RMA: A Pattern Based J2EE Development Tool

by

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Abstract

The development process for creating J2EE web applications is complex and tedious, and is thus error prone. The quality of a J2EE web application depends on correctness of code as well as the efficiency and flexibility of its architecture. Although the J2EE specification has promised to hide the distributed nature of the application, application developers still have to be aware of this fact in both the design (architecture) and implementation (code) perspectives. In this thesis, we present the detailed design of our pattern-based J2EE development tool, RoadMapAssembler (RMA). RMA demonstrates how patterns can be used to generate efficient architectural code while also hiding the deployment logic and distributed nature of J2EE applications in the implementation perspective. Furthermore, it shows the generation of a J2EE framework as a process of assembling patterns in an incremental fashion using known inter-pattern relationships.

Acknowledgement

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Chapter 1

Introduction

1.1 Introduction

J2EE is Sun Microsystem' solution to multi-tier enterprise web applications. J2EE simplifies web application development by providing a set of standardized components and services for communicating among these components. Although J2EE has hidden away most of the lower level distribution details, the development of J2EE applications is still known for its complexity, both in the design and implementation perspectives.

J2EE employs various technologies for web applications, such as Java Server Pages (JSP) and Enterprise Java Beans (EJB). The diversity of technology requires a highly integrated development environment for J2EE applications. J2EE development is also a multi-stage process. Thus, getting a J2EE application up and running usually includes two steps: the development process and the deployment process. The development process consists of designing and writing code, while the deployment process specifies deployment information for the application in both application code and external descriptor files. It would be preferable for the two stages to be done in the same environment.

1.1.1 The Development Process

Despite the fact that J2EE is designed to hide the complexity of distributed programming, J2EE still suffers from abstraction overflow at the design level. While J2EE containers have hidden the management of some issues, such as persistence and transactions, the efficiency of the application

is still largely up to the application developers. For example, developers have to deal with excessive amounts of communications between client and business components, with these communications potentially taking place across a network. Thus, in order to provide a good blueprint for guiding developers in their design, Sun has published its blueprint of a J2EE framework [1]. The framework is divided into three tiers: the presentation tier, the business tier, and the integration tier. The framework is made up of a set of design patterns. Most of these patterns tackle specific problems related to the underlying distributed environment. These patterns are arranged in such way that their interactions provide an efficient and reusable solution to a typical web application. It would be preferable that developers choose which patterns to use and assemble the selected patterns together correctly, since not all patterns need to be present in all applications.

J2EE also suffers abstraction overflow at the code level, especially for the Enterprise Java Bean (EJB). The EJB is the integral building block of the business tier. There are two kinds of EJB, the session EJB and the entity EJB. The session EJB implements the application logic, while the entity EJB acts as the manager of database tables. Because an entity EJB can be replaced with a *data access object* in many circumstances, we concentrate on session beans in this thesis. Thus, from this point on, the term EJB refers to a session bean unless otherwise noted. Both types of beans are intended to give developers the impression of writing a Plain Old Java Object (POJO) instead of distributed code. Unfortunately, EJBs fail to do so for two reasons. First, for every EJB, the developer needs to write three pieces of code: one EJB bean class and two interfaces to expose the methods for creating objects and other business methods to remote users. Furthermore, for each type of interface, there are two variations: one for remote clients and one for local clients. These interfaces are only used by J2EE and are generally not implemented by any class in the application. This makes it more difficult for new developers to appreciate the necessity of a POJO class with two interfaces that are not related in application code. Second, besides writing two extra interfaces for every EJB, when developers need to access an EJB they need to perform a lookup in a name space using the Java Naming Directory Interface (JNDI), which is another feature of distributed programming. In both cases, the code that handles the distributed aspects of the application has polluted the intended POJO class.

1.1.2 The Deployment Process

"A deployment descriptor is an XML-based text file whose elements describe how to assemble and deploy the unit into a specific environment."[26] The most common information that is specified in the descriptors is for an EJB and the EJBs that it references. However, specifying this information in XML format is rather tedious and error prone. Moreover, there is also a potential consistency problem if the namespace changes in either the application code or the deployment descriptors. To remedy this problem, the information needed for the deployment descriptors can be gathered while developers write the application code. For example, when developers decide to have one EJB reference another EJB, if the developer can somehow make their intention known to the development environment, the interfaces and JNDIs of the EJBs involved in the association can be identified and automatically added to the correct deployment descriptor. Thus, we can virtually incorporate development and deployment into a single process. Accordingly, when descriptors can be automatically generated we also solve the consistency problems in the name space between application code and descriptor files.

1.2 Contribution

RMA presents an approach to tackle the abstraction overflow problems that exist in J2EE application development. On the software architecture front, RMA incrementally builds up a J2EE application using the J2EE framework as a guide. Next, we extract the pattern relationships from the framework. Then, we identify the roles and constraints that make up these relationships. By generating code with a small amount of developer intervention, we are able to generate code to fulfill the roles and their constraints for most applications. Using a bottom-up incremental approach, the upper level patterns can fully utilize the code for existing pattern so RMA can generate much more concrete code than many other J2EE IDEs. Also, due to incremental construction, developers can easily customize the generated code if the need arises since they are fully aware of the purpose of the code generated at every step. RMA offers both flexibility and correctness during the development process by automating pattern assembly.

We have also devised a way to use J2EE design patterns to completely hide the deployment logic from application logic. As a result, developers can write POJOs while we address the J2EE-specific

problems, such as extra interfaces, name space management and deployment descriptor generation. To achieve our goal of hiding the extra interfaces and name space management we either refine the structure or expand the use of some existing patterns. We have combined the pattern generation and descriptor generation into a single seamless process. As a result, by removing deployment from the development process, the user can concentrate of their application code and not on the distributed J2EE execution environment.

1.2.1 RoadMapAssembler

Figure 1.1 shows the architecture and work flow of RMA. RMA is built on top of Eclipse [22] technology. Eclipse is an open architecture development platform that is based on plugins. The core of Eclipse provides a built-in Java Integrated Development Environment (IDE). Developed as a plugin of the Eclipse platform, RMA can leverage features from other existing Java plugins, such as refactoring and code completion. RMA is a pattern-based development tool. It constructs applications by assembling EJBs and other Java classes into pattern-based components according to the predefined roles and constraints. We will talk more about roles and constraints later in this thesis. RMA consists of a set of wizards that run in the Eclipse IDE's workbench. The wizards solicit required role and constraint information from the user. RMA's "Artifact Extractor" combines the solicited information with information derived from the application code to construct a concrete implementation of the required constraints. The implementations for constraints are assembled by RMA and passed into the "Code Generator" to produce architectural code for the application and necessary deployment descriptors. Eclipse automatically compiles the Java source files in the workspace into Java class files. The developer can export the application by invoking the "Packager" to pack both the Java class files and deployment descriptors into a deployable application file. As Figure 1.1 demonstrates, RMA incorporates both development and deployment processes into a single process.

1.3 Outline

This thesis is organized as follows. Chapter 2 offers an overview of the technologies involved in this thesis. Chapter 3 provides a brief discussion on the J2EE framework and some of its major patterns. Chapter 4 describes pattern relationships and the way that they are assembled in RMA using an

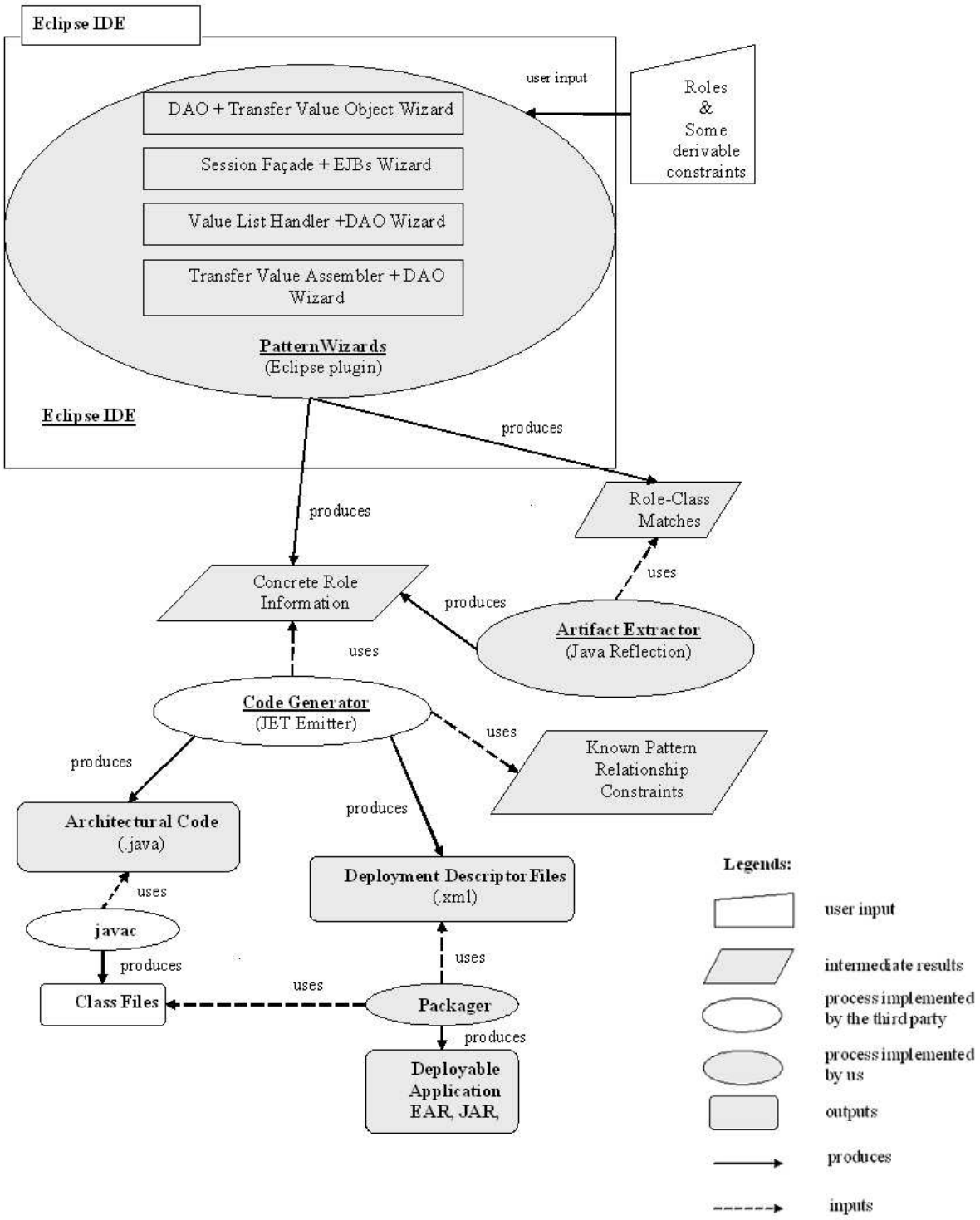


Figure 1.1: RMA Architecture

example application. In Chapter 5 we demonstrate how we hide the deployment logic. Chapter 6 gives a quantitative analysis of the code generated by our tool for our sample application. Chapter 7 describes related work done in J2EE development tools, especially those done in a pattern-based fashion. We also offer a comparison between RMA and other development tools in this chapter. Future work and conclusions are given in Chapter 8.

Chapter 2

Background

In this chapter, we survey the important background technologies used or referenced in the implementation of RMA. The two technologies that we will discuss are J2EE and Eclipse. J2EE is the multi-tier web application platform that is the target platform for RMA

2.1 J2EE

A typical web application consists of three tiers: the presentation or web tier, the business tier and the data or integration tier. The presentation tier handles the generation of the GUI for soliciting client requests and displaying the output of the request. The business tier components implement the business logic that processes client requests, while the data tier connects the business components to the underlying persistent database. The tiers can be implemented in different technologies. The components that are implemented in the different technologies need to communicate with each other in order to accomplish anything useful. Some of these components may even require remote invocations.

J2EE is Sun's solution for creating web applications, in which tiers are encapsulated into the different standardized components and communication among components is handled by the J2EE container. Figure 2.1 shows the break down of the J2EE server architecture. The J2EE server has two containers: the web container and the EJB or bean container. The web container manages the components that run in the web tier, while the EJB container manages the EJBs of the business tier. The components in the different tiers require different implementation technology. The following

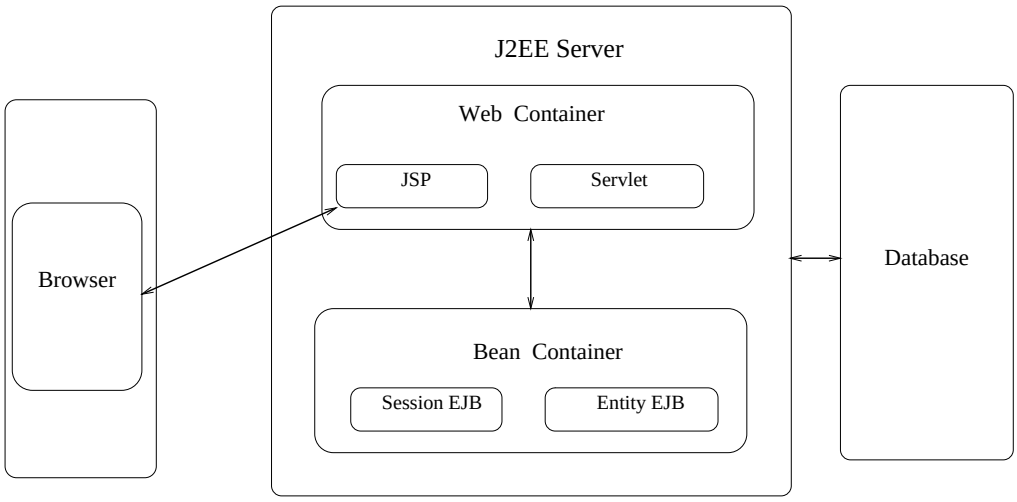


Figure 2.1: J2EE Container Architecture [3]

three sections contain a brief overview of some of these J2EE technologies.

2.1.1 Presentation Tier Technologies

The Java Servlet [4] and Java Server Page (JSP) [4] are the presentation tier technologies. Java Servlets and JSPs are managed by the web container. A Servlet contains the code that processes the HTTP requests made by clients. The Servlet processes the client input using HttpRequest objects, which are populated by the container. The output of the processing is written out as HTML pages and sent back to the clients by the web container. Java Servlets are very similar to other Common Gateway Interface (CGI) solutions, such as Perl. However, compared to other CGIs, Java Servlets are platform independent and have a richer set of powerful APIs. Developers can use both the standard Java libraries and those specialized for HTTP as they write Java Servlets. The Java Servlet's main pitfall is its poor maintainability. In Servlets, everything must be written in Java code, even for the output of the simplest static HTML tags. As the web page becomes complicated, the code for creating HTML and the code for the business logic becomes indistinguishable, thus further reducing the maintainability. Moreover, a good web page designer does not necessarily know Java well. Thus, forcing an experienced HTML developer to learn Java is an inefficient way of using human resources.

To solve the problems that surround the Servlet, Sun introduced JSP. A JSP is written in the fashion of an HTML page instead of a Java class. Developers create the static portion of an HTML

page using plain HTML tags. Developers are also allowed to mark certain parts of a JSP page to insert Java code to generate the dynamic portion of the page. A JSP is translated to a Servlet page before being deployed to the container. So a JSP page is just another way of writing a Java Servlet class but the former affords the benefit of cleaner separation of presentation logic and business logic.

2.1.2 EJBs

EJBs are the Java component architecture for server side distributed computing. There are two kinds of EJB in use: the Session EJB and the Entity EJB. The Session EJB is designed to contain business logic. The Session EJB can be further divided into two categories: the stateful Session EJB and stateless Session EJB. The stateless Session EJB does not keep the session state, so every invocation of a stateless Session EJB triggers an independent operation. The stateful Session EJB remembers the state of execution by storing the state information in instance variables.

The implementation of a Session Bean contains three classes: the home interface, the business interface, and the bean class. The home interface defines the methods for constructing a new instance of a bean. All of these methods have `create` as their method name and differ from each other according to different parameter signatures. The business interface defines the methods that the client can invoke on this session EJB. Both types of interface have variations for local or remote access, where remote access might include the remote exceptions. The bean class implements the create methods and business methods that the developer defined in the home and business interfaces. Note however that the bean class does not implement either of the two interfaces in any programmatic sense, because the method names do not match. For example, the `ejbCreate` methods of the bean class are exported as the `create` methods in the home interface. As a result, the container is responsible for generating the classes that implement these interfaces at deployment time. A Session bean class implements the `SessionBean` interface instead. Then the container-generated classes delegate the user request to the bean class that is running inside of the EJB container. Next, it is up to the container to map between the methods defined in the bean class and those defined in the interfaces. This obscurity is troublesome to many new comers to J2EE programming.

The Entity EJB is designed to represent the persistent relational database tables of a J2EE

application as an object model. Like the Session EJB, the Entity EJB also has home and business interfaces, and a bean class. The home interface of an Entity Bean contains the methods whose names start with `find`, instead of `create` as is the case for the Session Bean. There are two kinds of Entity Bean: the container-managed Entity Bean and the bean-managed Entity Bean. The container-managed Entity Bean relies on the container to provide the services for database manipulation. Thus, developers no longer need to write a concrete bean class. Instead, they are asked to write an abstract bean class and provide a set of SQL scripts for the different database operations. The container generates the concrete code for database management at deployment time. In the case of a bean-managed bean, the responsibility of writing code for database management belongs to developers. We will talk more of approaches to access database from a J2EE application in the following section.

EJBs are run inside of containers. Containers provide many essential services for EJBs. They manage the life cycle of an EJB and provide a pool for the EJB objects that have been deployed. For each type of EJB deployed, there are multiple instances of that EJB object in that pool, replicated by the container. The container is also responsible for workload distribution and consistency among the replicas. When the container receives a request for a specific type of EJB, an instance of that EJB is picked from pool to handle the client request. The container then manages the persistent connection between the clients and invoked beans. In the case of the Entity Bean, the container also manages transaction operations as well as the data consistency between the Entity Beans and the underlying database table. Accordingly, the container deactivates the beans that have not been used for a certain period of time by serializing the object onto the disk. The deactivated beans can be reactivated from the disk by the container as needed.

2.1.3 Data Access Technologies

There are two major approaches to accessing a persistent database from a J2EE application: Entity Beans and *data access object*s using a Java Database Connection (JDBC) driver. We have described how the Entity EJB works. Although the Entity EJB is believed to be an elegant architecture, it has been a controversial part of the J2EE architecture. Developers have been debating the benefits gained against the amount of resources invested in making an EJB work. Two of the major problems of Entity EJBs are their complexity and inflexibility. Moreover, for the container-

managed bean, J2EE introduces a new query language, EJB QL. EJB QL is new and not as well understood by developers as well as SQL. EJB QL also has many limitations. For example, EJB QL does not support the sub-query and the 'order by' clause that is commonly used in SQL. Developers also need to code complex EJB QL into already cumbersome deployment descriptors, a detail that will be discussed in detail later. For the bean-managed Entity bean, developers need to write more complicated database manipulation code by themselves. Yet, the flexibility gained by having developers write this code does not help much when fine-tuning the application. The bean-managed Entity bean allows developers to decide how a database table should be accessed but not when. For example, a database query may return a large set of matching Entity EJBs. As a result, the container might decide to initialize each Entity EJB before it is used, or wait until the first reference. Developers can optimize the SQL query to speed up the database processing, but they have no control over when the Entity EJB is initialized. The Entity EJBs usually have higher overhead than POJOs even when accessed through local interface [16].

A *data access object* (DAO) is an alternative to complicated Entity EJBs. A *data access object* is a light weight POJO class that can use various technologies to access databases. The DAO exports a simple data access interface to business tier components that is independent of the underlying database technology. If the database technology changes, only the DAO must be updated. Since the business logic is written using the simpler DAO interface, it is unaffected. However, despite the *data access object* not having access to some of the useful services offered by the Entity EJB container, some services, such as transactional management, can be migrated to the business logic tier components with careful design. Accordingly, because of their simplicity and flexibility, *data access object*s are commonly used in J2EE applications.

2.1.4 Deployment Tools

A J2EE application is deployed as a J2EE Application Archive (EAR) file. A typical EAR file contains a Web Archive (WAR), Java Archive (JAR) files and a set of descriptor files. The organization of the EAR file is shown in Figure 2.2. The WAR file contains the files for the presentation tier, such as HTML pages, JSPs and Servlet classes. The JAR files contains the class files that implement various business tier and data tier components. Examples of these business components are the EJBs and supporting POJOs. In short, an EAR file is a compressed file that packs the

- J2EE Application Archive (EAR)
  - -application.xml
  - -sun-j2ee-ri.xml
  - -Web Archive (WAR)
    - * web.xml
    - * JSP/Servlet
  - -Java Archive (JAR)
    - * ejb-jar.xml
    - * EJB classes

Figure 2.2: Hierarchy of a J2EE Application Archive

WAR, JAR and descriptor files.

After an EAR file is deployed in the J2EE container, the container needs to know what kind of components are contained in each compressed file and how they interact. "A deployment descriptor is an XML-based text file that the container uses to assemble and deploy the unit into a specific environment [26]". A typical J2EE application contains four descriptor files: 'application.xml', 'sun-j2ee-ri.xml', 'web.xml' and 'ejb-jar.xml'. Both the 'application.xml' and 'sun-j2ee-ri.xml' files are stored in the EAR. The 'application.xml' informs the J2EE container about the names of WAR file and the JAR files stored in this EAR file.

The 'sun-j2ee-ri.xml' is a file that captures the remote EJB references that exist in the JAR files of this application. EJBs can be remotely referenced by each other or by the servlets and JSPs in the web components. The container needs to know which EJBs are referenced, the variable names for references used in the code, and the JNDI names of these EJBs.

The 'web.xml' file is the deployment descriptor for the web components. It describes all of the JSP and Servlet pages contained within. The most common information about a JSP and Servlet page that is specified in the 'web.xml' file is the web alias for application users and the JNDI names of the referenced EJBs and databases. The web alias of a Servlet/JSP is a name that is different from the file name of the Servlet and JSP that is used to access the Servlet and JSP pages from a URL.

The 'ejb-jar.xml' file describes all the EJBs that are included in the current JAR file. The container needs to know the name of EJB bean class, remote and local home interfaces, and remote and local business interfaces. The information about EJB and database references using

JNDI names from an EJB also needs to be detailed. The 'ejb-jar.xml' also needs to describe some security details such as the method permissions of each bean. Other optional, but useful, configuration information, such as different transactional styles, can be set in the 'ejb-jar.xml' file.

As can be seen, the generation of a deployable J2EE application is rather cumbersome in nature. Putting aside the packing of files, writing the description files can be a daunting job by itself. As a result, Sun has provided a GUI-based deployment tool that allows developers to perform packaging and descriptor generation by importing files and entering some deployment information such as JNDI names. Even still, developers might find the deployment process tedious and error-prone even with a GUI because there are too many options they need to set. For example, even a task as simple as setting Servlet page with a reference to a database using JNDI needs at least six pages in the wizard, where each page has at least four entries to be filled in. Moreover, the supplied information must match the JNDI names and class structure exactly or the application will not deploy. Due to this difficulty, IDE developers have proposed many different ways of generating deployment descriptors. In some solutions, the deployment information can be gathered as developers write the application code [13] [21], while other solutions require application developers to write special tags in the application that are processed by a specialized parser to generate deployment output [5] [11]. We will talk more about descriptor generation later in Chapter 7.

2.2 Eclipse

Eclipse is an IDE developed by IBM [8]. It is a plugin-based platform in which developers can implement new tools and contribute them to the existing environment.

Eclipse Architecture

The Eclipse architecture consists of two main components: the UI and the Core. The UI is supported by the Standard Widget Toolkit (SWT) at the lowest level. JFace is a set of frameworks built on the top of the SWT. The framework defines the control flow and basic UI layout of components. An example of a pre-defined UI framework is the wizard. The wizard framework consists of a wizard class and a set of wizard page classes. Plugin developers extend the wizard superclass to override the default methods such as `addPages`. The wizard framework also defines the basic layout and behavior of a wizard. For instance, the "Back", "Next", and "Finish" buttons always

show up at the bottom of each wizard page. Clicking on the "Next" or "Back" button always brings the user to the next or the previous page respectively. Together, JFace and SWT implement the Eclipse workbench. The workbench defines the Eclipse graphical user interface, such as the editor and the resource explorer views.

The Core component is UI-independent. The Core component consists of a runtime engine and a workspace manager. The runtime engine looks for the available plugins at start-up and manages plugin loading in a lazy fashion, which means that plugins are not loaded into memory until explicitly invoked by the user. A typical Eclipse environment may include more than fifty plugins. The lazy-loading significantly improves the performance and scalability of Eclipse by reducing the application's memory usage. The workspace manages user resources, such as projects, and the mapping of these resources to the underlying file system.

Plugin Development

Every component of Eclipse is a plugin, even the UI and Core components. Each plugin contains a XML manifest file, which declares the extensions and extension points of this plugin. An extension is an interface of an existing plugin that this plugin contributes to. An extension point is an interface defined by a plugin that future plugins can contribute to. A good analogy for the relationship between the extension and the extension point is that of the power-strip and the power plug [22]. The Java classes that implement this plugin are packed into a JAR file and stored in the same directory as the manifest file.

JDT Plugin

Among all the plugins, the Java Development Tools (JDT) is the set of plugins most related to our research. JDT implements a complete IDE for editing, compiling, debugging, and testing a Java file. JDT provides APIs to programmatically manipulate Java resources. As a result, by extending the extension point declared by the JDT, we may add new features into Eclipse's Java IDE. The JDT consists of three components: the JDT Core, the JDT UI, and the JDT Debug.

