A Method for Systematically Building Object-Oriented Framework Based on UML

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ABSTRACT

Recently, object-oriented (OO) frameworks have been known to be highly effective and practical for software reuse. However, most of the current software development methodologies do not provide effective methods and instructions for modeling OO frameworks. Therefore, effective OO framework modeling techniques are needed.

In this paper, we use Unified Modeling Language (UML) as representative object-oriented methodology to provide the OO framework development techniques. The proposed process consists of three typical phases: analysis, design and implementation, and each phase is defined as a logical sequence of development tasks. Since the proposed process is based on UML diagrams and the basic Objectory perspectives, we believe that OO frameworks can be more efficiently developed by utilizing the proposed process, and higher quality OO frameworks can be produced. In order to show the applicability and effectiveness of the process, we present a case study of Business-to-Costumer Electronic Commerce application.

Keywords: Framework, UML, hot spot

1. INTRODUCTION

There are various definitions of object-oriented frameworks. Roberts and Johnson [1] define that a framework is a reusable design of all or part of a system that is represented by a set of abstract classes and the way their instances interact. A framework may be a reusable, “semi-complete” application that can be specialized to produce custom applications [2]. It is more powerful to reuse the design and the code rather than only code-level reuse.

However, it is not easy to develop frameworks as reusable software architecture. Currently, there are no methodologies that support OO framework development effectively and systematically. The guidelines for the framework development have been presented by Nikas Landan [3], Mattson [4], Johnson R. [2], Koskimies K. [5] et al.. However, the definite processes for the framework development is not yet defined.

Therefore, we focus on the systematic and procedural techniques of the OO framework development in this paper. Basically, we present framework design techniques based on *UML* [6] as the Object Management Group (OMG) standard for modeling language. We use the *use case diagram*, the *class diagram* and the *sequence diagram* provided by the UML to make *framework diagram*. Use case diagrams provide the functional analysis, the sequence diagrams provide the dynamic analysis, and the class diagrams provide the structural analysis in given domains.

In section 2, we will give an overview of object-oriented framework, the framework diagram notation, and the related works of framework development methods. Section 3 explains the OO framework development process, which is the analysis / design / implementation method, and the steps for building OO framework. Section 4 presents a case study of applying the method to Business-to-Customer Electronic Commerce domain. In section 5, we will make conclusions about this paper and discusses the future works.

2. RELATED WORK

2.1 Overview of Object-Oriented Framework

Object-Oriented framework is often characterized as a set of *abstract* and *concrete* classes that collaborates, and it provides the skeleton of an implementation for an application. It is typically implemented as a set of abstract classes that define the core functionality of the framework along with concrete classes for specific applications included for completeness.

Several different means of classifying frameworks have been proposed. Adair [7] defines three frameworks by scope, namely *application*, *domain*, and *support* frameworks. Johnson and Foote [2] define two types of frameworks, *white box* and *black box* by customization. Anderson Consulting [8] defines *called* and *calling* frameworks by how they interact with application extensions.

2.2 Framework Diagram Notation

Frameworks consist of classes with a common functionality and have control flows among classes internally. Figure 1 shows a framework diagram notation. It consists of classes, relationship among classes, hot spots, control flows among classes and interfaces. Interfaces play a role of a path to communicate with other frameworks or classes. There are six interfaces, f1(), f2(), f3(), f4(), f5(), and f6() in Figure 2.5.

Control flows of frameworks are indicated by forms of "interface name_control flow order". By this notation, we know the interfaces as starting points of control flows and get flows of controls by numbering.

Figure 1 shows two control flows. One is X.f1() → f1()_1 → f1()_2 → f1()_3. And the other is X.f3() → f3()_1 → f3()_2. "X" represents a framework. And, f1() and f3() represent the interfaces of framework X to communicate with external world.

