



SOFTWARE ENGINEERING

OBJECT-ORIENTED SE USING UML, PATTERNS AND JAVA

Dan CHIOREAN

Lecture 3 – **The Analysis model** – based on Bernd Bruegge's book

Introduction: An Optical Illusion

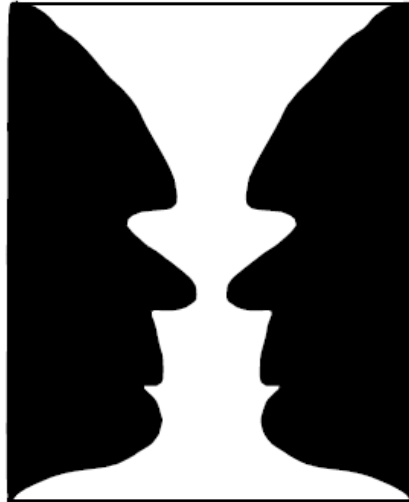


Figure 5-1 Ambiguity: what do you see?

- If the drawing in Figure 5-1 had been a requirements specification, which models should you have constructed? Specifications, like multi-stable images, contain ambiguities caused by the inaccuracies inherent to natural language and by the assumptions of the specification authors.

An Overview of Analysis

- Analysis focuses on producing a model of the system, called **the analysis model, which is correct, complete, consistent and verifiable**.
- Analysis is different from requirements elicitation in that developers focus on structuring and formalizing the requirements elicited from users.
- The formalization leads to new insights and to discovery of errors in requirements.

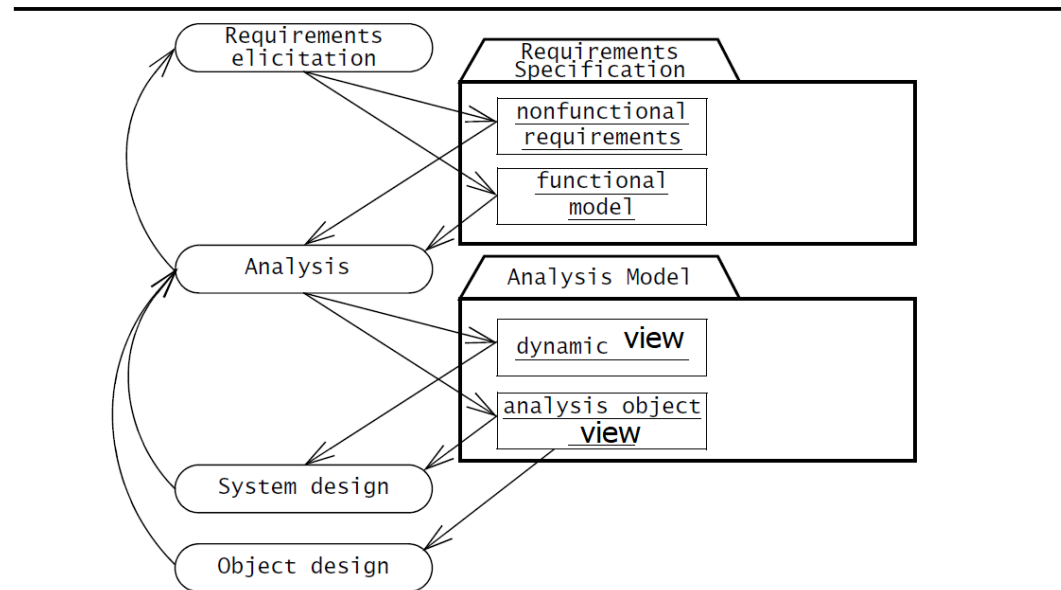
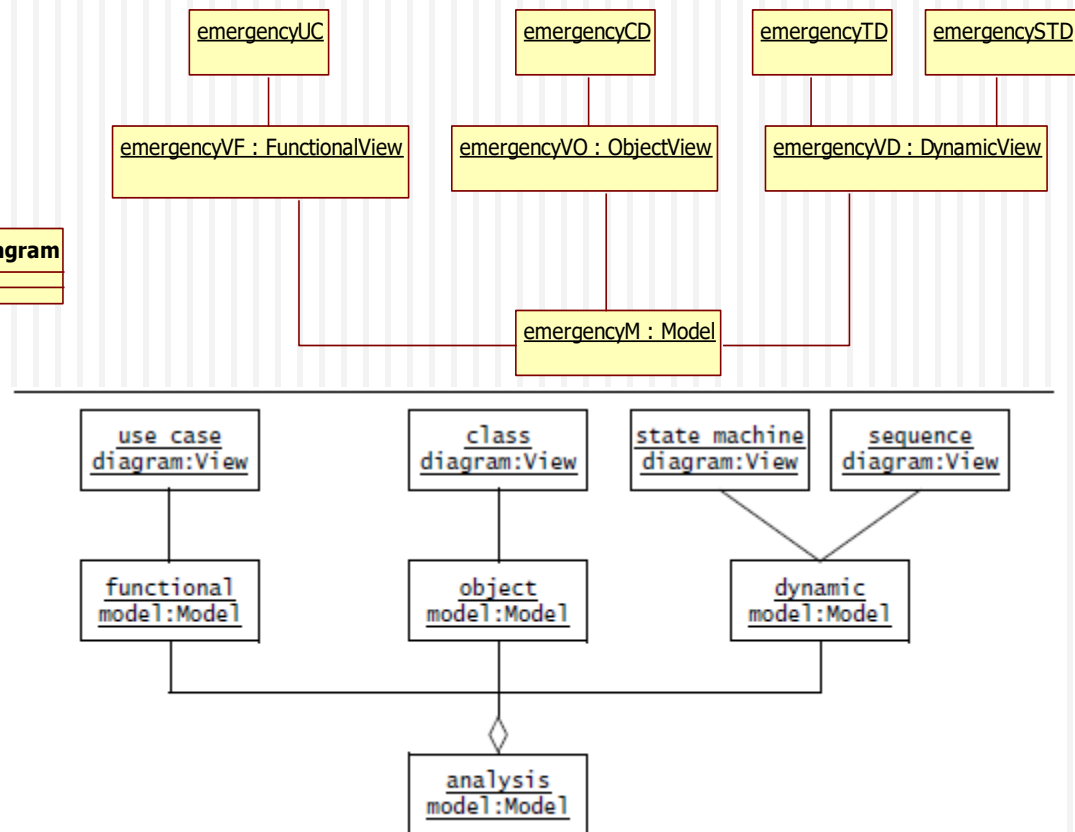
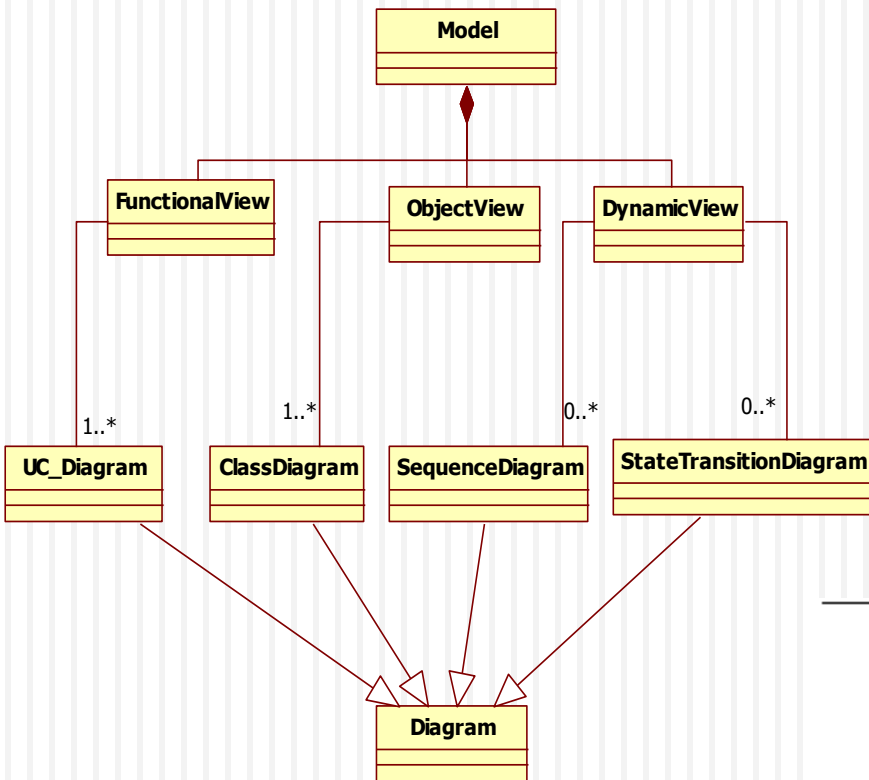


Figure 5-2 Products of requirements elicitation and analysis (UML activity diagram).