The JDT Core models the core Java elements and APIs. The JDT breaks down a Java project into a set of models with each model representing a specific type of Java element. For example, a class defined in a ".java" file is modelled as `IType`. The fields and methods defined in a class are

modeled as `IField` and `IMethod` accordingly. A plugin can programmatically traverse the resource tree to access and manipulate Java elements. For example, a plugin can parse a Java class that is modeled as `IType` to determine the fields that the class contains and automatically generate accessor methods for the fields. For code manipulation on even finer granularites, JDT provides powerful APIs to parse a whole Java file into a Document Object Model (DOM). Subsequently, using the JDT Core's DOM package, the plugin developer can manipulate the code within each method. The JDT Core also automatically maintains consistency between the model and underlying file system resources.

The JDT UI implements some Java-specific graphical user interfaces. The JDT Debug provides APIs for debugging support, such as launching a Java application in debug mode.

We chose Eclipse as the development platform for RMA because of Eclipse's flexibility in integrating new features as plugins and its richness in providing support for Java development. Our RMA extends the JDT to provide customized support for J2EE development. RMA also makes extensive uses of the APIs provided by other Eclipse plugins to exploit the benefits of existing features.

Chapter 3

J2EE Framework and Patterns

RMA is a pattern-based development tool. RMA's wizards gather information to create pattern based components, which will later be assembled into a complete application. Thus, it is important for us to understand the patterns supported by RMA before going any further into the discussion on application construction. This chapter briefly describes the patterns from the Sun blueprint, the framework that combines them into a complete architecture [1].

A software framework defines a reusable design and partial implementation of a solution to a certain problem domain. The framework specifies a typical control flow and architecture of a typical application of that problem domain. A framework's structure is usually made up of many sub-frameworks with each sub-framework solving some specific recurring problem. Accordingly, many such components can work together to solve a more complicated problem. The control flow of a framework dictates which subcomponents may interact with each other and how they should interact. In many situations, the subcomponents of a framework are implemented using existing design patterns. In that case, the framework becomes a collection of the known patterns and relationships among these patterns that can be used to solve a complicated design problem. A framework can be instantiated to only include a subset of its collection to meet specific needs. The addition and removal of the subcomponents can be checked against the relationships defined in the framework.

Design patterns act as the micro-architectural units within a pattern-based framework [15]. They are considered to be architectural elements because they also define the structural and behavioral rules of some objects. Patterns can be generally divided into three groups: creational

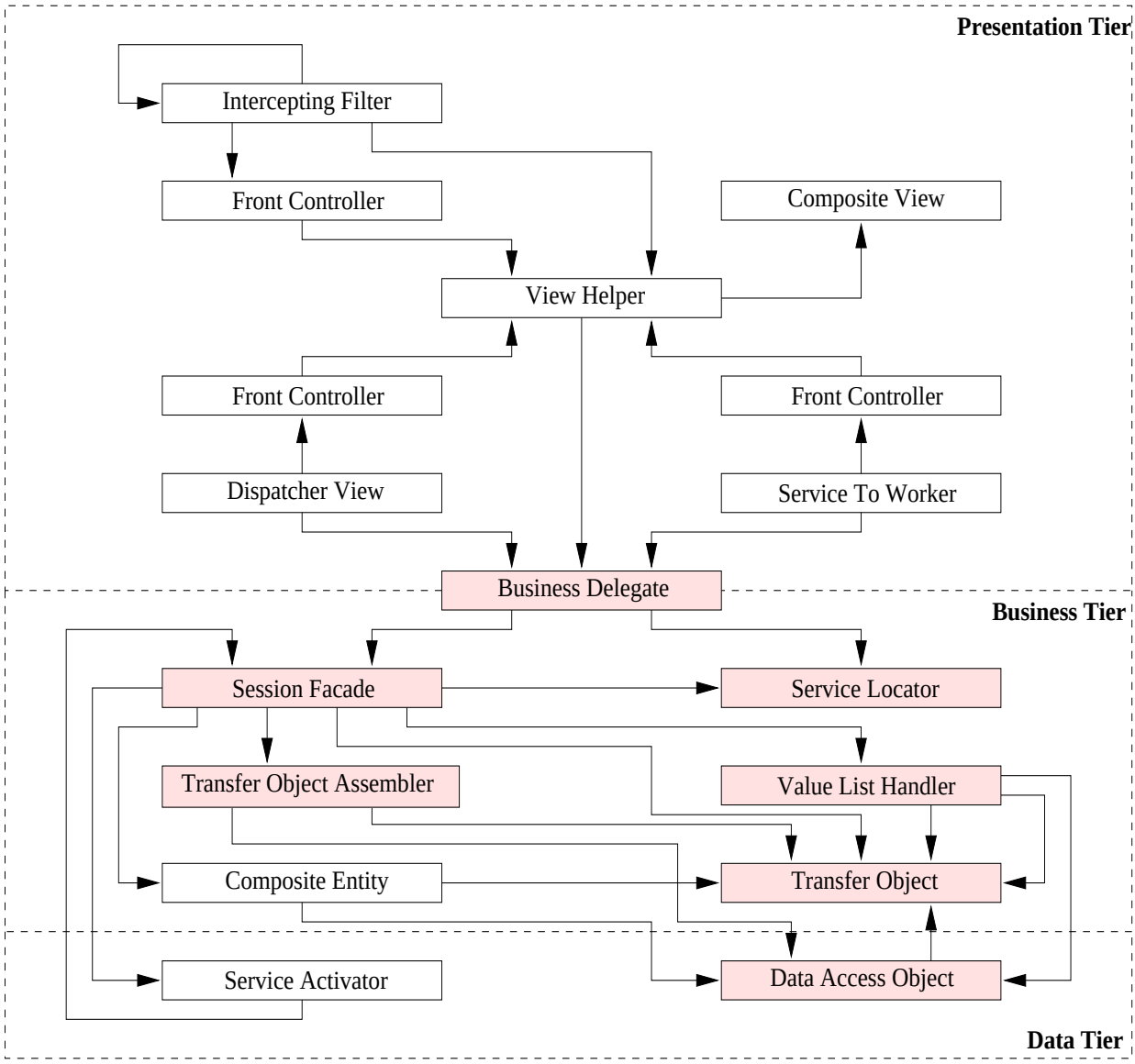


Figure 3.1: Sun's J2EE framework [1](The shaded patterns are supported by RMA)

patterns, behavioral patterns, and structural patterns [9]. The creational patterns capture some of the best practices for creating objects. The well-known Factory Pattern [9] is an example of such a pattern. The behavioral patterns capture good practices for complex object interactions, such as the Observer [9], while the structural patterns capture recurring structural arrangements of objects. The Composite pattern [9] is an example of a structural pattern. Combining the concept of framework and pattern, we believe there is a framework consisting entirely of patterns as its subcomponents. Thus, while the control flow of this framework might be captured by the relationships among behavioral patterns, the structural information is gathered by the structural patterns, and the process of creating and assembling the framework objects is dictated by the creational of patterns.

Frameworks are generally specific to a particular application domain, such as a GUI, a parallel computing structure, etc. J2EE has its own framework from Sun, as shown in Figure 3.1. As in many other frameworks, the J2EE framework is made up of a list of patterns, with these patterns grouped into three tiers: the presentation tier, the business tier, and the data tier. These different tiers have design patterns that are used for different purposes: the presentation tier is responsible for soliciting client requests and displaying the results returned from the server; the business tier is responsible for processing client requests using the business logic; and the data tier is mainly responsible for database access.

Our research work has concentrated on the patterns of the business tier and the data tier because we believe the structures and behaviors of these patterns are more intriguing and deserve a thorough investigation. In this chapter, we first describe the known J2EE patterns of the business and data tiers. Then, we study the relationships among these patterns in the next chapter.

3.1 Data Access Object

Persistent data is used in most web applications. As we have seen in Section 2.1.3, the Entity EJB and the *data access object* (DAO) are the two most commonly used approaches for database manipulation. However, the Entity EJB has been controversial due to its complexity and inflexibility. Conversely, the *data access object* is a light weight POJO object that encapsulates the code for managing persistent data and provides an interface for the business components to access this data.

The management of the persistent database includes connecting to various data sources and

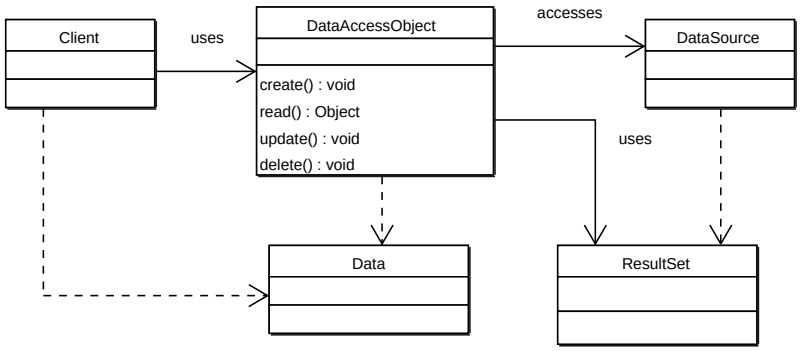


Figure 3.2: Data Access Object [1]

manipulating the data stored in those data sources. The relational database is the most common type of persistent data, but not the only one. In the domain of Internet computing, other data sources, such as flat files, are also used. Additionally, a data source can be an external system such as those used in Business-to-Business (B2B) systems. The code for manipulating the data is closely dependent on the data source that is used. Thus, keeping the code for handling the persistent data out of the business components to reduce the complexity of their code is important. The maintainability of the application is also improved by this decoupling because the changes in the data source only affect the *data access object*.

Figure 3.2 shows the class diagram for a typical *data access object*. The Client of a *data access object* can be any component from the business tier or the presentation tier. The DataAccessObject defines and implements a basic interface for manipulating the persistent database. The DataAccessObject accesses the underlying DataSource to either retrieve or update data. For retrieval, the matching data is stored in the ResultSet. ResultSet can be any data structure that is capable of storing data. The java.sql.ResultSet is usually used to satisfy the role of ResultSet if the DataSource is a relational database. The DataAccessObject packs the data into the ResultSet in the form of a *transfer value object*s and sends it back to the Client. For updates, the Client also needs to send the updated data in the form of a *transfer value object* to the DataAccessObject. The DataAccessObject unpacks the *transfer value object* and performs necessary operations to update the database.

A common *data access object* defines the basic database operations such as connect, select, insert, delete, and update. A more powerful *data access object* can accommodate more complex

search methods that return a list of matched data, packed in the form of a *transfer value object*, to clients. Furthermore, a *data access object* can cache frequently retrieved data to reduce the network workload. It is also possible to apply the Abstract Factory [9] pattern to the *data access object* to further improve the flexibility of the application by encapsulating the connection mechanism of different data sources into subclasses.

3.2 Transfer Value Object

The server side business components in J2EE applications are generally implemented as EJBs. Some business components, such as Entity EJBs, need to return data back to the client. The traditional way of accessing a Java object's state is by invoking its accessor methods. A client may need to invoke several accessor methods to retrieve all of the information it needs from a business component. If the business object is implemented as a remote object, the invocations of the fine-grained accessors might introduce significant network overhead. It is extremely inefficient for a remote invocation to retrieve a small piece of data.

The *transfer value object* (TO) efficiently ferries the client requests and responses between the J2EE components. A *transfer value object* packs all of the state of a business component into a single object. When a client requests data from a business component, the values of its instance variables are copied into that *transfer value object*. Then the *transfer value object* is passed back to the client by value [1]. The client can access the complete state of the remote business component from the *transfer value object* without paying network overhead for each individual (possibly fine-grained) access.

Figure 3.3 shows a class diagram for the *transfer value object*. In the class diagram the Client accesses the Components to retrieve the necessary information. The Component in the class diagram can be any J2EE component in the business or integration tier. Upon receiving the request, the Component creates a *transfer value object* and returns it to the client. Next, the client accesses data from the local *transfer value object*. The client can also perform changes on the values contained in the *transfer value object* and send the whole object back for update.

There are some variations in the implementation strategies of the *transfer value object*. The plain *transfer value object* only transfers the data for reading. The updatable *transfer value object* carries the data back to the component for updating. To implement the updatable *transfer value*

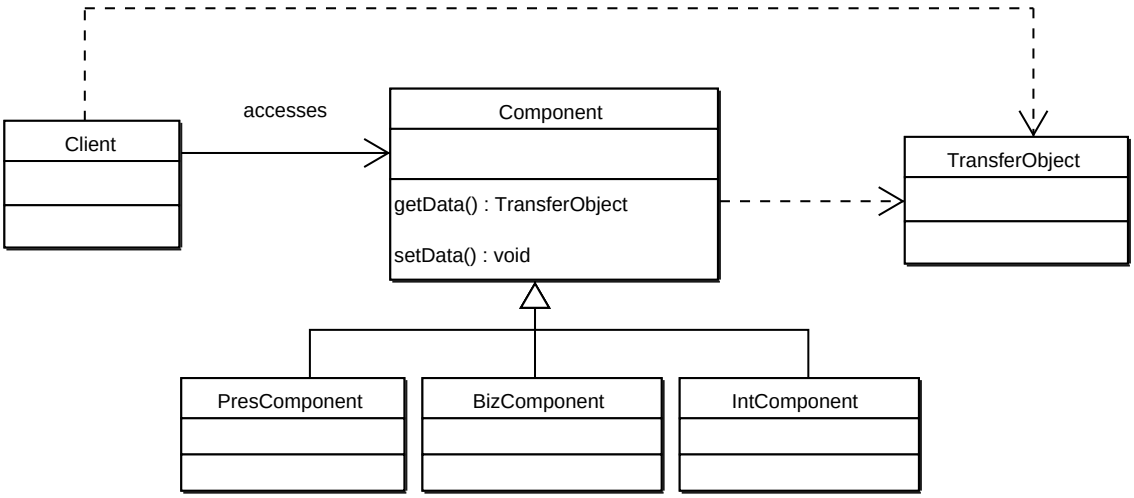


Figure 3.3: Transfer Value Object Class Diagram [1]

object, the component code needs to be modified to include a set method that accepts a *transfer value object*. The set method needs to copy the values stored in the *transfer value object* to the corresponding local instance variables. A more advanced design might include a flag for each variable in the *transfer value object* that is set only when its value is modified. Using the change flags can reduce the total number of update operations needed. A problem with updates is that different concurrent update operations from different clients may cause corrupted data in the Component. Thus, to solve this inconsistency, a time stamp can be set for every *transfer value object* before it is sent back. The update strategy complicates the design of both the *transfer value object* and the Components.

A Component may own multiple *transfer value object*s. Each *transfer value object* includes a different subset of data encapsulated in the Component. This is especially useful when the Component is a composite object itself.

3.3 Session Façade

In J2EE, the server side business components are implemented as EJBs or POJOs. These business components fulfill requests from the clients of the presentation tier. However, exposing those components to the clients is not always a good design decision. If the client directly uses these components, the clients are tightly coupled to the interfaces of the business components. If the

interfaces of the business components are changed, the client code needs to be changed as well. Moreover, a client request may require a complicated collaboration between multiple business components. Thus, in order to use such a business service, the developer for the client component needs to have a great deal of knowledge about how these business components interact. However, to force a presentation tier developer to know the implementation details of the business tier is a violation of the separation of concerns, which is practiced in industrial team environments. Also, these types of collaborations should be kept on the server side to reduce overhead caused by remote communications.

Even if the presentation tier developers do successfully implement the client code, the mingling of the code for the presentation tier and that for accessing business components reduces the maintainability of the software. If the code for accessing and coordinating components is handled by the clients, duplication of code will be unavoidable.

The direct access of business components not only produces poorly organized code, but it also affects the network traffic. For example, a client may request a task that is implemented using a set of fine-grained remote business components. In other words, the client must make many remote invocations to accomplish a single task. As a result, access to fine grained business components increases the communications between components and leads to a degradation of the performance [1].

The *session façade* (SF) provides a centralized contact point between the client and business components to simplify the interface between the presentation and business tiers. The façade encapsulates several business components behind a single interface. Methods in the façade may simply be delegated to the correct component, or higher-level methods that require the cooperation of several business components can be created. A *session façade* is also in an ideal place to insert access control for privileged components.

Figure 3.4 shows the class diagram for the *session façade*. The Client accesses the SessionFacade to invoke the services of the BusinessComponents. The SessionFacade delegates the work to the BusinessComponent that implements the Client's request. The ApplicationServices, DataAccessObject, and BusinessObject are all different types of BusinessComponent that exist in the J2EE environment. The SessionFacade object manages the business components by taking care of the name lookup and coordination of business components. Furthermore, the SessionFacade exposes

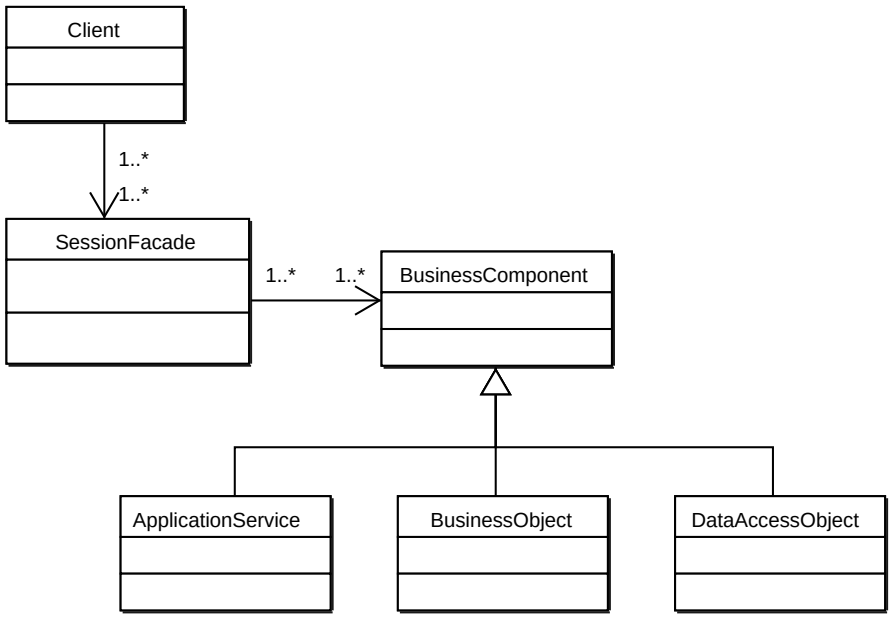


Figure 3.4: Session Façade Class Diagram [1]

only coarse-grained services to the client. If the services requested by the client, or business components that provide them, are not independent from each other, the SessionFacade should be implemented as a stateful Session EJB. Otherwise, a stateless Session EJB is sufficient.

3.4 Service Locator

In J2EE applications, many business tier components, such as EJBs, are registered in a centralized registry. The clients need to go through a series of lookups to locate the requested services using the JNDI name. However, handling the name space lookup can be quite complex. First, the developers need to get the InitialContext of the name space. Next, from the InitialContext, developers need to look up JNDI names to locate the business components. After this task, developers still need to perform a downcast and handle remote exceptions to retrieve the handle to the remote object. However, due to the complexity of the lookup process, errors can be introduced during the implementation. Moreover, because J2EE is a distributed system by nature, obtaining remote references is a common occurrence. If the lookup code is not isolated from the client code, the developers have to duplicate the lookup code whenever it is needed. Furthermore, the implementation of the InitialContext and the JNDI naming service is specific to a given vendor and presents an additional

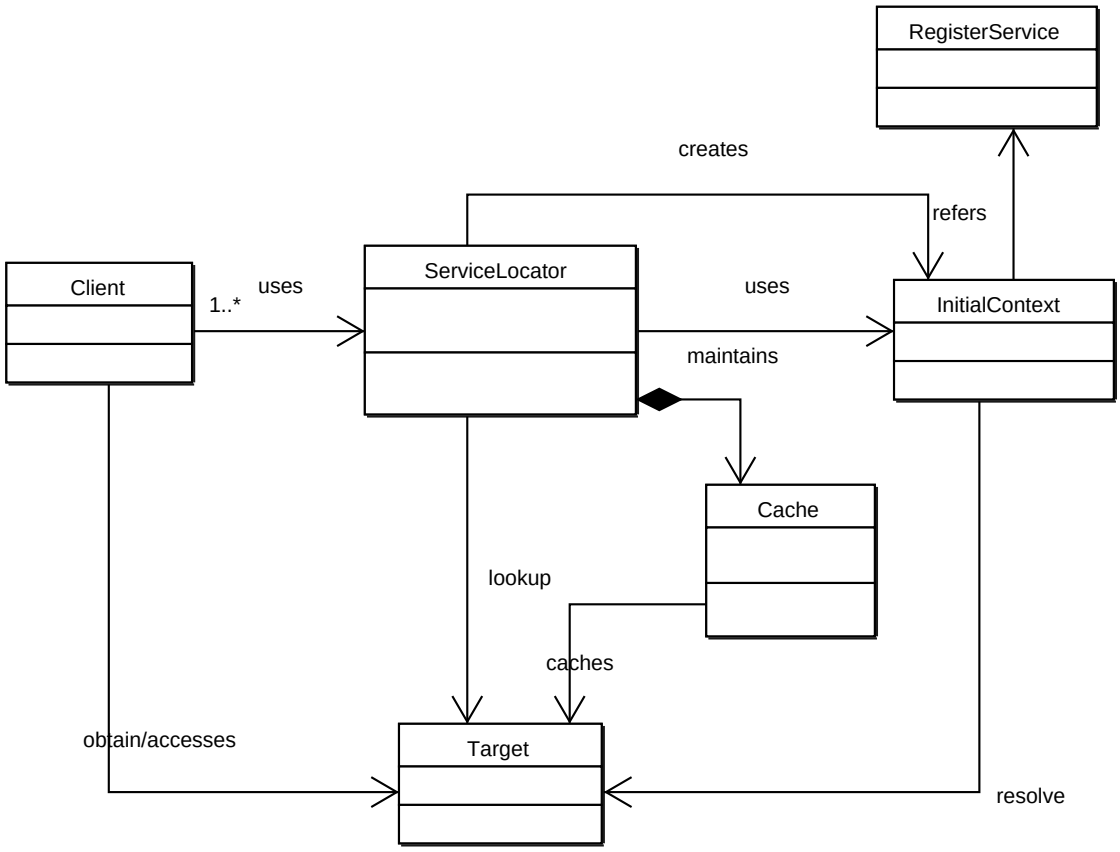


Figure 3.5: Service Locator [1]

problem. Different vendors may decide how a JNDI path is interpreted and resolved. Thus, in order to keep the client code portable, the developers should encapsulate the lookup process into an isolated class.

Figure 3.5 is the class diagram of *service locator* (SL) [1]. The Client represents any component that uses the ServiceLocator. In theory, only one ServiceLocator is necessary for a J2EE application. However, in practice, multiple identical ServiceLocators are used in a J2EE application because a single J2EE application may run on top of multiple Java Virtual Machines (JVM). For example, the web container and the EJB container can run in different JVMs, even on two physically separated machines. Upon receiving a request for a lookup, the ServiceLocator uses the InitialContext to consult the RegisterService to resolve the JNDI name. The ServiceLocator then proceeds to retrieve the handle to the Target resource. Next, the retrieved handle is returned to the Client. A more advanced implementation of the ServiceLocator may cache the handles to reduce future lookups.

EJBs are the most common Targets for the ServiceLocator to look up. The ServiceLocator uses the InitialContext to access the JNDI registry service, and then locates the EJBHome object of the requested EJB. Then, the ServiceLocator caches and returns the EJBHome object. Upon receiving of EJBHome object, the client needs to downcast the EJBHome to the desired subtype to create the EJBObject, the reference to the EJB that allows clients to invoke its methods. The EJB ServiceLocator needs to be able to handle both the local and remote EJB objects.

3.5 Transfer Object Assembler

During the development process, developers might want to provide a logical application model that is different from the underlying physical database tables. An application model is a set of data used by a particular application and encapsulated in the different business components in the business tier. If the clients need to use the application model, they need to access multiple business components and assemble the retrieved data. Consequently, a significant amount of the code for accessing business components is present in the client. Besides accessing the business components, the client may also need to construct the application model from data in the business components. This leads to a tight coupling between the client components and the business tier. As a result, changes to the interfaces of the business components in the business tier may cause many modifications in the client code. The code for accessing and constructing this model can increase the complexity of the client code. As well, if the code is embedded in individual clients, we will encounter a lot of undesirable code duplication. Moreover, if the business components and the clients from the presentation tier are running on separate machines, the performance can be degraded if the construction of the application model always needs multiple invocations to complete.

The *transfer object assembler* is used to centralize the creation of the application model and decouple the clients from the business tier. The driving forces behind the *transfer object assembler* and *session façade* are very similar. They are both designed to decouple the tiers and reduce network traffic. However, the difference lies in that the *session façade* aggregates the tasks while the *transfer object assembler* aggregates the data. The application model is an example of a *transfer value object*, and is returned by the *transfer object assembler*. It contains data assembled from a set of business tier components and presents clients with one logical application model.