2.3 Existing Framework Development Methods

2.3.1 Design a Framework by Stepwise Generation

When they design a framework, their main concern is to recognize things that should be *kept flexible*. These are called the *hot spots* [9] of the framework, i.e., the spots where the framework can be extended. In order to identify variant parts, some of questions are proposed as follows [5]:

(1) Which concepts of the problem domain exist in variants and should be treat uniformly?

(2) Is it possible to find a concrete concept that can be generalized?

(3) Which parts of the system might change?

(4) Where might a user want to hook custom code into the framework?

The author suggests a *two-phase* framework design method to build an initial version of a framework; the first phase is called *problem generalization* and the second phase is called *framework design* [5].

Problem generalization starts from the specification of a representative application of the intended framework, and generalizes it in a sequence of steps into the most general (sensible) form. This phase typically makes use of the questions (1) and (2) to find the next generalization. During the second phase the generalization levels of the previous phase are considered in reverse order leading to an implementation for each level. The second phase make use of the questions (3) and (4) and of general design experience and domain knowledge to find the hot spots in the framework.

The one of limitations of this method is that essential tasks to problem generalization or framework design are not defined concretely. Also, concrete guidelines to identify hot spot are not described in this method.

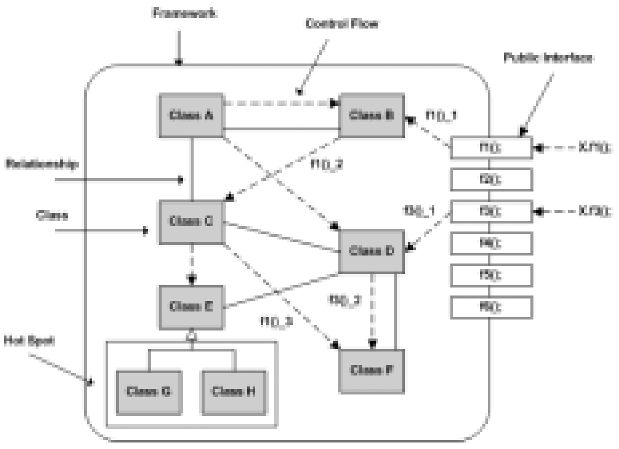


Figure 1. Framework Diagram Notation

2.3.2 Developing Object-Oriented Frameworks Using Domain Models

In this paper, they present an integrated approach to model the domain knowledge related to a framework and to map the identified domain models into object-oriented concepts [10]. The approach is described as follows:

(1) They first model the top-level structure of frameworks using the so-called *knowledge graphs*.

(2) Refining each node within a top-level knowledge graph into an acyclic sub-knowledge graph called *knowledge domain*.

(3) They identify which nodes in a knowledge domain can be included together in the top-level knowledge graph.

(4) Verifying whether the knowledge domains model the relevant knowledge, we match them against the use cases identified from the user requirements.

(5) Finally, they map knowledge domains into object-oriented concepts.

The main claim of this paper is that the framework refinement time may be reduced considerably by modeling the related domain knowledge explicitly. But, this paper just present five phase to developing framework, and within each phase they don't define concrete methods or guidelines to develop framework.

2.3.3 Framework Development with Domain Analysis

In this paper [11], they outline how they use a domain analysis technique – *Sherlock* – to extract reusable frameworks and present a case study regarding the development of a graphic user interface framework for business and management information system.

Sherlock activities are *definition of the context*, *domain characterization*, and *framework development*.

This paper present a domain analysis methodology targeted to frameworks such as Sherlock, which is the enabler to framework reuse. But, this methodology is not stabilized and no clear definition of all procedures.

3. UML-BASED OBJECT-ORIENTED FRAMEWORK DEVELOPMENT PROCESS

3.1 Overview of Process

As given in Figure 2, the object-oriented framework development process consists of three phases (e.g. analysis, design, implementation), and tasks for each phase are defined.

Analysis phase consists of making use case models through extracting common functionality from a set of similar applications, making activity diagram based on use case models, and partitioning use cases into four-module framework architecture.

