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Development of an online exam platform for the programming language course: ontology-based approach

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Abstract

As the programming competence has become one of the most fundamental skills for civil engineers, undergraduate students in many universities and colleges are now required to take a programming language course such as C++ or Java. Researchers have pointed out that the best way to expedite the learning process for students taking the programming language course is to ask them to write codes by themselves. However, plagiarism always exists among students' source codes and the course instructor does not have an effective means to verify whether a student truly understand the programming concepts or not. Use of the ontology for the programming language concepts may help resolve the above problem. In fact, the interaction between the instructor and the students is a knowledge exchange process.

In the Web Ontology Language (OWL) definition, the ontology consists of three components: individuals, properties, and classes. The relationships of these components and the characteristics of properties make the ontology be able to represent complicated concepts. The ontology also includes a reasoning mechanism which can automatically verify the rationality and consistency of the model and do the classification. This study constructs an ontology model to capture the concepts of the C++ programming language. With the ontology model, similar concepts of the programming language could be combined together by the OWL reasoner to generate a new question. This model can assist in creating an online exam platform that can contain a large number of question templates and generate a question dynamically. Preventing plagiarism can also be achieved by generating a unique set of questions for each student, i.e., changing the parameters or other status of a question. The instructor can concentrate more on the learning process of a student, while students' real learning performances can be evaluated by using this online exam platform.

Keywords: ontology, virtual learning environment, programming language, engineering education

1 Introduction

As use of the virtual learning environment (VLE) for professors and students is increasing worldwide, blended learning now is a norm for many courses in universities and colleges. As an old proverb quotes "learning by doing", for a programming language course asking students to write computer programs is considered to be one of the most effective teaching strategy (Lahtinen et al., 2005). However, because most current VLE systems do not provide any online exam mechanisms specific for the programming language course such as dynamical programming questions generation and verification of students' source codes submitted, instructors of the course may still need to conduct traditional paper-and-pencil exams for testing purposes. In addition, plagiarism always exists among students' programming assignments (Spinells et al., 2007). Hence, it is necessary to design a new mechanism to assist instructors in conducting exams and to prevent the occurrence of such plagiarism for the programming language course.

Moreover, understanding how to write a computer program has become one of the most important skills for undergraduate students regardless of whether their major is in computer science or in engineering. Typically in a programming language course for computer science students, the concepts pertaining to data structures and algorithms are main contents. However, because engineering students usually need to use programming skills to tackle various engineering problems, the contents of their programming language course should involve programming language concepts as well as mathematical background required for the engineering problems. For example, the set and matrix concepts are very important for solving many civil and structure engineering problems such as finding eigenvalues of a matrix. Hence, it is necessary for civil engineering students to familiarize themselves with the mathematical concepts first. Then instructors can show students the memory allocation and class mechanisms required to implement the mathematical concepts. Some researchers believed that compiling mathematical background knowledge into the programming language course may be a solution. They strived to design a graphical method to help students learn both mathematical and programming concepts in a more integral way (Fernández and Sánchez, 2004). Others argued that for novice programmers neither the memory allocation mechanisms nor the mathematical concepts are easy to understand (Lahtinen et al., 2005). Therefore, an appropriate approach that can alleviate students' burden associated with reviewing the mathematical concepts and can assist an instructor in teaching the new programming concepts in an iterative and incremental way may be needed.

This research aims at proposing an ontology-based approach to: (1) helping undergraduate students not only learn the new programming language concepts but recall their knowledge of the mathematical concepts which had been taught during their senior high school courses; and (2) assisting instructors in conducting online exams for the programming language course. The authors of this research believe that use of the ontology approach can help dynamically generate programming questions for each student so that plagiarism will be minimized. The ontology concept was initially applied in knowledge management and artificial intelligence. It could be used to construct an information model to describe domain concepts and their relationships and perform reasoning work. By bridging the gap between the mathematical and programming concept domains, the ontology approach may be able to represent and model complex knowledge, expedite information exchange, clarify ambiguous definitions, etc. The following sections describe literature review and development of the proposed ontology-based approach for online exam platform of the engineering programming language course.