Figure 3.6 shows the class diagram for the *transfer object assembler*. The Client accesses

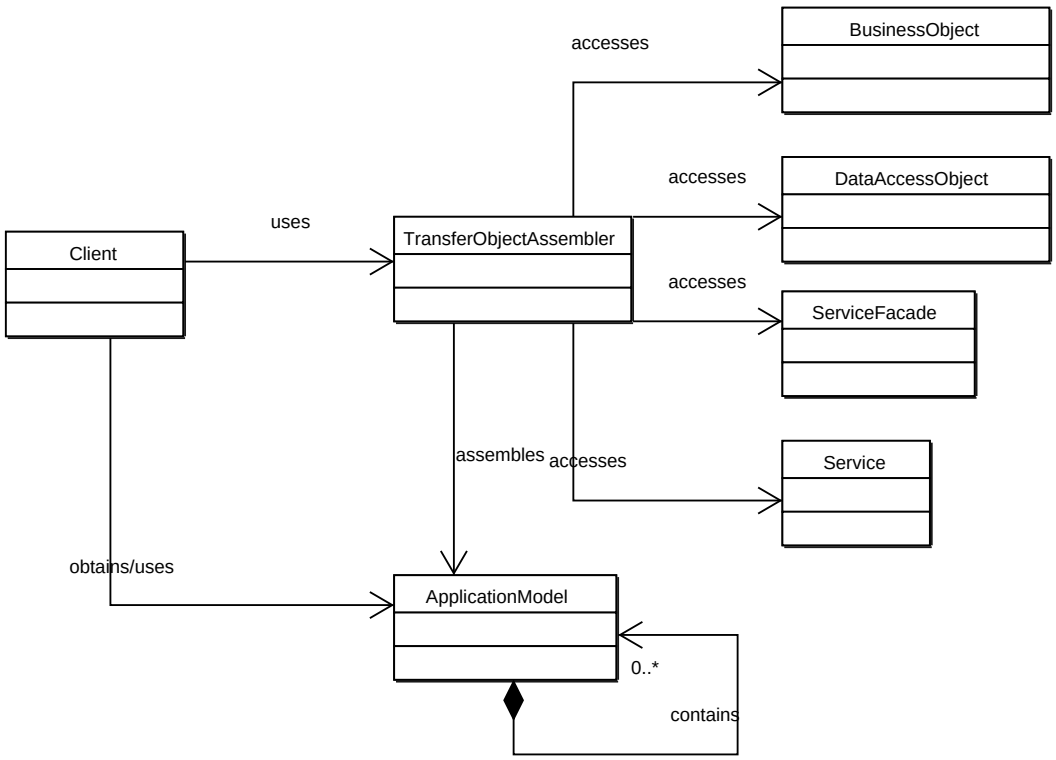


Figure 3.6: Transfer Object Assembler [1]

the TransferObjectAssembler for the application model. Then, the TransferObjectAssembler accesses the different underlying business components, such as the DataAccessObject, SessionFacade, BusinessObject, and Service, to assemble the requested application model.

The *transfer object assembler* can be implemented as a POJO or as a Session EJB. If the *transfer object assembler* is managed by a *session façade*, which exposes the construction of the snapshot of the application model as a business service, a stateless Session EJB is preferable. However, maintaining consistency between the application model and underlying object models is virtually impossible due to constant modifications . Thus, caching the retrieved data in the *transfer object assembler* using a stateful bean is not useful. A new *transfer value object* is created every time the *transfer object assembler* is called to create a new application model.

3.6 Value List Handler

In many web-based applications, the client performs some kind of search for data based on keyword queries. The server side business logic accesses the underlying database to retrieve matching data and returns them. Accordingly, the presentation tier modules are responsible for displaying the returned data. However, the result set for some searches can be very large. One example is an online search engine, which may result in hundreds of matched web links for each query. Moreover, delivering all of the results across tiers increases the network traffic and reduces the performance of the system. Furthermore, clients may not need all of the matched results. In the case of the search engine, clients generally abandon the results after they browse through the first few pages. In that case, transferring all of the results back is inefficient. As a result, the *transfer list handler* manages large data transfers between the business components and presentation tier components by sending results in batches and only on demand.

The class diagram of *value list handler* is shown in Figure 3.7. The Client accesses the ValueListHandler to query the information. The ValueListHandler queries the underlying database using the DataAccessObject. The DataAccessObject retrieves the query results and returns it to the ValueListHandler as a ValueList. The ValueList aggregates a list of *transfer value object*s. The client accesses the ValueListHandler for a sublist of the ValueList. The ValueIterator of that sublist can then be used to iterate through its elements.

The *value list handler* is generally implemented as a POJO class. In some cases, it might be

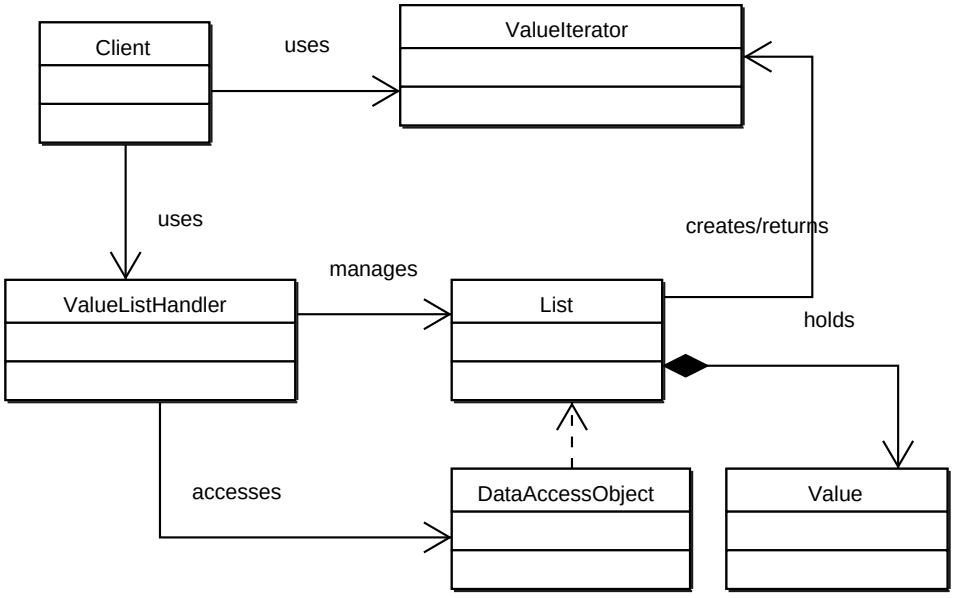


Figure 3.7: Value List Handler [1]

useful to keep the retrieved data cached for the whole session.

3.7 Business Delegate

Allowing the web tier components to directly access the business tier components is generally not a good idea. The direct accesses usually produce tight coupling between two tiers. As a result, changes in the interfaces of the business components may require changes to the code for the web tier components, thus reducing the maintainability of the system. This direct access also increases the complexity of web tier components. To access a remote component, the web component needs to manage the name space of the remote components and perform a set of complicated lookup operations. The web tier components are mainly responsible for the presentation logic. Thus, to include the code for handling distributed computing inside the presentation logic is a violation of separation of concerns. As a result, the *business delegate* sits between the client tier and business tier to hide the complexity of name space management. A *business delegate* usually maintains a one-to-one mapping with a *session façade* or other coarse-grained business component.

Figure 3.8 is the class diagram of a typical *business delegate* (BD) [1]. The Client accesses the BusinessDelegate for the remote services. The BusinessDelegate uses the ServiceLocator to

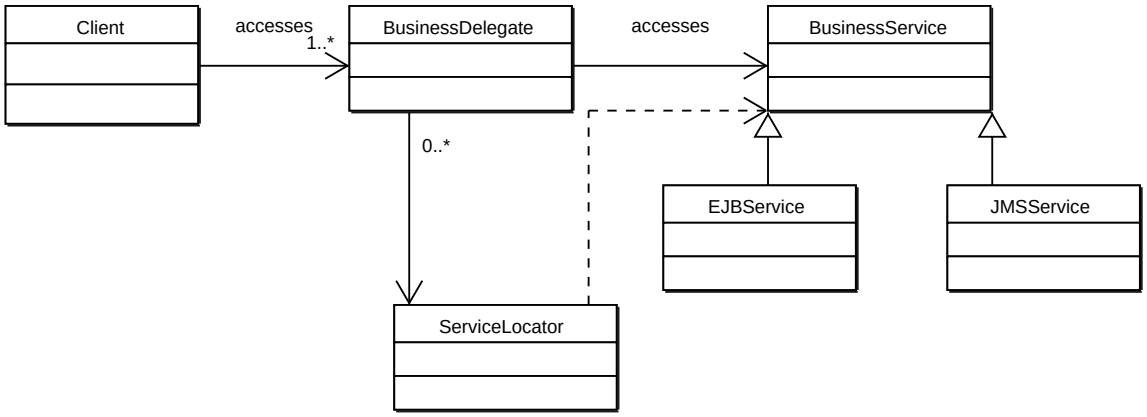


Figure 3.8: Business Delegate [1]

locate the BusinessService, and then invokes the appropriate method. The BusinessService can be an EJB component as well as a Java Messenger Service (JMS), which handles asynchronous messaging services such as a mail service.

Although the *business delegate* is a business tier pattern, it is usually deployed in the web tier as a local POJO to provide a logical abstraction to business tier components. A *session façade* is usually fronted by a *business delegate*. The *business delegate* manages access to the remote *session façade*. The invocation of methods in the *session façade* is delegated through proxy methods defined in the *business delegate*. Accordingly, the delegate methods can be used to catch remote exceptions and translate them into the application exceptions at the client. The methods can also be customized to cache the intermediate results of consecutive invocations.

In the J2EE framework, the *business delegate* is the middle man between the web tier and business tier. In Chapter 5, we will introduce our variation of the *business delegate* that can be used to abstract remote accesses not only between the business tier and web tier, but also those between the business tier components.

3.8 Summary

The J2EE patterns in the business tier have two main goals: to decouple the presentation tier from the business tier and to reduce the network overhead. Some patterns generally act as a middle man between the presentation tier and business tier. Those patterns reduce the network traffic by implementing facilities such as caching and aggregating small tasks into one bigger task. The

decoupling is also realized by hiding the interfaces of the business components and the complexity of coordinating them in these patterns. Examples of such patterns are the *business delegate* and *session façade*. Other patterns reduce the frequency of data transferred over the network by aggregating small pieces of data and sending them as one single object. The network traffic can be further reduced by caching, as is done with the search results using the *value list handler*. Examples of such patterns are *transfer value object* and *transfer object assembler*. Another problem addressed by business tier design patterns is to abstract the low-level name space management using the *service locator*. The data tier design patterns are designed to decouple the client code from that used to access different data sources. An example of a data tier pattern is *data access object*. After seeing the individual patterns, we can now examine how these patterns interact to solve more complicated problems.

Chapter 4

Pattern Relationships And Pattern Assembly

In this chapter, we will identify some important pattern relationships from Sun's J2EE blueprint. We also show how these pattern relationships can be used to assemble patterns into a complete application. Additionally, we concentrate on the pattern relationships from the business tier and data tier because their relationships are more intriguing and complex than those in the presentation tier.

4.1 Pattern Relationships

We define a pattern relationship as a set of roles and constraints. A role defines a participant in the relationship. A role contains a set of properties that an implementation class of this role must fulfill. Thus, each of these properties is a constraint of the role. An example of using roles and constraints to define a relationship is a pair of computers using the File Transfer Protocol (FTP). There are two roles in this relationship: the server role and the client role. Each role is played by a computer. Once we decide to establish this relationship, we must assign computers to each role. When selecting computers to play the different roles, we must ensure that their properties satisfy the necessary constraints. The server must be connected to the Internet and it must have FTP server software installed. The computer that plays the client role must have an Internet connection and FTP client software installed. Only when these constraints are properly satisfied is the FTP

server and client relationship established.

Pattern relationships can be built in an analogous manner. In RMA, a role is played by a Java class and a constraint can be anything, ranging from the class type to the signatures of the methods. In addition, we have categorized the constraints based on how they are implemented. We define the constraints that are implemented consistently across all applications as *static constraints*. Constraints whose values can be programmatically derived from application context are the *derivable constraints*, while *non-derivable constraints* are those that the developers must implement manually.

An example of a static constraint is the super-type of a Session EJB bean class. All Session EJB bean classes have to extend the `SessionBean` class. This static constraint is consistent throughout all applications. Derivable constraints can be best illustrated with the naming convention to which EJBs must adhere. For example, for an EJB bean class named "XYZBean", we can programmatically deduce the name of remote and home interfaces as "XYZ" and "XYZHome". Derivable constraints can be used not only for simple class name deduction but also for more complicated method body deduction, as we will see later. Derivable constraints may also require information solicited from the developer. For example, developers have to pick *transfer value objects* when creating a *transfer object assembler*. RMA derives the *data access object*s of these selected *transfer value object*s to access the necessary information. Non-derivable constraints have neither a default implementation nor a derivable implementation from the program context. For example, we know the `select` method in a DAO should select data from an underlying database table, but we have no idea how the selection should proceed until the developer specifies the SQL clause.

As shown in Figure 1.1 (page 5), developers start the development process by selecting a pattern relationship to instantiate. In the wizard responsible for the selected relationship, developers select a set of suitable objects to fulfill the different roles in the relationship. RMA is responsible for querying the workspace to create a list of possible candidate objects and presents them to developers to select in the wizard. Some simple derivable constraints, such as EJB bean class names, can be specified by the developers in the wizard. More complicated derivable constraints, such as the binding of *transfer value object* and *transfer object assembler*, requires the "Artifact Extractor" to process the Java classes using reflection. RMA combines information gathered from the developers as well as that extracted from the class files into the program model. At the code generation

stage, the program model is fed into a "Code Generator" to produce the concrete code. The "Code Generator" is implemented using an Eclipse Plugin called JET [24]. The generated code may add new classes or methods to existing classes to implement the constraints or it may use an existing constraint implementation.

In the following sections, we will examine some important relationships in the J2EE framework. Each relationship is discussed according to its participating roles and the constraints of these roles.

4.1.1 Transfer Value Object + Data Access Object

The *data access object* is a data-oriented pattern and is responsible for querying the database and returning the results back to the client. In order to reduce the number of fine-grained queries from a business component, the query results are aggregated into *transfer value object*s. Each tuple of the database table is packed into a *transfer value object*. Figure 4.1 is the class diagram that captures the relationship between a *transfer value object* and a *data access object*.

Roles

In this relationship, the *data access object* encapsulates and manages an underlying database table. The *transfer value object*s play two different roles in the collaboration. In one role, they stand for a tuple of data in the underlying database table, with each element in the tuple corresponding to an instance variable in the *transfer value object*. In another role, they model the primary key of the table. The primary key is a subset of fields in the database table that uniquely identifies a tuple. Because the primary key usually contains more than one field, aggregating them into a single class using a *transfer value object* is a good practice.

The *data access object* is responsible for processing the raw result set returned by the database, and assigning the corresponding values to the variables in the *transfer value object*. The client may then access the *transfer value object* for needed values.

Constraints

The *transfer value object* is a light weight POJO class. It has a set of variables that model all fields in the underlying table, which are exposed to other classes with a set of accessor methods. Given information of the owner of a *transfer value object*, we can derive the names of the fields that

should be included in the *transfer value object*. The accessor methods to these variables can also be easily derived.

The *data access object* implements basic database operations, such as select, insert, delete and update. The select method takes a primary key object, implemented as a *transfer value object*, and returns an array of matching tuples, which are disassembled and repacked into *transfer value object*s. The insert methods take in a *transfer value object*, which stores the values to be inserted, and returns a *transfer value object*, which represents the primary key of the inserted tuple. The delete methods take in a *transfer value object*, which contains the primary key, and returns a boolean value to indicate the result of the deletion. The update methods take in a *transfer value object* for new data to be stored in the database. The update methods should unpack the *transfer value object* to extract necessary information for update. The update method returns a boolean variable to signal the result of the update. While the signature of the database access query methods are static constraints, the implementation of the access methods in the *data access object* are specified as non-derivable constraints because no default SQL query statement can be accurate enough to meet the developers' intention.

We have enforced certain naming conventions on the *data access object* and its *transfer value object* and primary key class, so that the name of the primary key class and *transfer value object* class can be programmatically deduced from the name of the *data access object* and vice versa. We will discuss this convention later in this chapter.

Composite Subcomponent

The association between *transfer value objects* and *data access objects* is used frequently in other, more complicated, data-oriented relationships. Due to their close association, it is better to think of them as playing a single composite role of data management in the design phase. We would like to refer to this composite role as the *data access object subcomponent* in subsequent discussions. The constraints of the subcomponent are the aggregate of its elements' constraints.

4.1.2 Transfer Object Assembler + Data Access Object Subcomponent

The *transfer object assembler* is used to provide a coarse-grained view of the application model on the top of the fine-grained object models. The *transfer object assembler* queries the underlying

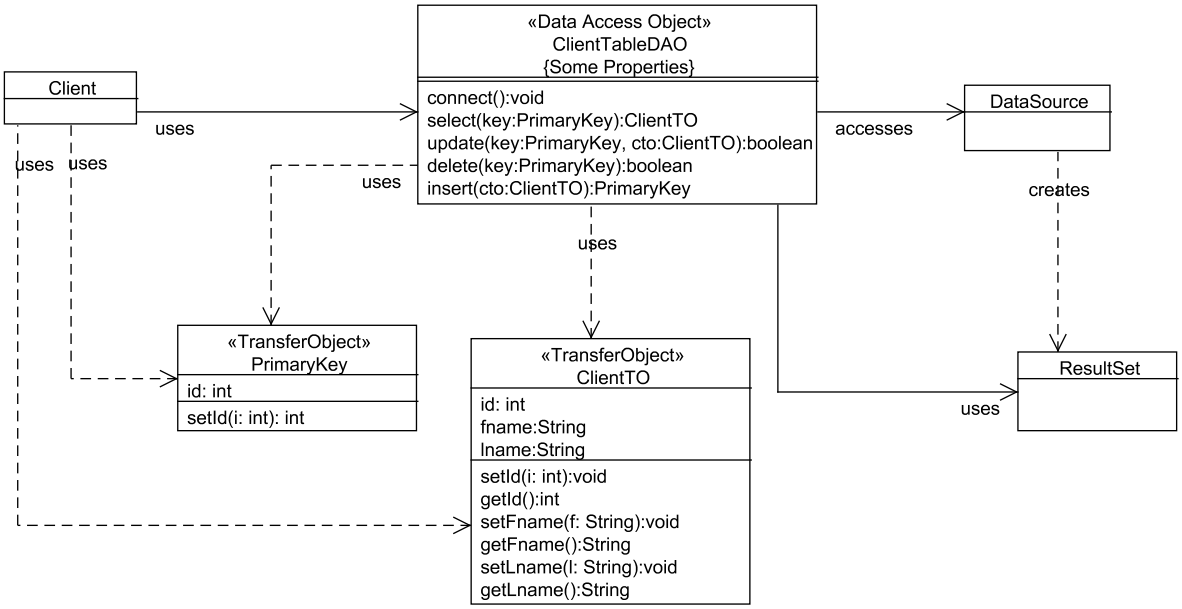


Figure 4.1: Transfer Value Object and Data Access Object

business components to retrieve data to assemble, while the *data access object subcomponent* manages the database queries and updates. The data transfers between the *transfer object assembler* and *data access object subcomponent* are packed as *transfer value objects*. Figure 4.2 shows the relationship between the *transfer object assembler*, the *data access object subcomponent*, and other helper patterns.

Roles

This relationship has three participants: the `Aggregator`, the *data access object subcomponent*, and the *transfer object assembler*. The *data access object subcomponent* plays the same role as it does in Section 4.1.1. Besides playing the roles of primary key and data entry in the subcomponent, the *transfer value object* also plays the role of creating the `Aggregator`. The `Aggregator` contains the *transfer value objects* that are put together by the *transfer object assembler*.

The *transfer object assembler* plays the roles of creating and packing the `Aggregator`. A set of fine-grained *data access object subcomponents* are managed and accessed by the *transfer object assembler*. The *transfer object assembler* first breaks up the client request into fine-grained tasks that are applied to individual *data access objects*. The results returned from the *data access objects* are all in the form of *transfer value objects*. Then, the *transfer object assembler* packs those results

into a coarse-grained *transfer value object*, the `Aggregator`, which is returned to the client.

Constraints

The *transfer object assembler* can be a light weight POJO or an EJB. It should cache handles to the underlying fine-grained data models (the DAOs), which can be stored as instance variables. The association between the *transfer object assembler* and the data models should be initialized first, inside of a constructor, before any specific operations are performed. The *transfer object assembler* also needs to have accessor methods that delegate the client requests to the individual *data access objects*. The getter method should take a primary key *transfer value object*, which can be used to fetch matching data. The data assembled in the *transfer object assembler* is usually related in the databases as either one-to-one or one-to-many relationships. Thus, given the primary key of one database table, the *transfer object assembler* should have sufficient information to extract all of the necessary parts from all of the tables. The getter methods should delegate the queries to the select methods in the *data access objects*, which also take in a primary key *transfer value object*. The getter methods put the results into an `Aggregator` and return it while the setter methods in the *transfer object assembler* take in an `Aggregator`. RMA extracts each *transfer value object* contained in the `Aggregator` and passes it to the update methods of the corresponding *data access object*. The *data access object subcomponents* maintain the same constraint as in Section 4.1.1.

The `Aggregator` follows all of the constraints of a *transfer value object* with the additional derivable constraints that all of its variables are *transfer value object*s.

The name of the *transfer object assembler* class can be solicited from the developer. The developer also selects a set of the *transfer value objects*. Using our naming convention, we can programmatically derive the name of the owner *data access object*. As a result, the constraints on the association between *transfer value object* and *data access object* are derivable. For each selected *transfer value object*, the user must then select the method in the *data access object* that returns that *transfer value object*. The candidate methods can be derived using the constraints we have just discussed, and the user selects the specific methods that should be used. Combining the above information, we can also derive most of the implementation of the *transfer object assembler*.

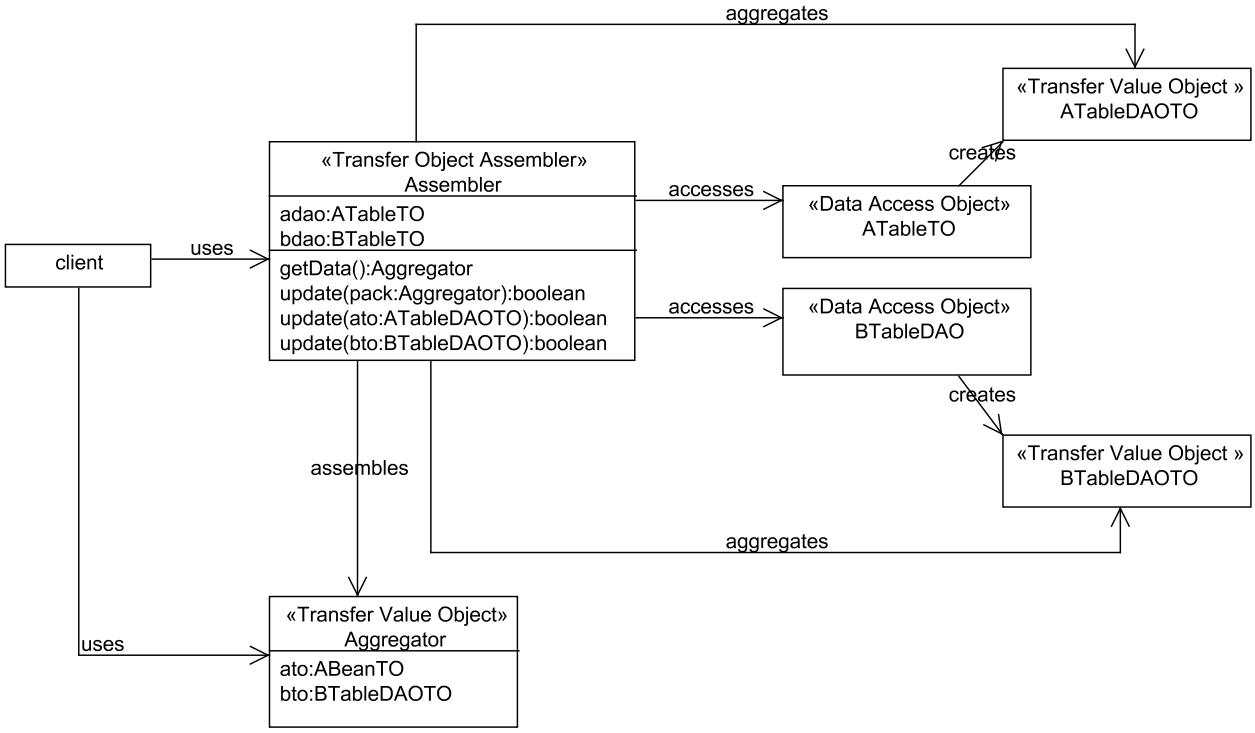


Figure 4.2: Transfer Value Object, Transfer Object Assembler and Data Access Object

4.1.3 Value List Handler + Data Access Object Subcomponent

The *value list handler* is used to cache query results from the database. It also provides a mechanism for sub-listing and iteration which allows the client to access only the desired portion of the data. The *data access object subcomponent* is used again to provide back-end database access. Figure 4.3 shows the relationships between the *value list handler* and other supporting patterns.

Roles

This relationship involves three J2EE patterns and one classic Gang of Four pattern, the Iterator [9]. The *data access object subcomponent* manages the database access. The *transfer value object* encapsulates a single tuple of values returned from the database query. The *transfer value object*s are aggregated into a value list object. A *value list handler* connects to a single database table only, so the *data access object* and *value list handler* maintain a one-to-one mapping.

In contrast to the *transfer object assembler*'s `Aggregator` that aggregates different types of *transfer value object*s, the value list object manages a list of the same type of *transfer value object*.

