Towards Domain-specific Modeling for Java Enterprise Applications

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Abstract. Enterprise Applications are usually developed in the context of certain frameworks and platforms, for example the Java Enterprise Edition. These environments determine specific software architectures for such applications with respect to modularization, distribution, and interface provision, so that the structure of the applications is often very similar. However, so far no domain-specific models for these architectures exist. In this position paper we propose a domain-specific model for such applications that considers design information available as meta data in the program code. This will enable graphical design, verification, monitoring, and design recovery for this class of enterprise applications.

1 Introduction

Enterprise applications are developed for and run in sophisticated server environments. These usually provide services for networking, persistence, modularization, distribution, and interface provision that the applications can use. By this means repeating tasks are shifted into the underlying platforms. Enterprise applications do therefore usually not consist of monolithic program code blocks, but of smaller units of code and configuration files using platform services provided by appropriate frameworks. If server platforms are standardized, like the Java Enterprise Edition (JEE), services and programming interfaces are independent from server implementations and a uniform programming model exists.

This kind of development influences software architectures of such applications since developers are in many aspects not free to choose, but bound to rules determined by the frameworks. Architectures of different applications are thus in many cases very similar. In addition, many frameworks use *inversion of control* [1]: Applications have only limited influence of their life cycle; instead, since they fulfill the purpose to answer requests over the network, they provide definitions of single modules that are instantiated and used by the server. This results in architectures consisting of well-defined modules with entry points published as interfaces, so that design information is available inside the applications.

Despite these very similar structures, currently no widely-accepted domain-specific models for enterprise applications exist. Most model-driven software development (MDSD) approaches focus on deriving implementations from abstract specifications with program code generation [2]. However, this is not yet widely accepted: The fact

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that abstract modeling languages do not cover implementation details often leads to tuning and amendment of generated code [3] and prevents continuous synchronization between models and code [4]. Efforts to specify detailed information in modeling languages lead to modeling language stacks being as complex as the platforms they are intended to abstract from [5].

Program code of enterprise applications is thus usually created manually. However, since they are often comparatively large and used in business-critical situations, they must meet certain demands to maintainability and reliability. Therefore, models for enterprise applications are desirable to enable efficient design, program comprehension, verification, debugging, and even design recovery. In this position paper we propose a domain-specific model for JEE applications that uses design information available inside enterprise applications instead of external modeling notations. Thus no inconsistencies between higher abstraction levels describing design information and lower abstraction levels of the implementation can occur, since both are already contained in JEE applications.

This contribution is structured as follows: We describe design information in JEE applications in section 2. A model specification based upon this is proposed in section 3. We describe the value of the model for design, verification, debugging, and design recovery in section 4, and evaluate the approach in section 5. Afterwards we consider related work in section 6 and conclude in section 7.

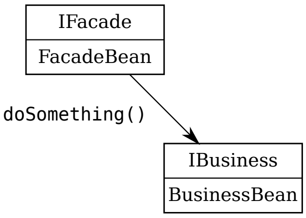
2 Design Information in JEE Applications

The JEE provides development and deployment of server-centric applications [6] comprising web applications, interface provision (e.g. with web services), business logic components, message services, and persistence components. As stated in the introduction, we consider design information contained in JEE applications to propose a domain-specific model. We will thus now explain the JEE's principles to represent design information, and afterwards describe the specific information containing the actual design of enterprise applications.

2.1 Design Information Representation

The JEE specifies two ways for describing components: For information concerning program code fragments, meta data in the code is used (*attribute-oriented programming* [7]) which is compilable and available at run time too. In Java the related concept is called *Java Annotations*. Second, design information that is not related to specific program code elements is given in configuration files, referred to as *deployment descriptors*. In general, components in the JEE are called *Enterprise Java Beans* (EJBs) [8] and are usually classes equipped with meta data so that they can be managed and executed by the server.

