Tool support for semi-automatic modularization of existing code bases

[Extended Abstract]

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ABSTRACT

Many component based systems and frameworks require the integration of external codes, for example, providing numerical functionalities. These numerical codes can be either sequential or parallelized, written in languages such as C, Fortran, Python, or Java. Frameworks provide support for workflow management, data management, using distributed computing resources, or a graphical user interface. Today, modern systems are based on Eclipse and OSGi or similar technologies.

For many frameworks, tight integration of pre-existing or third-party code requires manual source code changes to add the specific component interfaces to such code. As this is error-prone and time consuming, especially when large code bases must be integrated, tool support for these steps becomes useful, or even necessary.

Tool support for automatic integration of existing code (in different languages) comprises several sub-problems such as code analysis, code transformation, generation of wrapper code, generation of proper user interfaces, and others. In this paper, we focus on the aspect of modularization of existing Java OSGi workflow systems and present a new Eclipse-based tool which provides end-user support for the migration of previously unmodularized software into modules or components.

Categories and Subject Descriptors

C.2.4 [**Distributed Systems**]: Distributed applications; D.1.2 [**Programming Techniques**]: Automatic Programming

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1. INTRODUCTION

In many scientific and engineering domains, multidisciplinary coupled simulation is commonly used, for example, to design complex technical systems (ships, spacecrafts, automobiles etc.). Usually for each discipline, certain numerical codes exist which are often integrated into component based frameworks. Typical frameworks provide support for workflow management, data management, using distributed computing resources, or a graphical user interface. The numerical codes are written in languages such as C, C++, Fortran, Python, or Java. Often, they are parallelized and require HPC resources to run.

For many frameworks, tight integration of pre-existing or third-party code requires manual source code changes to add the specific component interfaces to such code. The component interface is defined by the component model of the framework (e.g., specified by CCA [3], OSGi, CORBA [4], or Web Services). A specific topic is the development of suitable wrapper code for external applications where the source code is not available or for code written in a different language than the framework. For example, for Java based component frameworks codes in C or Fortran could be be integrated by suitable JNI wrapper code. As the integration of numerical codes can be error-prone and time consuming, especially when large code bases must be integrated, tool support for these steps becomes useful, or even necessary.

Tool support for automatic integration of existing code in different languages comprises several sub-problems such as code analysis, code transformation, generation of wrapper code, generation of proper user interfaces, and others. In this paper, we focus on the aspect of modularization of existing Java code as a first step towards the long-term goal of generic, automatic, cross-language integration of code into OSGi-based systems. As part of this effort, a new Eclipse-based tool is developed. This tool provides end-user support for the migration of previously unmodularized software into modules with explicitly defined boundaries, exports, imports, and embedded module-private libraries. While there are separate tools for static dependency analysis, visualization, or rule checking, none of them are combined to provide useful OSGi modularization support inside the Eclipse IDE yet. Future versions of the tool are planned to support other programming languages, frameworks, and programming models.

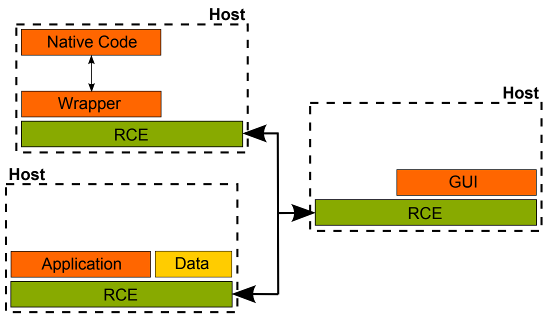


Figure 1: Deployment diagram of the distributed integration platform RCE.

The rest of this paper is organized as follows. Section 2 describes in brief the Eclipse-based component framework RCE (Remote Component Environment) that is used as the underlying framework for validation. The current version of the tool for analyzing and refactoring of Java code is described in Section 3. Finally, Section 4 shows the open topics for future work.

2. THE RCE FRAMEWORK

The Remote Component Environment (RCE) is a service oriented software framework to manage collaborative engineering processes. It hides the complexity of heterogeneous and distributed IT systems behind a common user interface and thereby enforces secure and uniform access of data and services. RCE is application independent and easily adaptable to a variety of application domains. It is based on OSGi (Open Services Gateway initiative), therefore RCE is platform independent and can be used on most architectures. The seamless integration of Grid technologies into RCE allows the transparent access to resources. RCE can be easily extended by application specific services which are added and managed as *plug-ins*, the central mechanism used in the Eclipse universe. Non-Java code, like C or Fortran, can be integrated via provided code wrapping technologies, which are designed to integrate existing code easily. It provides services for data management, data access, or workflow management. A workflow in RCE consists of plug-ins (i.e., application specific services). Plug-ins can have different requirements on the resources they are running on. Some have a high demand for computational power, others need a huge storage capacity. RCE is realized as a distributed system (Figure 1. It can run each plug-in of a workflow on the resource which meets its needs best. The only requirement is an installed RCE instance on each resource.