2 Literature review

Ontology originates from Philosophy, and now is commonly used for knowledge management and artificial intelligence in computer science. Most of the applications of ontology are doing the knowledge management for a domain. It can be used for constructing data model to describe the characteristics of domain knowledge and the relationship. With some settings of relationship, ontology can also perform some reasoning to infer the relationship between classes.

OWL (Web Ontology Language) is an ontology language designed for ontology applications. It can be classified to three categories according to their expressiveness: (1) OWL-Lite, (2) OWL-DL (Description Logic), and (3) OWL-Full, while OWL-Lite is the least expressive and OWL-Full is highly expressive. Because OWL-Lite is less expressive and because OWL-Full is more concerned on the expression and less computational, this study will use OWL-DL to develop the ontology model.

The three components of OWL ontology are individuals, classes, and properties. An individual may be a domain object; a class is a set contains individual; a property is similar with a function, which also has the domain and range, to connect the individuals in domain to the individuals in range. Figure 1 shows the representation of the components. The properties may be limited by different property characteristics, which extend the meaning of properties. The property characteristics includes inverse property, functional property, inverse functional property, etc (Horridge et al. 2007).

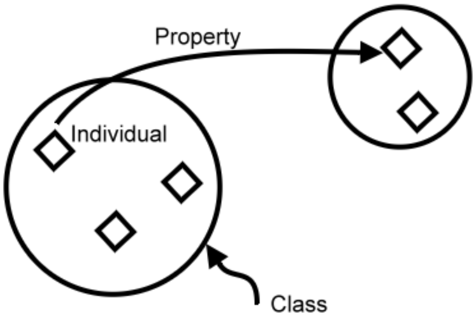


Figure 1. The use case diagram of the system

Taking civil engineering for instance, there was a study using ontology to construct a model and share the domain knowledge (El-Diraby and Kashif, 2005). Another example is to simulate the object-oriented software development, combine civil engineering and software design to help the communication between civil engineers and software designers (Hsieh and Lu, 2006).

3 System development

This system is expected to be used by teachers, grader, and students. Based on the functions the system provides, the users can be divided to four types: (1) question template creator, (2) question reviewer, (3) grader, and (4) student. Teachers who are more familiar with the course contents can act as question template creators, and junior teachers can act as question reviewers and graders. Teacher assistants can also be graders. Students can only be students. Figure 2 shows the use case diagram of the system. First, a question template creator creates the question templates, and puts them into the database. Next, the question reviewer sets some attributes of the exam, and adds questions from the database into the exam. After an exam is announced, students can do the exams on the platform. And then a grader will check the answers and give them scores.

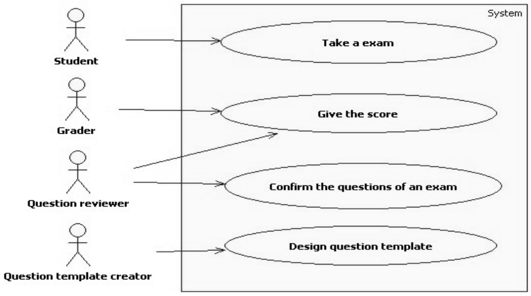


Figure 2. The use case diagram of the system

As shown in Figure 3, the data in the database can be roughly separated to user data and exam data. The user data includes the username and the password of a student, grader and question reviewer. It also includes the ID and name of a student. About the exam data, it can be simply divided to five portions: Exam, Tryout, Question, Solution, SampleAnswer. SampleAnswer is corresponding to Question as well as to give graders a reference. Solution is the answer of the student to reply the Question. Finally, the Questions form an Exam. Student can do the Exam within the number of times set by the question reviewer, every time when a student does the Exam, it creates a Tryout.