Access to design information in annotations and deployment descriptors is standardized by the programming language and the JEE specifications. Tools exist that read annotations from source code, for example Java IDEs like Eclipse. At run time, annotations can be accessed from inside the application server by means of structural reflection




```
@Stateless
@Remote(IFacade.class}
public class FacadeBean implements IFacade {
    @EJB
    IBusiness dependency;

    public void doSomething() {
        dependency.doSomething();
    }
}
```

Fig. 1. The concept of session beans and dependencies: At the left hand the conceptional view on two dependent beans, at the right hand the implementation of one bean in the program code containing necessary design information as annotations.

[9] and also in the compiled Java bytecode. The design information is thus accessible with standardized programming interfaces.

2.2 Business Logic Components

Business logic in JEE applications follows the *inversion of control* principle. Single units are a certain kind of EJBs called *session beans*. They have an implementation (the class) and an interface which can be simply the programming interface of the class, a separate Java interface publishing selected methods, or a web service interface provided by the server. By this means session beans define certain functionality of business logic that can be executed. However, they don't control actual execution. Instead, the server is responsible for receiving requests, instantiating the session bean they are targeted to, and forwarding related data.

This influences dependencies between session beans, which are specified descriptively. This is done with a class attribute annotated with meta data. The dependencies are then instantiated automatically too. All session beans are defined with meta data to be valid for single requests, user sessions managed by the server, or the life time of the whole application so that only a single instance exists. Thus a session bean or a network of dependent session beans is instantiated by the server according to the lifecycle definitions to serve single requests.

An example is shown in figure 1 with two dependent session beans. The `FacadeBean` has an interface `IFacade` published remotely as indicated with the annotation `@Remote`. It contains a dependency to a session bean with the interface `IBusiness` as specified by the annotation `@EJB`. The variable `dependency` is injected by the server with an appropriate implementation of the interface `IBusiness`. With these simple meta data annotations the network of session beans is defined so that it can be instrumented by the server at run time.

2.3 Composition of Applications

Session beans are a vital part of JEE applications since they provide the actual business logic. Therefore they are connected to other parts of the JEE environment. This is always the case for session bean interfaces that can be used at least from inside the

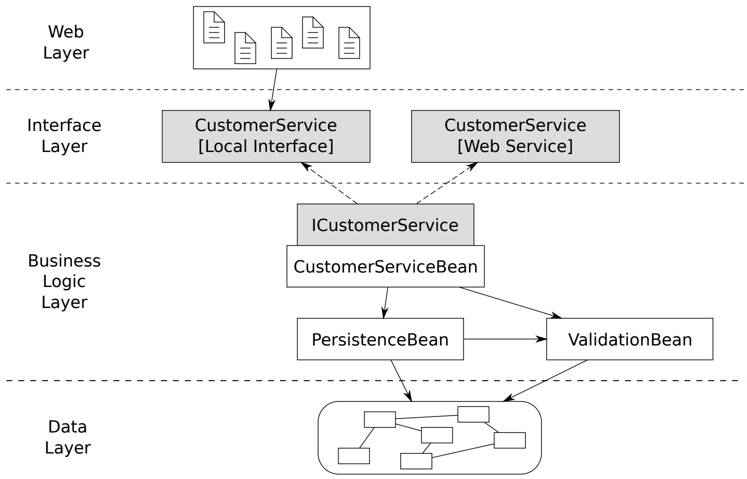


Fig. 2. The structural view on the model with layers for web applications, published interfaces, business logic, and data models. The core of the model is the business logic which is connected to the other layers.

server, for example from web applications on the same server instance. When interfaces are published they are handled by respective communication layers provided by the server. By this means remote access to the beans is possible, with different protocols being handled by the server.

