Bridging Java Annotations and UML Profiles with JUMP*

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Abstract. UML profiles support annotations at the modeling level. However, current modeling tools lack the capabilities to generate such annotations required for the programming level, which is desirable for reverse engineering and forward engineering scenarios. To overcome this shortcoming, we defined an effective conceptual mapping between Java annotations and UML profiles as a basis for implementing the JUMP tool. It automates the generation of profiles from annotation-based libraries and their application to generate profiled UML models. In this demonstration, we (i) compare our mapping with the different representational capabilities of current UML modeling tools, (ii) apply our tool to a model-based software modernization scenario, and (iii) evaluate its scalability with real-world libraries and applications.

1 Introduction

The value of UML profiles is a major ingredient for model-based software engineering [3] as they provide features supplementary to the UML metamodel in terms of lightweight extensions. This powerful capability of profiles can be employed as annotation mechanism [9], where stereotypes show similar capabilities as annotations in Java. In the ARTIST project [1], we exploit these capabilities, as we work towards a model-based engineering approach for modernizing applications by novel cloud offerings, which involves representing platform-specific models (PSM) that refer to the platform of existing applications, e.g., the Java Persistence API (JPA)³ when considering persistence, and the platform of “cloudified” applications, e.g., Objectify⁴ when considering cloud datastores. Clearly, the modernization process relies on the availability of the profiles that correspond to the used Java libraries.

Manually developing a rich set of profiles demands a huge effort when considering the large number of possible annotations in Java. To automate the generation of UML profiles requires an effective conceptual mapping of the two languages. In recent work, we defined such a mapping [2] based on which we implemented the JUMP tool. Hence, we continue with the long tradition of investigating mappings between Java and

* This work is co-funded by the European Commission, grant no. 317859.
³ http://oracle.com/technetwork/java/javaee/
⁴ https://code.google.com/p/objectify-appengine/
UML [7][8], though in this work we also consider Java annotations in the mapping.

The JUMP tool is intended to be used by (i) developers that produce platform-specific profiles to support transformations for reverse engineering and forward engineering scenarios or to enable platform-independent profiles abstracted from such platform-specific profiles and (ii) modelers that directly use the produced profiles to document important design decisions at the modeling level or to easier understand Java libraries by visualizing provided annotations in terms of UML profile diagrams.

In this demonstration, we discuss the benefits of JUMP compared to existing solutions of modeling tools that support annotations. Furthermore, we emphasize the unique capabilities of the JUMP tool to automatically generate profiles from annotation-based libraries, which are collected in the UML-Profile-Store. It leverages the generation of profiled models from applications. To report on the scalability, we measured the performance of JUMP tool by applying it to large Java code bases.

2 Bridging Java Annotations and UML: Profiles to the Rescue

UML profiles enable systematically introducing new language elements [5] without the need to adapt the underlying modeling environment, such as editors, model transformations, and model APIs [6]. UML provides a dedicated language to precisely define profiles and how stereotypes are applied on models. Similarly, Java provides an annotation language to declare annotation types that can be applied on the targeted code elements. Figure 1 demonstrates the relationship between the two languages based on the Objectify framework. On the left side, the application of annotation types, among them Cache, to the Customer class and the respective declaration of the Cache annotation type is shown. The corresponding UML-based representation shown on the right side demonstrates the stereotype application to the Customer class and the declaration of Cache by a Stereotype, which is part of the Objectify profile. To ensure that the Cache stereotype provides at least similar capabilities as the corresponding annotation type, the extension relationship references the UML meta-class Type. The Objectify profile generated by the JUMP tool enables modelers to refine UML class di-

