

Chapter 11

■ Requirements Modeling: Behavior, Patterns, and Web/Mobile Apps

Slide Set to accompany

Software Engineering: A Practitioner's Approach, 8/e
by Roger S. Pressman

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Introduction

- Aren't scenario-based and class-based modeling representations (static elements of the requirements model) enough? That depends
- Behavioral modeling is often required
 - In some situations, complex application requirements may demand an examination of how an application behave as a consequence of external events
- Pattern is often used
 - Whether existing domain knowledge can be adopted the current problem?
- Functionality of web/mobile apps
 - In the case of web-based or mobile systems and applications, how content and functionality meld to provide an end user with the ability to successfully navigate an application to achieve usage goals?

Behavioral Modeling

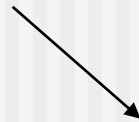
- The **behavioral model** indicates how software will respond to external events or stimuli. To create the model, the analyst must perform the following steps:
 - (1) Evaluate all use-cases to fully understand the sequence of interaction within the system.
 - (2) **Identify events** that drive the interaction sequence and understand how these events relate to specific objects.
 - (3) **Create a sequence** for each use-case.
 - (4) **Build a state diagram** for the system.
 - (5) **Review the behavioral** model to verify accuracy and consistency.

Identifying Events with the Use Case

- The use case represents a sequence of activities that involves actors and the system
- In general, an event occurs whenever the system and an actor **exchange information**
- Note: An event is **not the information that has been exchanged**, but rather the fact that information has been exchanged

Example: SafeHome security function

The homeowner uses the keypad to key in a four-digit password. The password is compared with the valid password stored in the system. If the password is incorrect, the control panel will beep once and reset itself for additional input. If the password is correct, the control panel awaits further action.



The underlined portions of the use case scenario indicate events

Example

“homeowner uses the keypad to key in a four-digit password”

- **Homeowner** transmits an event to the object **ControlPanel**
 - ➔ The event might be called *password entered*
 - The information transferred is the four digits that constitute the password, but this is not an essential part of the behavioral model.
- Impact on the flow of control
 - Some events have an explicit impact, while others have no direct impact on the flow of control
 - E.g.) *password entered* vs. *password compared*
 - The event *password compared* will have an explicit impact on the information and control flow of the SafeHome software

Connecting Events to Objects

- Once all events have been identified, they are allocated to the objects involved.
- Objects can be responsible for
 - Generating events
 - (e.g., **Homeowner** generates the *password entered* event)
 - Recognizing events that have occurred elsewhere
 - (e.g., **ControlPanel** recognizes the *binary result* of the *password compared* event)

