RUP Based Analysis and Design with Aspects

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Abstract

Aspect-Oriented Software Development (AOSD) is a new paradigm aiming to solve problems that are not adequately addressed by the Object-Oriented paradigm. Therefore, it seems appropriate to adapt software processes showing when and how crosscutting concerns should be considered. The Rational Unified Process (RUP) is one of the most widely used software development processes focusing on object-oriented software development, but RUP was not originally conceived considering separation of crosscutting concerns. This work proposes adjustments to one of the most affected RUP disciplines, Analysis and Design, in order to use new concepts and techniques of AOSD. A case study is developed to validate the proposed approach.

1. Introduction

Aspect-Oriented Software Development (AOSD) is a term to denote the use of Aspect Oriented Programming [8] during software development process. It is a new paradigm that comes to complement the Object-Oriented (OO) paradigm, solving problems that are not adequately solved by the later [13, 14]. These problems are related to the implementation of some concerns that are generally spread throughout the system (code scattering). In addition, this code is generally not related to the behaviour implemented in the context where it appears (code tangling).

AOSD implements these crosscutting concerns in a system as first class entities (named aspects). Each aspect defines behaviour that should be added to specific points in the program. This structure enables the separation and modularization of crosscutting concerns.

The Rational Unified Process (RUP) [9] is one of the most widely used software development processes. It defines disciplines, workflows, activities, roles and artifacts that control the software development, aiming to produce software with quality, on budget and within schedule. The RUP is designed to model an object-oriented process. It was not originally conceived to consider a different paradigm, as AOSD. On the other hand, as a process framework, the RUP can be specialized to specific domains and extended to incorporate new concepts and paradigms. Hence, it is possible (and seems appropriate) to adapt the RUP, analyzing when and how to consider the modelling of crosscutting concerns as aspects.

This work focuses on the Analysis and Design discipline. We show the adaptations to each activity in this workflow, suggesting changes and also including new activities. Thus, our main contribution is a set of guidelines on how to use AOSD with the RUP Analysis and Design discipline. Despite our focus on this discipline, others, such as Requirements and

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Implementation, are also considered. We discuss related work on the Requirements discipline which is the main input to Analysis and Design.
In particular, this work can be regarded as an extension of a previous work [15], where some new roles and activities to the Analysis and Design discipline in the presence of aspects are suggested. Here we further develop the ideas to propose a more precise description of the necessary adaptations to the RUP Analysis and Design (A&D) discipline. We give an overview of each workflow detail, proposing changes to the related activities and suggesting the creation of new ones. Moreover, we develop a case study to validate the proposed approach.
This paper is organized as follows. Section 2 gives an overview of the RUP singling out the Analysis and Design discipline. Next, we introduce the Requirements discipline making use of aspects in Section 3. Then we suggest the necessary adaptations to the Analysis and Design discipline in Section 4. In Section 5 we develop a case study based on the Analysis and Design discipline proposed. Section 6 discusses our conclusions, related and future work, presenting some suggestions and guidelines for the Implementation discipline.

2. The Rational Unified Process

The Rational Unified Process (RUP) [9] is a software engineering process. It can be viewed as a framework which is extensible to be adapted for particular project needs. It provides a disciplined approach to assigning tasks and responsibilities within a development organization. Its goal is to ensure the production of high-quality software that meets the needs of its end users within a predictable schedule and budget.
RUP is an object-oriented and Web-enabled software development process. It provides guidelines, templates, and examples for all aspects and program development phases. RUP and similar products, such as Catalysis [5] and the OPEN Process [6], are comprehensive software engineering tools that combine defined stages, techniques, and practices with other components of development (such as documents, models, manuals, code, and so on) within an unifying framework.
RUP establishes four development phases, each is organized in iterations that must satisfy defined criteria before the next phase is undertaken. The first phase is the inception, where developers define the scope of the project and its business case. Next, in the elaboration phase, developers analyze the project's needs in greater detail and define its architectural foundation. In the construction phase, developers create the application design and source code. Finally, in the transition phase, developers deliver the system to users. Using RUP allows the production of a functional prototype at the completion of each iteration. The way interactions and phases take place should be configured according to specific projects necessities and technologies.
There are four primary modelling elements: roles, activities, artifacts and workflows. Roles represent behaviours and responsibilities of the development team participants (i.e. system analysts, architects, designers). Activities are the work performed by the roles (i.e. find use cases and actors, review the design and execute a performance test). Artifacts are formation produced or used by the roles to perform activities (i.e. software architecture ocument, design model).
Workflows (or disciplines) describe the sequence of activities that produce some value result and show the interactions among roles. There are nine workflows considered in RUP: Business Modelling, Requirements, Analysis and Design, Implementation, Test, Deployment, Configuration and Change Management, Project Management, and Environment. Besides the last three ones, most of the artifacts produced in one workflow are part of the input to the next.