Fig. 1: JUMP in Action
Mapping Java Annotations to UML. Currently, three significantly different solutions exist to support Java annotations for UML models: (i) built-in annotation feature of modeling tools, (ii) generic profile for Java, which enables capturing annotations and their type declarations, and (iii) profiles which are specific to a Java library or even an application with custom annotation type declarations. The first solution is certainly the most tool specific one as it goes beyond Java and UML. It facilitates to capture Java annotations, though the type declaration of an annotation and its applications are not connected. A generic profile for Java emulates the representational capabilities of Java’s annotation language. Although with this approach the connection of annotation type declarations and their applications can be ensured, the native support of UML for annotating elements with stereotypes is still neglected. However, stereotypes specifically defined for annotation types would facilitate their application in a controlled UML standard-compliant way as they extend only the required UML metaclasses. From a language engineering perspective, such stereotypes facilitate defining constraints and model operations, such as model analysis or transformations, because they can directly be used in terms of explicit types similar to a metaclass in UML. Therefore, the JUMP tool is based on a mapping between Java’s annotation language and UML’s profile language [2], which enables the generation of specific stereotypes for corresponding annotation types that in turn leverage platform-specific profiles.

Existing Modeling Tools. Several commercial and open-source modeling tools support Java annotations at the modeling level as summarized in Table 1. While all evaluated modeling tools support the generation of annotated UML class diagrams from Java applications, none of them is capable of generating profiles for Java libraries, and so exploiting the powerful capabilities of stereotypes and profiles.

### Table 1: Comparison of Modeling Tools

<table>
<thead>
<tr>
<th>Modeling Tool</th>
<th>Mapping (Java → UML)</th>
<th>UML Profile Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altova UML</td>
<td>Generic</td>
<td>Interface</td>
</tr>
<tr>
<td>ArgouML</td>
<td>Generic</td>
<td>Interface</td>
</tr>
<tr>
<td>Enterprise Architect</td>
<td>Built-in</td>
<td>Interface</td>
</tr>
<tr>
<td>Magic Draw</td>
<td>Generic</td>
<td>Interface</td>
</tr>
<tr>
<td>Rational Software Architect</td>
<td>Specific Profile</td>
<td>Stereotype</td>
</tr>
<tr>
<td>Visual Paradigm</td>
<td>Built-in</td>
<td>Class</td>
</tr>
<tr>
<td>JUMP Tool</td>
<td>Specific Profiles</td>
<td>Stereotype</td>
</tr>
</tbody>
</table>

3 JUMP Tool

The JUMP tool envisages two main scenarios: **UML Profile Generation** and **Profiled UML Model Generation**. The first scenario is executed on a Java-based Eclipse project that covers the library from which a profile with the corresponding stereotypes is generated. Optionally, the generated profile is added to a local copy of the **UML-Profile**.
Store, which exposes frequently used profiles as plug-ins to facilitate their reuse, thereby avoiding to regenerate them again and again. The practical application of profiles is employed in the second scenario, which is integrated into the generation of UML class diagrams from Java applications. Annotation applications are replaced by the corresponding stereotypes applied to the reverse-engineered UML elements. The applied stereotypes are imported from the UML-Profile-Store. If user-defined annotation types are declared in the application, the respective profile is generated in a pre-processing step as they need to be defined prior their application. Such application-specific profiles are provided together with the generated UML class diagram rather than added by default to the UML-Profile-Store. Similarly to the first scenario, the second scenario is also executed on Java-based Eclipse projects.

**Prototypical Implementation.** To realize JUMP, we developed three transformation chains, i.e., JavaCode2UMLProfile, JavaCode2ProfiledUML, and ProfiledUML2JavaCode. For injecting Java code to our chains, we reuse MoDisco [4], which generates a Java model that is considered as input for the JUMP tool. Hence, it can be considered as a specific model discoverer to extract annotation types from Java libraries in terms of profiles. To generate Java code from such models we extended the code generator provided by Obeo Network[5] The prototype and the collected profiles from 20 Java libraries with over 700 stereotypes are available at our project web site [6].