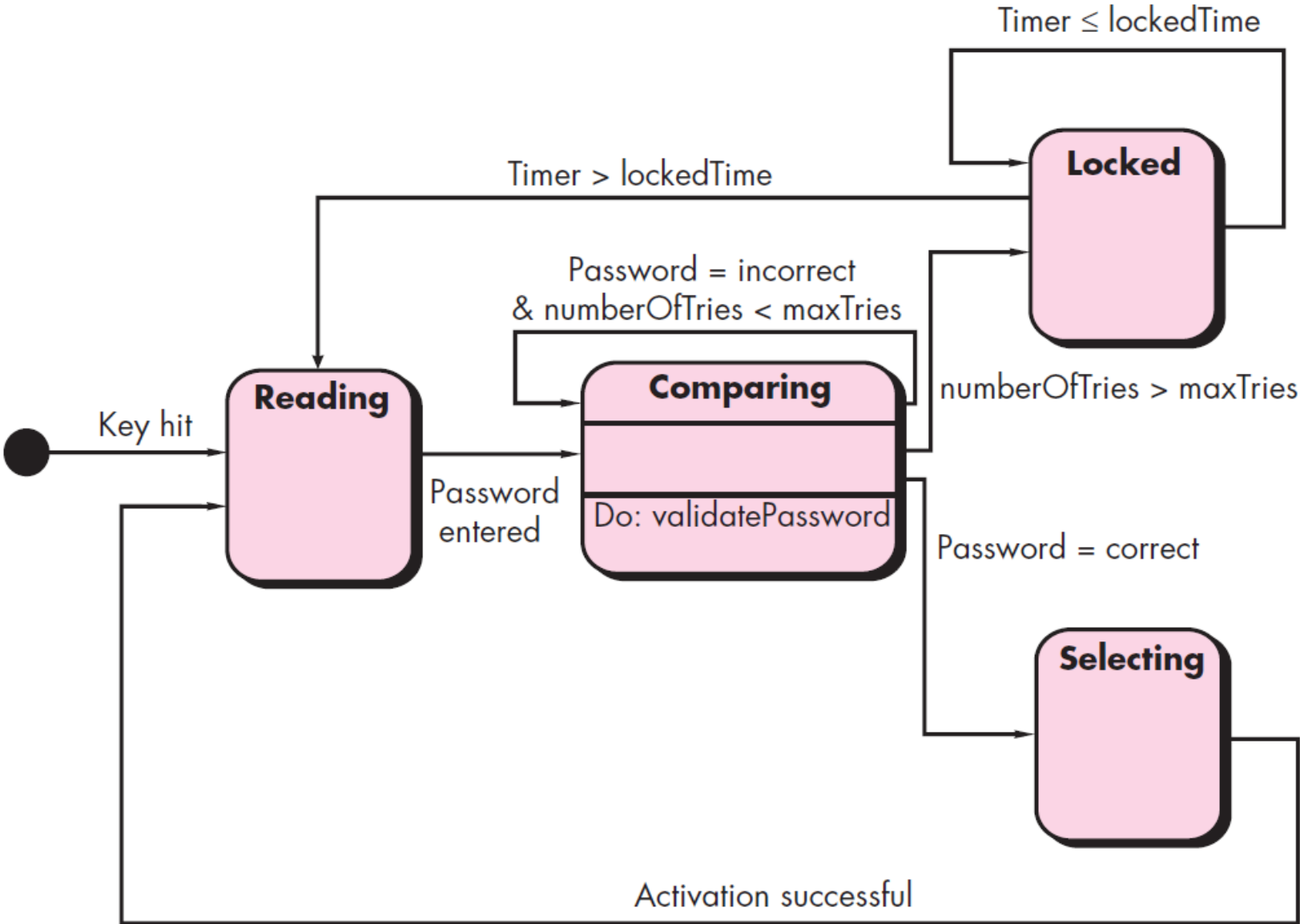
State Representations

- In the context of behavioral modeling, two different characterizations of states must be considered:
 - (1) the state of each class as the system performs its function and
 - (2) the state of the system as observed from the outside as the system performs its function
- The state of a class takes on both passive and active characteristics [CHA93].
 - A *passive state* is simply the current status of all of an object's attributes.
 - E.g.) the class Player: the current position & orientation attributes
 - The *active state* of an object indicates the current status of the object as it undergoes a continuing transformation or processing.
 - E.g.) the class Player: moving, at rest, injured, being cured, trapped, lost
- Two different behavioral representations
 - 1) State diagrams: indicates how an individual class changes state based on external events
 - 2) Sequence diagrams: the behavior of the software as a function of time

The States of a System

- **state**—a set of observable circumstances that characterizes the behavior of a system at a given time
- **state transition**—the movement from one state to another
- **event**—an occurrence that causes the system to exhibit some predictable form of behavior
- **action**—process that occurs as a consequence of making a transition

State Diagrams: Example for the ControlPanel Class



State Diagrams for Analysis Classes

- A UML state diagram
 - Represents active states for each class and the events (triggers) that cause changes between these active states.
- Notations
 - **State transition**: Each **arrow** represents a transition from one active state of an object to another.
 - **Event**: The **labels** shown for each arrow represent the event
 - **Condition for transition**: A **guard** is a Boolean condition that must be satisfied in order for the transition to occur.
 - E.g.) if (password input = 4 digits) then compare to stored password
 - The guard depends on the passive state of the object
 - **Action**: An **action** occurs concurrently with the state transition or as a consequence of it and generally involves one or more operations (responsibilities) of the object.
 - E.g.) an operation named `validatePassword()` performs a digit-by-digit comparison to validate the entered password.

