JavaParser: A Fine-Grained Concept Indexing Tool for Java Problems

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Abstract. The multi-concept nature of problems in the programming language domain requires fine-grained indexing which is critical for sequencing purposes. In this paper, we propose an approach for extracting this set of concepts in a reliable automated way using the JavaParser tool. To demonstrate the importance of fine-grained sequencing, we provide an example of how this information can be used for problem sequencing during exam preparation.

Keywords: indexing, sequencing, parser, java programming

1 Introduction

One of the oldest functions of adaptive educational systems is guiding students to the most appropriate educational problems at any time during their learning process. In classic ICAI and ITS systems, this function was known as task sequencing [1; 6]. In modern hypermedia-based systems, it is more often referred to as navigation support. The intelligent decision mechanism behind these approaches is typically based on a domain model that deconstructs the domain into a set of knowledge units. This domain model serves as the basis of a student overlay model and as a dictionary to index educational problems or tasks. Considering the learning goal and the current state of student knowledge reflected by the student model, various sequencing approaches are able to determine which task is currently the most appropriate.

An important aspect of this decision process is the granularity of the domain model and the task indexing. In general, the sequencing algorithm can better determine the appropriate task if the granularity of the domain model and the task indexing is finer. However, fine-grained domain models that dissect a domain into dozens or hundreds of knowledge units are much harder to develop and to use for indexing. As a result, many adaptive educational systems use relatively coarse-grained models where a knowledge unit corresponds to a sizable topic of learning material, sometimes even a whole lecture. With these coarse-grained models, each task is usually indexed with only 1-3 topics. In particular, this approach is used by the majority of adaptive systems in the area of programming [2; 4; 5; 7].

Our prior experience with adaptive hypermedia systems for programming [2; 4] demonstrated that adaptive navigation support based on coarse-grained problem in-

dexing is a surprisingly effective way to guide students through their coursework, yet it doesn't work well in specific cases such as remediation or exam preparation. In these special situations, students might have a reasonable overall understanding of the content (i.e., coarse-grained student model registers good level of knowledge), while still suffering some knowledge gaps and misconceptions that could only be registered using a finer-grained student model. In this situation, only a fine-grained indexing and sequencing tool is able to suggest learning tasks that can address these gaps and misconceptions.

To demonstrate the importance of fine-grained indexing, we look to a system called Knowledge Maximizer [3] that uses fine-grained concept-level problem indexing to identify gaps in user knowledge for exam preparation. This system assumes a student already completed a considerable amount of work: thus, the goal is to help her define gaps in knowledge and try to redress them as soon as possible. Fig. 1 represents the Knowledge Maximizer interface. The question with the highest rank is shown first. The user can navigate the ranked list of questions using navigation buttons at the top. The right-hand side of the panel shows the list of fine-grained concepts covered by the question. The color next to each concept visualizes the student's current knowledge level (from red to green). Evaluation results confirm that using fine-grained indexing in Knowledge Maximizer has a positive effect on students' performance and also shortens the time for exam preparation.

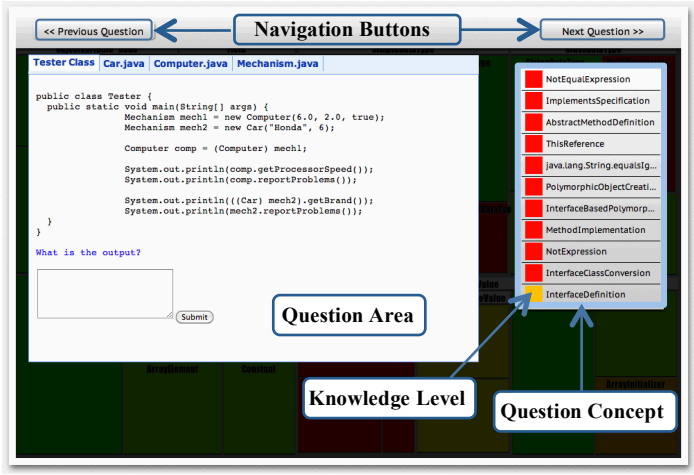

Fig. 1. The Knowledge Maximizer interface.