The Analysis Model



Analysis Object and Dynamic Views

- The Analysis Object View consists of **entity**, **boundary** and **control objects**
 - ▣ **Entity objects** represent the persistent information tracked by the system
 - ▣ **Boundary objects** represent the interaction between the actors and the system
 - ▣ **Control objects** are in charge of realizing use cases
- *Example:* In the 2Bwatch example, **Year**, **Month** and **Day** are **entity objects**, **Button** and **LCDDisplay** are **boundary objects**, **ChangeDataControl** is a **control object** that represents the activity of changing the date by pressing combination of buttons

Analysis Object and Dynamic Views/2

- To distinguish between different types of objects, UML provides the stereotype mechanism to enable the developer to attach such meta-information to modeling elements.

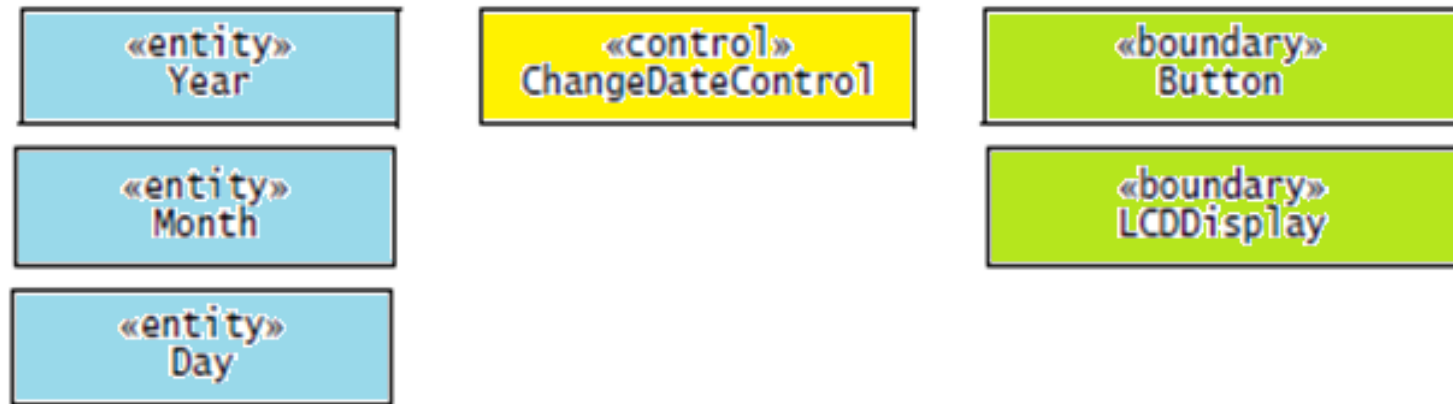
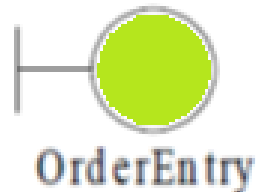


Figure 5-5 Analysis classes for the 2Bwatch example.

Analysis Stereotype Icons



«control»
PenTracker



«boundary»
OrderEntry



«entity»
BankAccount

Figure 4-2 Class Stereotypes

UML (1.5.1) Extension Mechanisms

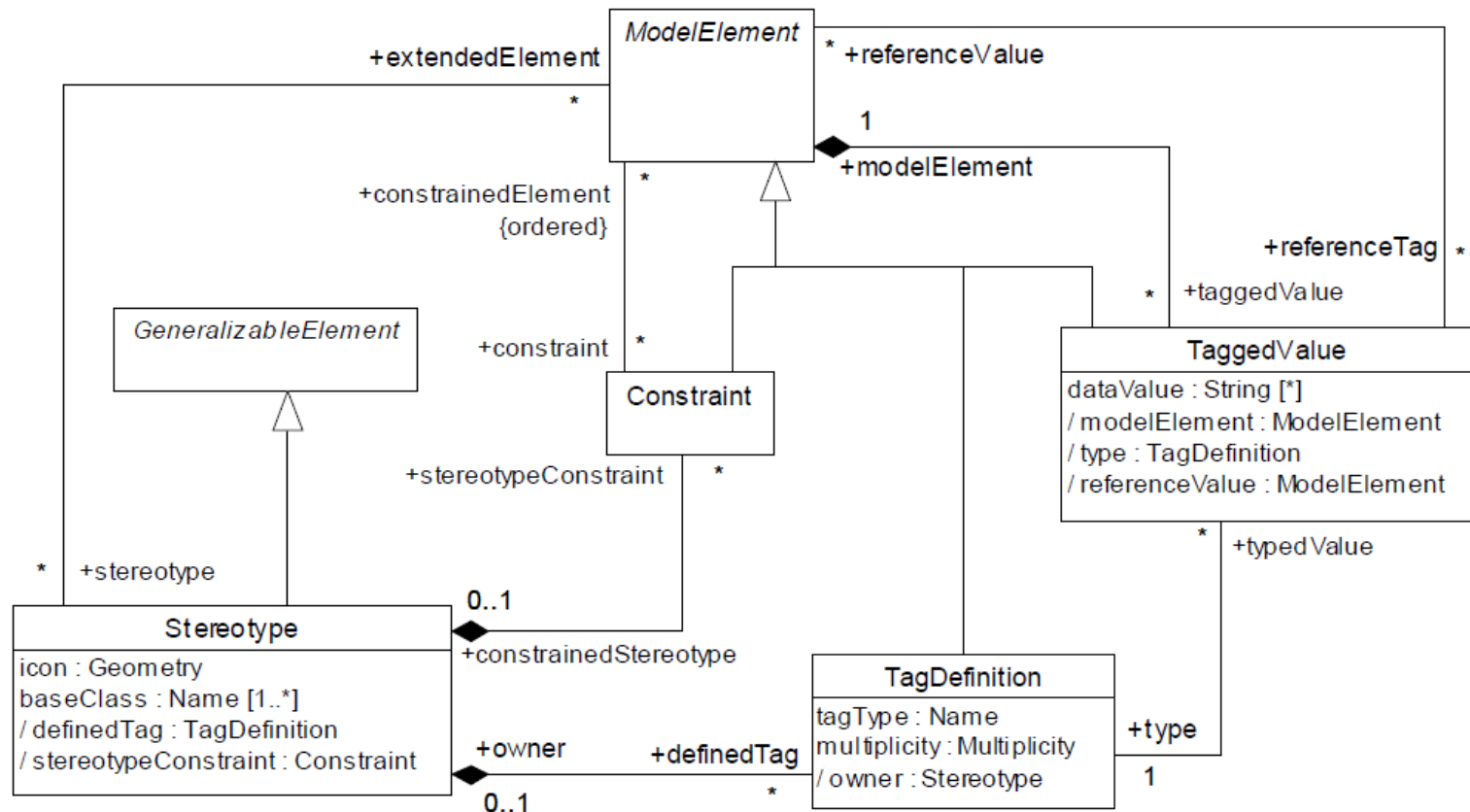
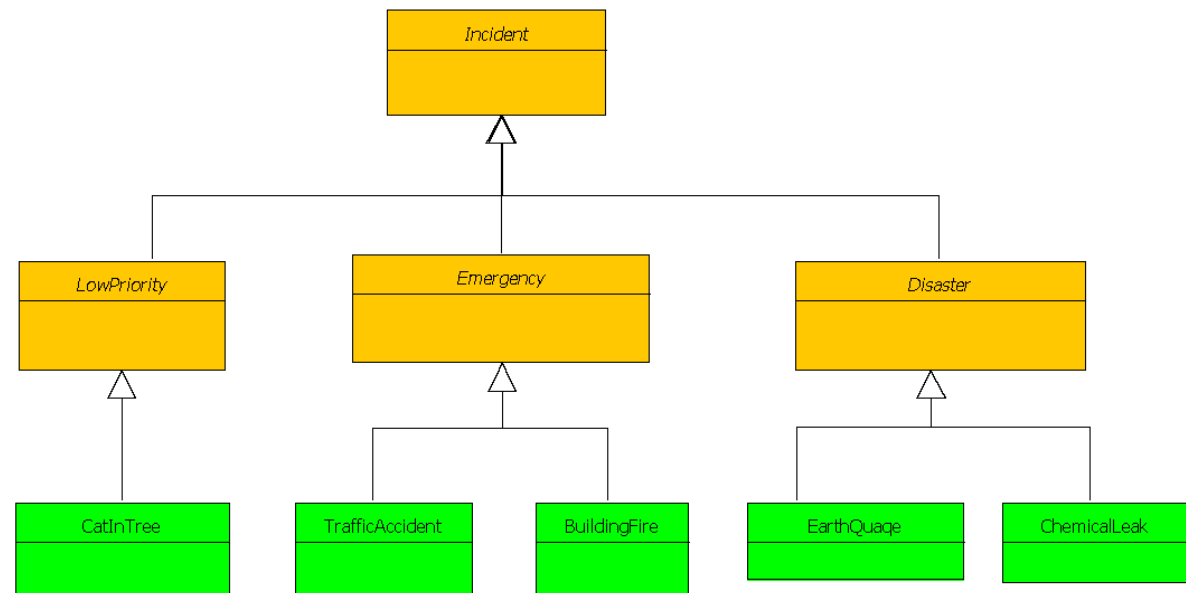