Sequence Diagrams

- Sequenced diagrams indicates how events cause transitions from object to object.
- Once events have been identified by examining a use case, the modeler creates a sequence diagram – A representation of how events cause flow from one object to another as a function of time.
- Once a complete sequence diagram has been developed, **all of the events that cause transitions between system objects can be collated into a set of input events and output events (from an object).**
 - This information is useful in the creation of an effective design for the system to be built.

Behavioral Modeling

- make a list of the different states of a system (How does the system behave?)
- indicate how the system makes a transition from one state to another (How does the system change state?)
 - indicate event
 - indicate action
- draw a **state diagram or a sequence diagram**

Patterns for Requirements Modeling

- Software patterns are a mechanism for capturing domain knowledge in a way that allows it to be reapplied when a new problem is encountered
 - domain knowledge can be applied to a new problem within the same application domain
 - the domain knowledge captured by a pattern can be applied by analogy to a completely different application domain.
- The original author of an analysis pattern **does not “create” the pattern**, but rather, **discovers it** as requirements engineering work is being conducted.
- Once the pattern has been discovered, it is documented

Discovering Analysis Patterns

- The most basic element in the description of a requirements model is the use case.
- A coherent set of use cases may serve as the basis for discovering one or more analysis patterns.
- A *semantic analysis pattern* (SAP) “is a pattern that describes a small set of coherent use cases that together describe a basic generic application.” [Fer00]

An Example

- Consider the following preliminary use case for software required to control and monitor a real-view camera and proximity sensor for an automobile:

Use case: *Monitor reverse motion*

Description: When the vehicle is placed in *reverse* gear, the control software enables a video feed from a rear-placed video camera to the dashboard display. The control software superimposes a variety of distance and orientation lines on the dashboard display so that the vehicle operator can maintain orientation as the vehicle moves in reverse. The control software also monitors a proximity sensor to determine whether an object is inside 10 feet of the rear of the vehicle. It will automatically break the vehicle if the proximity sensor indicates an object within 3 feet of the rear of the vehicle.

An Example

- This use case implies a variety of functionality that would be refined and elaborated (into a coherent set of use cases) during requirements gathering and modeling.
- Regardless of how much elaboration is accomplished, the use case(s) suggest(s) a simple, yet widely applicable SAP—the software-based monitoring and control of sensors and actuators in a physical system.
- In this case, the “sensors” provide information about proximity and video information. The “actuator” is the braking system of the vehicle (invoked if an object is very close to the vehicle).
- But in a more general case, a widely applicable pattern is discovered --> **Actuator-Sensor**

Actuator-Sensor Pattern—I

Pattern Name: *Actuator-Sensor*

Intent: Specify various kinds of sensors and actuators in an embedded system.

Motivation: Embedded systems usually have various kinds of sensors and actuators. These sensors and actuators are all either directly or indirectly connected to a control unit. Although many of the sensors and actuators look quite different, their behavior is similar enough to structure them into a pattern. The pattern shows how to specify the sensors and actuators for a system, including attributes and operations. *The Actuator-Sensor pattern uses a pull mechanism (explicit request for information) for PassiveSensors and a push mechanism (broadcast of information) for the ActiveSensors.*

Constraints:

Each *passive sensor must have some method to read sensor input and attributes* that represent the sensor value.

Each *active sensor must have capabilities to broadcast update messages* when its value changes.

Each active sensor should send a *life tick*, a status message issued within a specified time frame, to detect malfunctions.

Each actuator must have some method to invoke the appropriate response determined by the **ComputingComponent**.