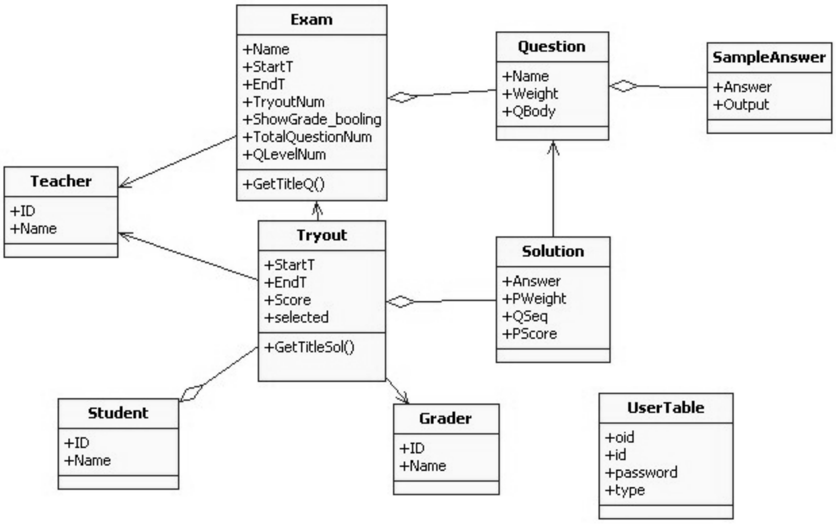
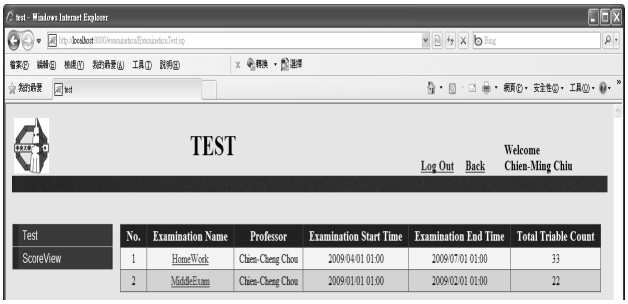


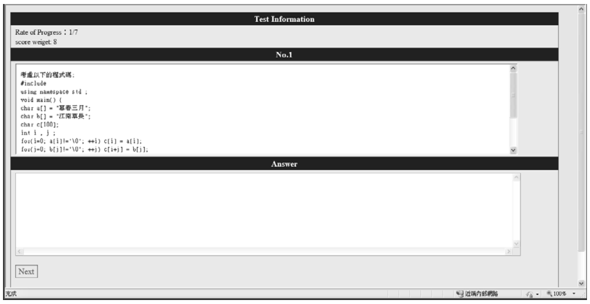
Figure 3. The database model of the system

The system interface for students is shown in Figure 4, and there are two functions at the left side of the page. The first one lists the available exams, and student can do the exam in this page. The other one can show the list of graded exam. When a student click to start an exam, a page looks like Figure 5 is shown. The upper column is about the exam information, shows the total number of questions of the exam, the current question number, and the score weight. The middle column shows the question content, and the lower one provides students a space to write down the answers.


test - Windows Internet Explorer
http://localhost:8080/examination/ExaminationTest.jsp
Bing
檔案(F) 編輯(E) 檢視(V) 我的最愛(A) 工具(T) 說明(H)
轉換 選擇
我的最愛
test
網頁(P) 安全性(S) 工具(O)
TEST
Log Out
Back
Welcome
Chien-Ming Chiu
Test
ScoreView

No.	Examination Name	Professor	Examination Start Time	Examination End Time	Total Triable Count
1	HomeWork	Chien-Cheng Chou	2009/04/01 01:00	2009/07/01 01:00	33
2	MiddleExam	Chien-Cheng Chou	2009/01/01 01:00	2009/02/01 01:00	22