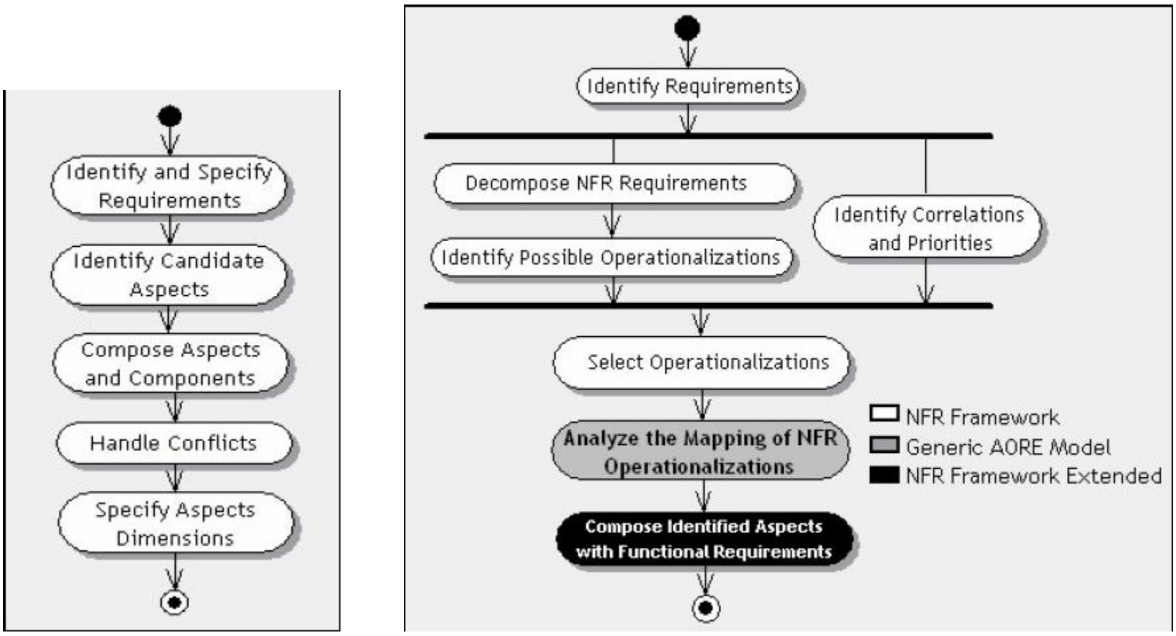
Requirements goals are to establish and maintain agreement with the customers and other stakeholders on what the system should do. It also provides a better understanding of the system domain and behaviour, allowing the definition of the the system´s scope and user-interface. In addition, it enables the estimation of costs and time to develop the system.
The purpose of Analysis and Design is to transform the requirements into a concrete design of the system, to construct a robust architecture for the system and to adapt the design to match the implementation environment. More details on this discipline are given in Section 4.
Implementation defines the code organization, structuring subsystems in layers. In this phase, the design elements are mapped to implementation elements (source files, binaries, executables, and others) and unit tests are performed to produce an executable system using the components produced by individual implementers (or teams).
This work focuses on the Analysis and Design discipline. However, it is important to consider the Requirements and the Implementation disciplines as they, respectively, generate part of the input and use part of the output produced by the Analysis and Design discipline. We only discuss those three disciplines, as the others are beyond the scope of this work.

3. Requirements Assumptions

The phase where aspects should be introduced during the software development process should be as early as possible [18, 19]. Early separation of crosscutting properties supports effective determination of their mapping and influence on latter development phases. Rashid et al. propose a generic model for Aspect Oriented Requirements Engineering (AORE) [18, 19]; some of the activities suggested can be seen in Figure 1(a).
An extension for the AORE model [22] suggests an adaptation to the NFR-Framework (Non-Functional Requirements-Framework) [4]. This adaptation is more adequate to deal with NFR *operationalizations* in the context of AORE because it better reflects how the crosscutting concern will be implemented. Therefore, it improves the composition and the mapping of crosscutting requirements onto artifacts at later development phases. Figure 1(b) shows the extended model.
We adopt the Requirements discipline considering aspects as described in [22] and thus we assume the existence of an artifact containing the aspect information as an input to the Analysis and Design discipline. This artifact describes, for instance, the mapping of the NFR *operationalizations* with respect to artifacts to be generated at later stages. Figure 2 shows an example of this information representation.

4. Analysis and Design Adaptations

This section presents the main contribution of this work. It is structured similar to the way RUP explains its workflow details and activities. We show a brief description of the workflow detail, and then we show the activities that compose it and the necessary steps to execute them. Only the activities affected by AOSD are presented and their descriptions include only the information relevant to AOSD. Some of them appear in more than one workflow detail. In these cases, only additional information and differences are showed. The repeated activities that do not change are only presented the first time they appear.



(a) AORE Generic Mode. (b) Adaptation of the NFR-Framework.

Figure 1. AORE and NFR-Framework Models.

The Analysis and Design discipline is composed of six workflow details: Perform Architectural Synthesis, Define a Candidate Architecture, Refine the Architecture, Analyze Behaviour, Design Components and Design the Database. Each workflow detail is composed of some activities and describes what to be done, which role is responsible and what are the artifacts produced or updated. This workflow can be seen in Figure 3.

The dynamics of the Analysis and Design discipline indicates how the workflow details are executed during RUP phases and interactions. This perspective of the Analysis and Design does not change from the already defined in RUP. Figure 4 shows the distribution of the workflow details during RUP phases.

In the Inception Phase, Analysis and Design is concerned with establishing whether the system as envisioned is feasible, and with assessing potential technologies for the solution (in *Perform Architectural Synthesis*). If it is felt that little risk attaches to the development then this workflow detail may be omitted.

The early Elaboration Phase focuses on creating an initial architecture for the system (*Define a Candidate Architecture*) to provide a starting point for the main analysis work. If the architecture already exists, the work will focus on changes to refine the architecture (*Refine the Architecture*). In addition, it is necessary to provide the appropriate behaviour by analyzing behaviour and creating an initial set of elements (*Analyze Behaviour*).