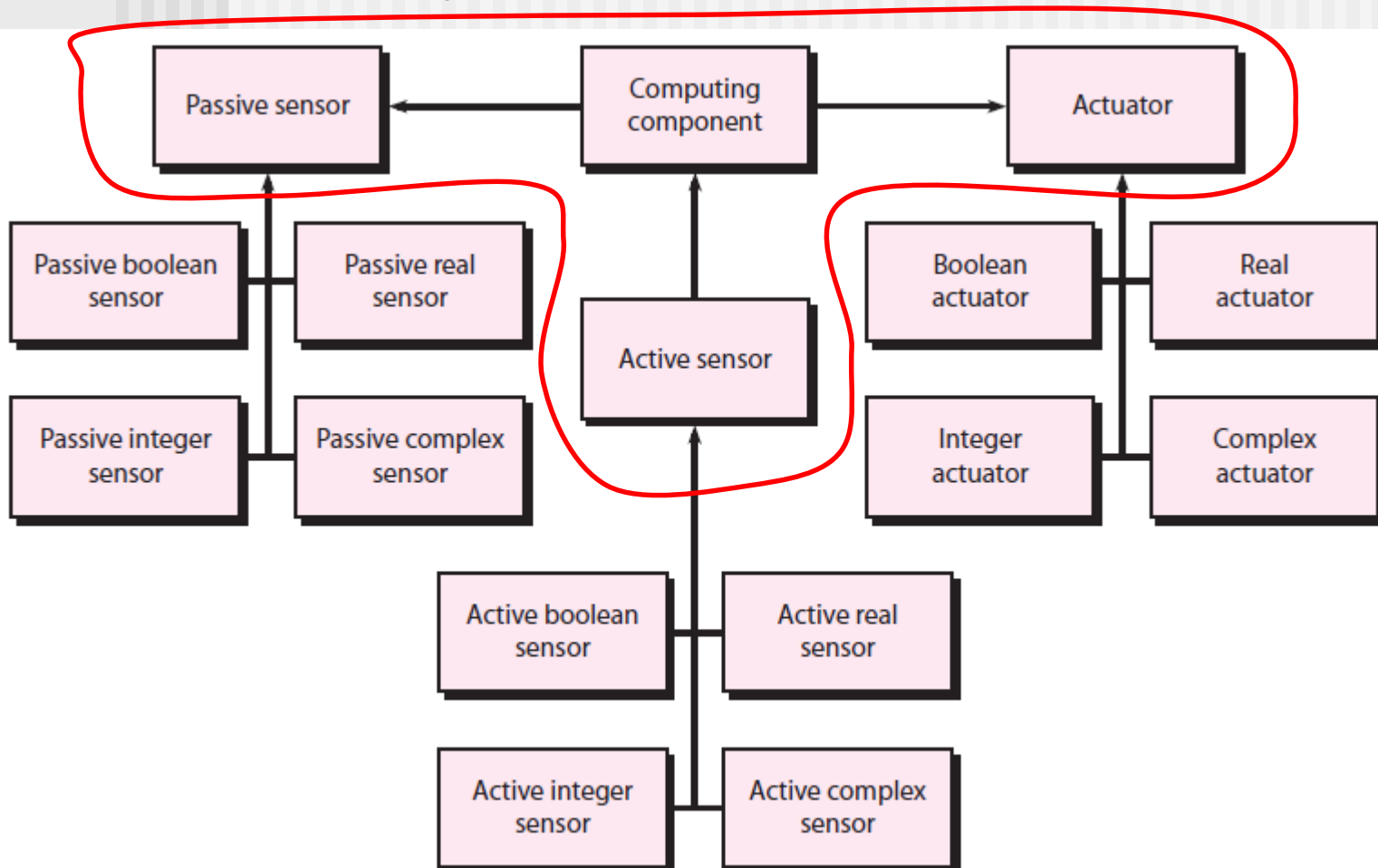
Each sensor and actuator should have a function implemented to check its own operation state.

Each sensor and actuator should be able to test the validity of the values received or sent and set its operation state if the values are outside of the specifications.