Figure 5-7 Extension Mechanisms

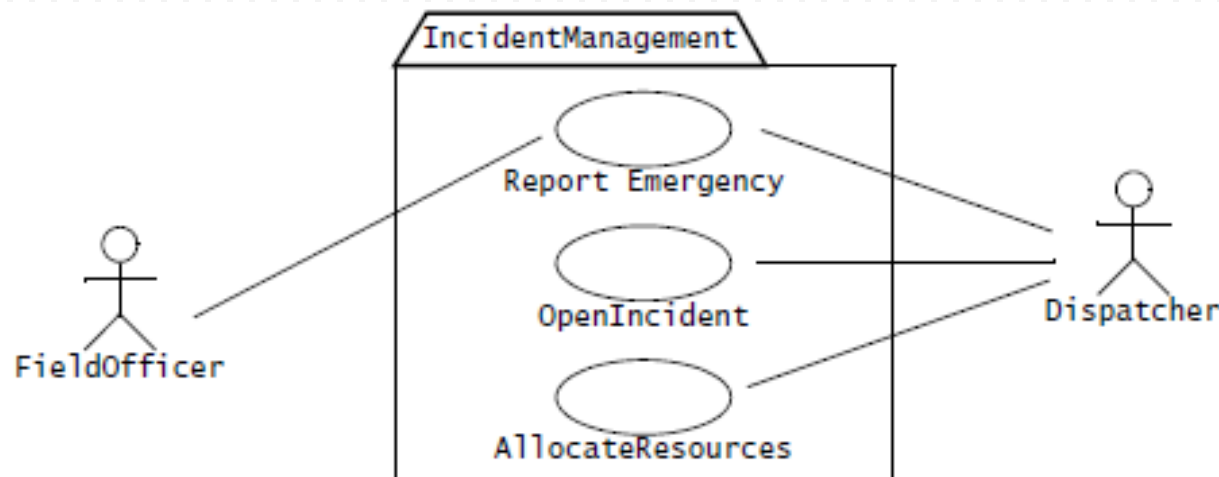
Analysis Object and Dynamic Views – Generalization and Specialization

- In both cases, generalization and specialization result in the specification of **inheritance relationships** between concepts. In some instances, modelers call inheritance relationships **generalization-specialization relationships**. In Bruegge's book, **inheritance** is used to **denote the relationship** and terms “**generalization**” and “**specialization**” to **denote activities** that find inheritance relationships.



The FRIEND system (book pp. 68)

- FRIEND – an accident management system in which field officers such as police officer or fire fighter have access to a wireless computer that enable them to interact with a dispatcher. The dispatcher in turn can visualize the current state of all its resources such as police cars or trucks, on a computer screen and dispatch a resource by issuing commands from a workstation.



The FRIED system - cont

<i>Use case name</i>	ReportEmergency
<i>Participating actors</i>	Initiated by FieldOfficer Communicates with Dispatcher
<i>Flow of events</i>	<ol style="list-style-type: none">1. The FieldOfficer activates the "Report Emergency" function of her terminal.2. FRIEND responds by presenting a form to the FieldOfficer.3. The FieldOfficer fills out the form by selecting the emergency level, type, location, and brief description of the situation. The FieldOfficer also describes possible responses to the emergency situation. Once the form is completed, the FieldOfficer submits the form.4. FRIEND receives the form and notifies the Dispatcher.5. The Dispatcher reviews the submitted information and creates an Incident in the database by invoking the OpenIncident use case. The Dispatcher selects a response and acknowledges the report.6. FRIEND displays the acknowledgment and the selected response to the FieldOfficer.
<i>Entry condition</i>	<ul style="list-style-type: none">• The FieldOfficer is logged into FRIEND.
<i>Exit condition</i>	<ul style="list-style-type: none">• The FieldOfficer has received an acknowledgment and the selected response from the Dispatcher, OR• The FieldOfficer has received an explanation indicating why the transaction could not be processed.
<i>Quality requirements</i>	<ul style="list-style-type: none">• The FieldOfficer's report is acknowledged within 30 seconds.• The selected response arrives no later than 30 seconds after it is sent by the Dispatcher.

Figure 2-14 An example of a use case, ReportEmergency.

Analysis Activities: From Use Cases to Objects

- Identifying Entity Objects,
- Identifying Boundary Objects,
- Identifying Control Objects,
- Mapping Use Cases to Objects with Sequence Diagrams
- Mapping Interactions among Objects with CRC Cards
- Identifying Associations
- Identifying Aggregates
- Identifying Attributes
- Modeling State-Dependent Behavior of Individual Objects
- Modeling Inheritance Relationships
- Reviewing the Analysis Model

Analysis Activities: Abbot's heuristics

- Natural language analysis [Abbott, 1983] is an intuitive set of heuristics for identifying objects, attributes, and associations from a requirements specification. Abbott's heuristics maps parts of speech (e.g., nouns, having verbs, being verbs, adjectives) to model components (e.g., objects, operations, inheritance relationships, classes).
- Natural language analysis has the advantage of focusing on the users' terms. However, it suffers from several limitations. First, the quality of the object model depends highly on the style of writing of the analyst.

Analysis Activities: Abbot's heuristics_2

- Natural language is an imprecise tool, and an object model derived literally from text risks being imprecise. Developers can address this limitation by rephrasing and clarifying the requirements specification as they identify and standardize objects and terms. A second limitation of natural language analysis is that there are many more nouns than relevant classes. Many nouns correspond to attributes or synonyms for other nouns. Sorting through all the nouns for a large requirements specification is a time-consuming activity.
- In general, Abbott's heuristics work well for generating a list of initial candidate objects from short descriptions, such as the flow of events of a scenario or a use case.

Abbot's heuristics_3 mapping parts of speech to model components

Table 5-1 Abbott's heuristics for mapping parts of speech to model components [Abbott, 1983].

Part of speech	Model component	Examples
Proper noun	Instance	Alice
Common noun	Class	Field officer
Doing verb	Operation	Creates, submits, selects
Being verb	Inheritance	Is a kind of, is one of either
Having verb	Aggregation	Has, consists of, includes
Modal verb	Constraints	Must be
Adjective	Attribute	Incident description

Analysis Activities: Identifying Entity Objects

Heuristics for identifying entity objects

- Terms that developers or users need to clarify in order to understand the use case
- Recurring nouns in the use case (e.g. Incident)
- Real-world entities that the system needs to track (e.g. FieldOfficer, Dispatcher, Resource)
- Real-world activities that the system needs to track (e.g. EmergencyOperationsPlan)
- Data sources or sinks (e.g. Printer)

Analysis Activities: Identifying Entity Objects/2

Table 5-2 Entity objects for the ReportEmergency use case.

Dispatcher	Police officer who manages Incidents. A Dispatcher opens, documents, and closes Incidents in response to Emergency Reports and other communication with FieldOfficers. Dispatchers are identified by badge numbers.
EmergencyReport	Initial report about an Incident from a FieldOfficer to a Dispatcher. An EmergencyReport usually triggers the creation of an Incident by the Dispatcher. An EmergencyReport is composed of an emergency level, a type (fire, road accident, other), a location, and a description.
FieldOfficer	Police or fire officer on duty. A FieldOfficer can be allocated to, at most, one Incident at a time. FieldOfficers are identified by badge numbers.
Incident	Situation requiring attention from a FieldOfficer. An Incident may be reported in the system by a FieldOfficer or anybody else external to the system. An Incident is composed of a description, a response, a status (open, closed, documented), a location, and a number of FieldOfficers.