After these elements are identified, they are further refined. The activity *Design Components* produces components to provide the appropriate behaviour to satisfy the system requirements. If the system includes a database, then the activity *Design the Database* occurs in parallel. The resulting components are further refined in the Implementation discipline.

Concerning roles and artifacts, we believe that the roles are only affected by the way each one executes its activities. We do not create or change any role. The artifacts, mainly diagrams, must be changed to represent aspect concepts. In Section 5, we use the aSide Modelling Language [3] to represent aspects as an extension of UML diagrams.

NFR CONCERN		NFR *OPERATIONALIZATION*	MAPPING
SECURITY	ACCURACY	*Limited Value*	Aspect
		Firewall	Architectural Decision
	CONFIDENTIALITY	*Data Encryption*	Aspect
		Identification	Aspect
		Internet Password Request	Aspect
		Personal Data Validation	Aspect
	AVAILABILITY	*Duplication Server*	Architectural Decision
		Mirroring Database	Architectural Decision

Figure 2. Mappings of NFR *operacionalizations*.

4.1. Perform Architectural Synthesis

The intent of this workflow detail is to construct and assess an Architectural Proof-of-Concept to demonstrate that the system, as envisioned, is feasible. It is conducted during the inception phase and is the responsibility of the Architect.

4.1.1. Architectural Analysis. The purpose of this activity is to define a candidate architecture for the system, based on experience obtained from similar systems or in similar problem domains and to define the architectural patterns, key mechanisms, and modelling conventions for the system. This activity includes the following steps adopted to consider AOSD.

- **Survey Available Assets**: In addition to regular assets consideration, this step should also look for assets related to aspects. For instance, a framework or component that may assist on the system architecture construction.
- **Identify Key Abstractions**: The abstractions selected in this phase should include the ones necessary to use the aspects uncovered in the Requirements discipline, guiding the architect on the Architectural Proof-of-Concept construction considering aspects.
- **Develop Deployment Overview**: The geographical distribution study in this step should consider the possibility of modelling distribution as an aspect.

4.1.2. Construct Architectural Proof-of-Concept. The purpose of this activity is to synthesize at least one solution (which may be conceptual) that meets the critical architectural requirements. It must incorporate critical aspects as they also need validation.

4.1.3. Assess Viability of Architectural Proof-of-Concept. In this activity, the synthesized Architectural Proof-of-Concept is evaluated to determine whether the critical architectural requirements are feasible and could be satisfied (by this or any other solution). It is important to consider the critical aspects that influence the architecture. For instance, the aspects signed as architectural decision, during the requirements discipline, directly contribute to the architecture construction.

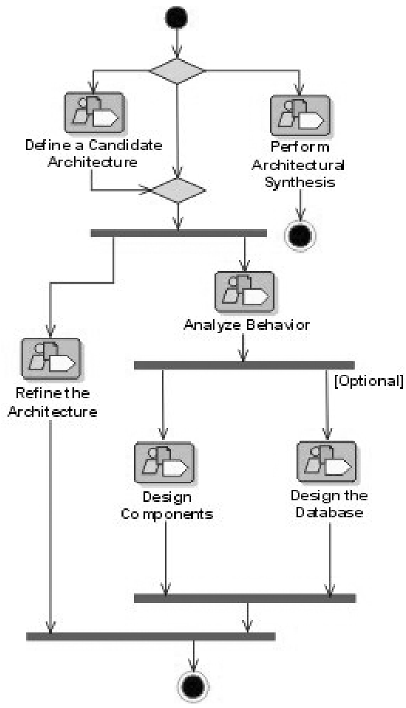


Figure 3.Analysis and Design Workflow.

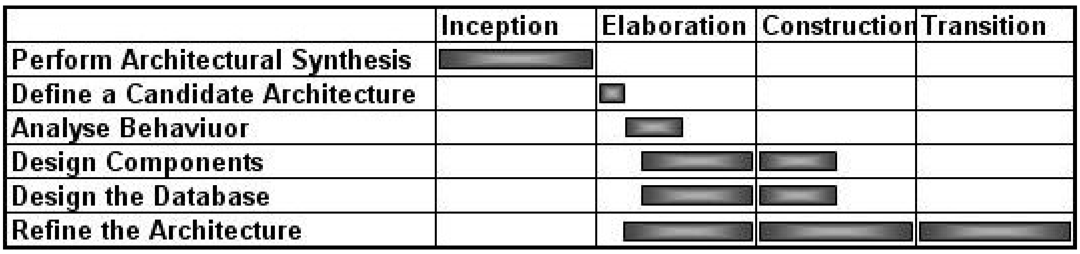


Figure 4. Dynamic Distribution of Workflow Details.

4.2. Define a Candidate Architecture

The purpose of this workflow detail is to create an initial sketch of the software architecture. Although modelling crosscutting concerns as aspects usually simplifies the architecture in general, most of the architectural modelling decisions must be aware of aspects because the architecture is directly affected by them. In addition, it is also important to work on subsystem and component interfaces, preparing them to offer the necessary join points to the aspects, although it is not mandatory. Thus, the architect should keep the aspects in mind even when modelling a simple architecture. However, some architectural decisions may be postponed because the aspects allow its future implementation in a non-invasive way. The architecture is also influenced by the goals, that map to architectural decision, as identified during the requirements workflow (see Section 3).

4.2.1. Architectural Analysis

- **Define the High-Level Organization of Subsystems:** This step should relate aspects to the layering organization and consider adaptations necessary to the patterns adopted.
- **Identify Key Abstractions:** The goals identified during requirements, which maps to an architecture decision, should be considered in this step.