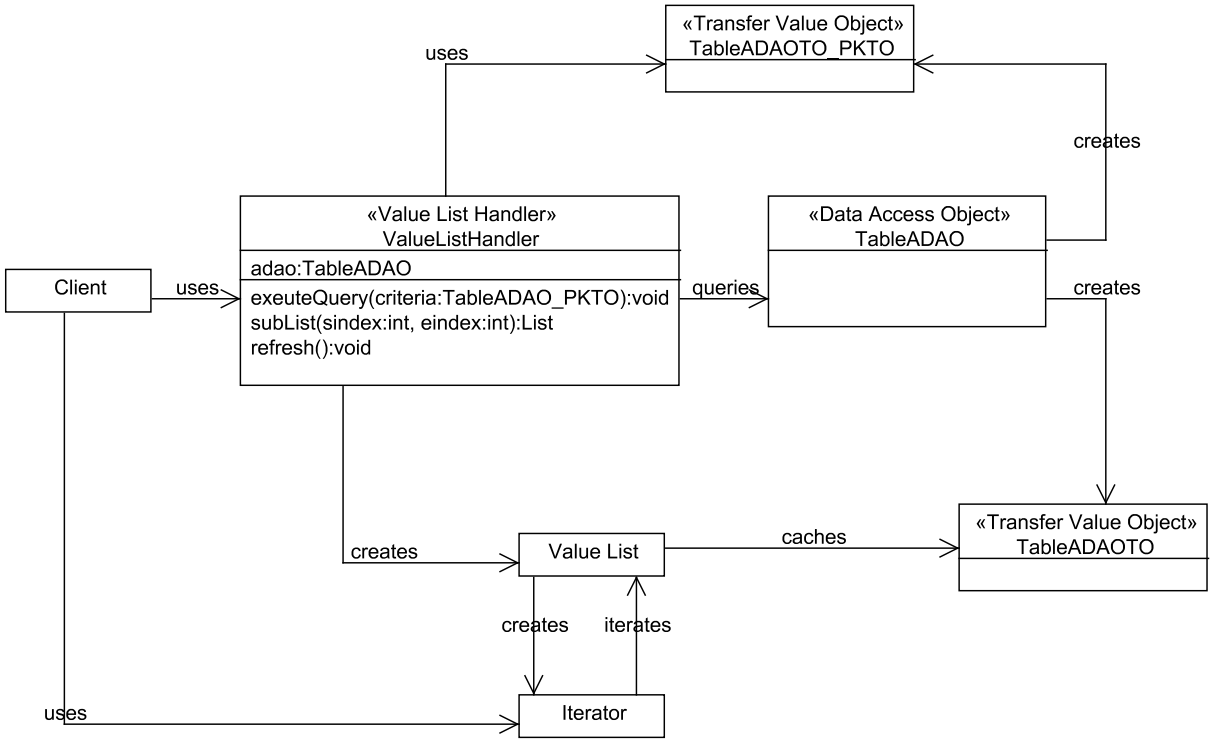


Figure 4.3: Transfer Value Object, Data Access Object and Value List Handler

The *value list handler* returns the data as a sequence of sublists using the Iterator pattern. The Iterator pattern is used to generate the iterator to traverse the query result. The *value list handler* handles the data caching and sublisting.

Constraints

The *value list handler* is implemented as either a light-weight POJO or as a Session EJB. If the *value list handler* is implemented as an EJB, it should be implemented as a stateful Session EJB because the data it caches should be held throughout the session. The *value list handler* maintains a handle to a *data access object subcomponent*, while the *data access object* maintains the same constraints as in its relationship with *transfer object assembler*. Because the handle needs to be properly instantiated before the *value list handler* can be used, the constructor of a *value list handler* should be coded to instantiate the *data access object subcomponent*. The *value list handler* should have a method that performs the database query. The query method should have a primary key *transfer value object* as the parameter, and delegate the query to an appropriate select method

in the corresponding *data access object*.

The query method should store the returned data in a data structure that includes support for an iterator.

The *value list handler* also needs a method to expose the sub-lists of cached items to the client. This method should take two parameters indicating the beginning and the end of the sub-list. The sub-list method creates a copy of the desired sub-list and returns it to client. There should also be a method in the *value list handler* where users can retrieve an iterator for the query result. The returned iterator and sub-list method should enumerate over the list, providing elements in the order required by the requesting client (front-to-back, back-to-back, etc). A reset method that refreshes the cached data by re-fetching them from the underlying database should also be included. All data that is fetched from the database should be packed in the form of a *transfer value object* before being placed into the storage list. As a result, all of the constraints discussed for the *value list handler* so far are derivable.

Given an application context, the developer can choose the DAO that will be associated with the *value list handler*. From the DAO, the developer can further select the appropriate *transfer value object,* and the method in the DAO that creates it, to complete the specification of the *value list handler*. With this context information, the derivable constraints on the method body of the constructor and query methods can all be programmatically fulfilled. Since the interface to the Iterator can be fixed, the `subList` method has a consistent implementation for all applications, and is thus a static constraint. Implementations for common iterators are usually available, making these derivable constraints since the user can simply select one. Moreover, specialized iterators could also be created manually making this a non-derivable constraint.

4.1.4 Session Façade + Business Components

Business services can be implemented using patterns such as the *value assembler*, the *data access object subcomponent* and the *value list handler*. While pattern-supported business components are robust and flexible, sometimes it is necessary for several business components to co-operate in order to fulfill complicated services. However, this collaboration should be kept at the server side to reduce the network overhead. In other cases, simplifying the interface to a set of business services by using a single object as the access point may be desirable. The *session façade* is a pattern that

provides a centralized location where business services implemented using different patterns can interact. Figure 4.4 shows a collaboration of a *session façade* and several other patterns.

Roles

There are three roles in this collaboration: the *session façade*, the business component, and the *service locator*. The client accesses the *session façade* for the services provided by the different business components.

The business components can be either data-oriented or task-oriented. A data-oriented business component can be implemented as a *value list assembler*, a *value list handler* or a *data access object*. Task-oriented business components are implemented as Session EJBs. If Session EJBs are accessed, the *session façade* needs the *service locator* to locate the handles of those EJBs.

The *session façade* plays the dual roles of delegating mediator and aggregator. It delegates the incoming requests to the corresponding business components. The *session façade* also plays the role of mediator by coordinating complicated interactions between business components. The intermediate results can also be cached at the *session façade*. Lastly, the *session façade* aggregates the results returned from the business components and returns them back to the client.

A Composite Role

The abstraction of business services using a *session façade* to hide the lookup services using the *service locator* is a common practice in many J2EE applications. It can be seen as a composite role that is useful when pattern collaborations involve components taht are implemented as EJBs. The *session façade* and *service locator* patterns together play the role of mediator that not only hides fine-grained communication but also the complexity of name lookups. We will refer to this composite pattern as a *session façade subcomponent*.

Constraints

The *session façade* is usually implemented as a Session EJB object that accepts requests from the web tier. If the *session façade* that handles the task needs several steps of fine-grained process interactions and produces intermediate results, the *session façade* must be implemented as a stateful Session EJB. Otherwise, a stateless Session Bean is sufficient. Moreover, the *session façade* should

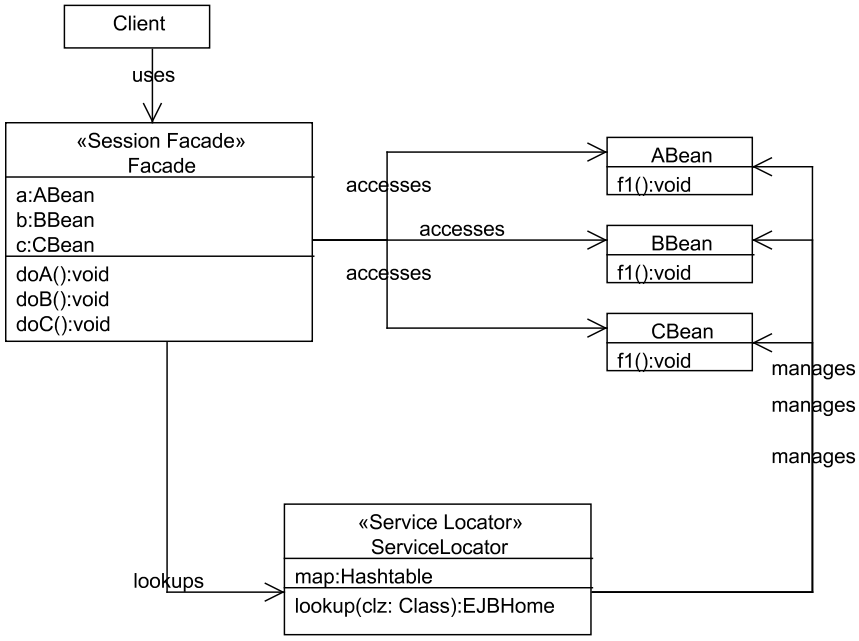


Figure 4.4: Session Façade and EJBs

contain business methods that delegate client requests to different components. Furthermore, the delegation methods should contain "try-catch" clauses that catch and handle possible exceptions and translate them to application level exception for clients. Additionally, the *session façade* should keep a reference to the *service locator* and the beans that it encapsulates.

The *service locator* should be able to handle name lookups for both remote and local EJBs using their JNDI names. The lookup methods take in a JNDI name and return the EJBHome object. Moreover, the lookup methods should also provide a mechanism to cache the mapping between a JNDI name and an EJBHome object to reduce the overhead of future lookups.

The business component can be implemented as either a POJO or an EJB. Also, once given the class names of the participating business components and a list of methods to export, the constraints for service delegation can be derived. However, the constraint of coordinating the invocations to business components is a non-derivable constraint that is left for the developer to implement. The implementation of the *service locator* is static over all applications.

4.1.5 Service Locator + Business Delegate + Session Façade Subcomponent

The business tier normally exposes its services through the coarse-grained *session façade*s which are implemented as Session EJBs. Thus, to access a *session façade*, the web tier components need to go through a complex name lookup process to obtain a handle. We would like to hide the need for these handles from the web developers. Instead, the web tier developers should use remote services as though they were using a local object. Figure 4.5 shows a collaboration of patterns that achieve this goal.

Roles

The participating patterns are the *business delegate*, *service locator* and *session façade subcomponent* identified in Section 4.1.4. The clients of this relationship are from the presentation tier. When a client requests a business service, it contacts the *business delegate*. The *business delegate* queries the *service locator* for the handle to its associated *session façade* in the business tier. Each business delegate is associated with a single *session façade*.

The *service locator* should contain a cache of handles to known remote objects. If a match cannot be found in the cached entries, the *service locator* performs a new lookup and caches the result. If the *service locator*'s lookup was successful, the *business delegate* can then delegate the client request to the *session façade subcomponent*, which may either handle the task itself or distribute the work to other business tier components. If the lookup failed in the *service locator*, the *business delegate* is responsible for retrying the connection. Remote exceptions that occur in the process of lookup and communication should be handled in the *business delegate*.

Constraints

The client of the *business delegate* is usually a JSP or Servlet from the presentation tier. The *business delegate* and *service locator* are implemented as POJOs. The connection between the *business delegate* and the remote *session façade* is maintained automatically for the client. The *business delegate* stores the JNDI name of the remote *session façade*. The constructor of the *business delegate* invokes the lookup operation on the *service locator* by providing target resource's JNDI name. The retrieved `EJBHome` object is used to create a handle to the associated `EJBObject`. The *business delegate* needs to have a set of methods that delegate its work to the methods defined

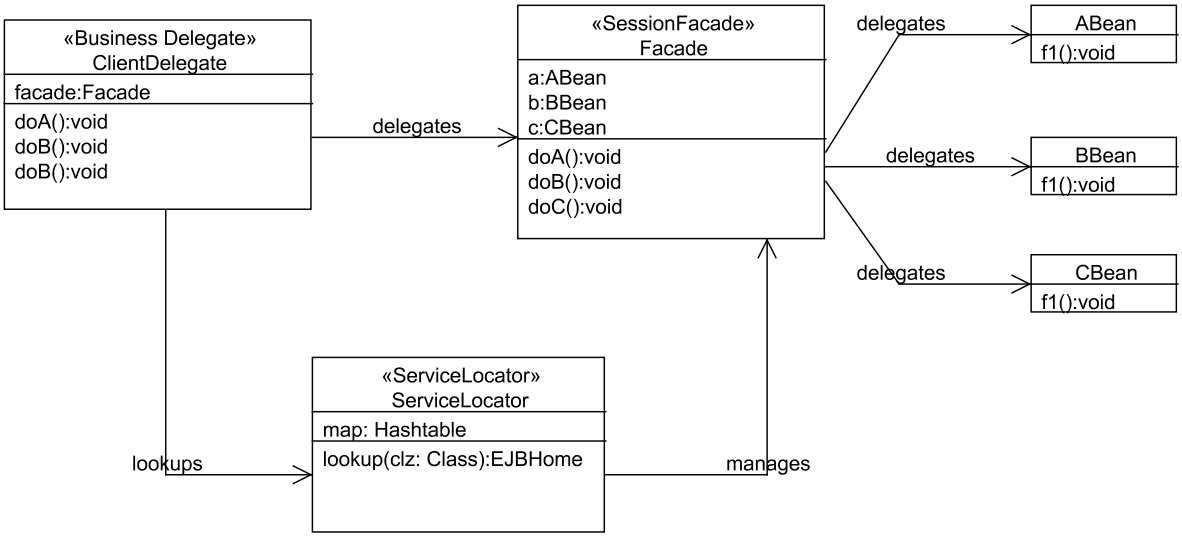


Figure 4.5: Service Locator + Business Delegate

by the remote *session façade*. Such proxy methods have the same signatures as the delegated methods. A try-catch clause should be present in each of the proxy methods to either handle the exceptions or translate caught network or name space exceptions to other application-level exceptions.

The *service locator* has the same constraints as the *service locator* in the *session façade subcomponent*. The only difference lies in the fact that this *service locator* is used in the web container instead of in the EJB container. It is good practice for the *service locator* to be kept as a singleton for each container in order to avoid confusion in namespace management. The *session façade subcomponent* maintains the same constraints as when it is used alone.

Given a *session façade* selected by the developer, the constraints for delegating client requests to the *session façade* can be derived by extracting the class name and method signatures of that *session façade* in the business tier. Furthermore, given the JNDI name of the *session façade*, the code for interacting with the *service locator* can also be derived. In Chapter 5, we will introduce a variation on the collaboration between the *service locator* and the *business delegate* in which both patterns have different constraints than those discussed in this section. Our variation improves the level of abstraction of the application.

4.1.6 Discussion on Pattern Relationships

Incremental Construction

So far, we have seen how a complicated relationship can be formed by composing simple patterns. For example, the collaboration between the *transfer value object* and the *data access object* forms the basis for more complicated relationships, which are made up of the *transfer value object*, *data access object* and *value list handler*. However, the collaboration of the patterns does not end there. The *value list handler* can also be hidden behind a *session façade* in a real world application. Furthermore, the *session façade* can be accessed through a *business delegate*. The web tier client accesses the *business delegate* to indirectly access the data managed by the *value list handler*. Thus, by assembling patterns or pattern-based subcomponents together, we have a flexible way to incrementally build up a complete web application.

Role Categorization

A close examination of the roles in the relationships we have discussed so far reveals that roles can be categorized into three types: the primary role, the supportive-pattern role, and the supportive-non-pattern role. Every pattern relationship we discussed has a pattern that acts as a primary role, and this primary pattern defines the relationship in which it is involved. In a relationship, a primary role coordinates the supportive roles to fulfill the goal of this relationship.

The supportive-non-pattern roles are the most fundamental building blocks of the whole application. They can be assembled into supportive-pattern roles by picking a pattern as the primary role in the relationship. The resulting relationship can be further used as a supportive-pattern role in other relationships. In other words, a concrete pattern relationship is defined by creating a new primary pattern role and using existing components or relationships to play the supportive roles. The whole application is constructed by recursively assembling the supportive roles into a relationship based on a primary role. Because we follow a bottom-up approach, the primary role can always find existing components to fulfill the supportive-pattern roles or supportive-non-pattern roles from the workspace. Table 4.1 shows the break down of roles in the relationships we have covered.

Table 4.1: The Categorization of Roles in the Relationships

Relationship	Primary Role	Supportive-Pattern Role	Supportive-Non-Pattern Role
TO + DAO	DAO	TO	
TO + DAO + TOA	TOA	TO, DAO	
TO + DAO + VLH	VLH	TO, DAO	
SF+Business Components	SF		Business Components
SL + BD + SF	BD	SL, SF	

Implicit and Explicit Relationships

There are differences in how closely patterns are related to each other in the pattern relationships. For example, the *transfer value object* is closely associated with most of the data-oriented patterns. On the other hand, the *service locator* is used extensively in task-oriented pattern collaborations. In most of their associations with other patterns, these two play support roles. They each have rather simple and consistent program structures and logic. The *transfer value object* contains nothing but a set of variables and their accessor methods. The *service locator* implements the logic for locating EJBs using JNDI names. The same lookup logic can be used for all EJBs. We consider the relationship between two highly correlated patterns such as that between a *transfer value object* and a *data access object* as an *implicit relationship*. The *data access object* is the primary pattern, while the *transfer value object* is a secondary support pattern. The existence of the primary pattern implies the existence of its supportive patterns. This idea is expressed in the composite roles for the *data access object subcomponent* and *session façade subcomponent*. Patterns related to each other through implicit relationships are considered to be one larger unit rather than a set of individual patterns.

There are other kinds of pattern relationships, such as those between a *session façade* and other business components. Because the relationship between such patterns only exists if the developer explicitly expresses it in the program, we called such a relationship an *explicit relationship*.

4.2 Pattern Assembly

In this section we explain how RMA assembles the pattern relationships we discussed in the previous section. The description of the assembly process is organized to emphasize the creation of the

primary roles. The use of different properties of a relationship is also discussed.

4.2.1 Assembly Processes

Pattern assembly consists of two main tasks: specifying relationship parameters and generating code. As we have discussed, the parameters of a relationship are the roles and constraints. The first task needs developer intervention with support from RMA. The second task is carried out by RMA based on the supplied parameters.

To specify a pattern relationship, the developers must go through three steps: picking a relationship to create, matching existing pattern instances to roles, and fulfilling the required constraint relationships. RMA provides a list of patterns from which the developers can choose one as the primary role. The patterns that are currently supported are those that were described in Chapter 3. The primary roles can be any of the patterns listed in the "Primary Role" column in Table 4.1.

When the developer decides to generate a particular primary role, RMA displays a list of existing pattern instances that might be used as candidates to fulfill the supporting roles in the relationship. Because RMA supports a bottom-up incremental build process, patterns for the supportive roles must already exist in the workspace. RMA deduces the compatibility of a pattern instance with a supportive role by analyzing the XML description files which are generated for most relationships. We will cover the details of these description files later in this chapter. Through wizards, the developer selects the classes that will make up this relationship.

RMA is also responsible for analyzing the selected pattern instances to provide developers with a list of pattern instance artifacts that can be used to fulfill the role constraints. Examples of typical role properties are class names, instance variable names and types, and method signatures, which can all be extracted from patterns using Java reflection. Through RMA wizards, the developers are responsible for mapping artifacts to the properties to fulfill the required constraints.

There are usually two types of code generated for a relationship: the code for the primary pattern and that for the supportive patterns that have an implicit association with the primary role. The classes which fulfill the primary roles usually contain handles to the classes of the supportive patterns. The code for handling the invocations of the supportive patterns from the primary pattern is generated according to constraints defined in the relationship. However, the code generated for the primary pattern is not always complete. Moreover, the degree of detail

for the code generated depends on the nature of the constraints. Roles defined using more static constraints and more derivable constraints than non-derivable constraints can be generated in more detail than others. For example, constraints defined for the *business delegate* in its relationship with a *session façade* are either derivable or static. Both the method signatures and method content can be deduced from the context. In contrast, non-derivable constraints are impossible to automatically fulfill. For example, the implementation of query methods in a *data access object* only defines the purpose, but not the programmatic make up of the SQL query statement. Yet, in the case of non-derivable constraints, we create a task description indicated by a tag, such as "EJB-TODO", in place of concrete code. The tasks also show up in the task list view of the Eclipse workbench so that developers can easily find those places where application code is needed. As we have discussed, the implicit supportive patterns generally have simple static constraints or derivable constraints, so they can be easily generated.

Besides the generation of code, RMA also maintains consistency between the code and XML description files resulting from changes to program components in the workspace. For example, the XML descriptor files are automatically updated when Session EJBs are added to or removed from the workspace. We will discuss code generation for the pattern relationships we have identified in the following sections.

Creating Data Access Objects and Transfer Value Objects

Because we are using a bottom-up incremental build approach, the components in the data tier must be created first. RMA allows developers to use either a connection string or a JNDI name to connect each *data access object* to its database. The JNDI name and connection string should be given to RMA by the developers through the DAO wizard. In order to generate the *data access object*, RMA also needs to know the data schema of the underlying database table. This wizard requests the name of each field of the database table as well as its type. The schema information is also used to generate the *transfer value object* that is automatically created for this *data access object*. The developers also need to inform RMA about the primary key of the underlying table so the primary key *transfer value object* can be created.

The relationship between *data access objects* and *transfer value objects* is implicit, so for each *data access object* created, two *transfer value object*s are created, one for a complete database tuple

```
int id;
public int getid(){
      return id;
}
public void setid(int p0){
      id=p0;
}
```

Figure 4.6: Sample Code for the Transfer Value Object

and one for primary key. Every *transfer value object* contains variables that model the fields in the table and accessors to those variables. Because the variables and accessor methods of a *transfer value object* are defined using derivable constraints, the *transfer value object* is fully implemented after generation. For example, a table column with type integer and name "id" produces an instance variable and two accessor methods in the *transfer value object* as shown in Figure 4.6.

The generated instance variable has the same name as the database table column. The name of the getter method follows the naming convention of `get` plus the variable name. The getter method returns the type of this variable, `int`. The setter method has a similar naming convention to the getter method and takes in a parameter with the type of this table column. The method body of setter performs a simple assignment of the parameter to the instance variable.

The *data access object* has both derivable and non-derivable constraints defined for it, so the generated code is incomplete. Because both the signatures and content of the methods for the database connection are defined using static constraints, RMA is able to generate complete code for it. RMA automatically inserts the connection string solicited by the wizard as the argument to the invocation of the database connection method from the constructor.

The method signatures for the database access methods are defined in the derivable constraints. We append the database table name with "DAO" to form the name of a *data access object*. The *transfer value object* always follows the naming convention of combining the name of its owner class and "TO". The name for the primary key class follows the naming convention of combining the name of its owner *data access object* and "_PKTO". As shown in Figure 4.7 and Figure 4.8, for a database called "SatelliteTable", the names for the *transfer value object* and primary key class are `SatelliteTableDAOTO` and `SatelliteTableDAO_PKTO`.

In contrast, the method bodies for the database queries are non-derivable constraints left for

```
public class SatelliteTableDAO implements Serializable{
    protected static String SELECT_SQL;
    protected static String UPDATE_SQL;
    protected static String INSERT_SQL;
    protected static String DELETE_SQL;
    //auto-generated constructor
    public SatelliteTableDAO() {
        try {
            SELECT_SQL="";
            UPDATE_SQL="";
            INSERT_SQL="";
            DELETE_SQL="";
            //database connection code
            init("jdbc:mysql://plg2:3306/solardisplay?user=root&password=root");
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
    //build the database connection
    private void init(String url) {
        try {
            Class.forName("com.mysql.jdbc.Driver").newInstance();
            conn = DriverManager.getConnection(url);
        } catch (Exception e) {
            System.err.println("Connection failed: " + e.getMessage());
            e.printStackTrace();
        }
    }
    //create method
    public SatelliteTableDAO_PKTO create(SatelliteTableDAOTO to) {
        Connection con = getConnection();
        SatelliteTableDAO_PKTO id = null;
        PreparedStatement prepstmt = null;
        try {
            prepstmt = con.prepareStatement(INSERT_SQL);
        //EJB-TODO: set TransferObject fields to statement
        } catch (Exception e) {
            e.printStackTrace();
        }
        return id;
    }
    //continued in next page
```

Figure 4.7: Sample Code for the Data Access Object-1

```
    //selection method
    public SatelliteTableDAOTO find(SatelliteTableDAO_PKTO key) {
        SatelliteTableDAOTO to = new SatelliteTableDAOTO();
        Connection con = getConnection();
        PreparedStatement prepstmt = null;
        ResultSet rs = null;
        try {
            prepstmt = con.prepareStatement(SELECT_SQL);
            //EJB-TODO: set primary key here
            rs = prepstmt.executeQuery();
            if (rs.next()) {
                //EJB-TODO: set values to each TransferObject fields
            }
        } catch (Exception e) {
            e.printStackTrace();
        }
        return to;
    }
    .......
    //connection methods
    public Connection getConnection() {
        return conn;
    }
    protected Connection conn;
    private DataSource ds;
}
```

Figure 4.8: Sample Code for the Data Access Object-2

the developer to fill in. Figure 4.7 and Figure 4.8 show the code that is automatically generated for the *data access object*. The comments starting with "EJB-TODO:" marks places where the developer may need to insert application-specific code. These places also appear in the task list of Eclipse so the developer can easily navigate to these parts of the code.

Besides generating code, RMA also generates an XML descriptor file describing the relationships between the *data access object* and the two *transfer value objects*. Each file records the names of the concrete classes participating in the relationship and the roles of the classes. For example, the entry for *transfer value object* contains information such as the name of its owner. Subsequently, the entry for *data access object* specifies its primary key class. This information is used to fulfill constraints when developers try to assemble this supportive-pattern role into other relationships.

So far, we have created database access code. We now proceed to build the components that manage or use the data returned from the *data access object*. The *transfer object assembler* and *value list handler* are two of the most common direct clients of *data access objects*.

Creating Transfer Object Assemblers

The *transfer object assembler* is used to assemble different physical data tables into a single logical view. If we view the *transfer object assembler* as an object that combines fields from multiple tables together, we might also consider the *transfer object assembler* as an aggregator of multiple *transfer value object*s from different *data access object*s. Following this line of thinking, RMA's wizard for creating a *transfer object assembler* starts by picking appropriate *transfer value object*s to assemble. RMA queries the workspace to parse the descriptor files for the relationships between *data access objects* and *transfer value objects*. First, all available *transfer value object*s are presented to the developer for selection. Next, for each selected *transfer value object*, RMA displays all compatible accessor methods in its owner class. The developer needs to explicitly select the method for updating and retrieving the *transfer value object* from the provided list. The methods in the selection list are programmatically filtered by RMA using derivable constraints defined for the accessors methods. For the updating methods, all methods without the parameters of the type of the selected *transfer value object* will be filtered out. For the retrieving methods, all methods that do not have a return type of the selected *transfer value object* are filtered out.

Another attribute the developer may try to set is the multiplicity of the *transfer value object*s.

The *transfer object assembler* usually assumes that there is a one-to-one multiplicity, so the logical data model needs only one instance of each *transfer value object*. In a one-to-many or many-to-many relationship, a *transfer value object* of one type might relate to multiple entries of other types of *transfer value object*s. By being able to handle different types of relationships, RMA has expanded the usefulness of the *transfer object assembler*.