Design phase consists of structural and dynamic modeling processes. The structural modeling consists of making class diagram based on use case models, making sequence diagram based on use case models, and identifying hot spots for the framework. The dynamic modeling consists of determining the internal control flows within frameworks and identifying interfaces within frameworks.

Implementation phase consists of implementing classes and interfaces of framework and building specific application by using implemented framework.

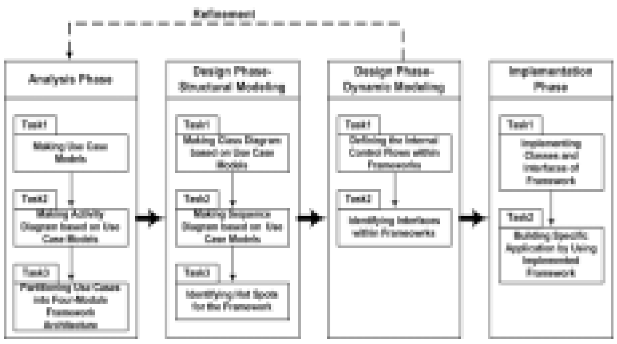

Refinement
Analysis Phase
Task1
Making Use Case Models
Task2
Making Activity Diagram based on Use Case Models
Task3
Partitioning Use Cases into Four-Module Framework Architecture
Design Phase-Structural Modeling
Task1
Making Class Diagram based on Use Case Models
Task2
Making Sequence Diagram based on Use Case Models
Task3
Identifying Hot Spots for the Framework
Design Phase-Dynamic Modeling
Task1
Defining the Internal Control Flows within Frameworks
Task2
Identifying Interfaces within Frameworks
Implementation Phase
Task1
Implementing Classes and Interfaces of Framework
Task2
Building Specific Application by Using Implemented Framework

Figure 2. Framework Development Process

3.2 Analysis Phase

3.2.1 Making Use Case Models

Use case models are means to communicate requirements between customers and developers and to structure object models into manageable views. They offer a systematic and intuitive means of capturing functional requirements with a focus on value added to the user.

Use case models consist of *use case diagrams* and *use case descriptions*. A use case diagram shows the relationship between actors and uses cases. A use case description is structured as Figure

3., where each use case has a unique name. Use cases may additionally be numbered for quick identification in diagrams and in their textural form.

Steps:

(1) Initially, identifying actors.

(2) Identifying use cases by listing all events from the outside environment to which we want to react.

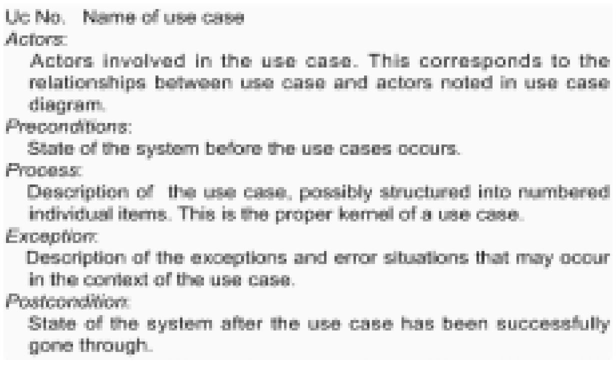
(3) Identifying communicates relationships between actors and use cases.

(4) Identifying shared descriptions of functionality: In order to reduce redundancy, this sharing can be extracted and described in a separate use case that can then be reused by the original use cases. We show this reuse relation with a use relationship.

(5) Identifying additional and optional descriptions of functionality.

(6) Making use case descriptions for some use cases based on the notation in Figure 3.

(7) Refining and elaborating as required.



Uc No.   Name of use case

Actors:

Actors involved in the use case. This corresponds to the relationships between use case and actors noted in use case diagram.

Preconditions:

State of the system before the use cases occurs.

Process:

Description of the use case, possibly structured into numbered individual items. This is the proper kernel of a use case.

Exception:

Description of the exceptions and error situations that may occur in the context of the use case.

Postcondition:

State of the system after the use case has been successfully gone through.