Actuator-Sensor Pattern—II

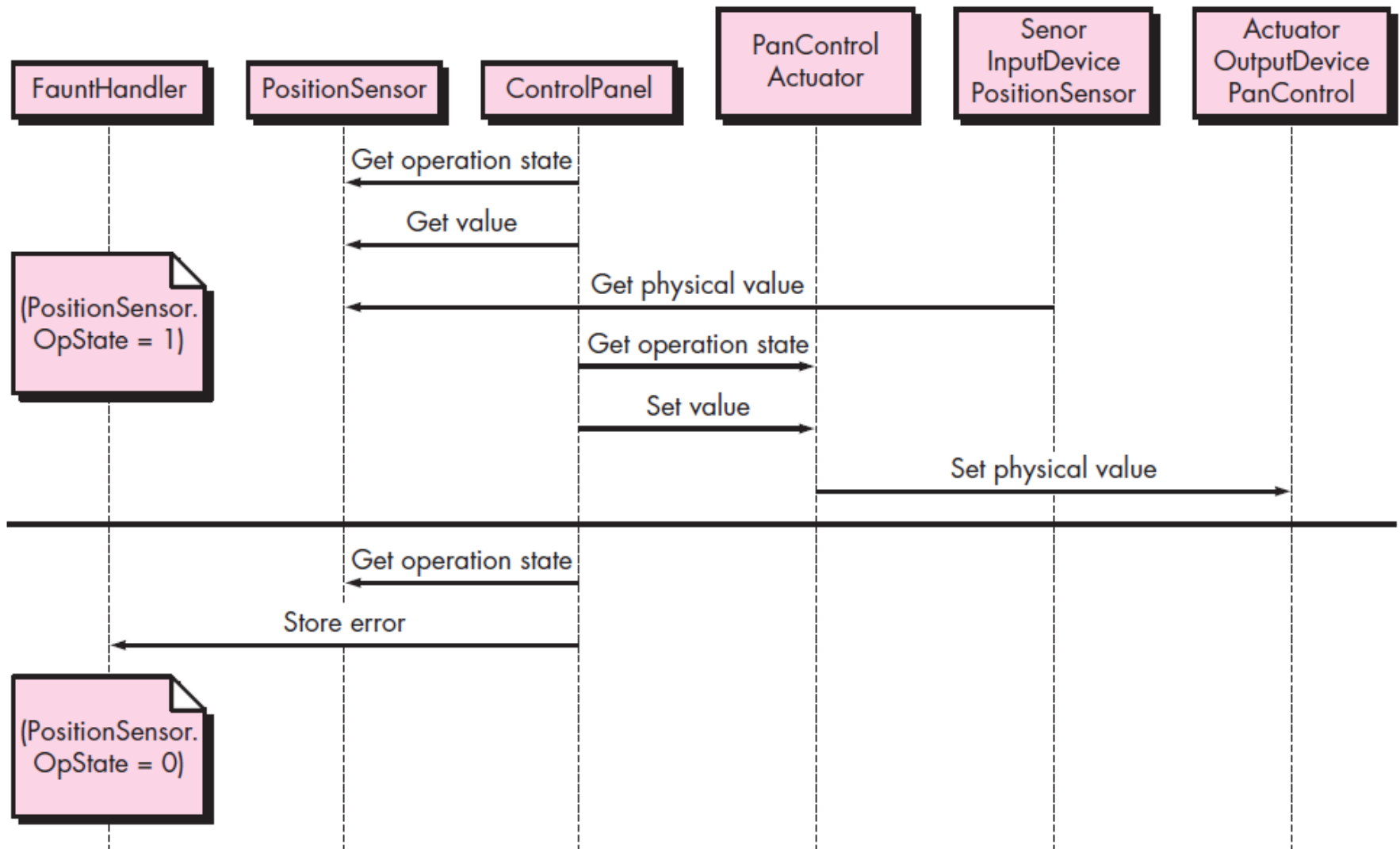
Applicability: Useful in any system in which multiple sensors and actuators are present.

Structure: A UML class diagram for the *Actuator-Sensor* Pattern is shown in Figure. **Actuator**, **PassiveSensor** and **ActiveSensor** are abstract classes and denoted in italics. There are four different types of sensors and actuators in this pattern. The Boolean, integer, and real classes represent the most common types of sensors and actuators. The complex classes are sensors or actuators that use values that cannot be easily represented in terms of primitive data types, such as a radar device. Nonetheless, these devices should still inherit the interface from the abstract classes since they should have basic functionalities such as querying the operation states.



Actuator-Sensor Pattern—III

Behavior. Figure presents a UML sequence diagram for an example of the **Actuator-Sensor** pattern as it might be applied for the *SafeHome* function that controls the positioning (e.g., pan, zoom) of a security camera.