There are two pieces of code generated for the *transfer object assembler*: the assembler class and the aggregator class. The aggregator class contains the *transfer value object*s that are aggregated by the assembler and is a *transfer value object* itself. If any aggregated *transfer value object* has multiplicity of more than one, an array is used to store them. The assembler class is implemented as a Session EJB. According to the constraints defined in Section 4.1.2, the `ejbCreate` method builds the connections from the assembler to the owners of *transfer value object*s. The `update` method takes a parameter of the aggregator type. It breaks the aggregator into individual *transfer value objects* which are then used to set the data at the owner *data access object* using the setter methods selected in the wizard. The `getData` method uses the previously selected getter methods on the owner to load the corresponding data from the *data access objects* and assemble them into the aggregator object. The developer might need to write code that initializes the search criteria. For example, in a one-to-one or one-to-many relationship, the developer has to assign the foreign key of one table as the search key of another table. The aggregator object is returned from the `getData` method. The method signature and body of both the `getData` and `update` methods result from derivable constraints, so RMA produces almost complete source code. The only non-derivable constraint is the initialization of the search criteria for the different DAOs. Figure 4.9 shows an example *transfer object assembler*.

RMA implements the *transfer object assembler* as a Session EJB. The XML descriptor file for the *transfer object assembler* is the same as that for other EJB modules. We will talk more about the generation of EJB modules and their descriptors later.

Creating Value List Handlers

A *value list handler* is an ideal choice to cache database query results and send large amounts of data back to clients in batches on demand.

The information needed by RMA to generate a *value list handler* is similar to that used for the

```
public class ClientInfoManagerBean implements SessionBean {
    explorer.dao.AddressTableDAO addresstabledao;
    explorer.dao.ClientTableDAO clienttabledao;
    public void ejbCreate()
        throws CreateException {
        this.addresstabledao = new AddressTableDAO();
        this.clienttabledao = new ClientTableDAO();
    }
    //access (getter) method
    public explorer.clientinfo.ClientInfo getData(Object criteria) {
        explorer.clientinfo.ClientInfo val = new explorer.clientinfo.ClientInfo();
        try {
            //EJB-TODO: please initialize the search criteria
            explorer.
                dao.
                ClientTableDAO_PKTO clienttabledao_pkto
                = (ClientTableDAO_PKTO) criteria;
            val.clienttabledaoto = clienttabledao.find(clienttabledao_pkto);
            //EJB-TODO: please initialize the search criteria
            explorer.
                dao.
                AddressTableDAO_PKTO addresstabledao_pkto
                = new explorer.dao.AddressTableDAO_PKTO();
            addresstabledao_pkto.clientid=clienttabledao_pkto.id;
            val.addresstabledaoto = addresstabledao.find(addresstabledao_pkto);
        } catch (Exception e) {
            e.printStackTrace();
        }
        return val;
    }
    //update (setter) method
    public void updateClientInfo(explorer.dao.ClientInfoTO cinfo) {
        this.clienttabledao.update(cinfo.clienttabledaoto);
        this.addresstabledao.update(cinfo.addresstabledaoto);
    }
}
```

Figure 4.9: Sample Code for the Assembler

transfer object assembler. The descriptor files for the relationships between a *transfer value object* and a *data access object* are parsed to generate a list of *data access objects*. The developer can select only one of them from the list, and specify the setter and getter methods for a *transfer value object* from the selected *data access object*. Then, RMA allows developers to select the option of generating the *value list handler* class as either a stateful Session EJB or a POJO class.

A *value list handler* is generated by RMA. The *data access object* is initialized either in the `ejbCreate` method or in the constructor according to the constraint defined in Section 4.1.3. The *value list handler* class contains a `getSubList` method, which is a static constraint discussed in Section 4.1.3. The signature and content of the `subList` method is also statically defined, and thus can be generated by RMA. RMA also needs to generate the query method `executeSearch` that populates the value list. The developer completes this derivable constraint by selecting the appropriate query method in the *data access object* from a list provided by the *value list handler* wizard. The developer might want to refine the generated code to refine the search criteria before passing it into the delegated method. RMA also generates an Iterator class for each *value list handler*. Through the wizard, developers can set options such as "backtrackable", "loopable" and the "iterating steps" of the iterator. RMA uses these options to customize the generated iterator to accommodate the developers' needs. An access method called `getIterator` is automatically inserted into the *value list handler*. Figure 4.10 shows an example *value list handler*.

Creating EJBs and Session Façades

The *data access object* forms the basis of data manipulation in a J2EE application, and the Session EJB forms the basis of business services. The Session EJBs access the *data access object*s to fulfill client needs. Common uses of EJBs for data manipulation include the *transfer object assembler* and the *value list handler*. Besides being incorporated into pattern-based relationships, EJBs might exist independently as well. The *session façade* is a pattern that organizes and coordinates several EJBs. The *session façade* may be used to simplify the interface to a large number of objects, create high-level services from more basic business components, or even control access to privileged administrative methods.

RMA provides a wizard to generate free-form Session EJBs. A new EJB is created given a class name and Java package entered by the user. A skeleton of the EJB bean class is generated.

```
package explorer.dao;
import java.util.*;
import javax.ejb.*;
public class SatelliteVListBean implements SessionBean {
    private SatelliteTableDAO dao = null;
    protected List valueList = null;
    //initializing the data access object
    public SatelliteVListBean() {
        try {
            this.dao = new SatelliteTableDAO();
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
    //executing the search by delegation
    public void executeSearch(SatelliteTableDAOTO criteria) {
        try {
            if (criteria != null) {
                List resultList = new ArrayList();
                SatelliteTableDAOTO[] stos=dao.findByMasterPlanet(criteria);
                for (int i=0; i<stos.length; i++){
                    resultList.add(stos[i]);
                }
            setList(resultList);
            }
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
    //retrieving the iterator
    public SatelliteVListIterator getIterator(){
        return (new SatelliteVListIterator(valueList, 1, true));{
    }
    ........
    //return sublist
    public List getSubList(int startPosition, int endPosition) {
        List sublist=new ArrayList();
        for (int i=startPosition; i<endPosition; i++){
            sublist.add(valueList.get(i));
        }
        return sublist;
    }
}
```

Figure 4.10: Sample Code for the Value List Handler

All of the necessary stub methods for the EJB bean class are generated with default content. The developer can modify the generated class to insert public methods that provide the business logic. Besides supporting the generation of a completely new free-form EJB, RMA also supports the generation of an EJB from an existing POJO class. Web application development involves the reuse of many existing codes. Many web-based applications are migrated from some form of non-distributed application. To speed up the migration process, many existing business components should be reused. Also, to exploit the benefit of transaction management and security checking, a POJO-based business component might need to be wrapped into a Session EJB. RMA allows the developer to pick a POJO class from the file system or a JAR file and create a wrapper EJB class. The wrapper EJB class has methods with the same signatures as those in the POJO class. The POJO class and required JAR file are also copied into the workspace by RMA.

RMA supports a wizard to assemble several EJBs into a *session façade*. RMA queries the workspace to extract all defined EJBs for the new façade. The developer can pick a subset of the EJBs. For each EJB, the developer can further decide which methods they want to expose in the *session façade*. In the case of naming conflicts, the developer can rename methods for the façade. Because the *session façade* follows a common derivable delegation constraint on its methods, the generated *session façade* has almost complete code. The generated method in the *session façade* delegates the requests to the corresponding method in the hidden EJBs. The method body tests the validity of the EJB handle and performs the delegation. Because the *session façade* is an EJB itself, it can also be aggregated by another *session façade* to create another layer of abstraction. The *session façade* is implicitly related to the *service locator*, which is used to locate the hidden EJBs. Figure 4.11 shows an example *session façade*. The only non-derivable constraints involve parameters to construct the hidden EJBs, which are application-dependent and left to the developer.

The methods that perform delegation to other business components are a derivable constraint. Any additional functionality, such as access control or higher-level methods, is a non-derivable constraint that is left for the developer to implement.

For each EJB generated, there are some additional actions that need to be performed, such as the generation of home and business interfaces and XML descriptors as well as updating the global *service locator*. The access interfaces define how EJBs are created and invoked. The descriptor file contains the deployment information for this EJB. A *service locator* is updated to contain

```
package explorer.admin;
import javax.ejb.*;
import java.rmi.*;
public class AdminBean implements SessionBean {
    //initialize the facaded beans
    public void ejbCreate() {
        login = new explorer.admin.LoginProxy(
        /*EJB-TODO: please insert constructor parameters if necessary*/
        );
        changeclientinfo = new explorer.admin.ChangeClientInfoProxy(
        /*EJB-TODO: please insert constructor parameters if necessary*/
        );
        register = new explorer.admin.RegisterProxy(
        /*EJB-TODO: please insert constructor parameters if necessary*/
        );
        }
        .....
        public void setSessionContext(SessionContext sc) {
            this.sc = sc;
        }
        //perform delegation
        public boolean doLogin(explorer.dao.ClientTableDAOTO p0) {
            if (login == null) {
                login = new explorer.admin.LoginProxy(
                /*EJB-TODO: please insert constructor parameters if necessary*/
                );
            }
            boolean result = false;
            try {
                result = login.doLogin(p0);
            } catch (Exception e) {
                e.printStackTrace();
            }
        }
    }
```

Figure 4.11: Sample Code for the Session Façade

the information about the newly generated EJB. We will examine these actions in more detail in Chapter 5. To complete the EJB, the developer implements the stub methods and inserts application-specific business methods.

Creating Business Delegates

The relationship between the *session façade* and the *business delegate* is implicit. There is always a one-to-one correspondence between the two patterns. The *business delegate* is automatically generated when a *session façade* is created through an RMA wizard. The methods in the *business delegate* also have a one-to-one correspondence with the methods in the *session façade*.

According to constraints defined in Section 4.1.5, the corresponding methods in the *business delegate* and *session façade* have the same signature. RMA is responsible for maintaining the consistency between the methods in the *session façade* and the *business delegate*. The addition, modification, and removal of public methods in the *session façade* is automatically reflected in the *business delegate*. In other words, RMA automatically enforces the relationship constraint between the *session façade* and the *business delegate*.

The generated code for the *business delegate* methods delegates client requests to the corresponding *session façade* method. The method body of the delegate methods in the *business delegate* is surrounded by a try-catch clause, which is a static constraint. Exceptions related to the remote connections are caught and handled. The *service locator* is another important participant in this relationship. The *service locator* is implicitly associated with the *business delegate*. The constructor of the *business delegate* initializes the handle of the *session façade*. The *service locator* is first invoked to locate the home object of the *session façade*, then the create method on the *session façade*'s home object is invoked. These are all static or derivable constraints, and as a result the business delegate is complete without any user code. Figure 4.12 shows an example *business delegate*.

4.2.2 Writing Application Code

RMA generates the code for the control flow and architecture based on relationships extracted from the J2EE framework. The developers are responsible for writing the code fulfilling the *non-derivable* constraints that remain. RMA provides a task-list window in the Eclipse IDE to guide

```
package explorer.admin;
import java.rmi.*;
public class AdminProxy {
    //using service locator to access find session facade
    public AdminProxy() {
        try {
            proxy =
                org
                    .locator
                    .ServiceLocator
                    .getInstance()
                    .get_explorer_admin_AdminHome()
                    .create();
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
    //perform delegation
    public boolean doLogin(explorer.dao.ClientTableDAOTO p0) {
        try {
            boolean result = false;
            result = proxy.doLogin(p0);
            return result;
        } catch (RemoteException e) {
            e.printStackTrace();
        }
        return false;
    }
    .......
}
```

Figure 4.12: Sample Code for the Business Delegate

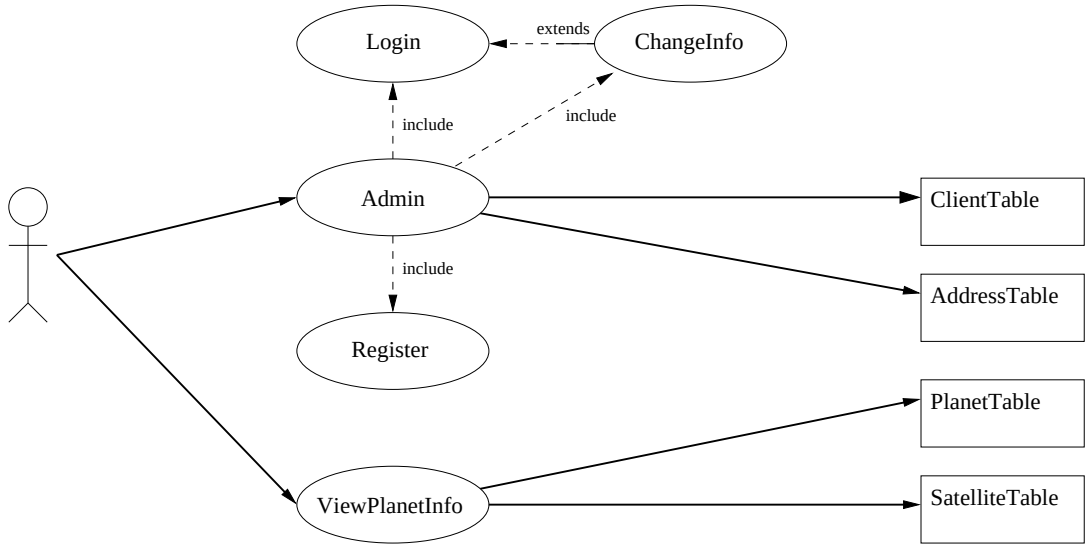


Figure 4.13: Use Cases for Sample Application

the developers through these tasks. Then, the developers input any application-specific logic into the generated code to complete the application logic.

4.3 A Sample Application

In order to demonstrate how RMA helps incrementally build up a web application and hides the deployment logic from application code, we present a simple web application to lay the ground for further discussion.

Our sample code models an online astronomer's club, as shown in Figure 4.13. It consists of four simple use cases: Login, Register, ChangeInfo and ViewContent. This example is simple but it captures some essential J2EE patterns. By analysis, we can quickly identity four database tables: Client, Address, Planet and Satellite. The Login use case accesses the Client table for password verification. The Register and ChangeInfo use cases need to access both the Client and Address tables, while the ViewContent use case displays the contents of the Planet and Satellite tables. Login, Register, and ChangeInfo are administrative use cases. Thus, we should provide a centralized access point for the administrative beans. Moreover, both ChangeInfo and Register need to read and write to two DAOs, but we would prefer a logical model that appears as one database table. In the case of ViewPlanetInfo, the amount of data returned could be large, so we

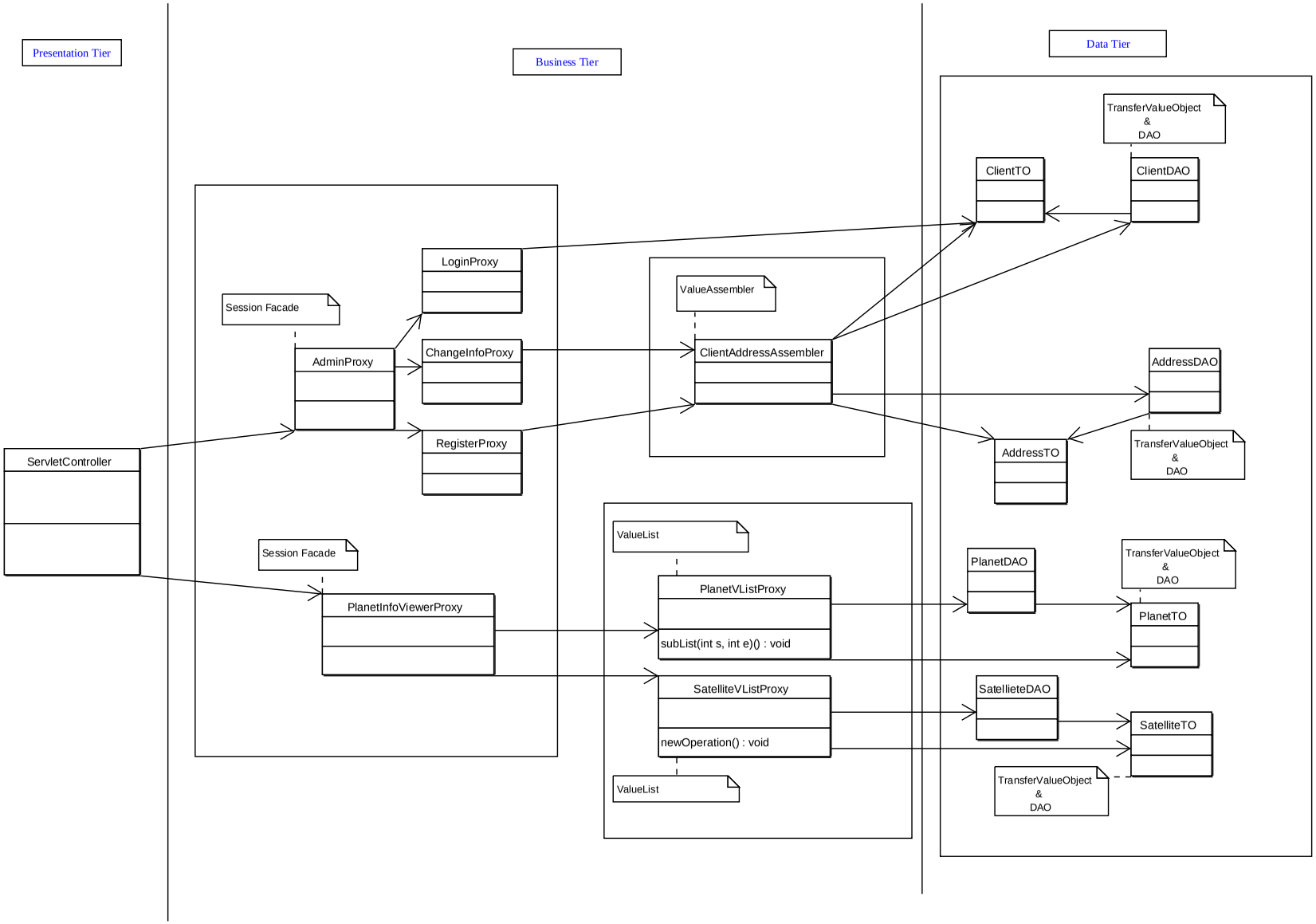


Figure 4.14: Simplified Architecture for Sample Application

would prefer that content be delivered only when needed in order to reduce network overhead.

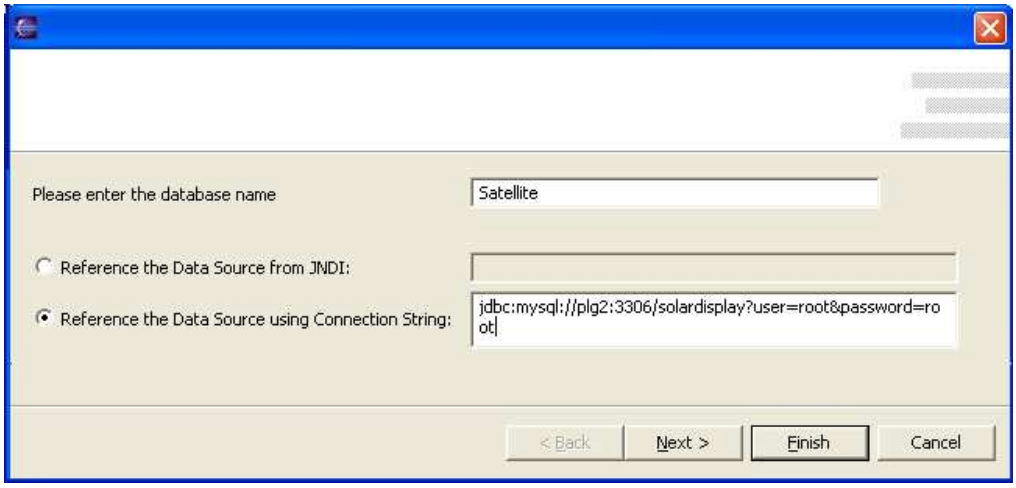
4.3.1 Assembling a Sample Application

Now, we show how to use RMA to create our sample application. Figure 4.14 shows the simplified class diagram of our sample application. Our process starts by constructing DAOs for each database table. We construct four DAOs: ClientTableDAO, AddressTableDAO, PlanetTableDAO, and SatelliteTableDAO, for our sample application. For each of the DAOs, RMA automatically creates one *transfer value object* class and one primary key class. RMA prompts the developers for information about the database connection parameters, such as the JNDI name of the database, the connection string, and the JDBC library, as shown in Figure 4.15(a). RMA then uses this information to produce code that connects the application to the database. Developers are also prompted to enter the fields of the modeled database table, as shown in Figure 4.15(b). This information is used to construct the primary key object as well as the *transfer value object* for this *data access object*. Finally, to make a DAO complete, the developers need to insert appropriate SQL query statements into the generated code.

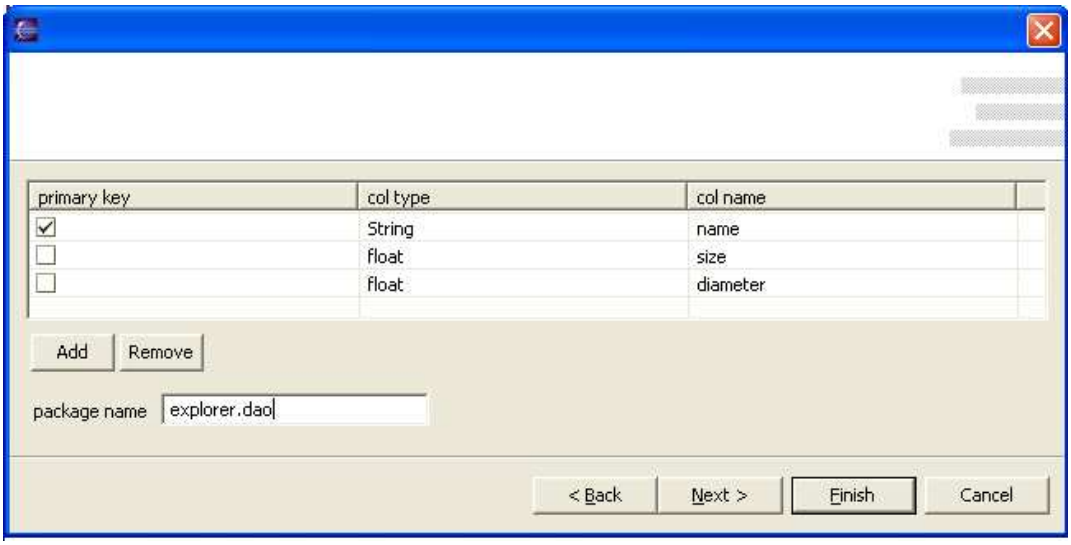
As shown in Figure 4.13, the sample application contains two main use cases in the business tier, Admin and ViewPlanetInfo. The Admin use case contains three smaller use cases: Login, Register, and ChangeInfo. Login performs a simple validation of the submitted client id and matches the password against the data stored in the client table. RMA provides a simple wizard to generate skeleton code for a Session EJB. We need to write up business methods for accessing the ClientTableDAO to validate the password.

The Register use case makes use of two DAOs: ClientTableDAO and AddressTableDAO. The application model of this use case consists of data from multiple database tables, so we apply the *transfer object assembler* pattern to make the two tables appear as one. This is an example where the application model is different than the underlying data model. In the *transfer object assembler* wizard of RMA, a list of *transfer object objects* that exist in the application domain are presented. Next, the developer selects the *transfer objects* to aggregate, as shown in Figure 4.16(a). In our sample application, ClientTableDAOTO and AddressTableDAOTO are chosen.