Analysis Activities: Boundary Objects

- Boundary objects represent the system interface with the actors. In each use case, each actor interacts with at least one boundary object. The boundary object collects the information from the actor and translates it into a form that can be used by both entity and control objects. Boundary objects model the user interface at a coarse level.
- Boundary objects do not describe in detail the visual aspects of the user interface. For example, boundary objects such as “menu item” or “scroll bar” are too detailed. First, developers can discuss user interface details more easily with sketches and mock-ups. Second, the design of the user interface continues to evolve as a consequence of usability tests, even after the functional specification of the system becomes stable.

Analysis Activities: Identifying Boundary Objects

Heuristics for identifying boundary objects

- Identify user interface controls that the user needs to initiate the use case (e.g., ReportEmergencyButton)
- Identify forms the users need to enter data into the system (e.g., EmergencyReportForm)
- Identify notices and messages the system uses to respond to the user (e.g. AcknoledgmentNotice)

Analysis Activities: Identifying Boundary Objects

Heuristics for identifying boundary objects

- When multiple actors are involved in a use case, identify actor terminals (e.g., DispatcherStation) to refer to the user interface under consideration
- Do not model the visual aspects of the interface with boundary objects (user mock-ups are better suited for that)
- Always use the end user's terms for describing interfaces; do not use terms from the solution or implementation domains.

Analysis Activities: Identifying Boundary Objects/3

Table 5-3 Boundary objects for the ReportEmergency use case.

AcknowledgmentNotice	Notice used for displaying the Dispatcher's acknowledgment to the FieldOfficer.
DispatcherStation	Computer used by the Dispatcher.
ReportEmergencyButton	Button used by a FieldOfficer to initiate the ReportEmergency use case.
EmergencyReportForm	Form used for the input of the ReportEmergency. This form is presented to the FieldOfficer on the FieldOfficerStation when the "Report Emergency" function is selected. The EmergencyReportForm contains fields for specifying all attributes of an emergency report and a button (or other control) for submitting the completed form.
FieldOfficerStation	Mobile computer used by the FieldOfficer.
IncidentForm	Form used for the creation of Incidents. This form is presented to the Dispatcher on the DispatcherStation when the EmergencyReport is received. The Dispatcher also uses this form to allocate resources and to acknowledge the FieldOfficer's report.

Analysis Activities: ControlObjects

- Control objects are responsible for coordinating boundary and entity objects. Control objects usually do not have a concrete counterpart in the real world. Often a close relationship exists between a use case and a control object; a control object is usually created at the beginning of a use case and ceases to exist at its end. It is responsible for collecting information from the boundary objects and dispatching it to entity objects. For example, control objects describe the behavior associated with the sequencing of forms, undo and history queues, and dispatching information in a distributed system.

Analysis Activities:

Heuristics for identifying control objects

- Identify one control object per use case
- Identify one control object per actor in the use case
- The life span of a control object should cover the extent of the use case or the extent of a user session. If it is difficult to identify the beginning and the end of a control object activation, the corresponding use case probably does not have well-defined entry and exit conditions

Analysis Activities: Identifying Control Objects/2

Table 5-4 Control objects for the ReportEmergency use case.

ReportEmergencyControl	Manages the ReportEmergency reporting function on the FieldOfficerStation. This object is created when the FieldOfficer selects the “Report Emergency” button. It then creates an EmergencyReportForm and presents it to the FieldOfficer. After submitting the form, this object then collects the information from the form, creates an EmergencyReport, and forwards it to the Dispatcher. The control object then waits for an acknowledgment to come back from the DispatcherStation. When the acknowledgment is received, the ReportEmergencyControl object creates an AcknowledgmentNotice and displays it to the FieldOfficer.
ManageEmergencyControl	Manages the ReportEmergency reporting function on the DispatcherStation. This object is created when an EmergencyReport is received. It then creates an IncidentForm and displays it to the Dispatcher. Once the Dispatcher has created an Incident, allocated Resources, and submitted an acknowledgment, ManageEmergencyControl forwards the acknowledgment to the FieldOfficerStation.

Mapping Use Cases to Objects with Sequence Diagrams

- A **sequence diagram** ties use cases with objects. It shows how the behavior of a use case (or scenario) is distributed among participating objects.

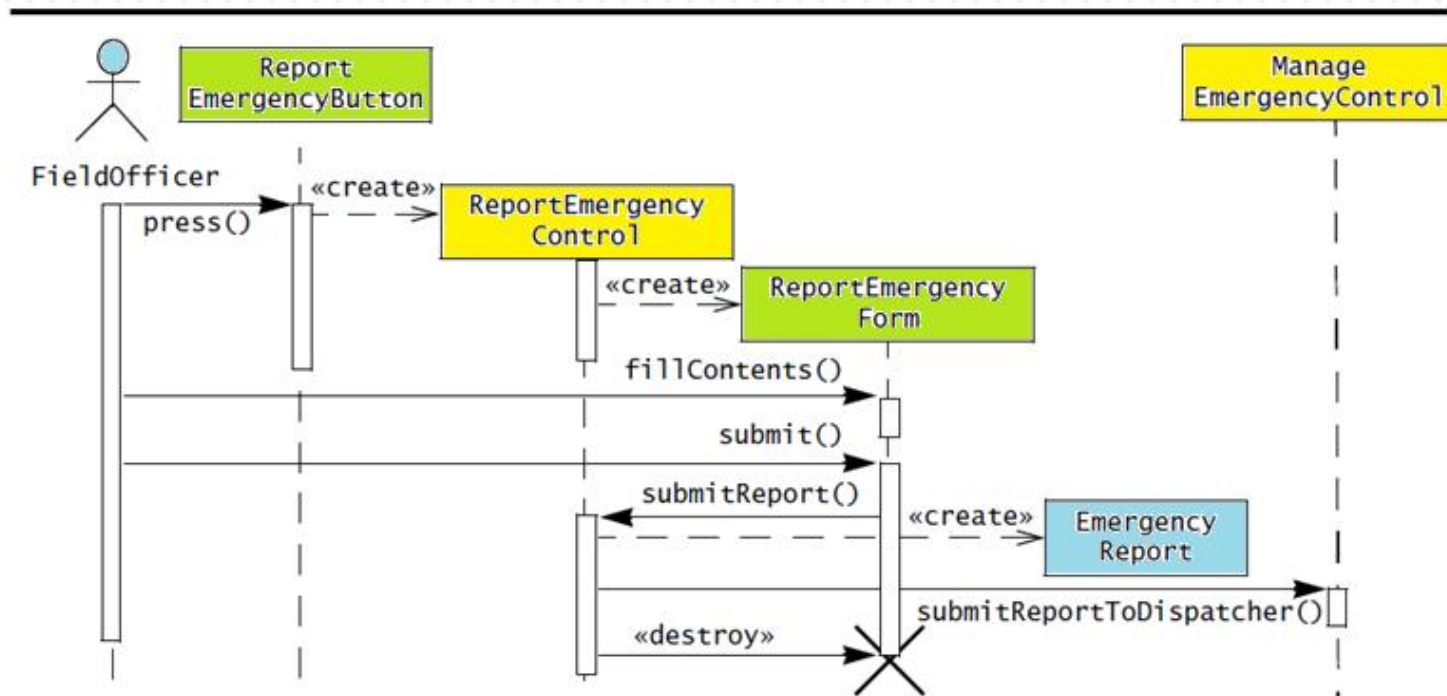


Figure 5-8 Sequence diagram for the ReportEmergency use case.