For workflows with complex, computationally intensive simulations, RCE provides a Grid interface that enables plug-ins to source computations out to the Grid. This interface is realized by integrating the Grid Application Toolkit (GAT) [1] into RCE. GAT provides a uniform API to access heterogeneous compute and data resources. By making use of adaptors it is able to support different Grid middleware (e.g., Globus or UNICORE) and resource systems by having one uniform and stable API. New technologies will be supported by adding an adaptor without the need to modify the API. This Grid interface of RCE allows workflows to be executed on the Grid. More precisely, their components (i.e., plug-ins) are enabled to run computations in the Grid. This concept allows the combination of plug-ins running in the Grid or on HPC resources with plug-ins being executed in RCE.

3. ECLIPSE TOOL SUPPORT

On the lowest abstraction level, the developed Eclipse tool provides a condensed model of dependencies between the Java types located in the analyzed projects and their sub-projects. Using the abstract source tree (AST) parser of the Eclipse Java Development Tools for character-level analysis, dependency patterns are detected and categorized to help the creation of higher-level models.

Binary types and packages are analyzed as dependency targets as well, together with references to the deployment containers (JAR files) from which they emerged. This information is important for several reasons. First, the OSGi specification forces the developer to either define an explicit import on required binary packages, or to completely embed the required JAR file inside the defined module. Having access to the deployment information of the referenced binary types allows the user to decide whether the automatic creation of import statements, or a complete inclusion of the affected JAR file is more appropriate.

A second reason why dependencies to binary types are important is the possible use of the developed tool in platform or library migration. By omitting the old platform from the list of valid dependencies, the user is presented with a list of forbidden references, which provides him with an automatic guideline for the necessary source code adaptations. This supports a “soft” migration, keeping the source code in a consistent and compiling state as long as possible. This option has a similarity to the Eclipse “Access Rules” feature, but has the advantage of operating on a virtual module definition. This allows to define the migration rules in a more flexible way. For example, the new rule set can define both source code as well as library elements as invalid, and is also not restricted to Eclipse project boundaries.

3.1 Visualization and User Interface

The most detailed view of the dependencies between the various elements is the modularization tree view (Figure 2). By various grouping options, the user can easily assess the source, destination and type of the current dependencies, with the default view showing only those that violate the access rules derived from the current modularization. Based on this information, the user can choose to manually eliminate certain dependencies, or to semi-automatically adapt the module configuration to the current dependencies. An analysis of dependency cycles on the type and package level is also provided.

While the tree view is useful in untangling low-level interdependencies, it does not scale well for large sets of interconnected packages. To address this situation, a dependency structure matrix [5, 7] is also provided (Figure 3). In its most basic form, its columns and rows are the same, with the cells showing the number of dependencies from the column to the row element. The cell background indicates the type of access permission between these elements under the current modularization design. By selecting a matrix cell, the underlying dependencies are shown in a smaller tree view below to assist the user in understanding the nature of the (possibly conflicting) access constellation. To improve on this basic design, several adaptations are being evaluated, including filtering and partitioning options, as well as allowing non-quadratic matrices and mixing of package and module elements along the axes.

3.2 Migration Workflow

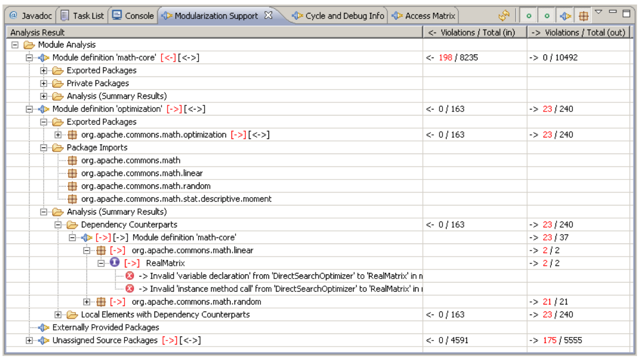
As choosing a top-level architecture for modular decomposition of an existing software is an inherently semantic process, no attempt is made to automate the selection of root modules. Instead, an incremental approach is proposed, gradually transforming a set of unassigned source packages into a network of modules.