Actuator-Sensor Pattern—IV

Behavior. Here, the **ControlPanel** queries a sensor (a passive position sensor) and an actuator (pan control) to check the operation state for diagnostic purposes before reading or setting a value. The messages *Set Physical Value* and *Get Physical Value* are not messages between objects. Instead, they describe the interaction between the physical devices of the system and their software counterparts. In the lower part of the diagram, below the horizontal line, the **PositionSensor** reports that the operation state is zero. The **ComputingComponent** (represented as **ControlPanel**) then sends the error code for a position sensor failure to the **FaultHandler** that will decide how this error affects the system and what actions are required. It gets the data from the sensors and computes the required response for the actuators.

Actuator-Sensor Pattern—V

- Participants
 - Itemizes the classes/objects that are included in the requirements pattern and describes the responsibilities of each class/object
- Collaborations
 - Describes how objects and classes interact with one another and how each carries out its responsibilities
- Consequences
 - 1. Sensor and actuator classes have a common interface.
 - 2. Class attributes can only be accessed through messages, and the class decides whether or not to accept the message.
 - 3. The complexity of the system is potentially reduced because of the uniformity of interfaces for actuators and sensors.

Requirements Modeling for Web and Mobile Apps: Introduction

- Developers of Web and mobile applications are often skeptical when the idea of requirements analysis is suggested.
 - “After all,” they argue, “the Web development process must be agile, and analysis is time consuming. It’ll slow us down just when we need to be designing and building the WebApp.”
- The question for every WebApp and mobile developer is simple— **are you sure you understand the requirements of the problem?**
- If the answer is an unequivocal “yes,” then it may be possible to skip requirements modeling, but **if the answer is “no,” then requirements modeling should be performed.**

Requirements Modeling for Web and Mobile Apps

- How much analysis is enough?
 - Although it is a good idea to analyze the problem *before* beginning design, *it is not true that all analysis must precede all design.*
 - The design of a specific part of the application only demands an analysis of those requirements that affect only that part of the application
 - You *only need to analyze that part of the problem that is relevant to the design work* for the increment to be delivered.

Requirements Modeling Input

- The inputs to the requirements model will be the information collected during the communication activity —
 - Anything from an informal e-mail to a detailed project brief complete with comprehensive usage scenarios and product specifications
- **Analysis** takes this information, structures it using a formally defined representation scheme (where appropriate), and then produces more rigorous models as an output.
- The requirements model provides a detailed indication of the true structure of the problem and provides insight into the shape of the solution.

Requirements Modeling

Concerns Missing Requirement Information

- Missing Requirement Information
 - This actually influence the overall design itself and relate more to an actual understanding of the requirements
- E.g.) SafeHome project
 - Q: What output video resolution is provided by *SafeHome* cameras?
 - Q: What occurs if an alarm condition is encountered while the camera is being monitored?
 - Q: How does the system handle cameras that can be panned and zoomed?
 - Q: What information should be provided along with the camera view? (For example, location? time/date? last previous access?)
- → the answers could have a substantial effect on different aspects of the design.

Requirements Modeling Output: Five main classes of model

- Content model.** The full spectrum of content to be provided by the WebApp is identified, including text, graphics and images, video, and audio data. Data modeling can be used to identify and describe each of the data objects.
- Interaction model.** The manner in which the user interacts with the app is described in detail. Use-cases can be developed to provide detailed descriptions of this interaction.
- Functional model.** The usage scenarios (use-cases) created as part of interaction analysis define the operations that will be applied to manipulate content and describes other processing functions
- Navigation model.** The overall navigation strategy for the app
- Configuration model.** The environment and infrastructure in which the WebApp resides are described in detail.

Content Model

- These structural elements encompass content objects and all **analysis classes** — user-visible entities that are created or manipulated as a user interacts with the app
- A **content object** might be
 - a textual description of a product,
 - an article describing a news event,
 - an action photograph taken at a sporting event,
 - a user's response on a discussion forum,
 - an animated representation of a corporate logo,
 - a short video of a speech, or
 - an audio overlay for a collection of presentation slides.