Figure 3. UML Notation for Use Case Description

3.2.2 Making Activity Diagram based on Use Case Models

The way the individual use cases interrelate could be noted textually within the use case descriptions, but would not be very clear. Activity diagrams convey such relationships visually and therefore in a way that is easier to see.

Activity diagrams can be subdivided into responsibility domains, the so-called *swim lanes*, which are graphically constructs that represent a partitioned set of actions. They are used to model the responsibilities of one or more objects for actions within an overall activity; that is, they divide the activity states into groups and assign these groups to objects that must perform the activities.

Steps:

(1) Structuring swim lanes.

(2) Corresponding each use case in use case diagram to each activity.

(3) Identifying event flow in use case description, we can define sequence between activities and conditions for outgoing transitions.

(4) If use cases are very abstract, we decompose them into more concrete use cases.

(5) Refining and elaborating as required.

3.2.3 Partitioning Use Cases into Four-Module Framework Architecture

By definition, the *layered* approach only allows a layer to communicate with the layers directly above and below it. Thus, in this task, we determine the *modules* of use cases on the degree of generality and specialty for each use case. The Framework is partitioned into four modules, which are *UI Component Module, Business Logics Module, Data Management Module,* and *Common Data Module*. The four-module framework architecture is depicted in Figure 4.

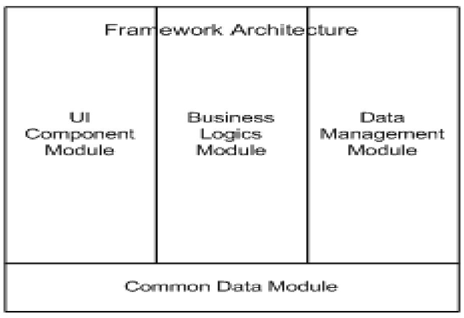


Figure 4. Four-Module Framework Architecture

3.3 Design Phase – Structural Modeling

3.3.1 Making Class Diagram based on Use Case Models

Class diagrams are realizations of use cases. A class is the definition of the attributes, the operations, and the semantics of a set of objects. A class diagram describes the types of objects in the system and the various kinds of static relationships that exist among them. There are two principal kinds of static relationships:

- *Associations* (for example, a customer may render a number of videos)
- *Subtypes* (a nurse is a kind of person)

Steps:

(1) Making individual classes according to use cases of the four-module framework architecture in the analysis phase.

(2) Tasks in use case descriptions are mapped to member functions of the specific classes in the class diagram.

(3) Regard classes found in step2 as classes of the intended framework.

(4) Making associations between classes and apply them to the intended framework.

(5) Refining and elaborating as required.

3.3.2 Making Sequence Diagram based on Use Case Models

A sequence diagram shows a series of messages exchanged by a selected set of objects in a temporally limited situation, with an emphasis on the chronological course of events.

Steps:

(1) Regard classes of the class diagram as objects of the sequence diagram.

(2) Tasks in use case descriptions are described as the messages in sequence diagrams.

(3) Refining and elaborating as required.

3.3.3 Identifying Hot Spots for the Framework

Guideline: In order to get the hot spots, we should extract common attributes and operations from classes in the class diagrams. And then we make abstract classes including them. The abstract classes are super classes and related concrete classes are sub classes. The abstract classes define function signatures without function bodies and concrete classes have implemented parts of the functions signatures defined in the abstract classes. The function signatures of the abstract classes can be implemented differently according to the various applications.

3.3.4 Relationships among Diagrams for Structural Modeling

In Figure 5, the use case description consists of six tasks, from T1 to T6. All of the tasks in use case description are mapped to the messages of the sequence diagrams. For example, T3 is mapped to F1 and T5 is mapped to F4. All of the messages in the sequence diagrams are mapped to the member functions of the classes. For example, F1 is mapped to function f1() in Class C and F4 is mapped to f4() in class A. Therefore, the tasks in use case description are mapped to the member functions of the classes in class diagrams. For example, T3 is mapped to f1() of class C and task T5 is mapped to f4() of class A. In the class diagram, an extracted hot spot is presented.