Mapping Use Cases to Objects with Sequence Diagrams_2

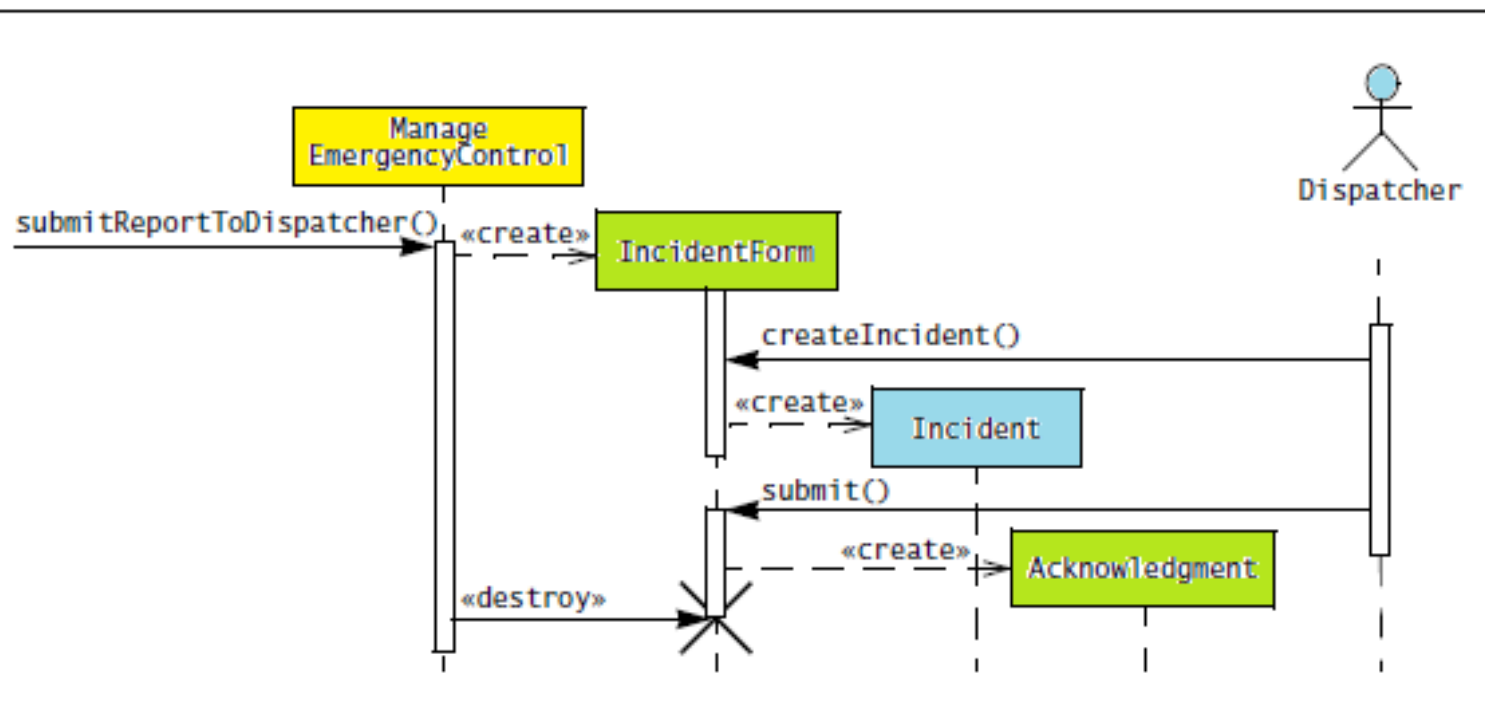


Figure 5-9 Sequence diagram for the ReportEmergency use case (continued from Figure 5-8).

Mapping Use Cases to Objects with Sequence Diagrams_3

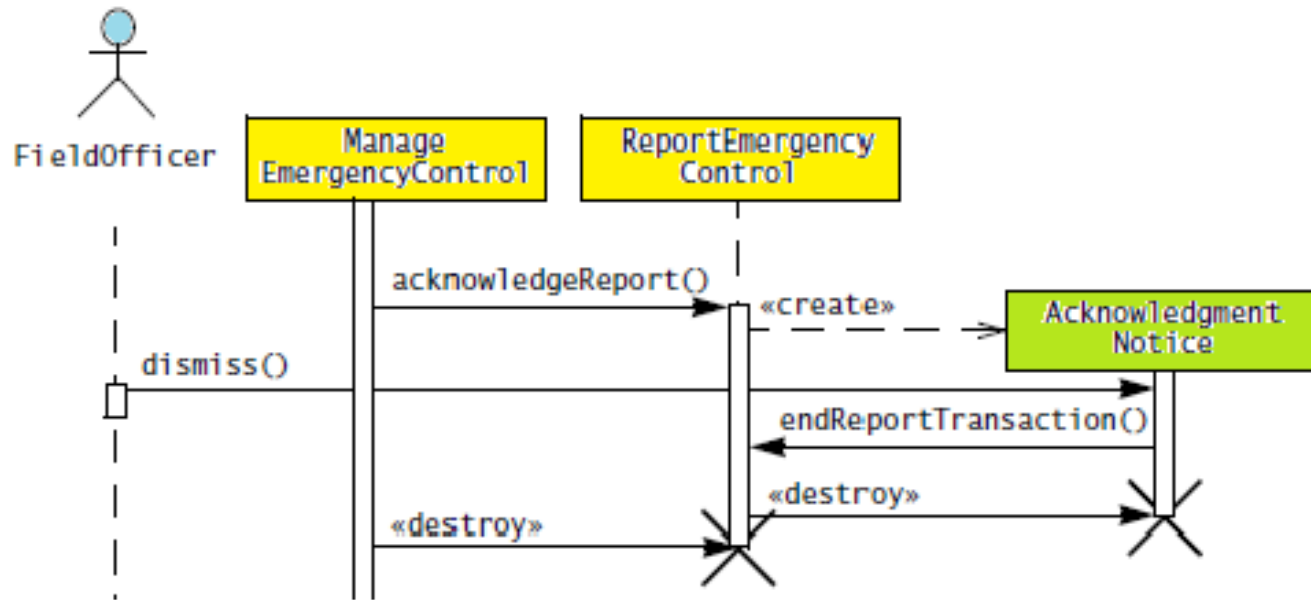


Figure 5-10 Sequence diagram for the ReportEmergency use case (continued from Figure 5-9).

Sequence diagrams allow the developers to find missing objects or grey areas in the requirements specification.

Mapping Use Cases to Objects with Sequence Diagrams

Heuristics for drawing sequence diagrams

- The **first column** should correspond to the **actor** who initiated the use case.
- The **second column** should be a **boundary object** (that the actor used to initiate the use case).
- The **third column** should be the **control object** that manages the rest of use case.

Mapping Use Cases to Objects with Sequence Diagrams/2

Heuristics for drawing sequence diagram_2

- **Control objects** are created by **boundary objects** initiating use cases.
- **Boundary objects** are created by **control objects**.
- **Entity objects are accessed by** control and boundary objects.
- **Entity objects never access** boundary or control objects; this makes it easier to share entity objects across use cases.

Modeling interactions among Objects with CRC Cards

- An alternative for identifying interactions among objects are CRC cards [Beck & Cunningham, 1989]. CRC cards (class, responsibilities, collaborators) were initially introduced as a tool for teaching object-orientation concepts to novices and to experienced developers unfamiliar with object-orientation.

Modeling interactions among Objects with CRC Cards/2

- Each class is represented with an index card. The name of the class is depicted on the top, its responsibilities on the left column, and the name of the classes it needs to accomplish the responsibilities are depicted on the right column.
- CRC cards and sequence diagrams are two different representations for supporting the same type of activity.

Modeling interactions among Objects with CRC Cards/3

- Sequence diagrams are a better tool for a single modeler or for documenting a sequence of interactions because they are more precise and compact. **CRC cards are a better tool for a group of developers refining and iterating over an object structure during a brainstorming session because they are easier to create and to modify.**

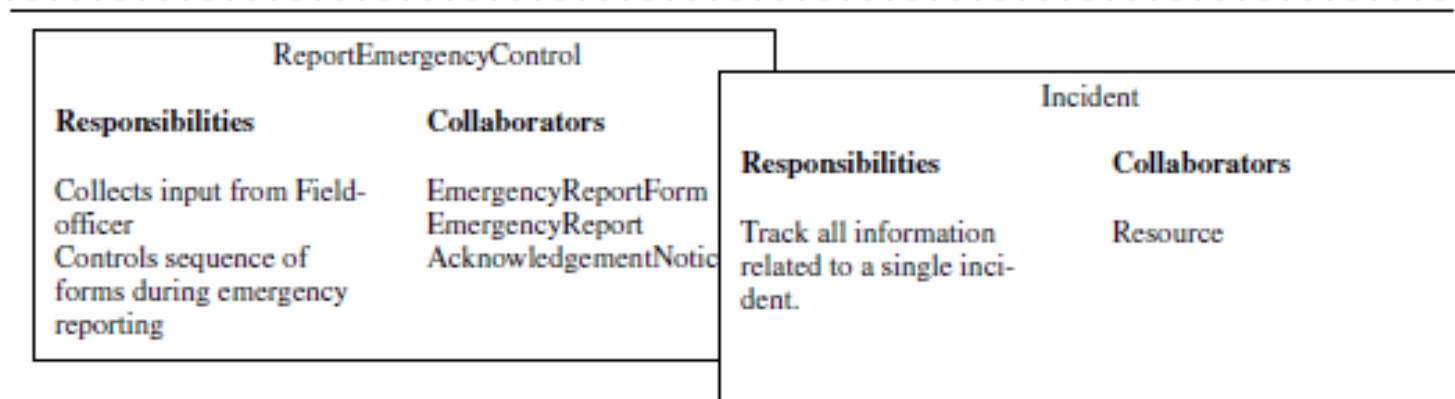


Figure 5-12 Examples of CRC cards for the `ReportEmergencyControl` and the `Incident` classes.