Figure 4. The user interface of a student

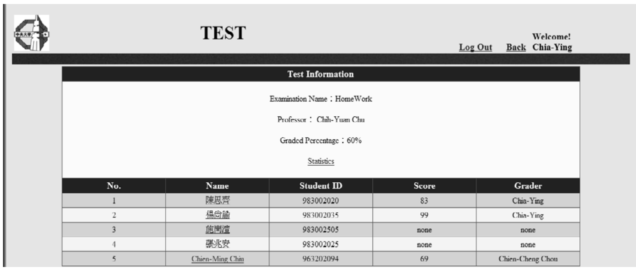


Rate of Progress：1/7
score weiget: 8

```
考慮以下的程式碼:
#include
using namespace std ;
void main() {
char a[] = "暮春三月";
char b[] = "江南草長";
char c[100];
int i , j ;
for(i=0; a[i]!='\0'; ++i) c[i] = a[i];
for(j=0; b[j]!='\0'; ++j) c[i+j] = b[j];
```

Figure 5. The user interface for a question

For graders, they can see the ended exams. After clicking on one exam, grader can see a page showing the test information and the student list. If the grader clicks on one student, there will be a popup window like Figure 6, showing all of the tryouts done by the selected student. The grader can choose one tryout to view the solution and give score, after grading the grader can select one graded tryout as the final score of the exam.



TEST

Welcome!
Log Out Back Chia-Ying

Test Information

Examination Name：HomeWork

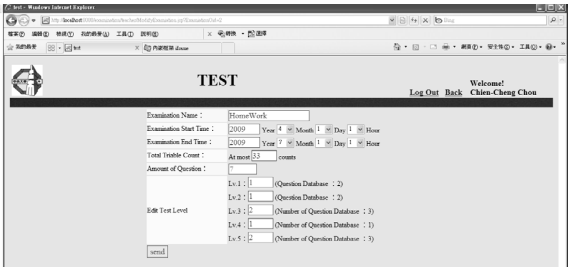
Professor： Chih-Yuan Chu

Graded Percentage：60%

Statistics

No.	Name	Student ID	Score	Grader
1	陳思齊	983002020	83	Chia-Ying
2	楊尚諭	983002035	99	Chia-Ying
3	施閔澧	983002505	none	none
4	張兆安	983002025	none	none
5	Chien-Ming Chin	963202094	69	Chien-Cheng Chou

Figure 6. The user interface of grader


test - Windows Internet Explorer
http://localhost:8080/examination/teacher/ModifyExamination.jsp?ExaminationOid=2
Bing
檔案(F) 編輯(E) 檢視(V) 我的最愛(A) 工具(T) 說明(H)
轉換 選擇
我的最愛
test
內嵌框架 iframe
網頁(P) 安全性(S) 工具(O)

TEST

Welcome!
Log Out Back Chien-Cheng Chou

Examination Name：	HomeWork
Examination Start Time：	2009 Year 4 Month 1 Day 1 Hour
Examination End Time：	2009 Year 7 Month 1 Day 1 Hour
Total Triable Count：	At most 33 counts
Amount of Question：	7
Edit Test Level	Lv.1：1 (Question Database ：2) Lv.2：1 (Question Database ：2) Lv.3：2 (Number of Question Database ：3) Lv.4：1 (Number of Question Database ：1) Lv.5：2 (Number of Question Database ：3)

send

Figure 7. The user interface of question reviewer

The question reviewer can set up a new exam as shown in Figure 7. The settings of an exam includes some fixed attributes, such as exam name, start time, end time, trial count, and the number of questions. The last row of the table shows an important function: Edit exam level. Question reviewers can set the exam level through adjusting the number of different question level. The question level is defined by the question template creator through the ontology model, which will be mentioned in the next section.

4 Proposed ontology

To implement the knowledge exchange, the system includes a subsystem for question template creators to construct a concept ontology model. The roles involved in the knowledge interchanging process are the teacher and the students. The students are assumed to have the concepts about the high school mathematics, and the teacher will introduce the C++ concepts to them. These concepts are expected to be combined together for the students after all.