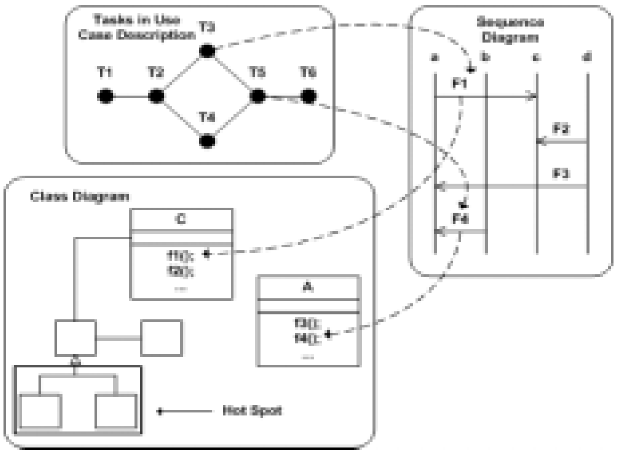


Figure 5. Relationships among Diagrams for Structural Modeling

3.4 Design Phase – Dynamic Modeling

3.4.1 Defining the Internal Control Flows within Frameworks

Steps:

(1) Find the messages of the sequence diagrams mapped to the tasks of the use case description.

(2) Find the message flows of the sequence

diagrams mapped to the control flows of the frameworks.

3.4.2 Identifying Interfaces within Frameworks

Steps:

(1) Find the method that is the starting point of the control flow.

(2) Regard the found method as the interface of the framework.

3.4.3 Relationships among Diagrams for Dynamic Modeling

Figure 6 shows the relationships between the use case descriptions and the sequence diagrams. Both the use case diagrams and the sequence diagrams are used to extract the control flows of the frameworks. In Figure 3.12., the flow of events of the use case description is T1 → T2 → T4 → T5 → T6. The flow of events is represented as the message flows of the sequence diagram, F1 → F2 → F3 → F4 → F5. The message flows in the sequence diagrams are mapped to the control flows among framework classes. In Figure 3.12., the flow of events in the use case descriptions is mapped to the control flow, f1()_1 → f1()_2 → f1()_3 → f1()_4f → f1()_5. X.f1() represents the framework interface.

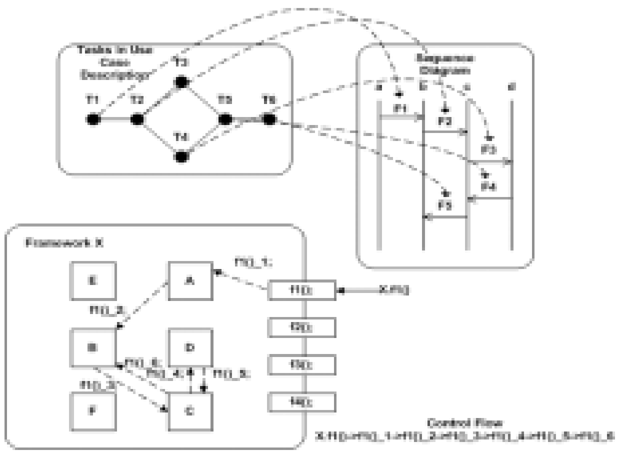


Figure 6. Relationships among Diagrams for Dynamic Modeling

3.5 Implementation Phase

Implementation phase consists of two tasks. First task is to implement classes and interfaces of framework. Implementing framework interface is to implement control flows between classes contained in a framework. Second task is to build specific application by using implemented framework. This task applies framework to specific application and implements hook method through sub-classing hot spot in the case of white box approach and through composing object into framework in the case of black box approach.

3.5.1 Implementing Classes and Interfaces of Framework

Steps:

(1) First of all, choosing the appropriate programming platform and language.

(2) Architectural implementation: we implement the four-module framework architecture.