Identifying associations

- An association shows a relationship between two or more different objects instantiated by different classes or by the same class (recursive association).
- Identifying associations has two advantages:
 - ▣ It clarifies the analysis model by making relationships between objects explicit (e.g. , an EmergencyReport can be created by a FieldOfficer or a Dispatcher).
 - ▣ It enables the developer to discover **boundary cases** associated with links. **Boundary cases** are exceptions that must be clarified in the model.

Identifying associations/2

- Association have several properties:
 - **Associations names are optional** and need not to be unique globally.
 - A **role** at each end, identifying the function of each class' instances with respect to the instances of the opposite end (e.g., author is the role played by FieldOfficer in relation with EmergencyReport).
 - A **multiplicity** at each end, identifying the possible number of instances.

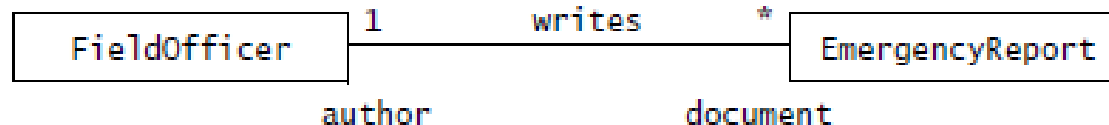


Figure 5-13 An example of association between the `EmergencyReport` and the `FieldOfficer` classes.

Identifying associations/3

Heuristics for identifying associations

- Examine verb phrases
- Name associations and roles as suggestive as possible
- Use qualifiers as often as possible to identify namespaces and key attributes
- Eliminate any association that can be derived from other associations
- Do not worry about multiplicity until the set of associations is stable
- Too many associations make a model unreadable

Identifying associations/4

Identifying Aggregates

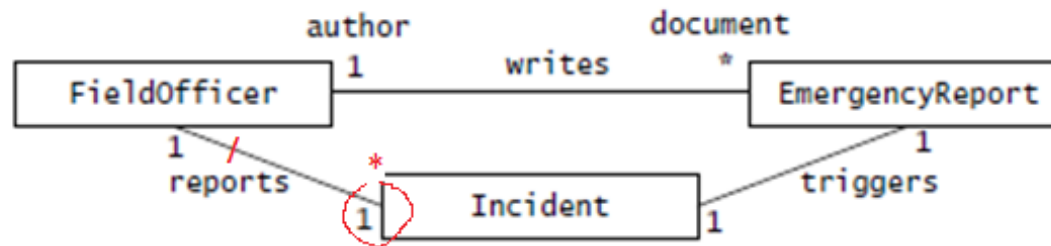


Figure 5-14 Eliminating redundant association. The receipt of an EmergencyReport triggers the creation of an Incident by a Dispatcher. Given that the EmergencyReport has an association with the FieldOfficer that wrote it, it is not necessary to keep an association between FieldOfficer and Incident. The utility of derivate associations is a debatable topic.

- Aggregations are special types of associations denoting a whole-part relationship.
- There are two types of aggregations: composition and shared.

Identifying associations/5

Identifying Aggregates

A solid diamond denotes composition. A composition indicates that the existence of the parts depends on the whole

A shared aggregation relationship indicate that the whole and the parts can exist independently

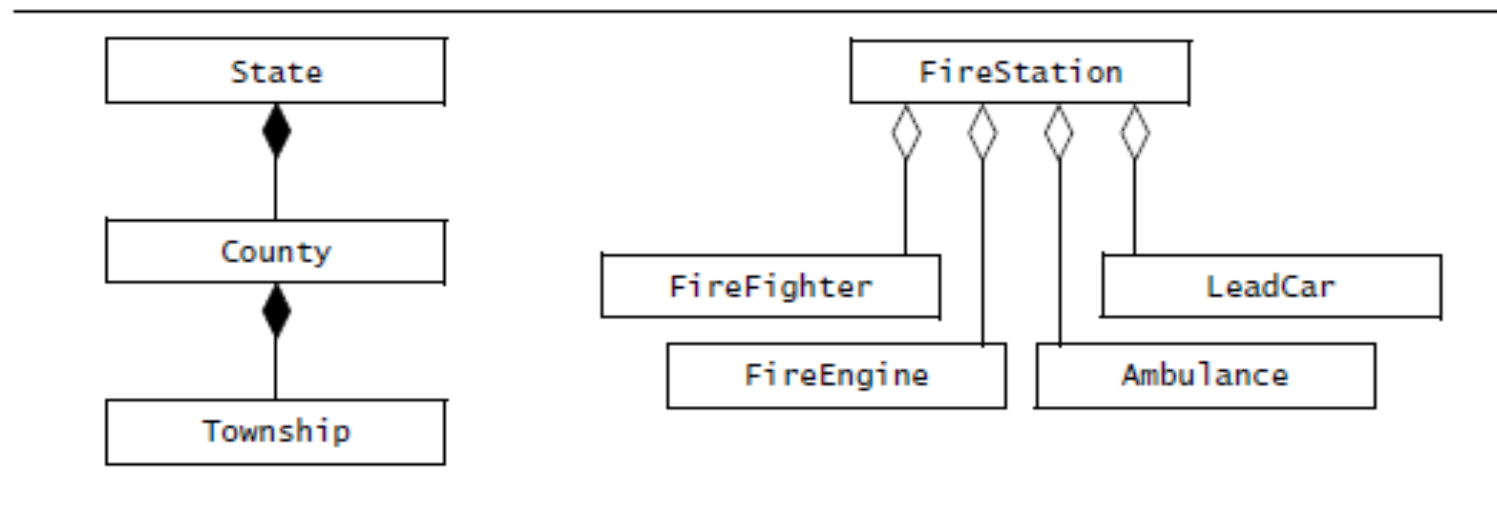


Figure 5-15 Examples of aggregations and compositions (UML class diagram). A State is composed of many Counties, which in turn is composed of many Townships. A FireStation includes FireFighters, FireEngines, Ambulances, and a LeadCar.

Identifying Attributes

- **Attributes are properties of individual objects**
- When identifying properties of objects, only the attributes relevant to the system should be considered.
- Properties that are represented by objects are not attributes
- Developers should identify as many associations as possible before identifying attributes to avoid confusing attributes and objects.

Identifying Attributes/2

- Attributes have:
 - ▣ A **name** identifying them within an object
 - ▣ A **brief description**
 - ▣ A **type** describing the legal values it can take

Identifying Attributes/3

Heuristics for identifying attributes

- Examine possessive phrases.
- Represent stored state as an attribute of the entity object.
- Describe each attribute.
- Do not represent an attribute as an object; use an association instead
- Do not waste time describing fine details before the object structure is stable.

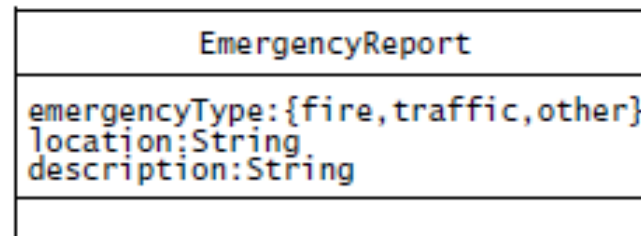


Figure 5-16 Attributes of the EmergencyReport class.

Modeling State-Dependent Behavior of Individual Objects

- Statechart diagrams represent behavior from the perspective of a single object. Viewing behavior from the perspective of each object enable the developer to build a more formal description of the behavior of the object, and consequently, to identify missing use cases.
- By focusing on individual states, developers may identify new behavior. By examining each transition in the statechart diagram that is triggered by a user action that triggers the transition.