Business logic of enterprise applications is almost every time related to data stored in databases. For this reason the JEE offers a persistence layer [10] that maps object-oriented data to databases. This is also mostly configured with annotations. The related *entity beans* are classes carrying information about the underlying relational schema, including information about relations between entities. Single attributes and methods can be decorated with validation information [6] restricting the value range of variables. Both entails that rich information is available about the data model and its possible state spaces. The mapping to an actual data base instance is configured in a separate deployment descriptor.

In summary, business logic in the JEE is described with respect to the provided program code fragments and its connections to the data in use as well as provided interfaces. Applications consist of different modules for web applications, business logic, and persistent data models. These modules can be merged into *packages* that contain deployment descriptors for the modules and are interpreted by the servers to start the enterprise applications.

3 Approach

We have so far outlined the design information that is embedded in program code and configuration files of JEE applications. Based on this we will now propose a basic domain-specific model that uses this information systematically.

3.1 Objectives

Our approach has the goal to apply the advantages of MDSD to Java enterprise applications. Selic defines the following to be the “quality of models” [11]: *Abstraction* hides implementation details and thus allows to cope with complexity; *understandability* finds representations that can be understood intuitively and thus with less effort; *accuracy* ensures that models represent a real-world system realistically; *predictiveness* allows to infer properties from a modeled system that are of interest, but not obvious, by formal analysis or experiments; finally, *inexpensiveness* is desirable since a system can be better analyzed and constructed when it is based on a model. We will use these desirable properties of models as objectives for creation (and, later on, as criteria for evaluation) of our model.

3.2 Structural View

A visual view on the structural elements of the model is illustrated in figure 2. The model is structured into four layers: The *business logic layer* contains actual business logic as session beans and the definition of interfaces at the level of the programming language. The *interface layer* is inferred from the business logic layer and represents resulting interfaces of session beans explicitly. The *web layer* is part of the model since web applications can be part of enterprise application compositions. Although they are not in the focus of our model, their interaction with session beans is comprehensible. The *data layer* contains data models with entity beans. Although we will not focus on data modeling here, we can use some of its properties to determine the state spaces the business logic is using.

Figure 2 contains a simple example with three session beans: The `CustomerServiceBean` has an interface `ICustomerService` published as a local interface and available inside the server instance. In this case it is used by a web application running on the same server. In addition, the interface is published as a web service accessible by clients over the network. The bean has dependencies to the `PersistenceBean` and the `ValidationBean`. Both have no separate interfaces and can thus only be accessed from inside the business logic. Both use a data model consisting of a set of entity beans.

In general, the structural view contains single units of program code for session beans, interfaces, and definitions of dependencies which can be used in session bean implementations to invoke methods of other session beans.

3.3 Behavioral View

Besides the structural view, behavioral aspects are represented in the model since related information is available in dependencies and method invocations between session beans. Thus a request from a client arrives at an interface and results in a sequence of method invocations. Possible sequences are determined by paths defined by the dependencies which can be visualized similar to UML sequence diagrams [12] as illustrated in figure 3. In this example, a request to the method `createCustomer` in the web service interface is handled by the interface implementation in the `CustomerServiceBean` and afterwards in the `PersistenceBean` and `ValidationBean`. Method

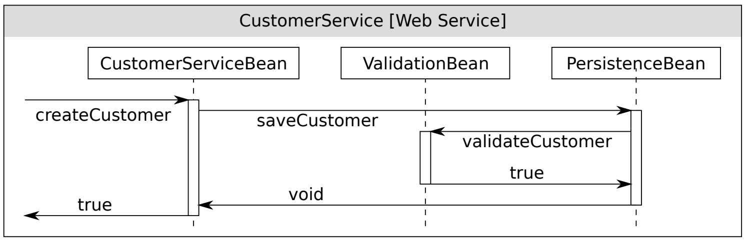


Fig. 3. The behavioral view on the domain-specific model. It contains sequences of method invocations that occur when a request arrives at the provided interfaces.

invocations are identified by method names and, in the case of parameter overloading, by the parameter types (not shown here for clarity of the illustration). Methods can return values or the placeholder `void`. Of course, similar to UML sequence diagrams, method invocations might occur only under certain conditions, which could also be supplemented in the diagram.