Having selected the *transfer objects*, the next step is to select the method in the owner DAO that creates and updates each *transfer object*. Figure 4.16(b) shows the wizard page for generating

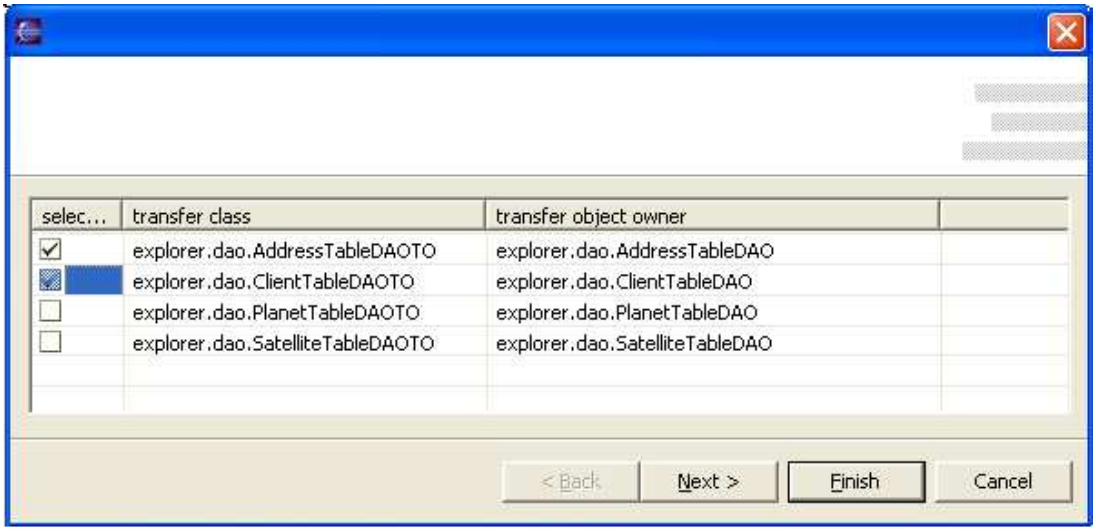


(a) Wizard Page for Generating DAO-1: Specifying the connection parameters

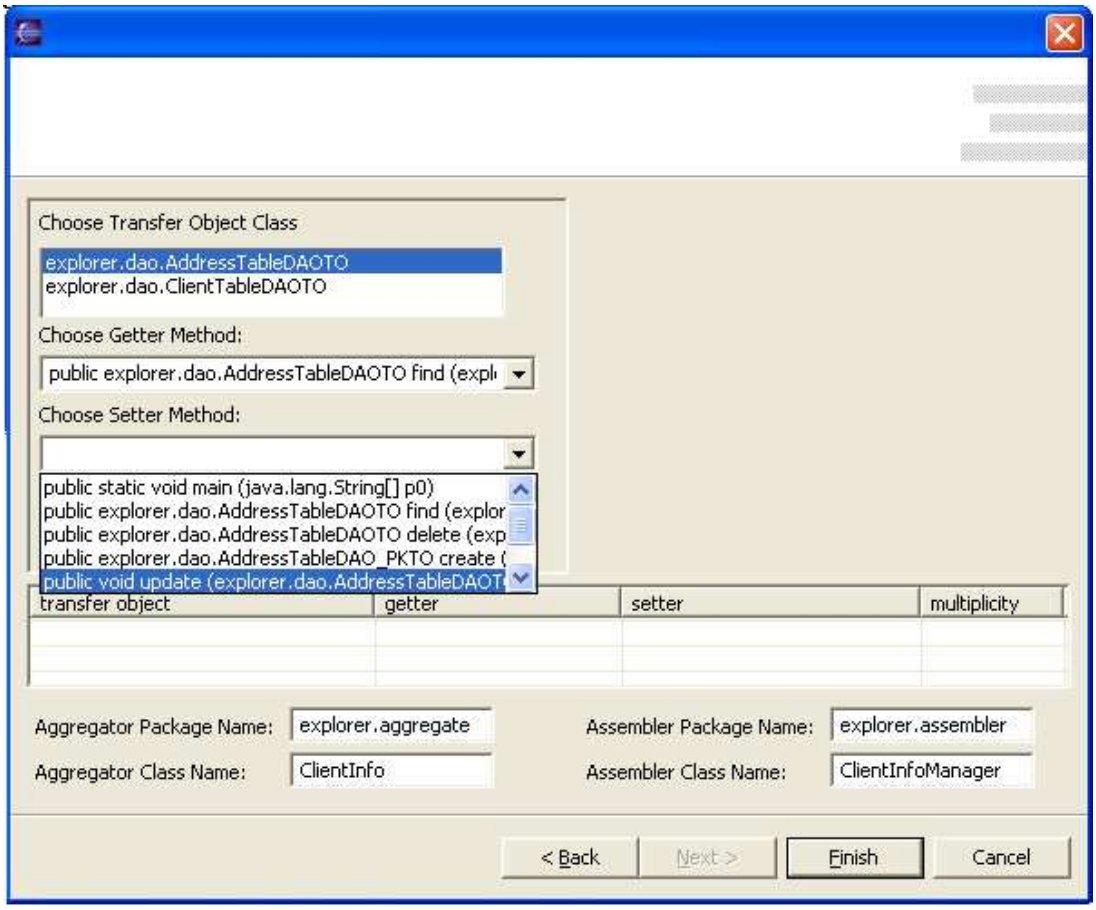


(b) Wizard Page for Generating DAO-2: Specifying the connection parameters

Figure 4.15: Wizard Pages for Generating DAO



(a) Wizard Page for Generating Assembler-1: Selecting Transfer Value Objects to assemble



(b) Wizard Page for Generating Assembler-2: Specifying the Getter and Setter methods of Transfer Value Objects

Figure 4.16: Wizard Pages for Generating the Transfer Object Assembler

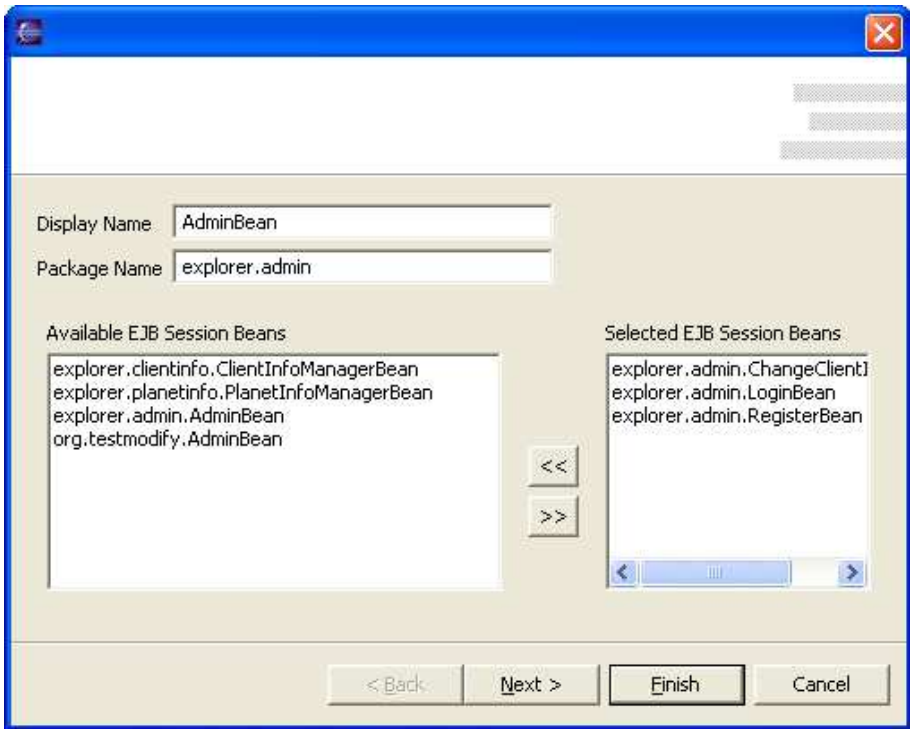
the *transfer object assembler*. These methods are used by the *transfer object assembler* to construct the aggregator. The end product generated by our development tool wizard is a *transfer object assembler*, which centralizes the retrieval and update of the application model while hiding away the underlying fine-grained data models. Along with each *transfer object assembler* class, an aggregator class that contains all of the *transfer value objects* managed by this *transfer object assembler* is produced, which is a *transfer value object* itself. No user code is needed for the *transfer object assembler* to add new client information to the database. We also generate an EJB for the Register use case, in which we write business methods that access the generated *transfer object assembler*.

The ChangeInfo use case is implemented in a similar fashion to the Register use case. In fact, it uses the *transfer object assembler* created for the Register use case. The only difference is that the business methods validate the client id and password before updating information.

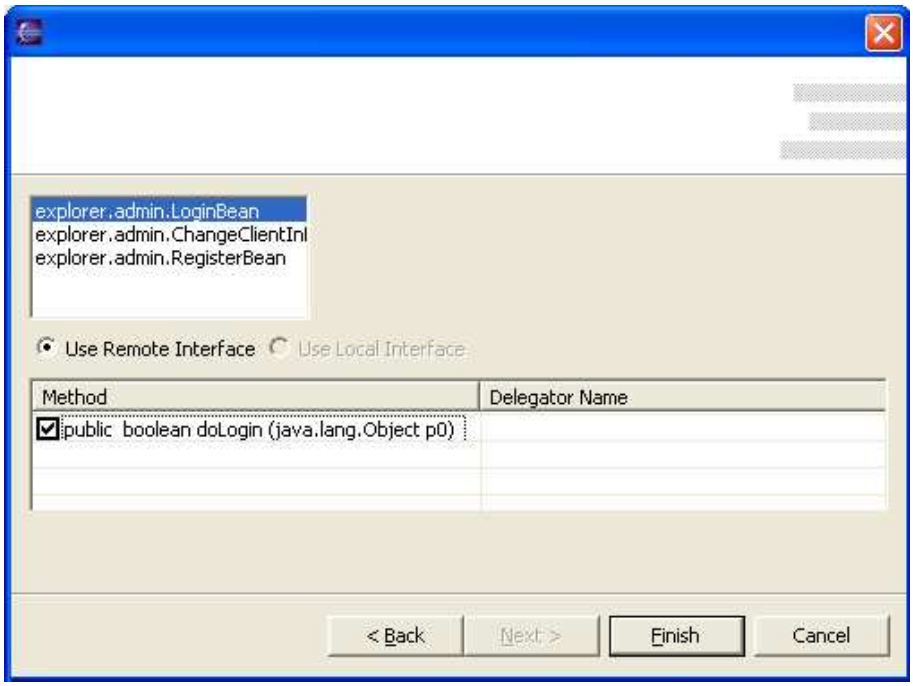
It would be beneficial to centralize access to the three administrative business components (Login, Register, and ChangeInfo). This centralization simplifies the interface between the presentation and business tiers and helps increase the granulity of communication. To do this, we apply the *session façade* pattern to create the Admin bean. RMA provides a *session façade* wizard that displays all beans within the application domain. Next, the developer selects the beans that will be encapsulated by the façade, as shown in Figure 4.17(a). For our application, we choose the three desired beans from the list of beans.

Once the set of beans is selected, the developer selects the business methods that will be accessible using the *session façade*. We pick `doLogin`, `register` and `changeInfo` as the business methods from each bean to expose. The generated code contains proper delegation from the *session façade* to methods of the façaded beans without the need for user code. Moreover, method names can be changed to resolve any conflicts, as shown in Figure 4.17(b).

For the ViewPlanetInfo use case, the business component needs to access two DAOs: PlanetTableDAO and SatelliteTableDAO. In the presentation tier, we decided to display one planet and all of its satellites in one page. Thus, it makes sense to cache all planet information on the server side and return them one by one as the client requests them. For example, if the client abandons the viewing half way through the list of planets, it would be wasteful to send the whole result set to the client. As a result, we build up the *value list handler*s for both SatelliteTableDAO and PlanetTableDAO. Each time a client sends a request, our business component returns one planet

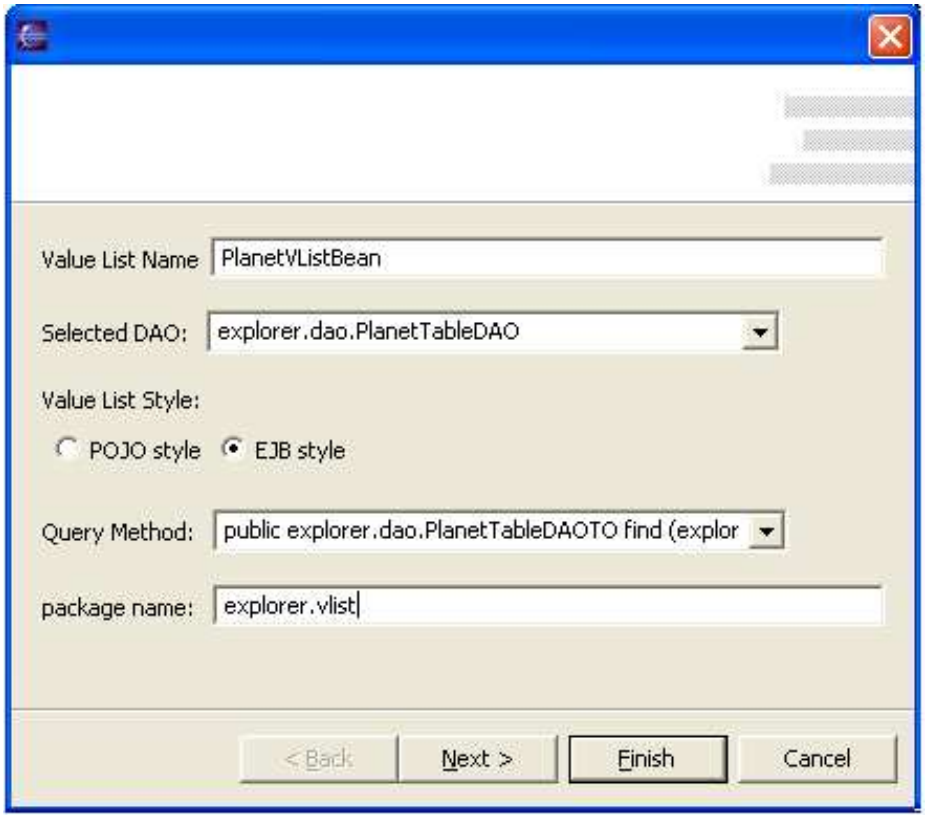


(a) Wizard Page for Generating Session Facade-1: Selecting the EJBs to be facaded

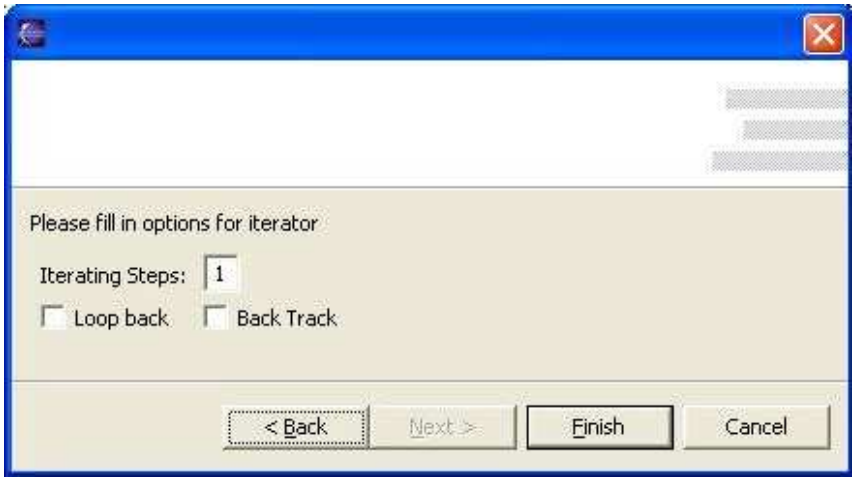


(b) Wizard Page for Generating Session Facade-2: Selecting the methods in the selected EJBs to expose

Figure 4.17: Wizard Pages for Generating Session Facade



(a) Wizard Page for Generating Value List Handler-1: Selecting Data Access Object whose Transfer Value Object will be cached



(b) Wizard Page for Generating Value List Handler-2: Setting Iterator parameters

Figure 4.18: Wizard Page for Generating Value List Handler

transfer value object and all of the satellite *transfer value object*s associated with that planet. This is a one-to-many relationship. Although we return all satellites of each planet back to the user each time, having a *value list handler* for satellites might still be reasonable in case the list is too long in some cases and we decide we need to cache them. In the *value list handler* wizard, we pick PlanetTableDAO as the *data access object*, whose *transfer value object* will be cached, as shown in Figure 4.18(a). Then, we pick the method that creates PlanetTableDAOTO objects from its owner class, PlanetTableDAO. The wizard generates a complete *value list handler* ready for use. After that, RMA solicits the parameters to customize the generated Iterator, as shown in Figure 4.18(b). The *value list handler* of SatelliteTableDAOTO is generated in the same fashion.

4.3.2 Discussion

The whole application development process takes an incremental bottom-up approach. Thus when developers create a pattern, they already have all lower tier components ready to use for assembly, as is the case with the *transfer object assembler* and *session façade*. This feature helps RMA to generate the method-to-method associations in the *transfer object assembler*, *value list handler*, and *session façade* patterns. In the case of the *transfer object assembler* and *value list handler* patterns, developers only need to write code to initialize the owner of the *transfer value object* if they want to use non-default constructors. This code is clearly marked using the task view feature in Eclipse. For the *session façade* pattern, the code is complete if delegation is the only purpose of that *session façade*. A *business delegate* is automatically generated for every *session façade*. Considering that the code for the *transfer value object* and *service locator* is always complete, in four of the five patterns used in our sample application, we generated complete or almost complete pattern implementation code. This leaves the application-specific code for the developer, rather than complex distributed architectural code. Thus, developer effort is focused on the application domain, where their expertise lies.

4.4 Summary

A J2EE application can be created by assembling business components according to the known relationships extracted from the framework. A relationship is made up of a set of pattern or non-pattern-based components, each playing a specific role. The role in a relationship can be a composite

role, which means it is also made up of a relationship. Each role has a set of properties or constraints that need to be satisfied in order to fulfill its role in the relationship. Moreover, the constraints differ in nature. Static and derivable constraints can be programmatically implemented, while non-derivable constraints need code provided by the programmer. RMA ensures the generated pattern and relationship code follows the framework specification in Sun's J2EE blueprint. By incrementally building the application, developers have complete knowledge of the code that is generated. This allows the code to be more easily understood and further modified. As a result of using RMA, developers not only save development time, but also ensure that their application has a sound architecture.

Chapter 5

Isolation of Deployment Logic

The J2EE EJB architecture is based on Java Remote Method Invocation (RMI). As a result, EJBs require interfaces to export methods to remote clients, similar to the Interface Definition Languages in other RMI solutions. Unfortunately, the interfaces have several characteristics that are counter-intuitive and make writing them error prone. Most of these problems revolve around the fact that the EJB bean class does not implement any of these extra interfaces. This has several ramifications. First, it can be difficult for developers new to J2EE programming to understand the need or relationship between an EJB bean class and its interfaces since there is no explicit association. Second, since the bean class does not implement the interfaces, we cannot rely on compile-time checking to be sure the interfaces are consistent with the implementation. As a result, the obvious solution is for the bean class to implement the interfaces, but this is only possible for the local business interface. The remote interfaces add the checked exception `RemoteException` to the list of exceptions each method can throw, so any class implementing these interfaces must also add it. The home interfaces cannot be implemented by the bean class because the method names do not match. The bean class implements a set of methods with the name `ejbCreate` with different initialization arguments, where the home interfaces export the same set of methods renamed `create`. The translation between these methods is performed by the J2EE container in which the bean executes. Developers must be aware of this mapping and be sure to use the correct names for the methods while still ensuring the remainder of the signatures match. This last characteristic can be particularly problematic.

Accessing EJB objects is even more obscure. Developers have to go through several steps of

```
private EJBHome getRemoteHome(String jndiHomeName, Class homeClassName) {
    EJBHome remoteHome = null;
    try {
        //1. check cache for Remote Object
        if (cache.containsKey(jndiHomeName)) {
            remoteHome = (EJBHome) cache.get(jndiHomeName);
        } else {
            //2. perform lookup
            Object objref = this.initialContext.lookup(jndiHomeName);
            //3. downcast
            Object obj = PortableRemoteObject.narrow(objref, homeClassName);
            remoteHome = (EJBHome) obj;
            //4. caching
            cache.put(jndiHomeName, remoteHome);-
            }
        } catch (NamingException nex) {
            nex.printStackTrace();
        } catch (Exception e) {
            e.printStackTrace();
        }
        //5. return the result
        return remoteHome;
    }
```

Figure 5.1: Code for Accessing an EJB

lookups to get a handle to an object. Figure 5.1 shows a snippet of code that details how an EJB object is accessed using a typical *service locator*.

Remembering a large set of JNDI and interfaces names is by no mean an easy task. Specifying the JNDI name of each bean, the JNDI names of beans it references as well as the interface information for all of these beans in the deployment descriptor is even more cumbersome. In RMA, our approach hides all of the interface definition/access as well as JNDI referencing from application code. In other words, developers can create and access an EJB in the same way as any POJO object. The deployment descriptors are generated automatically using relationship information that is either derived from pattern relationships or provided by the developer.

5.1 Removing Deployment Logic at the Code Level

To remove deployment logic at the code level, RMA has to hide the interface generation and name space lookup from the application code. This section describes our solution.

5.1.1 Generating Access Interfaces

First, let us examine how the access interfaces are hidden. RMA produces an EJB either by creating a new EJB class or converting an existing POJO. The generated EJB class contains default implementations of necessary EJB methods such as `ejbCreate` and `ejbPassivate`. Developers are responsible for customizing the default implementation of these methods and writing business methods. The method signatures of the `ejbCreate` methods are needed for creating home interfaces, and the method signatures of the business methods are needed for generating the business interfaces. The signature of a method can be extracted using either reflection or XDoclet [27]. XDoclet is a tag-based approach, similar to Javadoc [7]. It processes a Java class, and, whenever a recognized tag is encountered, it executes the pre-defined tasks associated with that tag. Apache XDoclet comes with a set of pre-implemented tags and associated tasks that are specifically designed for J2EE applications. For example, a method has to be decorated either with "@home-method" or "@business-method" in order to allow XDoclet to determine its purpose. XDoclet is responsible for extracting the method signatures of the methods and generating its interface counterpart in the appropriate interfaces. Developers also need to specify which access interfaces are needed, either local or remote, as a tag associated with the class.

The main drawback of the tag-based approach is that it needs too much user intervention. For every method created, developers need to write additional tags. This is rather cumbersome as the application grows larger, and embedding deployment information inside the application code is rather inelegant. Furthermore, the XDoclet tags are identical to ordinary Javadoc tags. Mixing the tags for generating interfaces and the tags for normal documentation together in the same file may cause maintainability problems, because the XDoclet tags may be mistakenly deleted as developers revise their program comments.

RMA tackles interface creation using Java's reflection technology. At any point after the bean class has been created, developers can invoke an interface generation wizard to specify the types of access (local or remote) that this EJB supports. RMA uses reflection to process the EJB class

to extract the signatures of the methods defined in the bean class. The methods are grouped using their names. Because all EJBs extend the same common abstract class, they all implement the same set of abstract methods to satisfy the inheritance requirements. Thus, we can filter out most of those methods whose purpose is to fulfill the subclass' contract to the parent class, except those named `ejbCreate`. All of the `ejbCreate` methods are parsed for their argument signatures. The gathered data are used to produce the `create` methods in the home interface. A `create` method has the same parameters as its `ejbCreate` counterpart, but a different name, and throws appropriate exceptions according to the type of interface to which it belongs. The remaining methods are developer-defined business methods. RMA extracts the signatures of those methods and produces the business interfaces. Each method in the business interface has the same signature as its counterpart in the bean class except for the addition of remote exceptions in the remote interface. The names of the generated access interfaces follow the naming convention defined by Sun [4] to simplify class management. RMA also monitors the EJB bean class for changes using JDT listeners provided by Eclipse. As a result, any addition, removal or modification of a method is captured by RMA, which refreshes the generated interfaces to ensure consistency between the interfaces and bean classes. The only potential drawback is that this solution automatically includes all public methods of the EJB bean class in the business interfaces, though this is the common case.

The creation and update of the access interface involves no tag annotations. Thus, compared to the XDoclet approach, RMA allows developers to simply write their program while automatically generating interfaces at the same time. More importantly, RMA provides a higher level of abstraction than XDoclet. Because RMA prompts developers for the access types instead of interface types, this leaves the developers with an impression that they have just set a property and they are completely unaware of the interface generation process. Furthermore, there are no references to those interfaces in the EJB class, while the "@home-method" and "@business-method" tags expose the abstraction.

So far, RMA has hidden the creation and update of interfaces, but the interfaces still need to be referenced in the instantiation of EJBs as shown in Figure 5.1. RMA fixes this problem by using a refined version of the *service locator* and proxies that we will discuss next.

5.1.2 Refined Service Locator

In Section 3.4, we discussed using the *service locator* to hide JNDI lookup and caching for EJB references. In that implementation, shown in Figure 5.1, the developers need to supply a JNDI name and the class representing the EJB home interface as the parameters to the *service locator*'s lookup method. The returned value of a lookup invocation is a generic EJB home object. Developers need to further cast it down to the appropriate type before using it to get a handle by invoking one of the `create` methods in the home interface. In other words, the developers need to be aware of the JNDI name and the EJB home interface before they can access an EJB object. Yet, the presence of the JNDI names in the business components violates our objective of separating the distributed nature of the J2EE application from application code. Furthermore, if developers create a new EJB, they need to assign a new JNDI name to the EJB before it can be referenced by other EJBs. Assigning the JNDI names is clearly another task of a distributed nature that should be removed from the application developer's list of responsibilities. We also want to continue to hide the home interface from the developers. It is constructed automatically from the bean class, and we do not want to expose it in the lookup service. In RMA, we propose a refined *service locator* which we believe can deliver a better separation of distributed code from application code than the traditional *service locator*.

The goal of our refined *service locator* is to hide the assignment and use of JNDI names. We will address hiding the home interface later. Clearly, we have to automatically generate a JNDI name for every EJB created in the workspace. Then, we have to store the generated JNDI names and manage them. So far, we have taken a rather simple approach to generating the JNDI names. For each EJB bean class generated in the workspace, we take its fully qualified class name and replace "." with "_". For example, an EJB with a fully qualified name of "org.club.astronomy.Client" has its JNDI name generated as "org_club_astronomy_Client_jndi". RMA can be modified to construct the JNDI names in more complex fashion, such as appending a random number, to reduce the risk of naming conflicts.

Because the developers no longer supply the target EJB's JNDI names and home class to the *service locator*'s lookup method, the logical conclusion is the *service locator* should store this information. There are two approaches for storing this information in the *service locator*: realMethod's per-EJB approach [6] and our singleton approach. In the first approach, a new *service locator* is

created for each EJB. The JNDI name and EJB home interface are hard-coded into the lookup methods of that *service locator*. Developers use different *service locator*s in the application code to retrieve the EJB home object of different EJBs. Because the lookup operation in each *service locator* is dedicated to a single EJB, the downcast from the generic EJB home object to the specific one can be performed in the *service locator* as well. There are shortcomings to this approach. In particular, it violates the constraints for the *service locator* defined in Sun's blueprint, which recommends the *service locator* be a singleton in each JVM. As the application gets more complicated, the number of *service locator*s in the workspace might increase and become hard to manage.

RMA takes advantage of the source code manipulation facilities offered by Eclipse to update the *service locator*. Eclipse provides APIs to parse a Java source file into a Document Object Model (DOM) tree and manipulate the tree by appending nodes to it. RMA monitors the workspace and, for every EJB created, a specific lookup method for that EJB is inserted into the DOM tree of the *service locator*. The JNDI name and name of the EJB home interface are hard-coded in each method. This information is passed into the generic lookup method shown in Figure 5.1 to retrieve the EJB home object. The specific lookup method performs the downcast on the generic EJB home object before passing it back to the client. With the flexibility offered by Eclipse, we insert lookup methods instead of classes. By doing so, we adhere to the constraints defined in Sun's blueprint. We also believe that methods are easier to manage than classes because most Java IDEs, such as Eclipse and JBuilder, provide popup or auto-fill facilities for completing method names. Thus, as long as we follow the conventions for naming the lookup methods, developers can easily pick out needed method from the popup list. Figure 5.2 and Figure 5.3 show the implementation of our refined *service locator*.