Modeling State-Dependent Behavior of Individual Objects_2

- Only objects with an extended lifespan and state-dependent behavior are worth considering. This is almost always the case for control objects, less often for entity objects, and almost never for boundary objects.

Modeling State-Dependent Behavior of Individual Objects/3

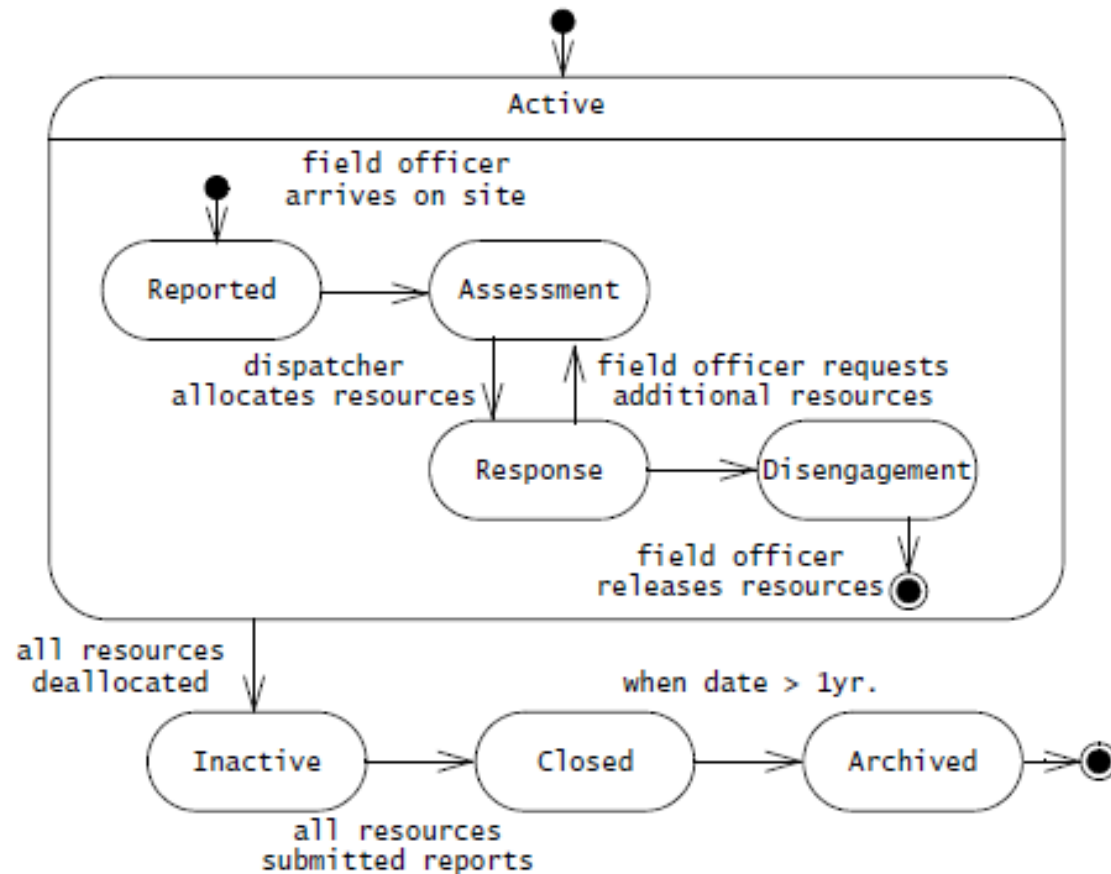


Figure 5-17 UML state machine for Incident.

Modeling Inheritance Relationships between Objects

- Generalization is used to eliminate redundancy from the analysis model. If two or more classes share attributes or behavior, the similarities are consolidated into an ascendent class. Both Dispatchers and FieldOfficers have a badgeNumber attribute that serves to identify them within a city. To model this similarity, we introduce an abstract *PoliceOfficer* class.

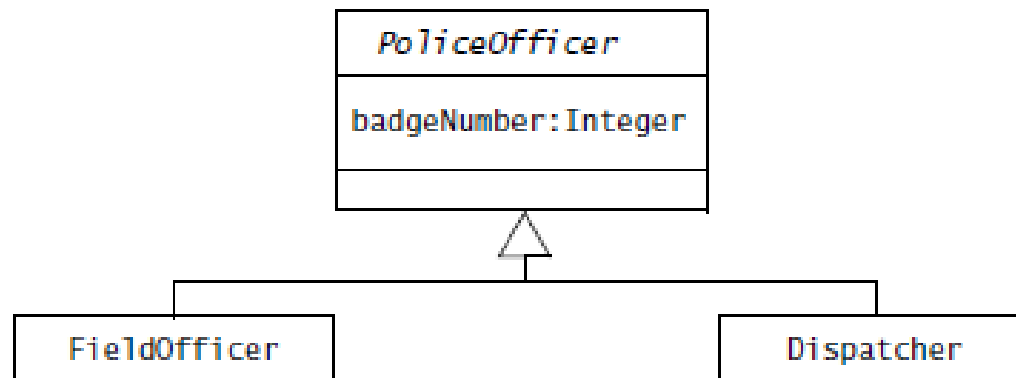


Figure 5-18 An example of inheritance relationship (UML class diagram).

Reviewing the Analysis Model

- The analysis model is built incrementally and iteratively. This model is seldom correct or even complete on the first pass. Before the analysis model converges toward a correct specification usable by the developers for design and implementation, several iterations with the client and the user are necessary.
- Once the analysis model becomes stable (i.e., when the number of changes to the models are minimal and the scope of the changes localized), the analysis model is reviewed, first by the developers (i.e., internal reviews), then jointly by the developers and the client.

Reviewing the Analysis Model/2

- The goal of the review is to make sure that the requirements specification is correct, complete, consistent and unambiguous.
- Developers should be prepared to discover errors downstream and make changes to the specification.

Reviewing the Analysis Model/3

- To ensure that **the model is correct**, the following questions should be asked:
 - ▣ Is the glossary of entity objects understandable by the user?
 - ▣ Do abstract classes correspond to user-level concepts?
 - ▣ Are all descriptions in accordance with the users' definitions?

Reviewing the Analysis Model/4

- To ensure that **the model is correct**, the following questions should be asked:
 - ▣ Do all entity and boundary objects have meaningful noun phrases as names?
 - ▣ Do all use cases and control objects have meaningful verb phrases as names?
 - ▣ Are all error cases described and handled?

Reviewing the Analysis Model/5

- To ensure that **the model is complete**, the following questions should be asked:
 - ▣ For each object: Is it needed by any use case? In which use case is it created? modified? Destroyed? Can it be accessed from a boundary object?
 - ▣ For each attribute: When is it set? What is its type? Should it be a qualifier?
 - ▣ For each association: When is it traversed? Why was the specific multiplicity chosen? Can associations with one-to-many multiplicities be qualified?

Reviewing the Analysis Model/6

- To ensure that **the model is complete**, the following questions should be asked:
 - ▣ For each control object: Does it have the necessary associations to access the objects participating in its corresponding use case?

Reviewing the Analysis Model/7

- To ensure that **the model is consistent**, the following questions should be asked:
 - ▣ Are there multiple classes or use cases with the same name?
 - ▣ Do entities (e.g., use cases, classes, attributes) with similar names denote similar concepts?
 - ▣ Are there objects with similar attributes and associations that are not in the same generalization hierarchy?

Reviewing the Analysis Model/8

- To ensure that the system described by **the analysis model is realistic**, the following questions should be asked:
 - ▣ Are there any novel features in the system? Were any studies or prototypes built to ensure their feasibility?
 - ▣ Can the performance and reliability requirements be met? Were these requirements verified by any prototypes running on the selected hardware?