3.4 Model Definition

Considered at an abstract level, the interface layer and the business logic layer thus consist of nodes, i.e. session beans and interfaces, and edges, i.e. dependencies, which are used by method calls from one session bean to another. The interfaces thus provide entry points to the model, and invocations of these interfaces lead to sequences of method invocations in the session bean implementations.

We thus define a domain-specific model for JEE applications to be a tuple $M = \langle E, I, B, D, S, C \rangle$. E is a set of entry points, each defined in an interface $i \in I$. B is a set of business logic units that are connected by the set of dependencies $D \subseteq B \times B$. E and D imply that, beginning with the entry points, a set of possible sequences S of method invocations exists. A subset $S_{Used} \subseteq S$ is realized as determined by method invocations between session beans. Each sequence $s \in S$ is not always strictly linear, but has a set P_s of possible paths that can be taken. P_s defines more than one path if conditions of the set C apply during method invocation that influence the specific path a sequence takes.

This definition is comparatively simple, but covers the specifications of the JEE business logic on an abstract level. It can be used to describe the structural as well as the behavioral view on the model, and is the foundation of our proposal for the application of MDSD techniques to JEE applications.

4 Value of the Model

The definition of the model as given above is no value in itself, but must be beneficial during development of enterprise applications according to the objectives given in section 3.1 during different stages of the development process.

At *design time* visual design of structural elements is possible, i.e. for session beans, interfaces, methods, and dependencies. When source code is written, the behavioral view can be extracted to analyze paths of method invocations. Both views thus support the design of enterprise applications and at the same time understandability and program comprehension. In addition, program code can participate in model-to-model-transformations: When abstract models are used for requirement definition, design, or specification of applications, appropriate transformations to our model can be created. Thus source code stubs of structural elements can be generated or differences can be detected. More important, design information in the source code can be extracted and transformed to abstract models if the transformation is bidirectional. The *implementation* of the enterprise application is supported since the visual design is tightly coupled with creation and modification of the source code. In addition, the implementation is structured by graphical representations of source code artifacts. The advantages regarding program comprehension and understandability apply here, too.

Several ways exist to use the model for *verification* since abstract specifications are connected to implementations directly. The model can be verified in structural and behavioral views, and inconsistencies between model elements can be discovered. On the implementation level static source code analysis can be applied since sequences and paths allow to reduce complexity with slicing [13]. By this means a possible impact of changes and resulting side effects can be detected at the level of the model. For sequences, assertions can be given so that model checking for the Java code [14] is possible. The state space is reduced for this purpose by considering only a limited set of variables in related methods. When entity beans are used, the state space is further reduced since value ranges and relations are limited. When source code is connected to the entry points, static analysis can be applied to analyse if the interface contracts are fulfilled by clients. In general, single elements of the model can be systematically used for annotation with constraints, for example with the Java Markup Language [15].

At run time design information is also available to a certain degree as explained in section 2.1 and can be used for *debugging and monitoring*. Graphical model representations can be reconstructed by means of reflection or bytecode analysis and thus support detection of errors, especially when they visualize method invocations. When contracts have been specified at model elements for verification, they can also be monitored at run time to discover deviations.

Finally, when existing systems are abandoned, successional systems often re-use existing processes or data to fulfill the same purposes. This is usually difficult since models are mostly used as documentation, and as such have the tendency to get out of sync with the running systems when adaption, maintenance, and tuning activities have been applied for years. Since our model can be reconstructed from source code and partly even from compiled program code, *design recovery* is possible by considering the static elements of JEE applications.

In summary, the domain-specific model as proposed here can support development and maintenance of JEE applications by different means in different stages of the development process.

5 Evaluation

We will now evaluate the approach by considering its fulfillment of the objectives defined in section 3.1.