- **Identify Analysis Mechanisms:** Decide which mechanisms map to aspects and make architecture understanding easier. Almost all the architectural mechanisms (for example, persistence and transaction management) can be represented as aspects.

4.2.2. Use Case Analysis

- **Find Analysis Aspects (New Step):** Considering the mapping suggested in the Requirement discipline (see Section 3), the designer should identify the model elements capable of achieving the requirement goals.
- **Distribute Behaviour to Analysis Classes:** Include aspects on the collaborations, showing aspects dependencies and responsibilities.
- **Describe Responsibilities:** In this step, the designer should describe the responsibilities of identified aspects.
- **Describe Attributes and Associations:** The designer should identify and define other classes and aspects on which the already identified aspects depends. It is also necessary to identify the classes affected by aspects and possibly determine the pointcuts used by them.
- **Qualify Analysis Mechanisms:** This step considers only the mechanisms not modelled as aspects.

4.3. Refine the Architecture

This workflow detail provides the natural transition from analysis activities to design activities, identifying: appropriate design elements from analysis elements and appropriate design mechanisms from related analysis mechanisms. It also describes the organization of the system's run-time and deployment architecture. The implementation model is organized to make the transition between design and implementation seamless. It is important to maintain the consistency and integrity of the architecture, ensuring that: new design elements identified for the current iteration are integrated with pre-existing design elements, and maximal re-use of available components and design elements is achieved as early as possible in the design effort.

4.3.1. Identify Design Elements. As aspects implement a set of concerns, this activity should include aspects on relationship diagrams and descriptions.

- **Identify Events and Signals:** This step should consider identifying the pointcuts required by aspects.
- **Identify Classes, Active Classes and Subsystems**: Refine the aspects identified during analysis and their relations to the new design elements. This step identifies the active classes (threads), therefore, concurrency should be considered during this activity. Concurrency is a common example of crosscutting concern. Generally, its effects are spread throughout the processes and consequently over different modules. Hence, concurrency control is a good candidate to be implemented as an aspect.
- **Identify Subsystem Interfaces:** Subsystems affected by aspects should provide an interface with the necessary pointcuts to be used by the affecting aspects. However, those interfaces must be clear and can not brake its intended contract.

4.3.2. Identify Design Mechanisms. As a refinement of the step *Qualify Analysis Mechanisms* in activity *Use case Analysis*, this activity considers only the mechanisms not implemented as aspects.

4.3.3. Incorporate Existing Design Elements.

- **Identify Reuse Opportunities:** Look for similarities and probably unification of interfaces affected by aspects. Another important consideration in this step is the identification of common aspect features as an indicative of an abstract aspect. This step also defines patterns used to refine the architecture. There are several patterns suggested to use aspects in a more organized way that should be considered in this step. For instance, the PaDA [20] is a pattern for distribution using aspects.

4.3.4. Describe Distribution. As a refinement to the *Deployment Model* created during *Architectural Analysis*, this activity is influenced by the use of AOSD only if the distribution is modelled with aspects. In this case, this activity should refine the *Deployment Model* to reflect the current design, showing how the distribution aspects affect the deployment configuration.

4.3.5. Describe the Runtime Architecture. This activity is mainly focused on processes and its organization. It identifies processes, how they communicate, their life cycle and finally how they share resources. Thus, new threads can be identified during this activity, implying on changes to concurrency policies. If concurrency is modelled with aspects, the aspects should be modified to control the new threads.

4.4. Analyze Behaviour

The purpose of this workflow detail is to transform the behavioural descriptions provided by the requirements into a set of elements upon which the design can be based. It occurs in every iteration where the necessary behavioural requirements are still not analyzed.
The activities concerning user interface are not affected by the use of AOSD. Other activities specified in this workflow detail (*Use Case Analysis* and *Identify Design Elements*) are affected and were already defined (see Sections 4.2 and 4.3).

4.5. Design Components

The purpose of this workflow detail is to refine the system design. The activities described are not directly affected by the use of AOSD. However, it is necessary to create a new activity called *Design Aspects*.

4.5.1. Design Aspects (New Activity). The purpose of this activity is to ensure that enough information is provided to unambiguously implement the aspects, to refine already identified join points, and to identify the pointcuts and advices.
Define Priorities and Precedence: This decisions should be based on the conflict identification and resolution from *IdentifyDesign Mechanisms* in the *Refine the Architecture* workflow detail.

- **Define Pointcuts:** This step is responsible for grouping join points on which the aspect depends, creating the necessary pointcuts and deciding the context that should be exposed to advices. It is necessary to put together all the join points that are similarly affected and are able to expose the same context. This step can also define abstract pointcuts to be used by advices. Those pointcuts can be further defined in a concrete aspect.
- **Define Advices:** Specify only the kinds of advice (i.e. before, after and around) and the context exposure based on the identified pointcuts.

- **Define Structure Influence:** This step is responsible for specifying how the aspects change the class hierarchy, identifying the new relationships. It also defines how aspects introduce behaviour to classes, indicating which attributes and methods must be introduced.

5. Example

This section shows an enactment of the proposed Analysis and Design discipline in the context of a commercial system. The Health Watcher [21] is a real web based system intended to improve the quality of the services provided by health care institutions. By allowing the public to register several kinds of health complaints, such as complaints against restaurants and food shops, health care institutions can promptly investigate the complaints and take the required actions. The system has a web-based user interface for registering complaints and performing several other associated operations.