RMA's *service locator* removes JNDI lookups from the developers. Yet developers still need to use the lookup methods to retrieve the `EJBHome` object and create a handle to the EJBs. As a result, they are still aware of, and must use, the home interface. Since this interface is generated automatically, we would prefer not to expose it. It would be better if developers could use EJBs just like any other POJO classes without writing any special code to do with name lookups or obtaining handles. This is solved using proxies as explained in the next section.

```
public class ServiceLocator {
    //lookup method dedicated to PlanetInfoManager assembler
    public explorer
        .planetinfo
        .PlanetInfoManagerHome get_explorer_planetinfo_PlanetInfoManagerHome() {
        return (explorer.planetinfo.PlanetInfoManagerHome) getRemoteHome(
            "explorer_planetinfo_PlanetInfoManagerBean_jndi",
            explorer.planetinfo.PlanetInfoManagerHome.class);
    }

    //lookup method dedicated to ShowPlantInfo value list handler
    public explorer
        .planetinfo
        .ShowPlanetInfoHome get_explorer_planetinfo_ShowPlanetInfoHome() {
        return (explorer.planetinfo.ShowPlanetInfoHome) getRemoteHome(
            "explorer_planetinfo_ShowPlanetInfoBean_jndi",
            explorer.planetinfo.ShowPlanetInfoHome.class);
    }

    //generic lookup method
    private EJBHome getRemoteHome(String jndiHomeName, Class homeClassName) {
        EJBHome remoteHome = null;
        try {
            if (cache.containsKey(jndiHomeName)) {
                remoteHome = (EJBHome) cache.get(jndiHomeName);
            } else {
                Object objref = initialContext.lookup(jndiHomeName);
                Object obj = PortableRemoteObject.narrow(objref, homeClassName);
                remoteHome = (EJBHome) obj;
                cache.put(jndiHomeName, remoteHome);
            }
        } catch (NamingException nex) {
            nex.printStackTrace();
        } catch (Exception e) {
            e.printStackTrace();
        }
        return remoteHome;
    }
    //continued in next page
```

Figure 5.2: Code for Refined Service Locator-1

```
    private InitialContext initialContext;
    private static ServiceLocator _instance;
    private Hashtable cache; static {
        try {
            _instance = new ServiceLocator();
        } catch (Exception e) {
            System.out.println(e);
            e.printStackTrace();
        }
    }
    //singleton private constructor
    private ServiceLocator() {
        try {
            initialContext = new InitialContext();
            cache = Collections.synchronizedMap(new HashMap());
        } catch (NamingException ne) {
            ne.printStackTrace();
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
    .....
}
```

Figure 5.3: Code for Refined Service Locator-2

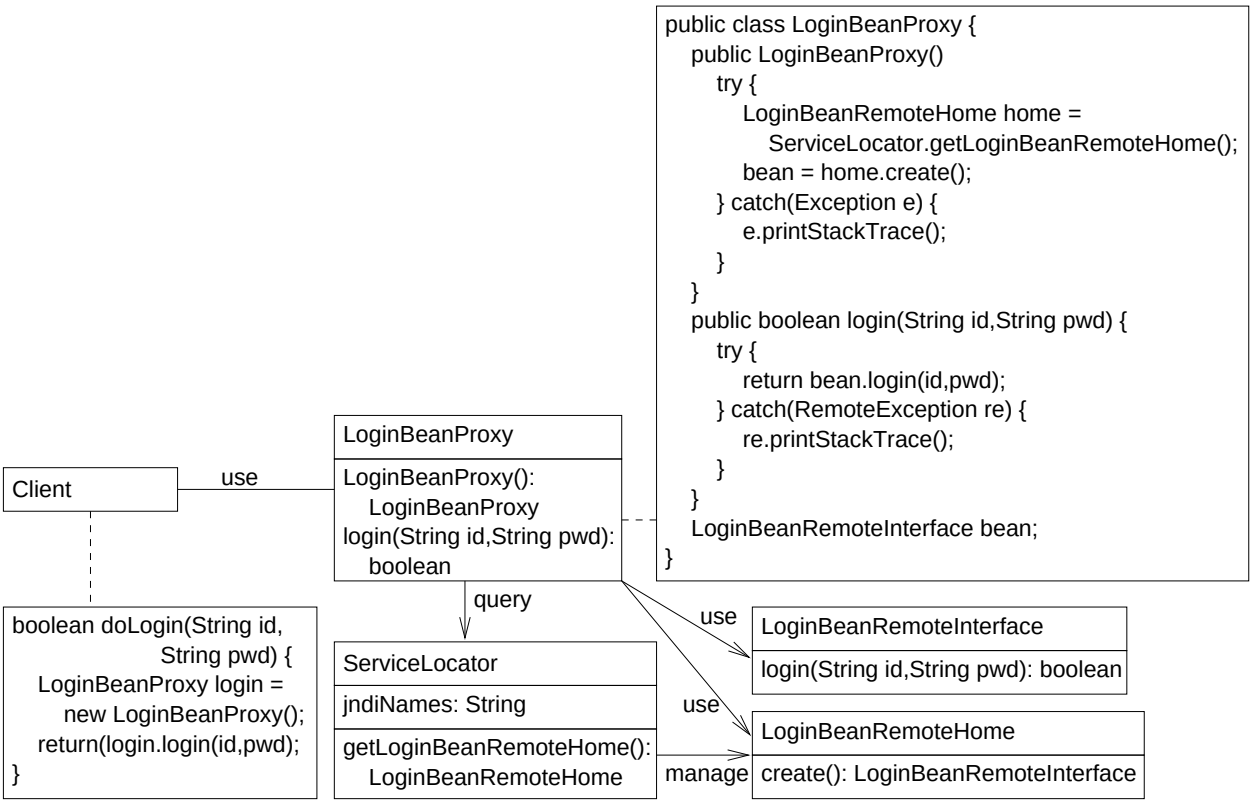


Figure 5.4: Class Diagram for EJB Proxy

5.1.3 Proxy for EJBs

The initialization of EJB objects requires three steps: locating the home object using the JNDI name, downcasting the generic EJB home object to the desired type, and creating the EJB object handle using the home object. The first and second steps are encapsulated into our refined *service locator*. As a result, developers still need to complete the last step to retrieve a handle to the EJB object. For the third step, a handle to the EJB object is created by calling one of the `create` methods on the EJB home object, instead of using a `new` keyword as with a POJO. The differences between using an EJB object and a POJO object have no doubt increased the learning curve of new J2EE programmers. More importantly, the differences have exposed the distributed nature of J2EE applications to the programmer. Our solution to this problem is to encapsulate all three steps into one by creating a proxy object for each EJB.

Figure 5.4 shows the class diagram for our proxy. A proxy is automatically created by RMA when an EJB is created in the workspace. Moreover, a proxy has an almost identical structure

as the *business delegate*. Thus, for every `create` method in the EJB home object, RMA creates a constructor in the proxy with the same parameter signature. Inside these constructors, the appropriate lookup method in the *service locator* is called to retrieve the EJB home object. Then, the `create` method of that EJB home object is called with the constructor parameters to create a handle to the bean object. As a result, the proxy covers all of the ways of initializing an EJB object allowed by the EJB home interface. For every method defined in the EJB bean class, a delegating method is created to delegate the work to the EJB object using the retrieved handle. Consequently, when developers want to reference an EJB in the code, they can create a proxy for that EJB using the `new` keyword followed by the appropriate constructor call. Every invocation of a method on the EJB object is done by calling the method with the same signature on the proxy. Thus, by combining the three step initialization into a simple constructor call for the proxy, the proxy has achieved its goal of giving developers the impression of using a POJO while actually accessing an EJB.

The proxy classes are used in place of EJB objects in the application code. For all of the EJB classes generated from pattern assembly, such as *session façades* or *transfer object assemblers*, RMA generates their proxy classes automatically. RMA can also generate proxy and *service locator* code for legacy EJB objects imported from other applications. RMA maintains consistency between an EJB bean class and its proxy. Every modification of the bean class is automatically reflected in the proxy class.

The proxy approach is very similar to that of the *business delegate* pattern we discussed in Section 3.7. The *business delegate* is only intended to be used between the presentation tier and the business tier, while the proxy can be used in the application code everywhere EJB references are needed. It is fair to say that our proxy approach expands the application domain of the *business delegate*. Furthermore, RMA automatically creates and manages the necessary code.

5.1.4 Discussion

The generation of access interfaces, the refined *service locator*, and EJB proxies are our three-pronged approach to removing distributed system code from J2EE application code. By generating the interfaces, we removed the RPC-style interface definition. Additionally, using the refined *service locator*, we removed complicated name space management and access for developers. The

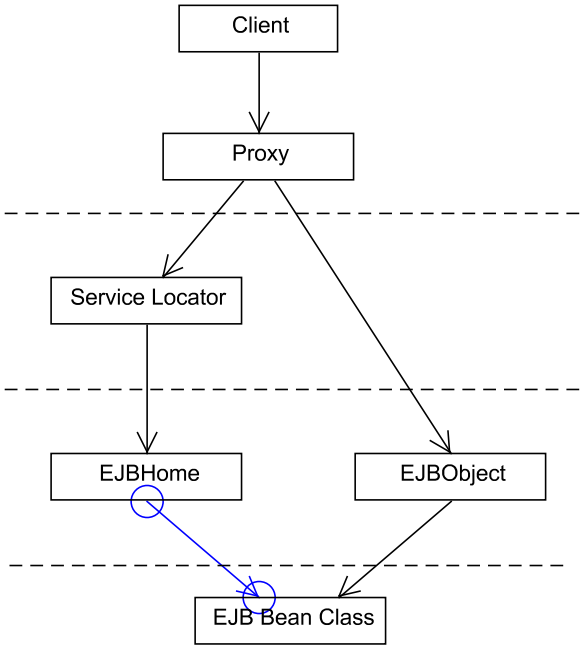


Figure 5.5: Layers for Generated Code of Hiding Distributed Computing

proxy provides a POJO reflection of an EJB that abstracts away the complicated *service locator* manipulation and EJB initialization from the developer.

The code generated by RMA forms a layered structure, shown in Figure 5.5. The layered structure reflects the dependencies among the generated code. RMA maintains the consistency of the generated code by refreshing the code according to the dependencies. AT the bottom of the hierarchy is the EJB bean class. Above the EJB bean class are the access interfaces. At the next level up, the *service locator* manipulates the home interface. The proxy forms the upper-most layer that uses the *service locator* and business interface for distributed programming. Unlike OptimalJ, in which changes are propagated from the top layer down to the bottom, RMA supports propagation of changes from the bottom layer up. Any addition or removal of methods in an EJB bean class affects the upper layer access interfaces and proxy class. Moreover, the creation of a bean class also affects the intermediate *service locator*. RMA keeps track of changes in the lower layer and automatically refreshes the affected upper level classes. In a black box view, developers provide a bean class to RMA as input and get a proxy class as output. Thus, all of the transformations in between the two ends of the black box are completely hidden from the developers.

Another important point to note is that patterns are not only useful in generating sound archi-

tectural code but also in hiding the deployment logic. The collaboration of the *business-delegate*-style proxy and the *service locator* abstract away all EJB references from the application code.

So far, we have separated the distributed system code from the application code. We must now consider another important aspect of J2EE application development: the creation of deployment descriptors. The deployment descriptor needs information such as the name of access interfaces to EJBs and the JNDI names of EJBs. Without a proper way to generate deployment descriptors automatically, all of the distributed information that we have tried so hard to hide at the code level will have to be exposed to the developers during deployment.

5.2 Generating Deployment Files

As discussed in Chapter 2, a J2EE application needs to be packed into an EAR file before it can be deployed to the container. An EAR file contains two types of data: class files that implement an application and the deployment descriptors. Because creating a deployable EAR is such a tedious and error-prone task, most current IDEs for J2EE provide tools to help generate this file. However, the differences lie in how each IDE handles the deployment descriptor generation. Most of them need some intervention from the developers to create the descriptor. For example, JBuilder solicits the JNDI names for each EJB from developer. Other IDEs follow the XDoclet approach and require the developers to specify the EJB references as tags in the code. Our goal is to hide the deployment descriptors from developers completely, just as we have hidden the code for distributed programming from the application code.

Before going into the details of how each descriptor file is generated, we first present some general ideas on how RMA handles the generation of deployment descriptors. RMA maintains a list of program models that represent the different XML descriptor files. RMA collects the necessary information as the application is developed in the workspace. A temporary descriptor file contains information gathered about each individual subcomponent. At packaging time, RMA parses those temporary files to assemble all of the information to create the program models. These models are written out as readable XML descriptor files that are ready to be incorporated into an EAR file.

5.2.1 Generating Deployment Descriptor Files

There are different types of deployment descriptor files to describe different types of J2EE components and the storage structure of each component. Figure 2.2 (page 12) shows the hierarchy of deployment descriptors.

Generating "ejb-jar.xml"

The "ejb-jar.xml" is the XML descriptor file that contains information about the EJBs contained in a particular JAR file. Examples of some important information contained in this file are the names of EJB bean classes and their access interfaces, the JNDI names for each EJB, and the EJB references in each EJB. The names of EJB classes and their interfaces can be gathered as the EJBs are generated in the workspace. Also, because RMA generates the default JNDI names, the names can be included in a temporary EJB descriptor file automatically. Because JNDI names are already hidden away in the application code, exposing them to the developers is not necessary.

EJB references occur when an EJB is referenced by another EJB in the application code. While the complexity of EJB references can be removed at the code level by RMA, as discussed in Section 5.1, the complexity of describing this association in the deployment descriptor remains. The necessary information for generating descriptors for the EJB references is the interface names, class names, and JNDI names of the referenced EJBs. Since development and deployment have to be done separately if there is no tool support, remembering which EJBs have been referenced by which other EJBs in the code would be hard for developers. Yet, even if they do remember the references, remembering the matching between EJBs and their JNDI names might also be a daunting task. It is essential for RMA to be able to catch the occurrences of EJB references in the workspace and generate the temporary descriptor files.

Currently, RMA is designed to handle EJB references resulting from pattern assembly. Hiding business components such as *transfer object assemblers* behind a *session façade* is an example of an EJB reference due to pattern assembly. For each EJB parsed, a program model for the EJB is created to store the information. As developers create associations between EJBs during pattern assembly, RMA uses the models of the selected EJBs to create the deployment descriptor. So as the code for the EJB reference is created at the code level, the deployment descriptor is generated in the back end. For example, when a developer adds a *transfer object assembler* to a *session*

façade using a wizard, RMA uses its internal models to add information about the assembler to the descriptor for the façade.

The EJB references can also occur in application-specific code written by the developers. In this case, it is difficult for RMA to know about an EJB reference. Thus, to fill this gap, RMA provides a wizard for the developer to add an EJB reference to the application code. The wizard is similar to the one for creating a *session façade*. In short, developers pick the EJBs that they want to reference and instead of generating a *session façade*, the proxies for these EJBs are inserted into the reference class as instance variables. The deployment descriptors for the EJB references are created in the background. We admit this is not an elegant solution, but it preserves the abstraction by displaying the selection as a list of proxies instead of JNDI names.

There are many other useful attributes, such as method permissions and transaction types, that can be set in the "ejb-jar.xml" file. RMA fills in these attributes with default values. The developers can modify the default settings as needed using other J2EE deployment tools, such as J2EE Deploytool [4]. Moreover, RMA could be extended to include these other attributes.

Generating Other Descriptor Files

The "sun-j2ee-ri.xml" is a runtime descriptor specific to the Sun J2EE container that captures the EJBs and their references that exist in the JAR file. It is a simplified version of the "ejb-jar.xml" file excluding some information such as the names of the access interfaces of EJBs. RMA generates this file along with the "ejb-jar.xml" file because all of the information needed for 'sun-j2ee-ri.xml' can be found in 'ejb-jar.xml'.

The "application.xml" file contains the names of the JAR files that contain class files for the application. RMA always names the JAR file "ejb-jar.jar" and writes this name into "application.xml" by default.

5.2.2 Packaging the EAR File

The final packaging is handled by "Packager" as shown in Figure 1.1 and consists of three steps. First, the necessary deployment descriptors are created by piecing together data contained in the temporary descriptor files. Second, the Java classes that implement this application are extracted and assembled in the package hierarchy. The extracted files include all Java classes defined in the

application's classpath. The classpath is tracked by the Eclipse environment. Thus, if a class in an external JAR file is referenced, RMA treats the whole JAR file as an exportable item. Third, the deployment descriptors and Java classes are combined to form the final deployable EAR file following the pre-defined file structure we described in Section 2.1.4. The "ejb-jar.xml" file is always packed into the "META-INF" directory of the JAR files. The 'application.xml' and 'sun-j2ee-ri.xml' files are packed into the "META-INF" directory in the EAR file.

5.3 Summary

RMA hides the distributed nature of J2EE application development on three fronts: generating access interfaces, removing name space lookup from the code level, and automating the generation of deployment descriptors. RMA provides a programmatic abstraction for using an EJB as though it were a POJO. RMA generates the code for managing the name space and EJB lookup. The generated code is divided into layers. RMA monitors these layers for changes and performs necessary updates to ensure consistency among layers. By automatically generating and updating access interfaces, RMA ensures the interface is consistent with its implementation. The generation of deployment descriptors by RMA frees developers from the cumbersome and tedious work of writing XML files. More importantly, combined with the code-level abstractions, it completes the goal of hiding the distributed nature of a J2EE application from developers.

Chapter 6

Analysis

RMA reduces the work of the application developer by generating code to improve the abstraction. Although it is hard for us to quantitatively show that RMA improves the process of developing J2EE applications, we believe that we can show that development effort has been reduced. In particular, an analysis of the astronomy club application shows that the developer only writes application-specific code. RMA generates architectural code, deployment logic, and extra distributed system artifacts (namespace, interfaces, etc.) needed by J2EE.

In our sample astronomy club application, RMA generates 1507 lines of code, about 74% of the 2039 lines that make up the complete program. This percentage is a function of the problem being solved and not an inherent property of the generated code. Applications with a large amount of complex application code may have a different proportion of generated code to total code.

We can divide the generated code into two categories: that for architecture and that for deploy-

Table 6.1: Code Distribution on Generated Code for Architecture

Category	Number of Line of Code	Percentage
Transfer Objects Code	252	29%
EJB Stub Methods Code	150	18%
Pattern Assembly Code	148	18%
Other Pattern Code	297	35%
Total	847	100%

Table 6.2: Code Distribution on Generated Code for Deployment Hiding

Category	Number of Lines of Code	Percentage
Service Locator Code	144	21%
Interfaces Code	139	21%
Proxy Code	377	58%
Total	660	100%

Table 6.3: Code Generated for Different J2EE Patterns. These values are the aggregate of all instances of each pattern.

Pattern Name	Num. LOC Generated	Num. LOC Manually Written	Total	Percentage of Manual Code
Transfer Value Object	252	0	252	0%
Data Access Object	141	438	579	76%
Transfer Object Assembler	111	7	118	6%
Value List Handler	145	7	152	8%
Session Facade	174	34	208	17%
Service Locator	144	0	144	0%
Business Delegate	377	0	377	0%
Business Components	163	46	209	22%
Totals	1507	532	2039	26%

ment logic. Of the 1507 lines of generated code, the architectural and deployment code consists of 847 and 660 lines of generated code respectively, as shown in Table 6.1 and 6.2. A significant portion, 252 lines, of architecture code is devoted to the *transfer value objects* and primary key objects, which only manage four database tables. These classes all share the characteristic of being straightforward to write but are unavoidable as there is no single, reusable version. Being able to automatically generate this code, while guaranteeing its correctness, removes a significant burden from developers. The assembly of patterns took up 148 lines. The stub functions, such as `ejbCreate`, for EJBs took up 150 lines for the eight session beans. Other generated code includes those methods special to each pattern, such as the connection methods for *data access objects* and the sublist retrieval methods for *value list handlers*.

In the 660 lines of deployment logic, proxies alone take up 377 lines. The *service locator* and access interfaces take up 144 and 139 lines of code respectively.

The most significant amount of hand-written code for this application was in the *data access object*s. As shown in Table 6.3, 438 out of 579 lines of code for the DAO were manually inserted. Most of this code is associated with constructing queries to access database tables. These queries are non-derivable constraints. We could include an SQL script generation facility similar to that in realMethods in the future. The *transfer object assembler* and *value list handler* need hand written code to initialize the searching criteria. The amount of code needed to fulfill these constraints is small; only 7 lines of code are needed in both cases. For the *session façade*, code is needed for customizing the coordination of invocations. The *service locator*, *business delegate* and *transfer value object* require no application-specific code.

Another thing to note is that manual code is always inserted at specific locations. For example, manual code for a DAO pattern always goes into its query methods. Developers can easily find the places to start manual coding. RMA also uses the Eclipse task list to direct developers to places in the generated code that need application-specific code. This feature improves the usability of the RMA.

With respect to the development time, the majority was spent coding the non-derivable constraints, especially those for the *data access object*. Coding and debugging the four *data access objects* in our sample application took about 45 minutes. However, the *business delegates* and *transfer value objects* take almost no development time because they are generated automatically

when their owners are defined, according to implicit relationships. The *session façade*, *transfer object assembler*, and *value list handler* only require the time for RMA to solicit context information from the developer to generate code fulfilling the derivable constraints. The wizard pages for the above three patterns have an average of ten inputs, where most of these options can be specified with a simple mouse click. In all, it took us less than 10 minutes to work through the wizards for all uses of these three patterns. In total, we spent less than two hours in developing our sample application, which includes all application code and all deployment descriptors.

To get a better sense of the benefits of RMA, we would like to better understand how the proportion of generated code against the total amount of code in an application changes as the complexity of an application increases. It would still be safe to deduce that as the complexity of the business logic increases, the percentage of generated code will fall. But we also believe it will not be a waste of effort to generate code for the following reasons. First, the generated code guarantees correctness, especially for pattern assembly. Second, as the code becomes more complicated, it is expected to have more EJBs and data objects such as DAOs in the application. Using our sample application as an example, which is relatively simple in nature, it takes around 125 lines of transfer object code for each DAO and 90 lines of deployment code for all EJBs in the application. As the application becomes more complicated, these numbers will only grow because they are closely related to factors like the size of the database tables (number of elements in the tuples) and their number, and the number of business methods and variables in the classes. The total amount of time saved by not having to write this code in a large application that incorporates hundreds of EJBs and tables will be significant.

Chapter 7

Related Work

After seeing how RMA works to solve problems in the development of J2EE applications, we will now take a look of other available J2EE IDEs and compare them with RMA whenever applicable.

7.1 COPS for Parallel Programming

We start our survey with something outside of the J2EE domain, that still gives insight into some common characteristics of development tools for distributed programming. COPS [18] is a pattern-based development tool for parallel programming that generates code for each pattern instance used in an application. Accordingly, developers are responsible for writing code to hook the generated patterns together as needed. Moreover, this generated code must be well-structured and presented since developers need to work with this code manually.

COPS divides the generated code into three layers: the patterns layer, the intermediate code level and low level native code layer. For each pattern instance generated by COPS, the development tool provides a class that contains the hook methods for this pattern. These hook methods are called by the pattern code in the runtime system. Moreover, developers need to fill in the application logic in the hook methods. Thus, the classes that contain the empty hook methods make up the pattern level code. The intermediate level contains the code that models the pattern structure and behavior. If developers find the pattern provided by COPS does not exactly fit the requirements, developers can modify the code in this layer to customize the pattern. In the low level native layer, developers can fine tune the code responsible for the distributed communication.

Because COPS has isolated the generated code according to its different concerns, developers generally have a good idea where and how to customize the generated code. In addition, to accommodate developers' customization of the pattern code at the patterns layer, COPS provides templates for each pattern. Accordingly, there are attributes on each template that can be set to produce different variations of a pattern. For example, the developer can specify different mesh styles to generate a desired Mesh pattern. However, producing customized pattern code using the template attributes is much easier than doing it manually in the intermediate code layer. Even though template attributes are sufficient for creating pattern variations in most circumstances, the possibility of modifying code in the lower layers offers application developers even greater flexibility. Another big advantage of COPS is its extensibility. COPS allows developers to write and add new patterns into the pattern tool through MetaCOPS [19], a support tool that comes with COPS.

We believe that the approach employed by COPS in the parallel programming domain should also be applicable to the domain of J2EE web applications. A web application can also be assembled from the pattern instances using a pre-defined framework as the guideline. While the J2EE containers have hidden much of the remote access code, there are still some aspects of J2EE applications, such as name space management and deployment descriptor generation, that can be hidden away using a layered structure. Moreover, the flexibility of the development tool relies on how well the generated code is structured so that developers can easily customize the code for their specific needs. The similar nature of the parallel domain and the web application domain has led us to build our J2EE development tool using some of the ideas in COPS to help solve the problem of creating J2EE web applications.

7.2 Tools for J2EE Development

A J2EE application is a kind of web-based distributed program. J2EE development tools should have similar properties to other distributed system development tools. These properties include the hiding of low level code while providing a high degree of flexibility and maintainability. Besides these general properties, a J2EE development tool needs to address other issues, such as JNDI name space management and deployment descriptor generation. There are two main approaches to J2EE development: the *code-centric* approach and *architecture-centric* approach. In the code-centric approach, the development tool produces pieces of skeleton code for developers to fill in and

assemble into a working program. The development tool offers no help on how these individual pieces fit together to form an application. In the architecture-centric approach, development tool generates the code skeleton that follows a certain framework architecture. The framework code defines the control flow of the application. The application-specific code is inserted to complete the application.

7.2.1 JBuilder and WebSphere

Both JBuilder [21] and WebSphere [13] follow the *code-centric* approach to J2EE development. JBuilder and WebSphere provide wizards that help developers produce independent modules for JSPs, Servlets, and EJBs. These independent modules must be assembled into a complete application by the programmer. Accordingly, some simple skeleton code can be generated as the modules are formed. Moreover, since both systems provide a built-in web-server, developers can easily deploy their application onto the server to test their implementation. Both JBuilder and WebSphere adopt Apache's XDoclet technology to produce the deployment descriptors. XDoclet provides a set of specialized Javadoc-style tags that developers need to insert into the application code. Some of the most commonly tagged information is the purpose of methods (creation or business) and the EJB references. At code generation time, the code generation engine parses the code to extract the tags and generates the deployment descriptors and interfaces. This tag-based approach relies on developers to ensure the correctness of the specified deployment information. As the complexity of the application grows, more tags must be maintained and the correctness becomes harder to ensure. Furthermore, neither JBuilder nor WebSphere address architectural concerns in the generated code. They also offer little tool support for helping developers to exploit the benefits of proven good designs for developing J2EE applications.