The model certainly enables *abstraction* for JEE applications. It is based on information available in the program code, but extracts structures that are more coarse-grained and simplified. This is true for the structural view, which is reduced to interfaces, business logic classes, and dependencies, and also for the behavioral view, which considers paths through the application. Design information in the program code is therefore systematically used to enable working at different abstraction levels. For the same reason, the model facilitates *understandability* since the abstraction can be used to create visual representations as boxes-and-arrows-diagrams which are easily understandable. This is especially true in comparison to the "traditional" enterprise application development, which consists of manual creation of compilation units and distributed creation and adaption of meta data fragments in program code.

The model can also contribute to *accuracy*: With model-to-model transformations and visual representations, the implementation of enterprise applications is more systematic and can be partly automated. Usage of the model for verification as proposed in section 4 enables *predictiveness*, since appropriate tools can infer properties of model and implementation at different abstraction levels.

When such tools as described here are available for different development tasks, the development of enterprise applications can be *less expensive*: Model-to-model-transformations can be used to generate substantial structural parts of the source code. Visual design tools allow for faster creation of the structures, and can also shorten the time needed for program comprehension. The verification mechanisms can help to prevent some classes of errors, and integration in debugging tools can fasten the detection of errors that occur at run time.

In summary, we think that such models support the objectives and therefore fulfill the requirements. However, this is so far only a proposal, so that no implementation and no empirical evaluation exist. In addition, the model definition is so far limited to the business logic and does not cover all JEE specifications.

6 Related Work

As mentioned in the introduction, most MDSD approaches consider source code a result of automated derivation from high-level notations. This leads to problems when requirements, programming interfaces, libraries, or integration into existing or customized source code are not supported by modeling tools. In contrast, we consider models that already exist as design information in JEE applications. Thus we do not need round-trip engineering [16] between notations since the program code contains all necessary abstraction levels.

For the same reason we do not propose domain-specific languages (DSL) [17] with separate notations. Model execution [18] is not applicable since the execution of JEE applications is completely controlled by the application server. The models proposed here are also not derived from abstract models and embedded in the program code [19], but use only semantics of the JEE framework that are already available.

Since our approach relies on well-known program code structures, neither design recovery [20] nor pattern detection [21] are applicable since they aim at detecting design information that is not known beforehand and thus work with fuzzy data. For the same reason tool support for program comprehension of arbitrary program code [22] is not necessary.

7 Conclusions

We proposed a domain-specific model for JEE enterprise applications. This model does not rely on any specific notation, but considers design information that is available in program code of JEE applications, which are based on attribute-oriented programming with the respective meta data. This enables working at different abstraction levels, in which we see the potential for appropriate design, verification, debugging, and design recovery tools.

The approach has been evaluated theoretically with respect to desirable properties of models: Abstraction, understandability, accuracy, predictiveness, and inexpensiveness. These are from our point of view given since appropriate tools can enable program comprehension, accurate implementation of requirements, verification of the related program code, and reduction of effort for these tasks. However, the tools are still to be developed to verify these assumptions. In addition, the model specification is not complete, since only the most important aspects of the business logic are covered.

For the future we thus plan implementations of tools to demonstrate the feasibility of the approach. For this purpose a bachelor's thesis is currently written at our working group that implements, as a first step, the visualization of design information as extracted from the program code. We will also consider the coverage of different JEE specifications and for thus purpose define the model more precisely. In summary, we are convinced that the approach to consider design information in enterprise application frameworks is promising and want to stimulate discussion about its potential.