For simplicity, we work only with a subset of use cases of the original system. Figure 5 shows the use case diagram for the chosen ones. The system has two actors: users, who can add a complaint to the system, and employees, who needs authentication to change the complaint status. The use case details can be seen in Figure 6.

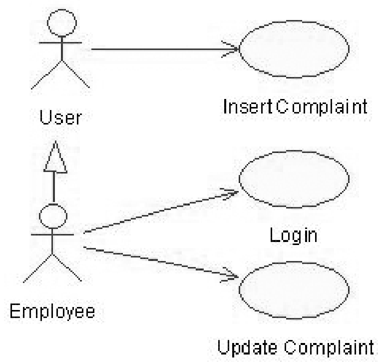


Figure 5. Use Case Diagram for the Health Watcher System.

We also simplified the non-functional requirements considering only one to be analyzed and modeled with aspects. The non-functional requirement used is distribution. Although persistence could also be modeled with aspects [16, 17, 2], it would increase the complexity of the example making it difficult to understand.

The system should be distributed separating the execution of user interface from the business related processes. This separation provides better scalability, performance and availability. The Requirements discipline execution according to the model previously described [22] (see Section 3) produces an indication that this non-functional requirement would generate an aspect. Only during design we will find out that this aspect crosscuts all three use cases.

The HealthWatcher system uses an existing architecture model. Hence we skip the *Perform Architectural Synthesis* workflow detail and begin with the *Define a Candidate Architecture* during the elaboration phase. In order to achieve modularity and extensibility, a layered architecture and associated design patterns [7, 11] are used in the system. This layered architecture helps to separate data management, business, communication (distribution), and presentation (user interface) concerns.

Use Case	**Insert Complaint**
Description	Registers a complaint in the system. Complaints may be of three types: Animal related, Food related, and General complaint
Preconditions	None
Output and Post conditions	The new complaint is registered in the system
Basic Flow of Events	1. User chooses complaint type
	2. System registers complaint type, date and time
	3. System presents a screen with the needed information for the complaint type
	4. User fills in the information
	5. System registers the complaint and presents the complaint number
Use Case	**Login**
Description	Authenticates employees to use restricted system operations
Preconditions	None
Output and Post conditions	Employee is identified and authenticated
Basic Flow of Events	1. Employee informs login and password
	2. System verifies password
Alternative Flows	In step 2, show an error message if the password is invalid
Use Case	**Update Complaint**
Description	Updates the status of a registered complaint
Preconditions	There is a registered complaint with an OPEN status and the employee is logged in
Output and Post conditions	Status is updated to CLOSED
Basic Flow of Events	1. Employee informs the complaint number
	2. System shows the complaint information
	3. Employee fills in the medical opinion
	4. System updates the complaint including the employee id

Figure 6. Use Case Details.

The *Architectural Analysis* during elaboration, only identifies and creates an analysis element to represent the aspects that influence the architecture. Analysis elements should also be created to represent the aspects indicated in requirements. Next, the *Use Case Analysis* activity identifies the analysis elements according to the chosen architecture. For each identified entity, there is a related class that represents an entity collection. In addition, each use case has an interface and a controller. The resulting architecture with the identified analysis elements is shown in Figure 7. For now, the distribution aspect has no relations, as we do not know how it will affect the other analysis elements.

There are several approaches to model aspect-oriented systems [25, 24, 27, 3]. Our solution is not attached to a particular modelling language, however we chose the aSide [3] modelling language for it is less dependent on a programming language. The aSide modelling language is an extension to UML to represent the aspects design. In the aSide (see Figure 7), the diamond shape represents an aspect. The crosscutting interfaces (the way aspects crosscuts other elements) are represented as circles attached to the aspects. The rectangle on the right contains the crosscutting interfaces and their affecting parameters[1]. For simplicity, we do not expand the aspect representation and focus only on its relationships. More details are explained as the need arises during the example development.

[1] Crosscutting interfaces represent affecting roles, they may have associated parameters that represent how theaffected class changes behaviour.

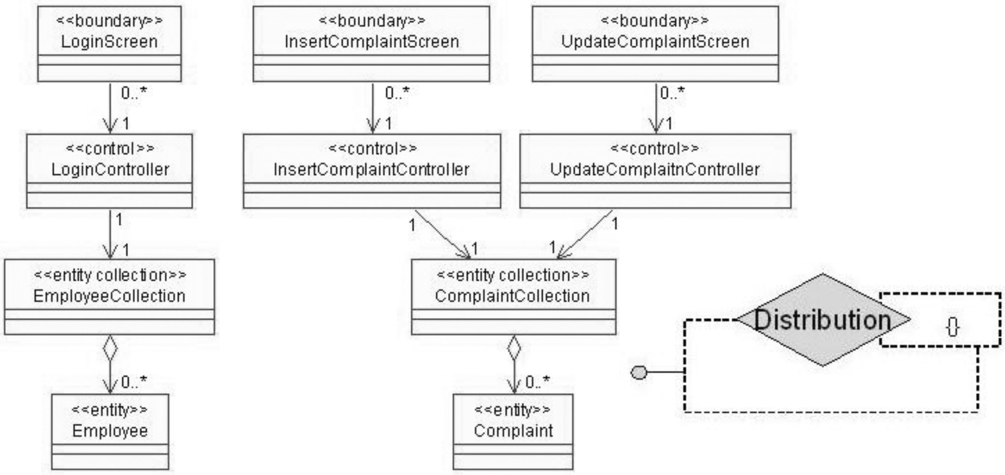


Figure 7. Analysis Elements.

