 no. 1, pp.141-160, 2005

[42] T.A. Letsche, M.W. Berry, "Large-Scale Information Retrieval with Latent Semantic Indexing," *Information Sciences—Applications*, Vol. 100, no.1-4, pp. 105-137, 1997

[43] S. Li, B. Davies, J. Edwards, R. Kinman, Y. Duan.," Integrating group Delphi, fuzzy logic and expert systems for marketing strategy development: The hybridisation and its effectiveness", *Marketing Intelligence & Planning*, Vo. 20 no. 5, pp. 273-284, 2003

[44] H.Y. Lin, S.S. Tseng, J.M. Su, J.F. Weng, "Design and Implementation of an Object Oriented Learning Activity System", the 10th World Multiconference on Systemics, Cybernetics and Informatics (WMSCI 2006) Orlando, USA, 2006

[45] K. Mahalingam, M.N. Huhns, "Ontology tools for semantic reconciliation in distributed heterogeneous information environments," *Intelligent Automation and Soft Computing*, 1999

[46] O. Manoliadis, I. Tsolas, A. Nakou, "NOTE Sustainable construction and drivers of change in Greece: a Delphi study". *Construction Management & Economics*, Vol. 24 no. 2, pp.113-120, 2006

[47] B.R. Maxim, W.I. Grosky, J.P. Baugh, “Work In Progress - Introducing Information Technology Through Game Design”, 37th ASEE/IEEE Frontiers in Education Conference, 2007

[48] R. Madala , T. Takenobu, T. Hozumi, “The Use of WordNet in Information Retrieval. Montreal,” *Proceeding of Conf. Use of WordNet in Natural Language Processing Systems*, pp. 31-37, 1998

[49] J. Magidson, “The Chaid approach to segmentation modeling: Chi-squared automatic interaction detection,” *R. P. Bagozzi, editor, Advanced Methods of Marketing Research*, pp.118-159. Blackwell Business, Cambridge Massechusetts, 1994

[50] A. Maguitman, D. Leake, T. Reichherzer, F. Menczer, “Dynamic extraction topic descriptors and discriminators towards automatic context-based topic search”, *Proceedings of the thirteenth ACM conference on Information and knowledge management*, 2004

[51] R. Mason, “Methodologies for evaluating applications of computer conferencing in Kaye,” A.R.(ed) Collaborative Learning through Computer Conferencing: Heidelberg: Springer-Verlag, 1991

[52] B.R. Maxim, W.I. Grosky, J.P. Baugh, “Work In Progress - Introducing Information Technology Through Game Design”, 37th ASEE/IEEE Frontiers in Education Conference, 2007

[53] J.H. McClellan, L.D. Harvel, R. Velmurugan, M. Borkar, C. Scheibe, “CNT: concept-map based navigation and discovery in a repository of learning content”, *Frontiers in Education, FIE 2004. 34th Annual 2004* , Vol. 2, pp.13-18, 2004.

[54] B. Meyer, P. Heisig, “The future of knowledge management: an international delphi study”, *Journal of Knowledge Management*, Vol. 8 no. 2, pp.19-35, 2004.

[55] M. Mehta, R. Agrawal, & J. Rissanen, “SLIQ : A fast scalable classifier for data mining.” *In Proc. 1996 Int. Conf. Extending Database Technology (EDBT'96)*, Avignon, France, 1996

[56] A. Moreno, N. Myller, E. Sutinen, JeCo, “A Collaborative Learning Tool for Programming”, *IEEE Symposium on Visual Languages and Human Centric Computing*, pp. 261-263, 2004

[57] S.K. Murthy, “Automatic Construction of Decision Trees from Data: A Multi-Diciplinary Survey,” *Data Mining and Knowledge Discovery*, Vol. 2 no.4 pp.345-389, 1998

[58] Newman, B. Webb, C. Cochrane, "A content analysis method to measure critical thinking in face-to-face and computer supported group learning." *Queen's University Belfast, Information Management Dept*, 1994

[59] C. Okoli, S. D. Pawlowski, "The Delphi method as a research tool: an example, design consideration and applications," *Information and Management*, Vol. 42 no. 1, pp.15-29, 2004

[60] D. Preston, "PAIR programming as a model of collaborative learning: a review of the research", *Journal of Computing Sciences in Colleges* , Vol. 20 no. 4, pp. 39-45, 2005