References

1. Fayad, M., Schmidt, D.C.: Object-Oriented Application Frameworks. Communications of the ACM 40 (1997) 32–38
2. Brown, A.W., Iyengar, S., Johnston, S.: A Rational approach to model-driven development. IBM Systems Journal 45 (2006) 463–480
3. Hailpern, B., Tarr, P.: Model-driven development: The good, the bad, and the ugly. IBM Systems Journal 45 (2006) 451–461
4. Baker, P., Loh, S., Weil, F.: Model-Driven Engineering in a Large Industrial Context – Motorola Case Study. In Briand, L., Williams, C., eds.: Model Driven Engineering Languages and Systems, 8th International Conference, MoDELS 2005, Montego Bay, Jamaica, October 2-7, 2005, Proceedings. Volume 3713 of LNCS., Springer (2005) 476–491
5. Fowler, M.: PlatformIndependentMalapropism (2003) http://www.martinfowler.com/bliki/PlatformIndependentMalapropism.html.
6. Sun Microsystems, Inc.: Introduction to the Java EE 6 Platform. White Paper (2009)
7. Schwarz, D.: Peeking Inside the Box: Attribute-Oriented Programming with Java 1.5. ONJava.com (2004) http://www.onjava.com/pub/a/onjava/2004/06/30/insidebox1.html.

8. Sun Microsystems, Inc.: JSR 318: Enterprise JavaBeans™3.1 - Proposed Final Draft (2008) http://jcp.org/en/jsr/detail?id=318.
9. Demers, F.N., Malenfant, J.: Reflection in logic, functional and object-oriented programming: a short comparative study. In: In IJCAI '95 Workshop on Reflection and Metalevel Architectures and their Applications in AI. (1995) 29–38
10. Sun Microsystems, Inc.: JSR 220: Enterprise JavaBeans™, Version 3.0 - Java Persistence API (2006) http://jcp.org/en/jsr/detail?id=220.
11. Selic, B.: The Pragmatics of Model-Driven Development. IEEE Software 20 (2003) 19–25
12. Raistrick, C., Francis, P., Wright, J.: Model Driven Architecture with Executable UML. Cambridge University Press, New York, NY, USA (2004)
13. Weiser, M.: Program Slicing. In: ICSE '81: Proceedings of the 5th International Conference on Software Engineering, Piscataway, NJ, USA, IEEE Press (1981) 439–449
14. Visser, W., Havelund, K., Brat, G., Park, S., Lerda, F.: Model Checking Programs. Automated Software Engineering Journal 10 (2003)
15. Beckert, B., Hhnle, R., Schmitt, P.H.: Verification of Object-Oriented Software. The KeY Approach. Springer-Verlag New York, Inc. (2007)
16. Sendall, S., Kster, J.: Taming Model Round-Trip Engineering. In: Proceedings of Workshop on Best Practices for Model-Driven Software Development. (2004)
17. van Deursen, A., Klint, P., Visser, J.: Domain-Specific Languages: An Annotated Bibliography. ACM SIGPLAN Notices 35 (2000) 26–36
18. Hen-Tov, A., Lorenz, D.H., Schachter, L.: ModelTalk: A Framework for Developing Domain Specific Executable Models. In: Proceedings of the 8th OOPSLA Workshop on Domain-Specific Modeling. (2008)
19. Bravenboer, M., Visser, E.: Concrete Syntax for Objects: Domain-Specific Language Embedding and Assimilation without Restrictions. In: OOPSLA '04: Proceedings of the 19th annual ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications, New York, NY, USA, ACM (2004) 365–383
20. Kraemer, C., Prechelt, L.: Design recovery by automated search for structural design patterns in object-oriented software. In: Proceedings. 3rd Working Conference on Reverse Engineering, Monterey, CA 1996. Los Alamitos, Calif. (1996) 208–215
21. Philippow, I., Streitferdt, D., Riebisch, M., Naumann, S.: An approach for reverse engineering of design patterns. Software and Systems Modeling 4 (2005) 55–70
22. Schauer, R., Keller, R.K.: Pattern Visualization for Software Comprehension. In: IWPC '98: Proceedings of the 6th International Workshop on Program Comprehension, Washington, DC, USA, IEEE Computer Society (1998) 4