The next workflow detail is *Analyze Behaviour*. For a matter of space, we omit the activities related to user interface and data base design. Hence, we start with the activity *Identify Design Elements*. First, we choose to use the Facade [7] design pattern to provide a single access point to the system business rules. Thus, the controllers used by the interface elements merge into a single design element, which is the system facade. We also choose to use servlets to implement the user interface. Thus, each interface element generates a servlet in the design.

The entity collections are designed with the PDC pattern [11], which consists of a structure that uses four classes for each entity. One is the entity record, which is responsible for the business logic related to the entity. Another is the repository interface, which is a simple interface providing operations to store a collection of entities. It is also necessary to provide an implementation to the repository interface. Finally, there is a class to represent the entity itself. Thus, each entity collection originates three classes: an entity record, an interface to an entity repository, and the repository implementation. As a consequence, we may have different repository (persistence) implementations without affecting other parts of the system.

We choose to represent the distribution requirement with a client/server model, where the clients are the user interface elements and the server is the system facade. As a result, we create two design elements from the analysis aspect, one is the client aspect and the other is the server aspect. Figure 8 shows the resulting architecture.

At this point, we carry out activity *Use Case Analysis* again. This time we focus on design elements behaviour and relationships. For simplicity, we describe only what is necessary to understand the aspects design. Starting with the server aspect, it is necessary to identify how it will affect other classes. In a client/server model, the server should make the system façade remote. Thus, we create a crosscutting interface (`Remote`) indicating that the affected object will become remote. The other concern relative to the server aspect is to allow the necessary objects to be transported through the remote channel. Thus, we create a second crosscutting interface (`Serializable`) responsible for allowing the necessary classes to be transported through the communication channel. Next, we associate those crosscutting interfaces with the affected classes.

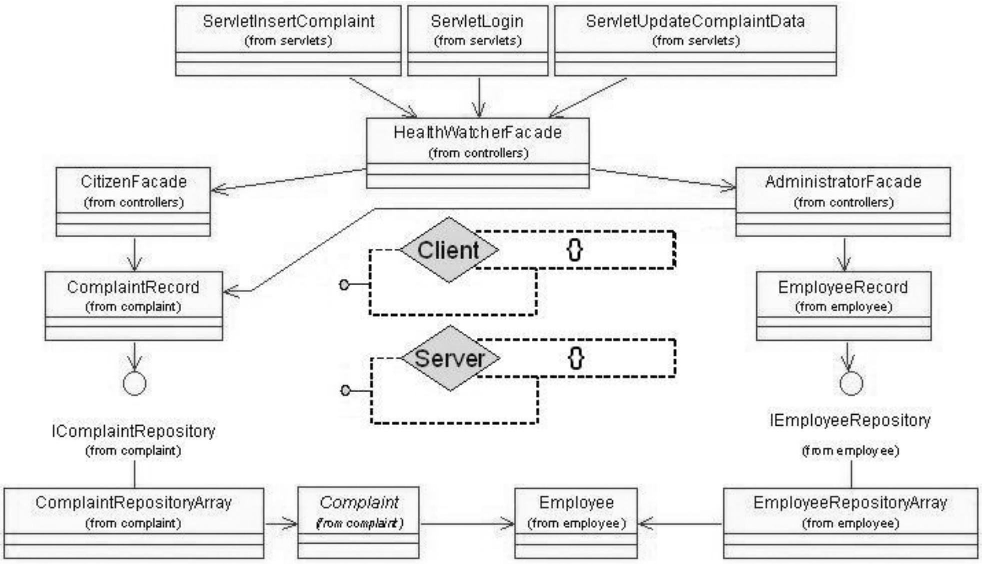


Figure 8. Design Elements.

Figure 9 shows the resulting server aspect. Each crosscutting interface appears in the parameter list, to indicate what class elements it affects, and it also appears as a circle connecting the aspect and the affected class. This association also represents what class elements are to be connected to the aspect parameters. For instance, the label `<remoteOP->All>` indicates that every operation in the class `HealthWatcherFacade` will be remotely available.

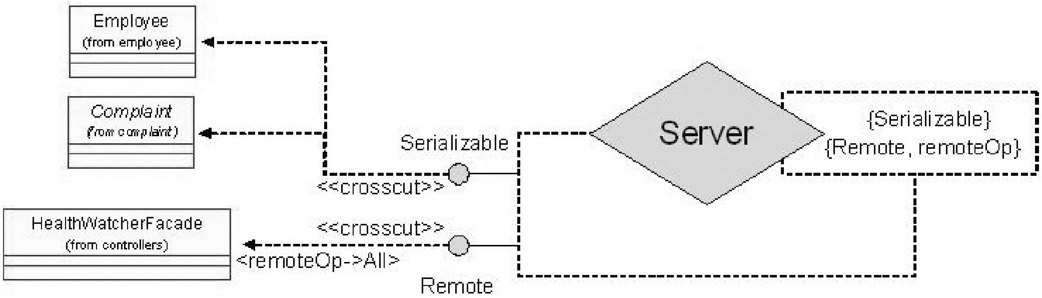


Figure 9. Server Aspect.

Designing the client aspect is similar. The client aspect is initially responsible for making the remote facade available for the user interface classes. Then, the aspect redirects calls originally addressing the local system facade to the remote facade. Thus, the resulting aspect has two crosscutting interfaces: the first (`RemoteAccess`) is associated with user interface classes and affects its facade attribute; the second (`RemoteRedirect`) affects the local system facade and redirects all the facade operations to a remote facade. The client aspect design is shown in Figure 10.