[61] H.A. Ramadhan, "Improving the engineering of model tracing based intelligent program diagnosis", *IEEE Proceedings Software Engineering*, Vol. 144, no. 3, pp.149-161, 1997

[62] R. Rastogi, K. Shim, "Public: A decision tree classifier that integrates building and pruning." In Proc. 1998 *Int. Conf. Very Large Data Bases*, pp.404-415, New York, 1998

[63] L. Rourke, T. Anderson, D.R. Garisson, W. Archer, "Assessing social presence in asynchronous text-based computer," *Journal of Distance Education*, Vol. 14 no. 2, pp.50-71, 2001

[64] J. Ryoo, F. Fonseca, D.S. Janzen, "Teaching Object-Oriented Software Engineering through Problem-Based Learning in the Context of Game Design", *Proceedings of the 2008 21st Conference on*, 2008

[65] F. Salisbury, "Effect drill and practice strategies," in *Instructional Designs for Microcomputer Courseware,* D. H. Jonassen, ed., Lawrence Erlbaum Associates, pp.103-124, 2008

[66] D. Sampson, C. Karagiannidis, F. Cardinali, "An Architecture for Web-based e-Learning Promoting Re-usable Adaptive Educational e-Content", Educational Technology & Society, 2002.

[67] K. Sade, Y. Levo, S. Kivity, "A Content Analysis of Web-Based Expert Forum on Asthma and Allergy". *Journal of Allergy and Clinical Immunology*, Vol.117 no. 2, pp. S54-S54, 2006

[68] Salton, M.J. McGill, "Introduction to Modern Information Retrieval," McGraw & Hill, New York, 1983

[69] A. Simpson, L. Reynolds, I. Light, J. Attenborough, "Talking with the experts: evaluation of an online discussion forum involving mental health service users in

the education of mental health nursing students", *Nurse education today*, Vol. 28 no. 5, pp. 633-640, 2008

[70] J. Sitthiworachart, M. Joy, "Effective Peer Assessment for Learning Computer Programming," *Innovation and Technology in Computer Science Education*. Leeds,United Kingdom, 2004

[71] K.A. Smith, R.L. Johnson, "Medical opinion on abortion in Jamaica: a national Delphi survey of physician, nurses, and midwives", *JSTOR Arts and Sciences*, Vol. 7 no. 12, pp.334-339, 1976

[72] L. Spalazzi, "A survey on case-based planning", *Artificial Intelligence Review*, 16, 3–36, 2001

[73] J.M. Su, S.S. Tseng, C.T. Chen, W.N. Tsai, " Adaptive learning environment for pedagogical needs," *Journal of Information Science and Engineering*, Vol. 20 no. 6, pp.1057-1077, 2004

[74] P.C. Tsai, S.S. Tseng, J.F. Weng, N.K. Si," Developing an Ontology based Assessment System for Secondary School Mathematics," Interactive Computer Aided Learning International Conference, （ICL2006）Villach, Austria, 27-29, Sep, 2006

[75] Y.C. Wang, J.C. Wu, T. Liang, & J.S. Chang, "Web-based Unsupervised Learning for Query Formulation in Question Answering," *IJCNLP 2005, Lecture Notes in Artificial Intelligence 3651*, pp. 519-529, 2005

[76] C.Y. Wang, Y.C. Lei, P.C. Cheng, S.S. Tseng, "A Level-wise Clustering Algorithm on Structured Documents, " *Proceedings of NCS2003*, Taiwan, 2003

[77] J. Yearwood, A. Stranieri, "Narrative-based Interactive Learning Environments from Modelling Reasoning", *Educational Technology & Society*, Vol. 10 no. 3, pp.192-208, 2007

[78] Protégé, The Protégé Ontology Editor and Knowledge Acquisition System, http://protege.stanford.edu/, accessed January 2010.

[79] L.M. Rudner, PARAM-3PL Calibration Software for the 3 Parameter Logistic IRT Model (freeware), http://edres.org/irt/param, accessed January 2010.

[80] A.G. Wright, "Semantic Web-Folksonomy" http://www.agwright.com/blog/archives/000900.html, accessed January 2010.

[81] G. Schussel, Client/Server past, present, and future. http://news.dci.com/geos/dbsejava.htm, accessed 1995