**Scalability Evaluation.** To report on the scalability of the JUMP tool, we measured the execution time of applying the JavaCode2UMLProfile and JavaCode2ProfiledUML transformation chain to real-world libraries and applications. For obtaining the measures, we executed them in Eclipse Kepler SR2 with Java 1.7 on commodity hardware: Intel Core i5-2520M CPU, 2.50 GHz, 8,00 GB RAM, Windows 7 Professional 64 Bit.

Table 2 summarizes our obtained results by emphasizing (i) the number of code elements in the intermediate Java model, (ii) the number of declared and applied stereotypes and (iii) the measured execution times. The rationale behind our selection of libraries (JPA, Objectify, Spring 7 and EclipseLink 8) and applications (Petstore 9, DEWS-Core 10, Findbugs 11 and once more EclipseLink) is to consider small-sized to large-sized libraries and applications with varying number of declared and applied stereotypes. Clearly, the size of the input models passed to the transformation

<table>
<thead>
<tr>
<th>Library</th>
<th>Code Elements</th>
<th>Declared Stereotypes</th>
<th>Execution Time in Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>JPA</td>
<td>20K</td>
<td>84</td>
<td>2.362</td>
</tr>
<tr>
<td>Objectify</td>
<td>40K</td>
<td>18</td>
<td>1.842</td>
</tr>
<tr>
<td>Spring</td>
<td>500K</td>
<td>63</td>
<td>10.292</td>
</tr>
<tr>
<td>EclipseLink</td>
<td>700K</td>
<td>127</td>
<td>29.614</td>
</tr>
<tr>
<td>Petstore</td>
<td>10K</td>
<td>287 (12 Profiles)</td>
<td>4.581</td>
</tr>
<tr>
<td>DEWS-Core</td>
<td>30K</td>
<td>253 (2 Profiles)</td>
<td>3.116</td>
</tr>
<tr>
<td>Findbugs</td>
<td>100K</td>
<td>1808 (3 Profiles)</td>
<td>26.620</td>
</tr>
<tr>
<td>EclipseLink</td>
<td>700K</td>
<td>7117 (3 Profiles)</td>
<td>199.028</td>
</tr>
</tbody>
</table>

Table 2: Performance Measures

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5 http://marketplace.eclipse.org/content/uml-java-generator
6 http://code.google.com/a/eclipselabs.org/p/uml-profile-store
7 http://projects.spring.io/spring-framework
8 https://www.eclipse.org/eclipselink
9 http://oracle.com/technetwork/java/index-136650.html
10 Distant Early Warning System (DEWS), a use-case of the ARTIST project [1]
11 http://findbugs.sourceforge.net
chains has a strong impact on the execution time of the JUMP tool as they are traversed throughout the generation of profiles and profiled models. Regarding the profile generation, the number of generated stereotypes is another main factor that impacts on the execution time. The more stereotypes are generated the more extensions to UML metaclasses need to be created. For instance, even though the JPA is compared to Objectify smaller in size the execution time is higher because a lot more transformation rules are applied when considering the number of declared stereotypes. Similarly, the number of applied stereotypes and their respective profiles impacts on the execution time. For instance, in the Petstore application, stereotypes are applied from 12 different profiles, which explains the higher execution time compared to DEWS-Core, even though the latter is larger in size. Finally, the execution time of generating profiled models is generally higher compared to profiles because the class structure of the former is much larger in size compared to the latter. For instance, considering EclipseLink and the number of generated stereotypes compared to classes the factor is almost 30.

4 Future Work

The JUMP tool aims at closing the gap between programming and modeling concerning annotation mechanisms. Still, open challenges remain to further integrate the two areas. For instance, with the latest Java version (1.8) we have repeating annotations that enable the same annotation to be repeated multiple times in one place which is currently not supported by stereotypes in UML. Furthermore, we plan to incorporate the production of UML activity diagrams for Java method implementations in JUMP in order to represent also annotation applications on the statement level in UML. Another line of research we plan to investigate is to further evaluate the JUMP tool in the context of the ARTIST project by empirical studies with our use case providers to determine the practical benefits for understanding and migrating legacy applications.

References