The next workflow detail is *Design Components*. The only relevant activity here is *Design Aspects*, which defines the necessary pointcuts and advices for the aspects. In our example, the join points can be derived from the aspect associations. The advices indicate how the aspect parameters affect the associated classes. For instance, the expression `<remoteOp->All>` indicates that there is one advice around all operations in the associated class. The advice representation comes from the symbol. When it appears before the operation, it indicates a before advice. It happens similarly when it appears after the operation. When it appears before and after the operation, it indicates an around advice. This activity also identifies how the class hierarchy is affected. This happens only in our server aspect, as it changes the ancestors of class `HeathWatcherFacade` to make it remote. The server may also change the classes with the relation `Serializable`, making them implement this interface to allow their serialization through the communication channel.

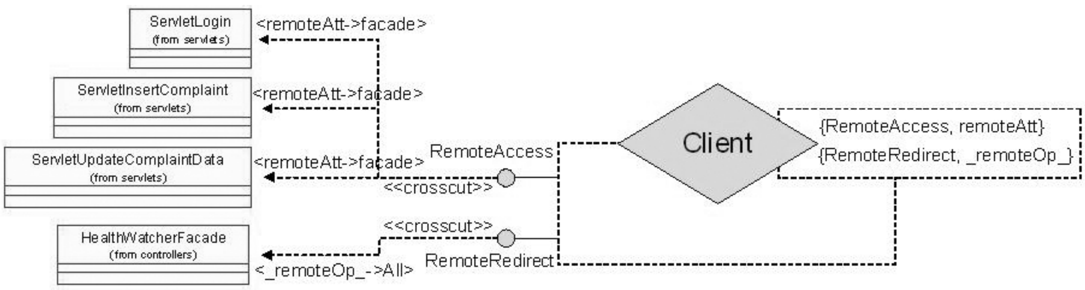


Figure 10. Client Aspect.

The last workflow detail is *Refine the Architecture*. It is responsible for unifying the design realized by different designers. In our example, it means we would generalize our aspects to control other user interface elements and entities. For a matter of space, we do not describe the related activities in detail.

This concludes the elaboration phase. As mentioned earlier (see Section 4) during the construction phase, we execute *Design Components* and *Refine the Architecture* in each iteration to improve our existing design and incorporate possible changes to the system requirements.

6. Conclusion

We have proposed adaptations to activities of the RUP [9] Analysis and Design discipline in order to incorporate the concepts of AOSD. A related work [15] suggests some changes to the roles, activities and artifacts of the Analysis and Design discipline in the presence of AOSD. We have further developed their ideas and proposed a more precise description of the necessary adaptations to the RUP Analysis and Design discipline. We gave an overview of each workflow detail, proposing changes to the related activities and suggested the creation of a new activity, Design Aspects. As far as we are aware, there is no other detailed proposal, in the literature, for systematizing the Analysis and Design discipline, including aspects, as we have proposed here. Another important contribution of our work is to integrate isolated efforts towards dealing with aspects in a software process. We have adopted the work reported in [22] for requirements, showing how the information captured at the requirements level could be used as input to the proposed Analysis and Design discipline. We have also adopted the modelling conventions suggested in [3].

This work focuses on one discipline defined by the RUP. Although some disciplines are not affected by the use of AOSD, there are disciplines, other than Analysis and Design, which need to be adapted. Hence, future work would deal with the adaptation of the Implementation discipline as it is strongly affected by the use of AOSD and it occurs just after the Analysis and Design discipline. One of the primary impacts is on the implementation language, which generally is an extension to an existing language or a framework. Once the developer is used to the new language, there are necessary adaptations to the way classes are implemented, to incorporate aspect implementations. In a similar way, the tests should be adapted to explore the concerns implemented by aspects.

However, there are related problems that are discussed elsewhere. The representation of crosscutting features in UML is discussed in [25] and the the representation of join points in UML is discussed in [24]. The expression of aspects and its relationships to classes and other aspects is proposed in [27], as an extension to the UML eXchange Format [26]. Finally, the aSide Modelling Language [3] is an UML extension that allows a more abstract representation of aspects and its relationships. We adopted this last approach to represent the aspect model in the example (see Section 5).
RUP instantiations are common as it is an adaptable process that should be tailored to specific companies and projects. Nevertheless, there are general instantiations that maintain the general propose of the framework. Kruchten [10] suggests adaptations to RUP with the objective of evolving a legacy project. Moraes [12] adapts the RUP to incorporate concepts of the Architecture Based Development Process, which uses the architecture as a bridge between the requirements and the implementation. Furthermore, their adaptations are mainly on the Analysis and Design discipline.
There are also instantiations to use RUP in more specific domains. Ara´ujo and Souza [1, 23] focused on adaptations to the Analysis and Design discipline to developWeb based applications.