(3) Outlining the file components: the source code that implements a class resides in a file component. Thus we must outline the file component and consider its scope, namely *namespace*.

(4) Generating code from the operations and attributes that are defined in the class diagram.

(5) Making the file component provide the right interfaces.

3.5.2 Building Specific Application by Using Implemented Framework

Steps:

(1) First, implementing Common Data Module of implemented framework through inheritance or composition and overriding hook methods.

(2) Next, implementing Data Management Module of implemented framework through inheritance or composition and overriding hook methods with suitable data management algorithms.

(3) Next, implementing Business Logics Module of implemented framework through inheritance or composition and overriding hook methods with algorithms of business logics.

(4) Finally, implementing UI Component Module of implemented framework and reusing the UI components of implemented framework or adding specific user interfaces of your own application.

4. CASE STUDY

In this section, we apply the mapping techniques between UML diagrams and framework diagrams to the Business-to-Consumer Electronic Commerce (EC) domain. Currently, EC is a spotlighted field and it will be very useful for development of applications if efficient EC frameworks are developed.

Many of web applications for B2C EC domain have been established. Therefore, we collected similar application requirement specifications and extracted common functions from them. The common functions are ‘Searching For Products’, ‘Browsing Catalog’, ‘Account’, ‘Shopping Cart’, and ‘Checkout’.

The use case diagram for these functions is depicted in Figure 7. Figure 8 shows a use case description for use case Search for Products.

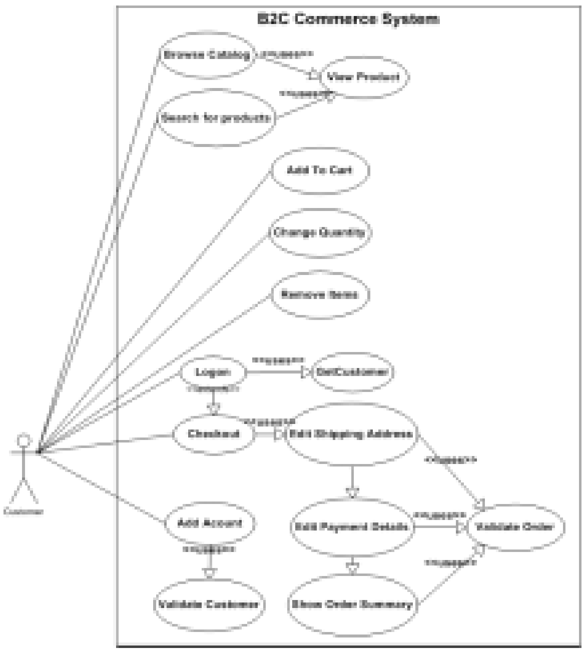


Figure 7. Use Case Diagram for B2C EC Domain

Sequence and workflow of among use cases in a framework are described through activity diagram, which is depicted in Figure 9. We structure the activity diagram into swim lanes that are *Main Process*, *Business Logics*, and *Data Management*. We also decompose the use cases of the use case diagram in Figure 7 to more concrete use cases to fulfill the purpose of swim lanes.

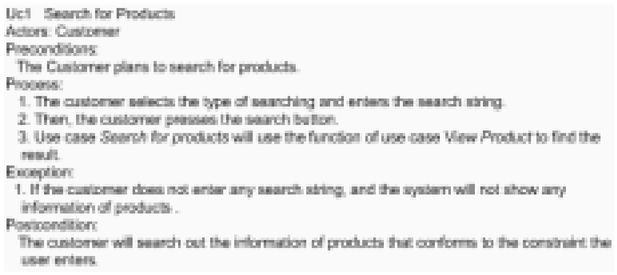

Uc1 Search for Products
Actors: Customer
Preconditions:
The Customer plans to search for products.
Process:
1. The customer selects the type of searching and enters the search string.
2. Then, the customer presses the search button.
3. Use case *Search for products* will use the function of use case *View Product* to find the result.
Exception:
1. If the customer does not enter any search string, and the system will not show any information of products .
Postcondition:
The customer will search out the information of products that conforms to the constraint the user enters.