Initially, the user is presented a list of all source packages within the project scope. From these, the user defines an arbitrary number of modules that outline the basic modularization intent. Additionally, a set of source and binary packages can be defined that describes the environment the final modules will be deployed to. Each package from the project scope can be assigned at most to one module or to this "provided" set. The unassigned packages are kept in automatic "unassigned source" and "unassigned binary" sets.

The new Eclipse tool support continually displays the incoming and outgoing references between the defined modules and these special package sets. After the initial modules have been defined, three workflow stages are repeated until a valid modularization state is reached. These three stages resolve package cycles, invalid outgoing dependencies, and invalid incoming dependencies.

In the first stage, package cycles affecting any of the defined modules are examined. If a cycle affects only one module, one option is to add the whole cyclic chain to the affected module, which, by definition, makes the cyclic dependencies valid under the OSGi access rules. Of course, this approach is only desirable if the connected packages have a high internal cohesion, in which case such a tight coupling is acceptable. If the user decides that this is inappropriate, he can use the tool support to identify the connecting dependencies and decouple them manually or by using existing refactorings. If a cyclic dependency affects more than one defined module, the user is forced to resolve this situation on the code level, as such a cycle makes an automatic assignment impossible.

After all cyclic dependencies with packages outside the modules have been resolved, the second stage aims at resolving all outbound dependencies that violate the defined access rules. The basic forms of invalid external references are dependencies on unassigned source or binary packages, references to platform-provided packages without corresponding import declarations, and references to other modules which are not backed by any (package or module) import declaration. Without going into the detailed options for each case, tool support is provided to either create missing imports, to declare referenced packages as "provided", to define new target modules, or to merge the referenced packages into the referring module.



Analysis Result	<- Violations / Total (in)	-> Violations / Total (out)
Module Analysis		
Module definition 'math-core' [<-] [<->]	<- 198 / 8235	-> 0 / 10492
Exported Packages		
Private Packages		
Analysis (Summary Results)		
Module definition 'optimization' [->] [<->]	<- 0 / 163	-> 23 / 240
Exported Packages		
org.apache.commons.math.optimization [->] [<->]	<- 0 / 163	-> 23 / 240
Package Imports		
org.apache.commons.math		
org.apache.commons.math.linear		
org.apache.commons.math.random		
org.apache.commons.math.stat.descriptive.moment		
Analysis (Summary Results)		
Dependency Counterparts	<- 0 / 163	-> 23 / 240
[->] [->] Module definition 'math-core'		-> 23 / 37
[->] org.apache.commons.math.linear		-> 2 / 2
[->] RealMatrix		-> 2 / 2
-> Invalid 'variable declaration' from 'DirectSearchOptimizer' to 'RealMatrix' in n		
-> Invalid 'instance method call' from 'DirectSearchOptimizer' to 'RealMatrix' in i		
[->] org.apache.commons.math.random		-> 21 / 21
Local Elements with Dependency Counterparts	<- 0 / 163	-> 23 / 240
Externally Provided Packages		
Unassigned Source Packages [->] [<->]	<- 0 / 4591	-> 175 / 5555

Figure 2: Work-in-progress screenshot of the analysis and configuration tree view.

After completing the second stage, all modules are valid in the sense that they have no outgoing dependencies preventing their deployment as modules. However, there may, however, be unassigned source packages referencing these modules in violation of the defined access rules. The third stage of the proposed workflow covers the resolution of these invalid references. Using the tree or the matrix views, the incoming references can be examined. Based on this inspection, the user can decide between adding the external package to the affected module, creating a new module, adding the package to another module, or removing the dependency by using existing refactorings. In the cases where additional modules are affected, appropriate export and import statements can be added semi-automatically to the target and source modules.