While JBuilder and Websphere only generate skeletons of stand-alone EJBs, RMA generates and assembles EJBs using architecturally-sound design patterns. In other words, RMA is better than JBuilder and Websphere at providing a good architecture for the application. As for handling distributed aspects of web applications, RMA automatically handles the generation of the deployment descriptors and manages the namespace. The information for deployment descriptors is collected at development time, so RMA frees developers from writing deployment tags in the application code. While JBuilder and Websphere leave the namespace management to the developers,

RMA handles it automatically, as discussed in Chapter 5. We believe RMA has achieved a much better separation of application logic and deployment logic than both JBuilder and WebSphere.

7.2.2 Struts

Struts is a simple but useful tool for J2EE presentation tier components [2]. Struts follows the Model View Controller (MVC) architecture. It creates a servlet controller using a configuration file. The controller delegates the client requests to the different JSP and Servlet pages. The client data are encapsulated in a POJO and passed to the JSP or Servlet pages. Struts has been widely used and has been incorporated into other development tools such as JBuilder.

Struts only supports patterns for the presentation tier, and relies on other tools for the development of the distributed aspects of an application. In contrast, RMA only supports patterns for the business and data tiers. RMA and Struts could be used together to support the complete process of developing J2EE application, though we would need to incorporate some of the abstractions in RMA into Struts if we are to preserve our goal of hiding deployment logic and descriptors from developers.

7.2.3 Pattern Transformation based JAFAR

JAFAR [11] is a framework-based J2EE development tool based on Rational XDE (eXtended Development Environment). JAFAR defines a framework for J2EE applications. The framework consists of components for all three tiers. The framework components help developers design an application by capturing proven solutions to some frequently performed tasks performed in each tier. Some of these framework components are fully implemented while others are architectural skeletons. For components that offer simple but fully implemented services, such as the mail service, developers can simply include the component in their application. For tasks where the architectural skeleton is given, application developers need to write code to complete application-specific logic. Form Validation, which provides basic control flow for validating forms submitted by clients over the Internet, is an example of an architecture component in JAFAR. JAFAR provides tools to help developers create their own components and hook them into the framework.

The development of a J2EE application using JAFAR centers on the development of the application-specific components. The development consists of four steps: creating a project, de-

signing components, applying pattern-based transformations, and writing application-specific code. The application is created by specifying the needed model templates and package structure of the selected models. JAFAR supports all five models promoted by the 4+1 view model of the architecture [17]. JAFAR instantiates the models from the model templates and creates the specified packages as the project is created. The model design is performed using a tool that supports the Unified Modeling Language (UML), such as Rational XDE. The two design elements that developers need to model are *key abstractions* and *component interfaces*. A key abstraction is an object-oriented model for a database table. The component interfaces define the business interfaces of business logic components. The interface of a component is defined as a UML interface of a UML subsystem artifact. With the design model ready, developers can start applying pattern transformations on the models.

JAFAR provides three kinds of pattern transformation: Entity EJB, Session EJB, and Dispatcher. The Entity EJB is derived from the key abstraction defined in the design model. As the transformation is performed on the key abstraction, an Entity EJB is created with all of the attributes defined in the key abstraction. Session EJBs are generated from the business interfaces defined in the design model. All of the methods defined in business interfaces are mapped to public methods in a Session EJB. JAFAR also supports the creation of skeleton code for the Dispatcher class that distributes client requests to the correct business components. The Dispatcher class is implemented in the web tier using a servlet. For all three transformations, code is not only generated for the bean classes and dispatcher classes but also for other auxiliary classes as well. For example, home and business interfaces are automatically generated for each bean class. Some simple J2EE patterns are also applied during the pattern transformation. For instance, the Entity Bean is associated with a transfer value object that aggregates all of its instance variables by default. The Session Bean always has a POJO delegate, which hides the complexity of name space lookup.

Some of the deployment information is gathered while developers model the EJBs and Dispatchers. For example, the component interfaces provide information about the name of the bean classes and all of their public methods. Unfortunately, it is not clear how JAFAR handles the name space in the deployment descriptor.

The JAFAR IDE supports pattern-oriented development. Providing developers with a high-

level control flow, they can concentrate on developing application-specific code. JAFAR generates many useful J2EE patterns, but in some cases developers have to assemble them together. However, it is not clear if JAFAR frameworks are accessible to developers. Furthermore, JAFAR does not offer enough help in applying design patterns to user components that might need to collaborate with each other. For instance, the code generated for the Dispatcher class still needs customized code to select the worker to which an incoming job should be dispatched. This drawback limits the benefits that the developers can exploit by using design patterns. It is also not clear how EJB references among components defined by the application developer are reflected in the deployment descriptor if the deployment information is only gathered at the modelling stage. This can limit the use of legacy code in a JAFAR project.

RMA is an improvement over JAFAR at the architectural level in three ways. First, RMA allows developers to assemble EJBs into pattern relationships and generates code to create the binding. Thus, developers can create architecturally-sound applications but they are not bound to a single pre-built framework. Second, RMA does not require developers to make use of the whole framework as JAFAR does. Developers can incrementally build their applications in a bottom-up fashion and use only the components that they think are necessary. Consequently, only the code needed for an application is generated, which can make the code easier for developers to work with and improve performance [18] [19]. Because developers are fully aware of what code they are generating, RMA's generated code is more accessible than that of JAFAR. Third, RMA supports more business tier patterns than JAFAR does. Design patterns such as the *transfer object assembler* and the *value list handler* are not supported in JAFAR. In terms of handling the distributed nature of the application, we believe RMA is an improvement over JAFAR because of its ability to automatically handle the namespace management.

7.2.4 Model Transformation based OptimalJ

OptimalJ [5] is a Model Drive Architecture (MDA) based J2EE tool. MDA allows developers to specify the class relationships with XML tags, which the transformation engine uses to produce the concrete code that reflects the description [23]. OptimalJ defines a generic framework for J2EE applications. Then, developers are asked to design the application-specific models. OptimalJ instantiates a dynamic concrete framework that inherits from the pre-defined generic framework

and incorporates the developer-defined models. Lastly, developers are asked to fill in the business logic to complete the application. OptimalJ distinguishes itself in the way it uses MDA models in its code generation.

OptimalJ has three levels of abstraction: the Domain Model, the Application Model, and the Code Model. The Domain Model is a Platform Independent Model (PIM). It defines business domains without any application detail [5]. For example, a developer can define a Customer artifact with properties, such as the name and birthday, in the Domain Model. The Domain Model does not describe what kind of programming language the Customer artifact will be implemented in and the type of program construct that will be used to implement it. The Application Model defines the application in terms of the programming technology that will be used to implement the application. The Application Model is a Platform Specific Model (PSM) and still contains no implementation detail. The Application Model defines what is to be generated for each Domain Model artifact in the web tier, the EJB tier, and the data tier. For the Customer example, the Application Model may decide to use an Entity EJB to model the Customer and the schema of the underlying database table. Thus, the schema information is needed for generating the Entity Bean. The Code Model is the actual implementation of the application. For the Customer example, its Code Model contains an Entity EJB object class, the interfaces for the EJB, and other associated auxiliary classes such as the primary key class. In the development process, the business analyst defines the Domain Model. OptimalJ automatically performs a series of model transformations to produce the concrete framework code. As we will see, the pattern information is used in the model transformation.

There are two types of patterns used in OptimalJ: transformation patterns and functional patterns. The transformation patterns are used to map of an upper level model to the next level model. The transformation patterns can be further divided into two types: technology patterns and implementation patterns. The technology patterns are the J2EE patterns that are used for mapping artifacts defined in the Domain Model to the Application Model. For example, a Domain Model level composite artifact such as Department may contain a set of Employee artifacts. OptimalJ automatically applies the *Composite Entity* pattern [1] to the Department artifact by some advanced analysis of the Domain Model. Employees are modelled as leaves and the Department as the aggregator of the *Composite Entity* pattern. The implementation patterns transform the

Application Model into the Code Model. An implementation pattern for an Entity EJB generates the Entity bean's home and business interfaces, the primary key class, and some simple DBMS SQL scripts.

The functional patterns capture and reuse user-defined patterns by allowing developers to merge artifacts into one larger, single unit. For example, if the developers frequently use the Customer and Address artifacts, then they might decide to combine two artifacts into a single "CustomerContact" artifact for future reuse. The merging can be performed at all three levels.

The deployment descriptors for the application are generated by gathering information from the Code Model transformation. For example, the names for the EJB bean class and interfaces are generated only after Code Model transformation is applied using implementation patterns. The descriptors can be created during the transformation process.

OptimalJ is no doubt a powerful development tool. It provides multiple layers of abstractions, similar to the approach taken by COPS. Because the developers generate the framework at a much higher abstraction than the detailed implementation technology, the design decisions can be reapplied to other implementation technologies besides J2EE, given the appropriate technology patterns. OptimalJ has great flexibility in its ability to include new patterns, but it fails to provide developers with good access to the generated code. OptimalJ employs automatic reasoning to make decisions about the generation of the implementation code. The generated code is too complicated for the developer to quickly understand in order to fine tune it.

The main difference between RMA and OptimalJ is the different approach they take in constructing and generating the architecture of the application. While MDA technologies can only specify class-level bindings, RMA's roles and constraints enables it to generate method-level bindings, which are more concrete. RMA also improves over OptimalJ by providing incremental construction of the application, so the developers are fully aware of what code is generated at each stage. Thus, RMA provides a better understanding of the generated code than OptimalJ. It is interesting to note that both RMA and OptimalJ use a layered structure to enforce consistency in the generated code. Both RMA and OptimalJ create deployment descriptors and manage the name space automatically.

7.2.5 Role/Constraint based Fred

Fred is another pattern-based J2EE tool [12]. Fred tackles the design problems of EJBs in the business tier using the same patterns as those used in JAFAR and OptimalJ. Similar to JAFAR, which used Rational XDE as its development environment, Fred exploits the existing prototype tool also called Fred [12]. The Fred prototype tool provides an easy way to create an EJB-sensitive source code editor and other useful services in the development process. Fred has distinguished itself from other J2EE development tools in two main aspects: a flexible code generation cycle and extensibility.

In both JAFAR and OptimalJ, the pattern or framework engine creates architectural code based on developer specifications. The generated architectural code is difficult for developers to read and understand, and thus is hard to modify. Fred allows the developer to carry out the code generation step by step. For every piece of pattern code generated, Fred provides the developer with a list of tasks that need to be carried out in order to complete the application. For instance, when a developer creates an Entity EJB using Fred, Fred creates tasks prompting the developer to complete the finder methods specified in the generation wizard. The task list is dynamically generated. As a task is completed, it is automatically removed from the list. New tasks can also be dynamically added to the task list due to the completion of a previous task.

Fred's ability to manage the task lists to guide developers through the development process results from its view of a pattern as an aggregation of roles and constraints. A role describes a set of properties that a program element should have in order to play the role. Each such property is called a constraint. Roles and constraints can be applied to most program elements, such as classes and methods. A pattern in Fred defines two types of roles: a bound role and an unbound role. The bound roles of a pattern are the roles that are common to every instance of that pattern and show up in the framework with a specific name. In other words, the bound roles are the roles that the pattern needs to fulfill in order to be hooked into the framework. On the other hand, the unbound roles are pattern-specific. For example, a *session façade* needs to play bound roles of implementing the `EJBHome` and `EJBObject` interfaces, which are common to all EJBs. At the same time, the *session façade* plays the unbounded role of accessing façaded Entity/Session EJBs. Moreover, for each role, there is a list of properties specifying the requirements that are needed to fulfill that role. For instance, the *session façade* contains an unbound role named "session".

"Session" has a constraint that states that it must contain instance variables of type `EJBObject` in its implementation. After the pattern code is generated, the environment monitors the code input by the developer to check whether the constraints still hold. The "session" task is kept in the task list until an `EJBObject` is specified for the *session façade*. While some roles need to be manually written by the developer, others can be completed using default values provided by the environment. For example, the default value for an instance variable required by the "session" role is null.

Fred also employs the concept of composite patterns to handle patterns that are closely related to each other. For example, each Entity Bean always has a *transfer value object* that stores the persistent fields of the Entity Bean. The suggestion to generate related patterns appears in the task list as an optional task when Fred believes there is enough information to generate them. Then, the developer can use wizards to carry out the generation.

There is no predefined set of patterns that will be sufficient for all application development. Developers always run into difficulty when they cannot find the pattern they are looking for in a pattern-based development tool. Thus, Fred provides a set of wizards for creating new patterns by a pattern developer. For each pattern, developers need to specify the different roles that this pattern needs to play and the constraints on each role. As the patterns are instantiated, the roles specified by the pattern developer are loaded to generate the concrete task and constraint list. Subsequently, the newly-added patterns are used in the same fashion as any other existing patterns.

The deployment descriptors can be generated using the values of the role properties filled in by the user. The association between EJBs can be captured by binding roles to the business components.

Fred offers significantly more flexibility, both in constructing the application and in using patterns, than OptimalJ and JAFAR. Because the code is no longer generated automatically but rather because of direct interaction with the developer, developers have a better understanding of the purpose of the generated code. The developer-written code is also automatically checked against the pattern constraints by the environment. This kind of constraint checking helps developers improve the correctness of their code. Furthermore, the ability to extend Fred's pattern pool is another feature that increases the utility of the tool. While Fred performs constraint checking on developer-written code, there is the possibility that such code can be automatically generated

with some wizard support. For example, when developers create a *session façade* for hiding a set of Entity or Session beans, they have to manually write code to include those beans as fields, instantiate them, and use them. In short, if developers want to use methods from those beans, they also need to write delegating methods. It would be better if developers could launch a wizard to pick out the bean they want to use and have the tool generate implementation code, including the delegating methods. In this scenario, the development tool can not only improve the correctness of code but also reduces development effort.

Fred is most like RMA; both of them use the concepts of roles and constraints. While Fred only uses roles and constraints to guide developers through development, RMA generates code to implement the constraints to fulfill roles where possible. In other words, Fred only tells developers what they should do in order to instantiate a pattern-relationship, while RMA goes further by generating as much of the concrete implementation of a pattern relationship as possible. For those constraints that cannot be automatically generated, RMA provides tool support to guide developers to manually construct them. In terms of handling the distributed nature of the application, both Fred and RMA collect information during the development stage to generate deployment descriptors. It is also important to note that RMA-style name space management is not found in Fred.

7.3 Summary

To summarize, we believe that RMA has been successful at addressing some of the major shortcomings of other development tools. First, RMA efficiently uses pattern and framework knowledge in code generation. This knowledge allows us to generate concrete pattern implementations including method-level relationships. Second, RMA presents the generated code to developers in a usable fashion, so the developers can modify the code as needed. Third, RMA enables developers to build applications incrementally, allowing them to have full knowledge of the purpose of each piece of code generated. The clarity in presentation and incremental construction of architectural code exemplify the flexibility of RMA. Lastly, the deployment logic is automatically generated by RMA. Moreover, changes to the user code are captured by RMA and automatically reflected in the descriptors without developer intervention.

Chapter 8

Future Work and Conclusion

8.1 Future Work

First of all, we would like to implement additional applications that contain a more complicated architecture and behavior than our current sample application. Additionally, we would like to know how much effort can be saved by RMA on these larger programs. This work would allow us to better understand the strengths of the tool and address any weaknesses. At the same time, we may also like to discover additional pattern relationships that can be automatically generated by RMA.

Currently we have implemented some of the patterns of the business tier and the integration tier. We have left out the patterns from the presentation tier because we did not want to duplicate the efforts of Struts, which provides good support for presentation tier patterns. A typical EAR file contains two components, a WAR file that contains presentation tier JSPs or Servlets and a JAR file that contains EJBs. Because RMA does not support the presentation tier, the WAR file needs to be filled in by the developer afterward. In order for Servlets and JSPs to use the EJBs, the JNDI names of those EJBs need to be specified in the deployment descriptor of the referencing Servlet or JSP. The only place for presentation tier developers to get the JNDI name is from the deployment descriptor of the EJB JAR. This omission results in a hole in our abstraction of deployment logic, but only because we have not incorporated the presentation tier into the current system. One possible improvement is to extend RMA with presentation tier patterns to cover the entire development process and completely hide deployment logic across the complete application. Another possible solution is to provide a simple wizard that inserts an existing WAR file produced

by other tools into the EAR produced by RMA. Lastly, to make the framework complete at the integration tier, we would also like to accommodate Entity EJBs, applying the same approach we used for Session beans.

Our next goal is to make our pattern tool extensible. One of the shortcomings of pattern-based software tools is their inflexibility in incorporating new patterns. Thus, it would be ideal if application developers could create or refine a pattern and plug it into our tool, as can be done in DPnDP [25], PAS [10], and COPS [19]. The new pattern should work in the same fashion as the existing patterns. We believe that the Eclipse plugin architecture is a promising solution to solve this problem. Moreover, any Eclipse plugin can define its own extension points for other plugins to add new features. Thus, we propose creating a pattern generation engine that provides a standard interface as its extensible interface to all patterns. Patterns can be implemented as plugins to hook up to the pattern generation engine. Each pattern plugin contains its own user interface wizard and code generation template and model. As new patterns are added to the core engine, they show up in the menus of the core plugin. Yet, the difficulty lies in finding an efficient means of enforcing consistencies on constraints and roles of the same pattern relationship produced by different pattern plugins. For example, if there are two plugins that generate a *transfer object assembler* to aggregate some existing *data access object*s, we might expect both of them to hook up to *data access objects* appropriately. The *transfer object assembler*s produced by both plugins should also be acceptable to a plugin that handles the *session façade* and EJB relationship.

We are also considering the possibility of incorporating a task-driven development methodology [12] into RMA. RMA should guide developers through the process of pattern assembly by suggesting the next possible steps. For example, it could suggest the creation of a *session façade* when the tool finds more than three EJBs have been created. We may also enforce constraints on pattern relationships for imported legacy code or for generated framework code that has been changed by the user.

8.2 Conclusion

Design patterns are more useful when they work together than when they work alone. In this thesis, we have presented RMA, which incrementally constructs a J2EE web application by assembling patterns according to relationship roles and constraints. RMA follows an incremental bottom-up

approach in assembling patterns. The lowest level data tier patterns are first assembled, followed by the upper level business tier patterns. As a result, RMA can produce concrete code instead of an architectural description as is done in pattern-based J2EE IDEs. By generating concrete pattern implementation code, RMA allows developers to focus on their application code, which is where their expertise lies. The construction steps are controlled by developers, so they are fully aware of the purpose of the code generated. This improves the developers' ability to work with the generated code if necessary. RMA has distinguished itself from other pattern-based J2EE tools in that it places more emphasis on capturing pattern relationships than on static code generation for a predefined architectural description.

In RMA, we use pattern relationships to hide the distributed nature of a J2EE application at both the architectural and code levels. We use the collaboration between our refined *service locator* and *proxy* patterns to hide the name space management at the code level. We also show that the deployment descriptors can be generated using information gathered during the development phase. Through RMA, we have shown that deployment logic can be provided automatically with appropriate tool support rather than being exposed to application developers. Lastly, we have successfully developed RMA as an Eclipse plugin, using one of the most popular Java IDEs. In this way, the rich functionality of Eclipse, such as code generation, can easily be incorporated into our tool. The flexibility of Eclipse also opens the possibility of implementing more complex functionality, such as implementing pattern generation engines as plugins to provide extensibility.

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Appendix A

Acronyms

Term	Expansion	Definition
BD	Business Delegate	"A design pattern that encapsulates access to a business service [1]." See Section 3.7 for details.
DAO	Data Access Object	"A design pattern that abstracts and encapsulates access to persistent store [1]." See Section 3.1 for details.
EJB	Enterprise Java Bean	"A server-side component architecture for writing reusable business logic and portable enterprise applications [14]."
IDE	Integrated Development Environment	"A system for supporting the process of writing software [14]."
J2EE	Java 2 Enterprise Edition	"Sun's Java platform for multi-tier server-oriented enterprise applications [14]."
JAR	Java Archive	"A compressed archive file containing Java class files, filename extension: ".jar" [14]."
JDBC	Java Database Connectivity	"Part of the Java Development Kit which defines an application programming interface for Java for standard SQL access to databases from Java programs [14]."

Term	Expansion	Definition
JNDI	Java Naming Directory Interface	"Part of the Java platform, providing applications based on Java technology with a unified interface to multiple naming and directory services [14]."
JSP	Java Server Page	"A freely available specification for extending the Java Servlet API to generate dynamic web pages on a web server [14]."
POJO	Plain Old Java Object	A normal Java class.
RMA	RoadMapAssembler	A pattern-based J2EE development tool developed by us.
SF	Session Façade	"A design pattern that encapsulates business-tier components and exposes a coarse-grained service to remote clients [1]." See Section 3.3 for details.
SL	Service Locator	"A design pattern that encapsulates service and component lookups [1]." See Section 3.4 for details.
SQL	Structured Query Language	"An industry-standard language for creating, updating and, querying relational database management systems [14]."
TO	Transfer Value Object	"A design pattern that carries data across the tier [1]." See Section 3.2 for details.
TOA	Transfer Value Object Assembler	"A design pattern that assembles a composite transfer object from multiple data sources [1]." See Section 3.5 for details.
VLH	Value List Handler	"A design pattern that handles the search, caches the results, and provide the ability to traverse and select items from the results [1]." See Section 3.6 for details.
WAR	Web Archive	A special kind of JAR file that contains files for the presentation tier of a J2EE application.

Appendix B

UML Legends

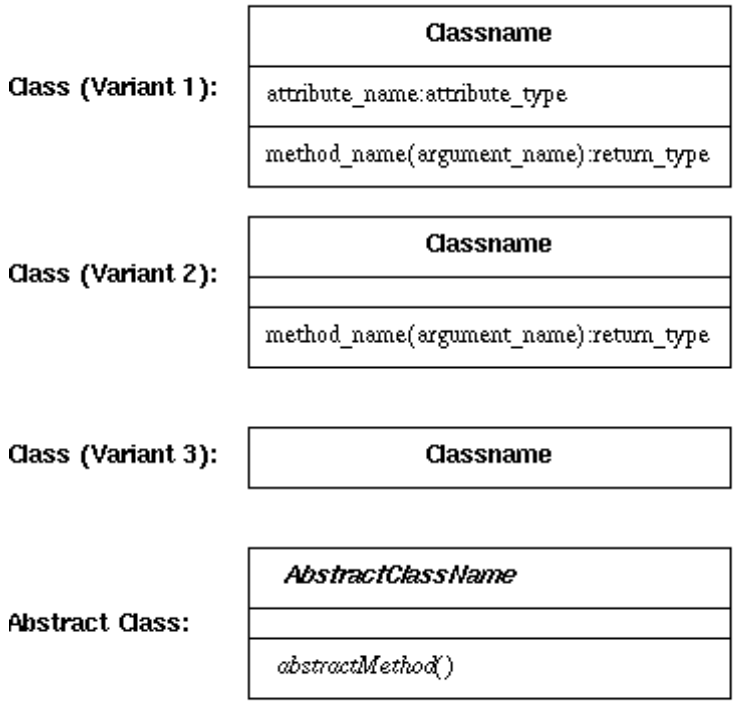

Figure B.1: UML Legend-Class Symbols [20]

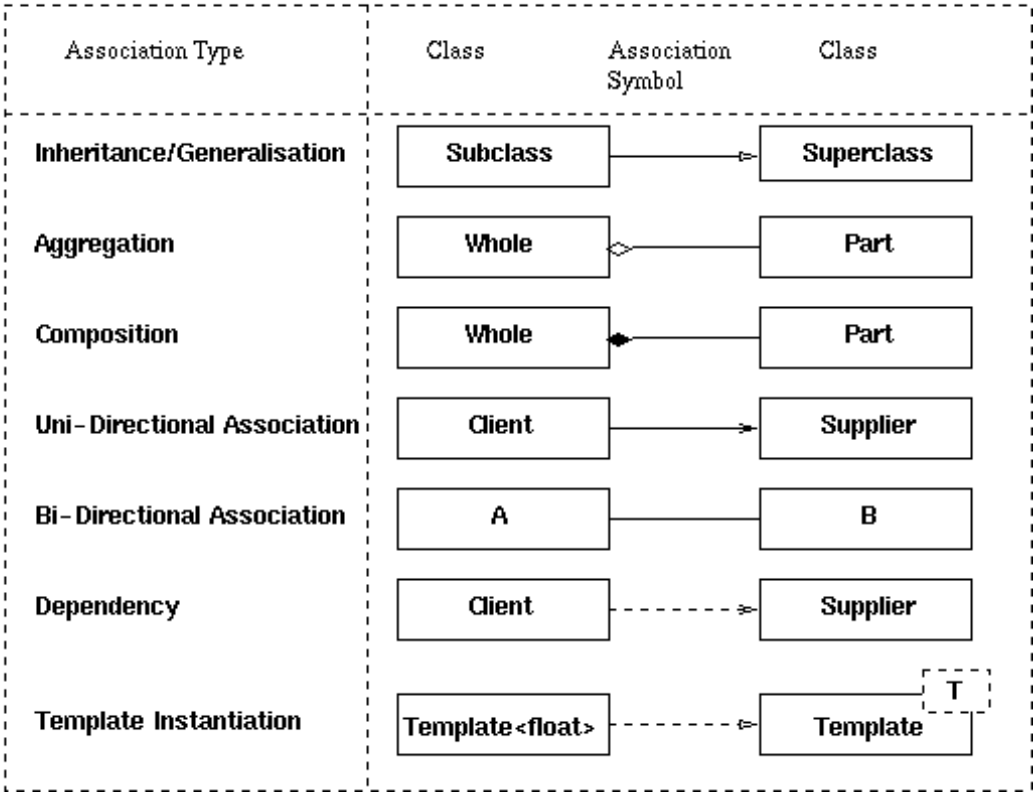

Figure B.2: UML Legend-Association Symbols [20]