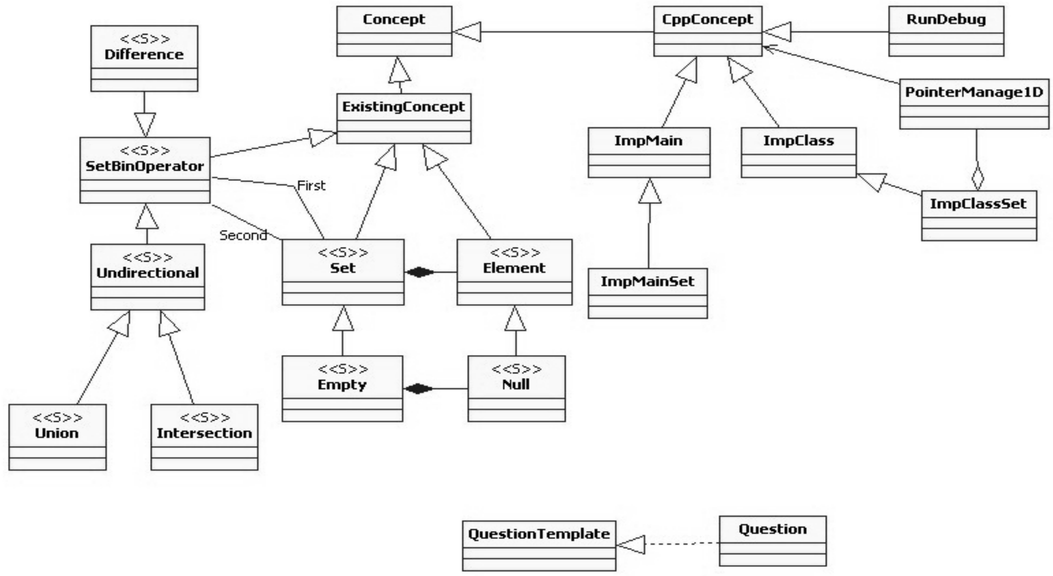


Figure 8. The ontology model of set concept

Figure 8 is an example of the ontology model for the set concept. There are two categories of the concepts: Existing concepts and C++ concepts. Existing concepts represent the knowledge that students may already know; C++ concepts means the C++ programming concepts, which may be used for carrying out the program about the existing concepts. Programming questions will be dynamically generated based on the set concepts, followed by the C++ concepts.

The rectangles with a symbol “<<s>>” mean the stereotype type of the set concept. Set is considered a cluster of Elements. A Set without Elements is called Empty, and an Element without value is called Null. They inherit the characteristics of Set and Element individually. Using SetBinOperator (set binary operator), we can do some operations with sets. The binary operators are defined as two categories: bidirectional and unidirectional. The unidirectional one only has one subclass named Difference; The bidirectional one includes Union and Intersection, which will not be influenced after changing the positions of the operands.

In the part of the C++ concept, it includes the necessary knowledge of implementing a program with set. The foundation parts of the concepts are to implement a main function (ImpMain), deal with the classes (ImpClass), run the program and debug (RunDebug). These are the basic concepts for writing a C++ program, not only for performing a program with sets. The rest parts of the C++ concepts are to implement a main function of sets (ImpMainSet), one dimension pointer management (PointerManage1D), and to deal with the classes about sets. To implement a program with sets, students must have knowledge of these C++ concepts.

With the constructed concept model, some reasoning work is performed to generate questions to check the understanding of students. To execute this function, first we have to check what concepts exist at the students’ parts. After knowing the existing concepts, both concepts can be combined together. For example, if a student mentioned he/she does not have the concept of set difference, the system may give him/her a question, which will be different to another students’ which may focus on the concept of set empty.

5 Conclusion

A number of issues in VLE for programming language were studies, but less of them concerned about the difference between teaching civil engineering students and computer science students. This study constructs an ontology model to represent knowledge of existing concepts of students and C++ concepts. The “set” concept in high school mathematics is chosen as an example of existing concepts. The concepts from the set theory and the C++ mechanisms will be integrated, and based on the combination the system will dynamically generate questions for students to practice. In the future research, the ontology model for the matrix concepts is planned to be constructed.

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