References

1. Araújo, A. C. M. Framework de Análise e Projeto Baseado no RUP para o Desenvolvimento de Aplicações Web, Master thesis, Informatics Centre – Federal University of Pernambuco, February 2001.
2. Camargo, V., Ramos, R., Penteado, R., Masiero, P. C. Projeto Baseado em Aspectos do Padrão Camada de Persistência. In: XVII Brazillian Symposium on Software Engineering - SBES, October 2003.
3. Chavez, C. A Model-Driven Approach for Aspect-Oriented Design. PhD thesis, Pontifícia Universidade Católica do Rio de Janeiro, April 2004.
4. Chung, L., Nixon, B. A., Yu, E., Mylopoulos, J. Non-Functional Requirements in Software Engineering, volume 5 of The Kluwer International Series In Software Engineering. Kluwer Academic Publishers, October 1999.
5. D'Souza, D. F., Wills, A. C. Objects, Components, and Frameworks with UML : The Catalysis(SM) Approach. Addison-Wesley Pub Co, October 1998.
6. Firesmith, D., Henderson-Sellers, B. The OPEN Process Framework. An Introduction. Addison-Wesley, December 2001.
7. Gamma, E., Helm, R., Johnson, R., Vlissides, J. Design Patterns: Elements of Reusable Object–Oriented Software. Addison–Wesley, 1994.
8. Kiczales, G., Lamping, J., Mendhekar, A., Maeda, C., Lopes, C., Loingtier, J.-M., Irwin, J. Aspect-oriented programming. In: Aksit, M., Matsuoka, S., editors, 11th European Conf. Object-Oriented Programming, volume 1241 of *LNCS*, pages 220–242. Springer Verlag, 1997.
9. Kruchten, P. The Rational Unified Process: An Introduction, Second Edition. Addison-Wesley Longman Publishing Co., Inc., 2000.
10. Kruchten, P. Using the RUP to Evolve a Legacy System. Available URL:http://www-106.ibm.com/developerworks/rational/library/389.html, May 2001, last visited in July 2004.
11. Massoni, T., Alves, V., Soares, S., Borba, P. PDC: Persistent Data Collections pattern. In: First Latin American Conference on Pattern Languages Programming—SugarLoafPLoP, pages 161 – 173, Rio de Janeiro, Brazil, October 2001. UFRJ Magazine: Special Issue on Software Patterns.

12. Moraes, M. A. F. Um Framework de Análise e Projeto Baseado em Arquitetura de Software. Master thesis, Informatics Centre – Federal University of Pernambuco, June 2002.
13. Ossher, H., Kaplan, M., Katz, A., Harrison, W., Kruskal, V. Specifying subject–oriented composition. TAPOS, 2(3):179–202, 1996. Special Issue on Subjectivity in OO Systems.
14. Ossher, H., Tarr, P. Using subject–oriented programming to overcome common problems in object–oriented software development/evolution. In: International Conference on Software Engineering, ICSE'99, pages 698–688. ACM, 1999.
15. Piveta, E. K., Devegili, A. J. Aspects in the Rational Unified Process Analysis and DesignWorkflow. In: Aspect Oriented Design Workshop, AOSD 2002, Enschende, Netherlands, 2002.
16. Rashid, A. On to aspect persistence. In: Proceedings of the Second International Symposium on Generative and Component-Based Software Engineering-Revised Papers, pages 26–36. Springer-Verlag, 2001.
17. Rashid, A., Chitchyan, R. Persistence as an aspect. In: Proceedings of the 2nd international conference on Aspect-oriented software development, pages 120–129. ACM Press, 2003.
18. Rashid, A., Moreira, A., Araújo, J. Modularisation and composition of aspectual requirements. In: 2nd International Conference on Aspect-Oriented Software Development, pages 11–20. ACM, 2003.
19. Rashid, A., Sawyer, P., Moreira, A., Araújo, J. Early aspects: A model for aspectoriented requirements engineering. In: IEEE Joint International Conference on Requirements Engineering, pages 199–202. IEEE, IEEE Computer Society Press, 2002.
20. Soares, S., Borba, P. PaDA: A Pattern for Distribution Aspects. In: Second Latin American Conference on Pattern Languages Programming — SugarLoafPLoP, Itaipava, Rio de Janeiro, Brazil, August 2002.
21. Soares, S., Laureano, E., Borba, P. Implementing distribution and persistence aspects with AspectJ. In: Proceedings of the OOPSLA 2002 conference on Object Oriented Programming Systems Languages and Applications, pages 174 – 190. ACM Press, November 2002.
22. Sousa, G. M. C., Silva, I. G. L., Castro, J. B. Adapting the NFR Framework to Aspect-Oriented Requirements Engineering. In: XVII Brazillian Symposium on Software Engineering - SBES, October 2003.
23. Souza, R. A. C., Vasconcelos, A. M. L. Uma Extensão do Fluxo de Análise e Projeto do RUP para o Desenvolvimento de Aplicações WEB. In: XVII Brazillian Symposium on Software Engineering - SBES, October 2003.
24. Stein, D., Hanenberg, S., Unland, R. On representing join points in the UML. In: Kandé, M., Aldawud, O., Booch, G., Harrison, B., editors, Workshop on Aspect-Oriented Modeling with UML, 2002.
25. Stein, D., Hanenberg, S., Unland, R. A uml-based aspect-oriented design notation for AspectJ. In: Proceedings of the 1st international conference on Aspect-oriented software development, pages 106–112. ACM Press, 2002.
26. Suzuki, J., Yamamoto, Y. Making UML models interoperable with UXF. In: Bézivin, J., Muller, P.-A., editors, The Unified Modeling Language, UML'98 - Beyond the Notation. First International Workshop, Mulhouse, France, June 1998, Selected Papers, volume 1618 of LNCS, pages 78–91. Springer, 1998.
27. Suzuki, J., Yamamoto, Y. Extending UML with aspects: Aspect support in the design phase. In: ECOOP Workshops, pages 299–300, 1999.