Figure 8. Use Case Description for Search for Products

After determining activity diagram, we partition the use cases into four-module framework architecture, which is depicted in Figure 10.

In the structural modeling of design phase, we should construct a class diagram (Figure 11) based on four-module framework architecture that is depicted in Figure 10. Then, we make sequence diagrams (Figure 12) for different use cases. Next, we identify the hot spots of the intended framework (Figure 13).

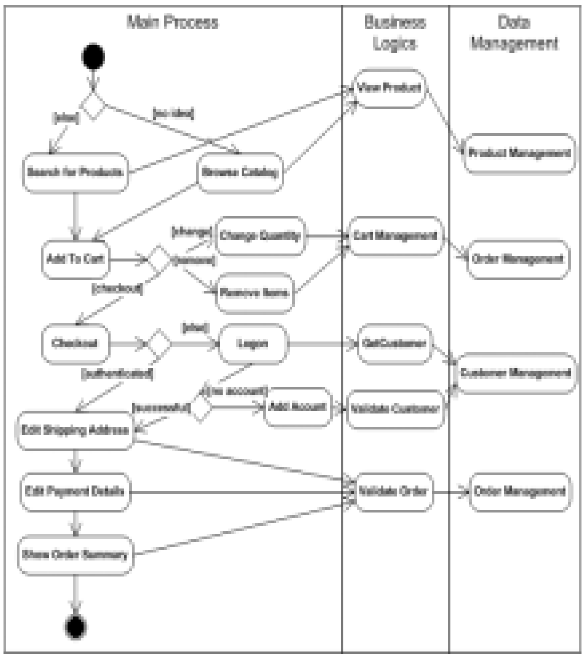


Figure 9. Activity Diagram for B2C EC Domain

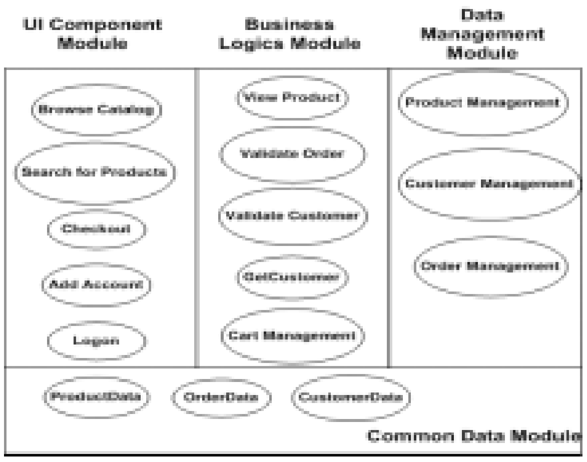


Figure 10. The Four-Module Framework Architecture for B2C EC Domain

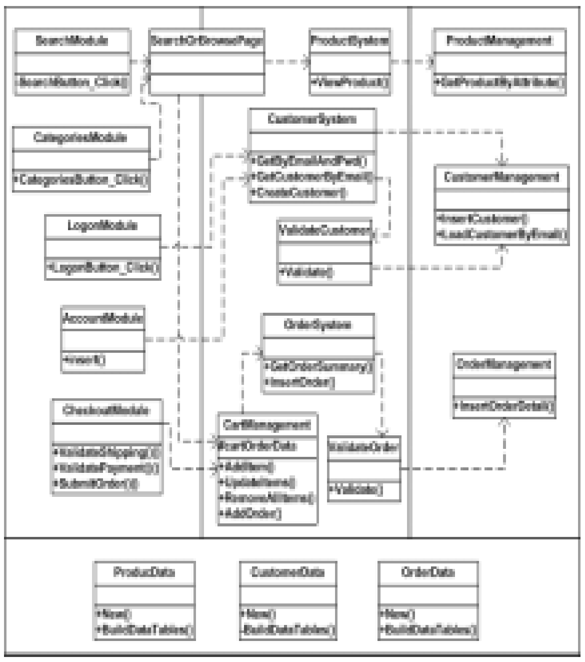


Figure 11. The Class Diagram for B2C EC Domain

Figure 14 shows the final framework diagram. The start points of the internal control flows of the framework are the interfaces of the framework.