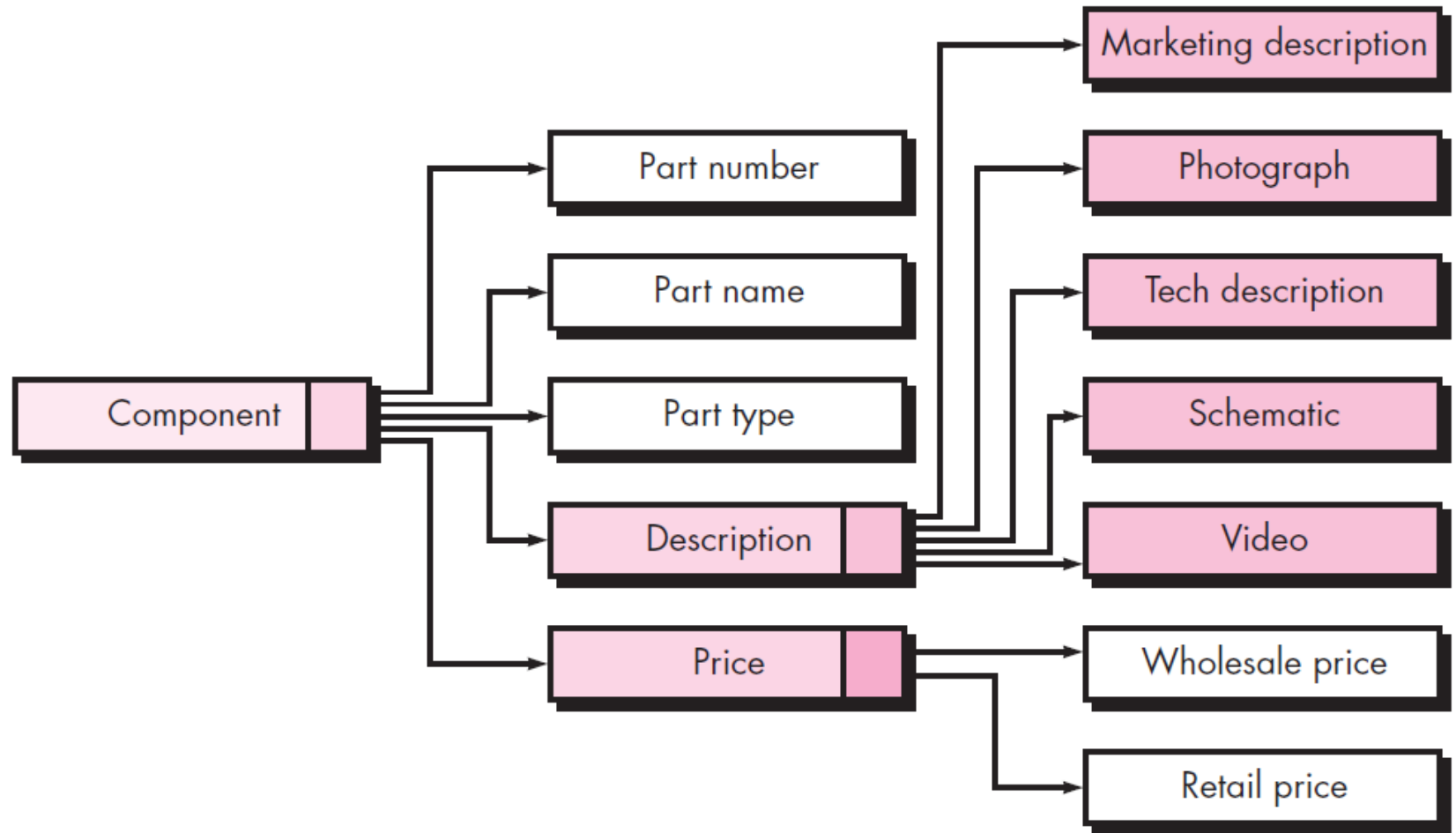
Content Model

- **Content objects** are extracted from use-cases
 - By examining the scenario description for direct and indirect references to content
 - E.g.)
 - A WebApp that supports *SafeHome* is established at **SafeHomeAssured.com**. A use case, *Purchasing Select SafeHome Components*, describes the scenario required to purchase a *SafeHome* component and contains the sentence:
→ *I will be able to get descriptive and pricing information for each product component.*

Content Model

- **Attributes** of each content object are identified
- The **relationships** among content objects and/or the hierarchy of content maintained by a WebApp
 - Relationships— **entity-relationship diagram** or UML
 - Hierarchy— **data tree** or UML