The problem with finer-grained indexing, such as that used by the Knowledge Maximizer, is the high cost of indexing. While a fine-grained domain model has to be developed just once, the indexing process has to be repeated for any new question. Given that most complex questions in our domain involve more than 50 concepts each, the high cost of indexing effectively prevents an increase in the number of problems represented in the system. To resolve this problem, we developed an automatic approach to fine-grained indexing for programming problems in Java based on program parsing. This approach is presented in the following section.

2 Java Parser

Java parser is a tool that we developed to index Java programs according to concepts in a Java ontology developed by our group (http://www.sis.pitt.edu/~paws/ont/java.owl). This tool provides the user with semi-automated indexing support during the development of new learning materials for a Java Programming Language course. This parser was developed using the Eclipse Abstract Syntax Tree framework. This framework generates an Abstract Syntax Tree (AST) that completely represents the program source. AST consists of several nodes, each containing sets of information known as structural properties. For example, Fig. 2 shows the structural properties for the following method declaration:

```
public void start(BundleContext context) throws Exception {
        super.start(context);
}
```

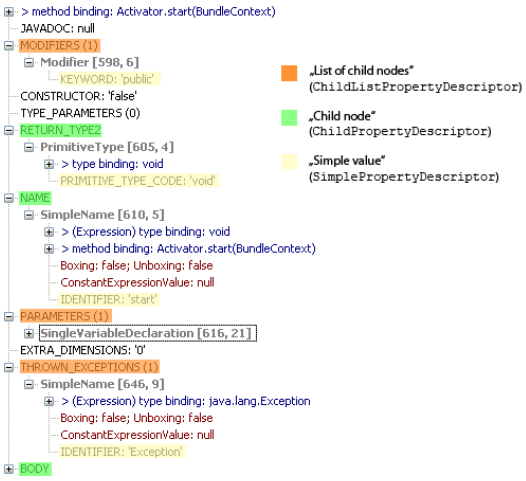

Fig. 2. Structural properties of a method declaration

Table 1. Sample of JavaParser output

Source	Output
public void start(BundleContext context) throws Exception { *super.start(context);* *}*	PublicAccessSpecifier, MethodDefinition, VoidDataType, FormalMethodParameter, ThrowsSpecification, ExceptionClass, SuperReference, SuperclassMethodCall, ExpressionStatement

After building the tree using Eclipse AST API, the parser performs a semantic analysis using the information in each node. This information is used to identify fine-grained indexes for the source program. Table 1 shows the output concepts of Ja-

vaParser for the code fragment mentioned above. Note that the goal of the parser is to detect the lowest level ontological concepts behind the code as the upper level concepts can be deduced using ontology link propagation. For example, parser detects "PublicAccessSpecifier" ignoring the upper-level concept of "Modifier".

We compared the accuracy of JavaParser with manual indexing for 103 Java problems and determined that our parser was able to index 93% of the manually indexed concepts. Therefore, an automatic parser can replace the time-consuming process of manual indexing with a high precision and open the way to community-driven problem authoring and targeted expansion in the size of the body of problems.

3 Conclusion

Having fine-grained indexing for programming problems is necessary for better sequencing of learning materials for students; however, the cost of manual fine-grained indexing is prohibitively high. In this paper, we presented a fine-grained indexing approach and tool for the automatic indexing of Java problems. We also explored an application of fine-grained problem indexing during exam preparation, where smaller grain size of knowledge units is critical to finding the sequence of problems which will fill the gaps in student knowledge. Results show that the proposed automatic indexing tool can offer the quality of indexing that is comparable with manual indexing by an expert at a fraction of the cost.

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