In the implementation phase, we choose Microsoft .NET Framework as the platform and VB.NET as the programming language. Then we implement all classes and interfaces of the Framework B2C that are depicted in Figure 14. Next, we build the specific application by using the implemented Framework B2C. We inherit the abstract classes and override the hook method from the Framework B2C.

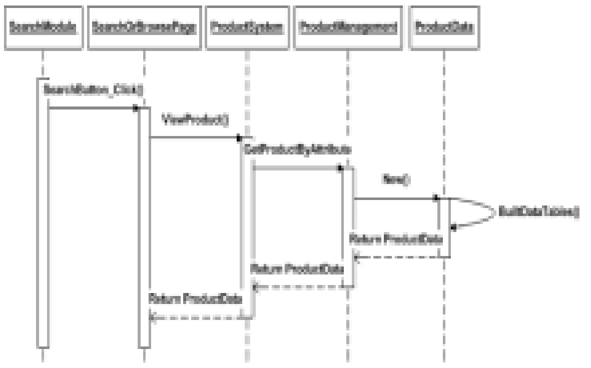


Figure 12. Sequence Diagram for Use Case Search for Products

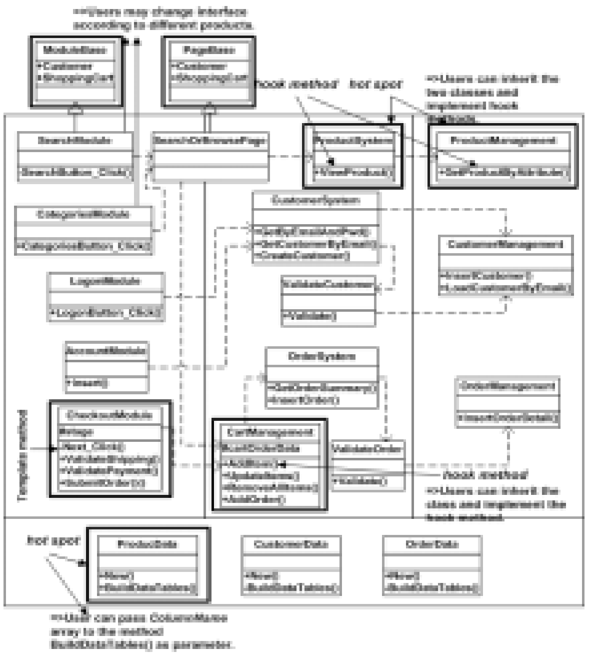


Figure 13. Identifying Hot Spots for B2C EC Domain

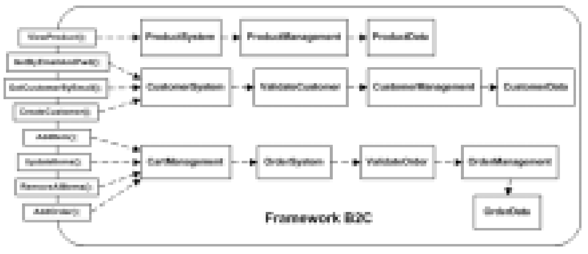


Figure 14. The Final Framework Diagram for B2C EC Domain

5. CONCLUSIONS

In this paper, we proposed a practical

object-oriented framework development process that is based on UML notations and semantics. We defined development phases (analysis, design, implementation) and tasks for each phases. We defined essential tasks for framework development and applied UML notations to each task. Each task is given a set of steps on how to carry out the task. Since the proposed process is based on UML diagrams and the basic Objectory process, we believe that object-oriented frameworks can be more efficiently developed by utilizing the proposed process, and higher quality object-oriented frameworks can be produced.

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