Analysis Summary

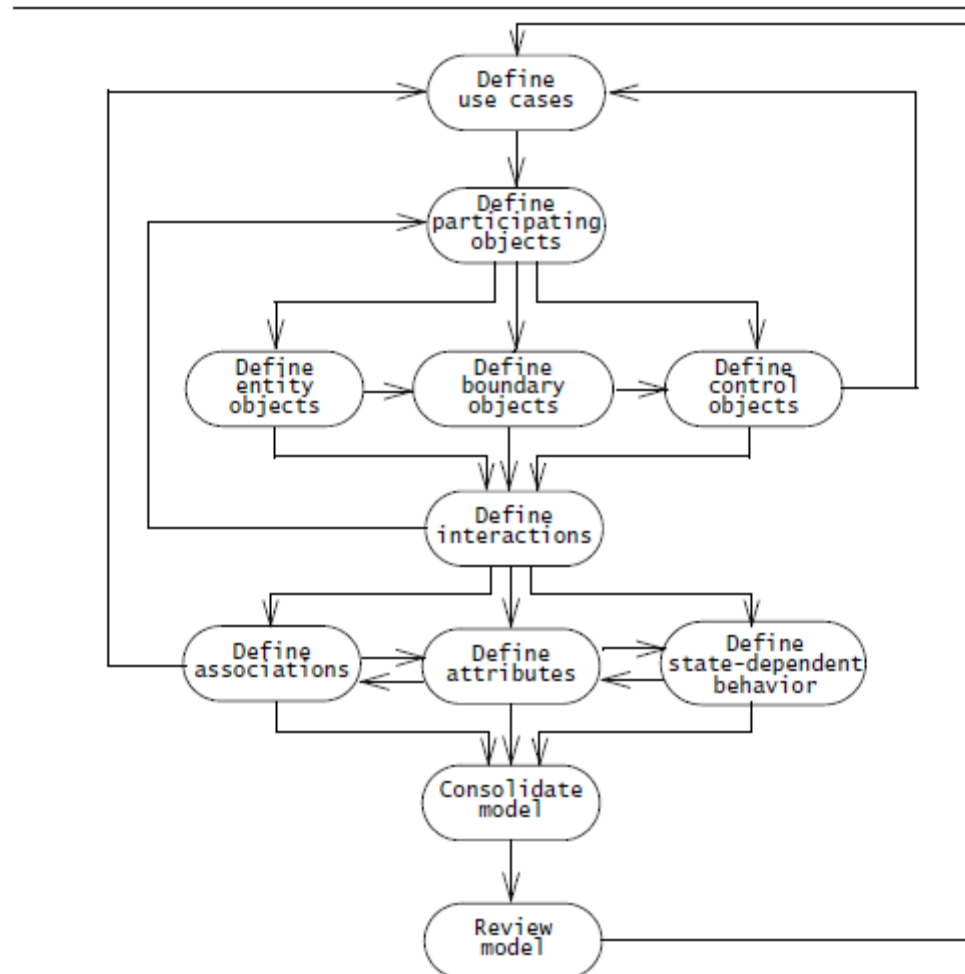


Figure 5-19 Analysis activities (UML activities diagram).

Managing Analysis – Documenting Analysis

- The primary challenge in managing requirements is to maintain consistency while using so many resources.
- The requirements elicitation and analysis activities are documented in the **Requirements Analysis Document (RAD)**. During analysis the sections of the above document are revised as ambiguities and new functionality are discovered.

Managing Analysis – Documenting Analysis/2

- The **object model** documents in detail all the objects identified with their attributes and associations.
- The **dynamic model** documents the behavior of the object model by means of stateChart diagrams and sequence diagrams.
- The revision history of the **RAD** will provide a history of changes, including the author responsible for each change.

Managing Analysis – Documenting Analysis_2

Requirements Analysis Document

1. Introduction
2. Current system
3. Proposed system
 - 3.1 Overview
 - 3.2 Functional requirements
 - 3.3 Nonfunctional requirements
 - 3.4 System models
 - 3.4.1 Scenarios
 - 3.4.2 Use case model
 - 3.4.3 Object model
 - 3.4.3.1 Data dictionary
 - 3.4.3.2 Class diagrams
 - 3.4.4 Dynamic models
 - 3.4.5 User interface—navigational paths and screen mock-ups
4. Glossary

Figure 5-20 Overview outline of the Requirements Analysis Document (RAD). See Figure 4-16 for a detailed outline.

Assigning Responsibilities

- Analysis requires the participation of a wide range of individuals:
 - ▣ The target user provides application domain knowledge.
 - ▣ The client funds the project and coordinates the user side of the effort.
 - ▣ The analyst elicits application domain knowledge and formalizes it.
 - ▣ Developers provide feedback on feasibility and cost.
 - ▣ The project manager coordinates the effort on the development side.

Assigning Responsibilities/2

- For large systems, many users, analysts and developers may be involved, introducing additional challenges during integration and communication requirements. **These challenges can be met by assigning well-defined roles and scopes to individuals.**
- There are **three main types of roles**:
 - ▣ generation of information,
 - ▣ **integration** and
 - ▣ **review.**

Client sign-off

Represents the acceptance of the analysis model (as documented by the requirements analysis document) by the client. The client and the developers converge on a single idea and agree about the functions and features that the system will have.

In addition, they agree on:

- a list of priorities
- a revision process
- a schedule and a budget.
- a list of criteria that will be used to accept or reject the system

Client sign-off/2

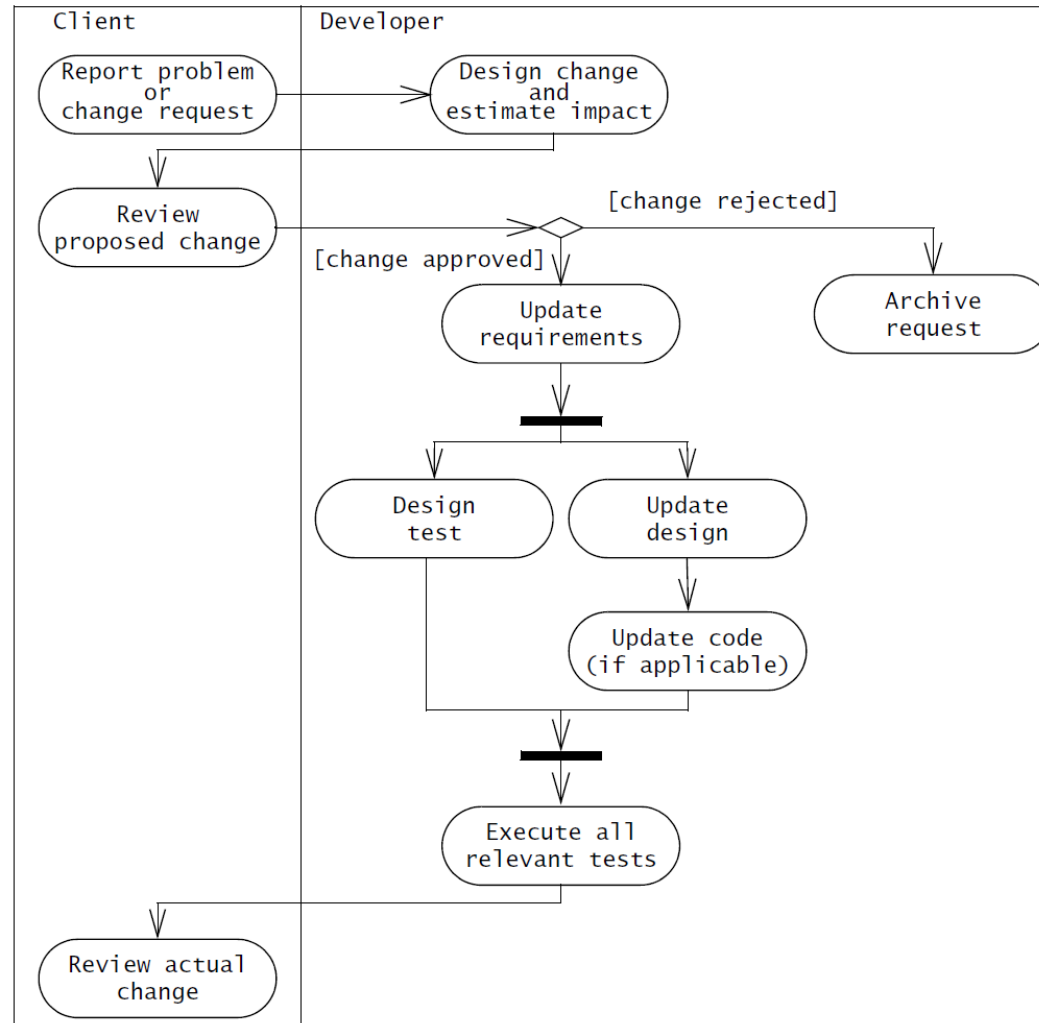


Figure 5-22 An example of a revision process (UML activity diagram).

SE is ... more than programming

Software engineering



... includes programming, but is more than programming

As von Clausewitz did not write: "the continuation of programming through other means".