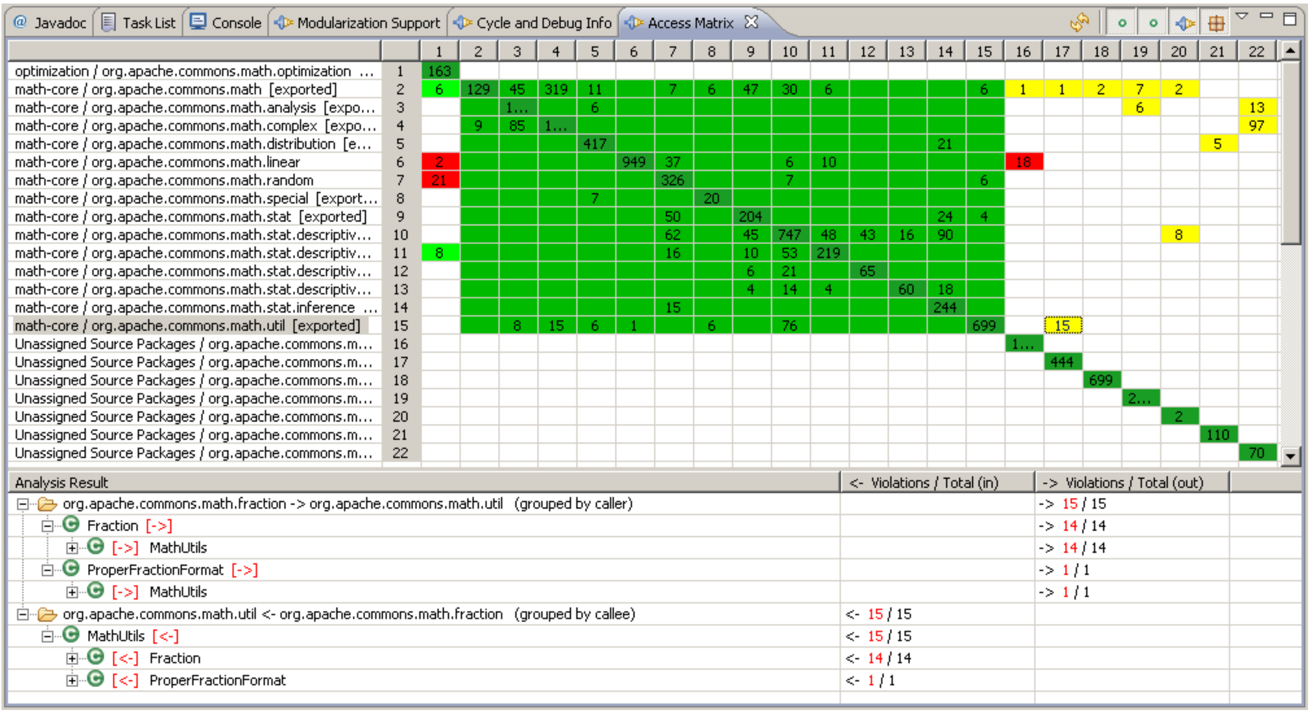
As adding previously unassigned packages to modules in stage three can possibly introduce new cycles or new outgoing references, a new iteration from stage one is performed until no stage effects a change anymore, resulting in an exhaustive and completely valid modularization setup.

In an optional fourth stage, the exported packages of all defined modules can be examined for unnecessary exports, and possible reductions in type coupling and visibility. The amount of tool support for this stage is not determined yet.

4. FUTURE WORK

While the developed tool provides support for the migration of existing Java code to an OSGi environment, it only represents a first step towards the long-term goal of automatic integration. A useful integration support would be a tool that only leaves the essential, behaviour-defining decisions to the user, while completely automating the laborious steps of refactoring, untangling, interface wrapping, and target platform adaptation. While this goal is out of reach of current software technology, it can serve as a guideline to determine pragmatic steps towards better integration support.

There are three principal topics for medium-term work. The first is the definition of an abstract model of cross-language code integration, and the creation of tool support for the specific properties of the supported target languages. C and Fortran will be supported first, but the underlying model



		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
optimization / org.apache.commons.math.optimization …	1	163																					
math-core / org.apache.commons.math [exported]	2	6	129	45	319	11		7	6	47	30	6				6	1	1	2	7	2		
math-core / org.apache.commons.math.analysis [expo…	3			1…		6														6			13
math-core / org.apache.commons.math.complex [expo…	4		9	85	1…																		97
math-core / org.apache.commons.math.distribution [e…	5					417									21							5	
math-core / org.apache.commons.math.linear	6	2					949	37			6	10					18						
math-core / org.apache.commons.math.random	7	21						326			7					6							
math-core / org.apache.commons.math.special [export…	8					7			20														
math-core / org.apache.commons.math.stat [exported]	9							50		204					24	4							
math-core / org.apache.commons.math.stat.descriptiv…	10							62		45	747	48	43	16	90						8		
math-core / org.apache.commons.math.stat.descriptiv…	11	8						16		10	53	219											
math-core / org.apache.commons.math.stat.descriptiv…	12									6	21		65										
math-core / org.apache.commons.math.stat.descriptiv…	13									4	14	4		60	18								
math-core / org.apache.commons.math.stat.inference …	14							15							244								
math-core / org.apache.commons.math.util [exported]	15			8	15	6	1		6		76					699		15					
Unassigned Source Packages / org.apache.commons.m…	16																1…						
Unassigned Source Packages / org.apache.commons.m…	17																	444					
Unassigned Source Packages / org.apache.commons.m…	18																		699				
Unassigned Source Packages / org.apache.commons.m…	19																			2…			
Unassigned Source Packages / org.apache.commons.m…	20																				2		
Unassigned Source Packages / org.apache.commons.m…	21																					110	
Unassigned Source Packages / org.apache.commons.m…	22																						70

Analysis Result	<- Violations / Total (in)	-> Violations / Total (out)
org.apache.commons.math.fraction -> org.apache.commons.math.util (grouped by caller)		-> 15 / 15
Fraction [->]		-> 14 / 14
[->] MathUtils		-> 14 / 14
ProperFractionFormat [->]		-> 1 / 1
[->] MathUtils		-> 1 / 1
org.apache.commons.math.util <- org.apache.commons.math.fraction (grouped by callee)	<- 15 / 15	
MathUtils [<-]	<- 15 / 15	
[<-] Fraction	<- 14 / 14	
[<-] ProperFractionFormat	<- 1 / 1	

Figure 3: Work-in-progress screenshot of the DSM view. The lower section shows detail information about the selected matrix cell.

should be generic enough to cover all relavant platforms. One part of this model would be a cross-language definition of all possible dependency constellations. As every target language has a different set of existing tools and possible refactorings, an abstract description of their respective properties should also be aimed at to allow a generic evaluation of design options.

The second topic will be the adaption of the current modularization support and workflow to the properties of the target languages. As the goal for all underlying programming languages is the creation of OSGi-compliant modules, the modularization model itself is unlikely to change. However, it must be evaluated how the specifics of each language can be mapped to OSGi, which was designed primarily as a Java framework. For example, code written in C might depend on precompiled, platform-specific libraries, which must be provided at runtime within the OSGi environment. Such requirements should be abstracted, and generic solutions should be collected in form of a pattern library.

The third research topics will be the integration of existing wrapper generation tools [2, 6] into the migration workflow. Together, these elements should help the integration of existing code into OSGi environments. Future versions of the tool are planned to support other programming languages, frameworks, and programming models.

5. REFERENCES

[1] G. Allen, K. Davis, T. Dramlitsch, T. Goodale, I. Kelley, G. Lanfermann, J. Novotny, T. Radke, K. Rasul, M. Russell, E. Seidel, and O. Wehrens. The gridlab grid application toolkit. In *HPDC*, page 411, 2002.

[2] D. M. Beazley. Automated scientific software scripting with SWIG. *Future Generation Computer Systems*, 19(5):599–609, 2003.

[3] D. E. Bernholdt, B. A. Allan, R. Armstrong, F. Bertrand, K. Chiu, T. L. Dahlgren, K. Damevski, W. R. Elwasif, T. G. W. Epperly, M. Govindaraju, D. S. Katz, J. A. Kohl, M. Krishnan, G. Kumfert, J. W. Larson, S. Lefantzi, M. J. Lewis, A. D. Malony, L. C. Mclnnes, J. Nieplocha, B. Norris, S. G. Parker, J. Ray, S. Shende, T. L. Windus, and S. Zhou. A component architecture for high-performance scientific computing. *International Journal of High Performance Computing Applications*, 20(2):163–202, 2006.

[4] T. Forkert, G. K. Kloss, C. Krause, and A. Schreiber. Techniques for wrapping scientific applications to CORBA components. In *9th International Workshop on High-Level Programming Models and Supportive Environments (HIPS 2004)*, pages 100–108. IEEE Computer Society, 2004.

[5] N. Sangal, E. Jordan, V. Sinha, and D. Jackson. Using dependency models to manage complex software architecture. In *OOPSLA*, pages 167–176. ACM, 2005.

[6] A. Schreiber. Automatic generation of wrapper code and test scripts for problem solving environments. In J. Dongarra, K. Madsen, and J. Wasniewski, editors, *PARA 2004, Lyngby, Denmark*, volume 3732 of *Lecture Notes in Computer Science*, pages 680–689. Springer, 2006.

[7] K. J. Sullivan, W. G. Griswold, Y. Cai, and B. Hallen. The structure and value of modularity in software design. In *ESEC / SIGSOFT FSE*, pages 99–108, 2001.