Data Tree

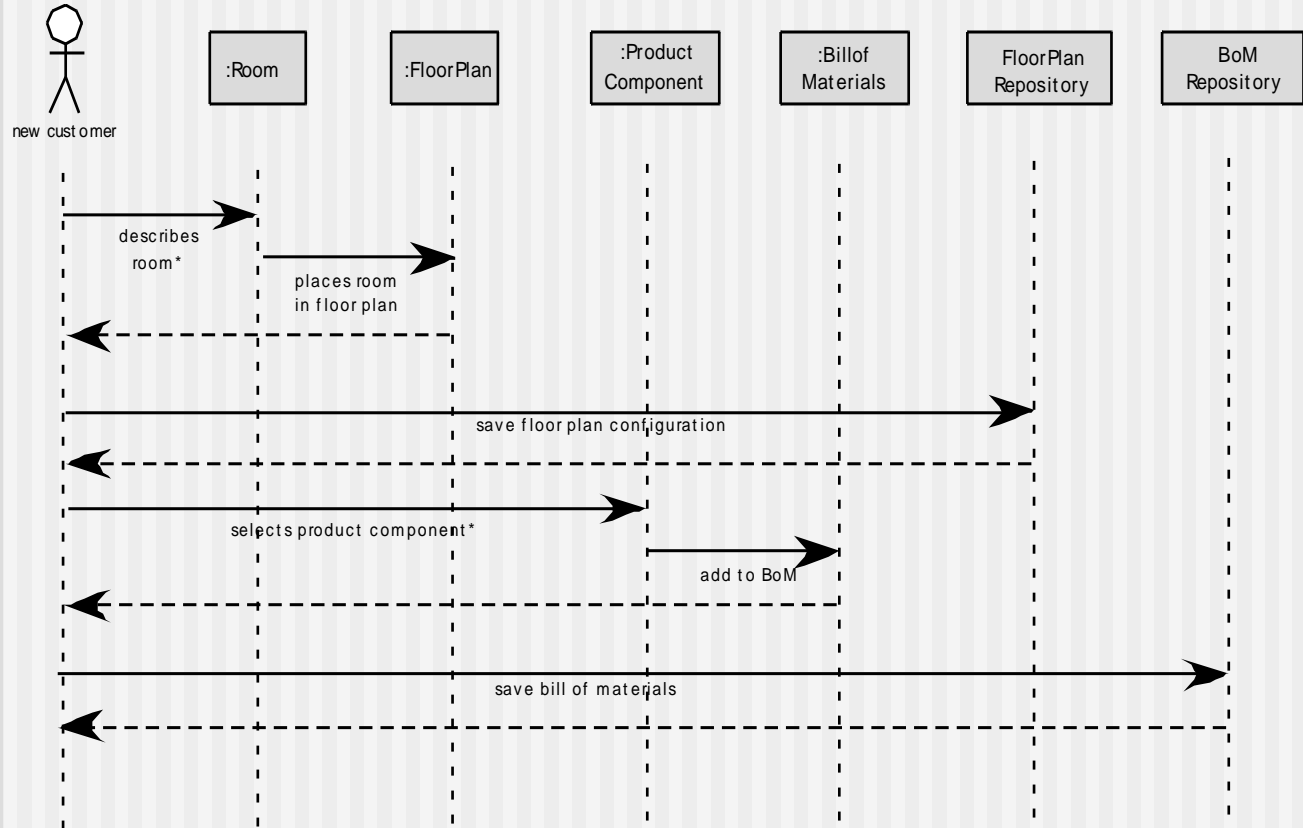


Simple or composite data items (one or more data values) are represented as unshaded rectangles. Content objects are represented as shaded rectangles. In the figure, description is defined by five content objects (the shaded rectangles). In some cases, one or more of these objects would be further refined as the data tree expands.

The Interaction Model

- Describes a “conversation” between an end user and application functionality, content, and behavior
- Composed of four elements:
 - use-cases
 - sequence diagrams
 - state diagrams
 - a user interface prototype → chap 15.
- Each of these is an important UML notation and is described in Appendix I

Sequence Diagram



State Diagram

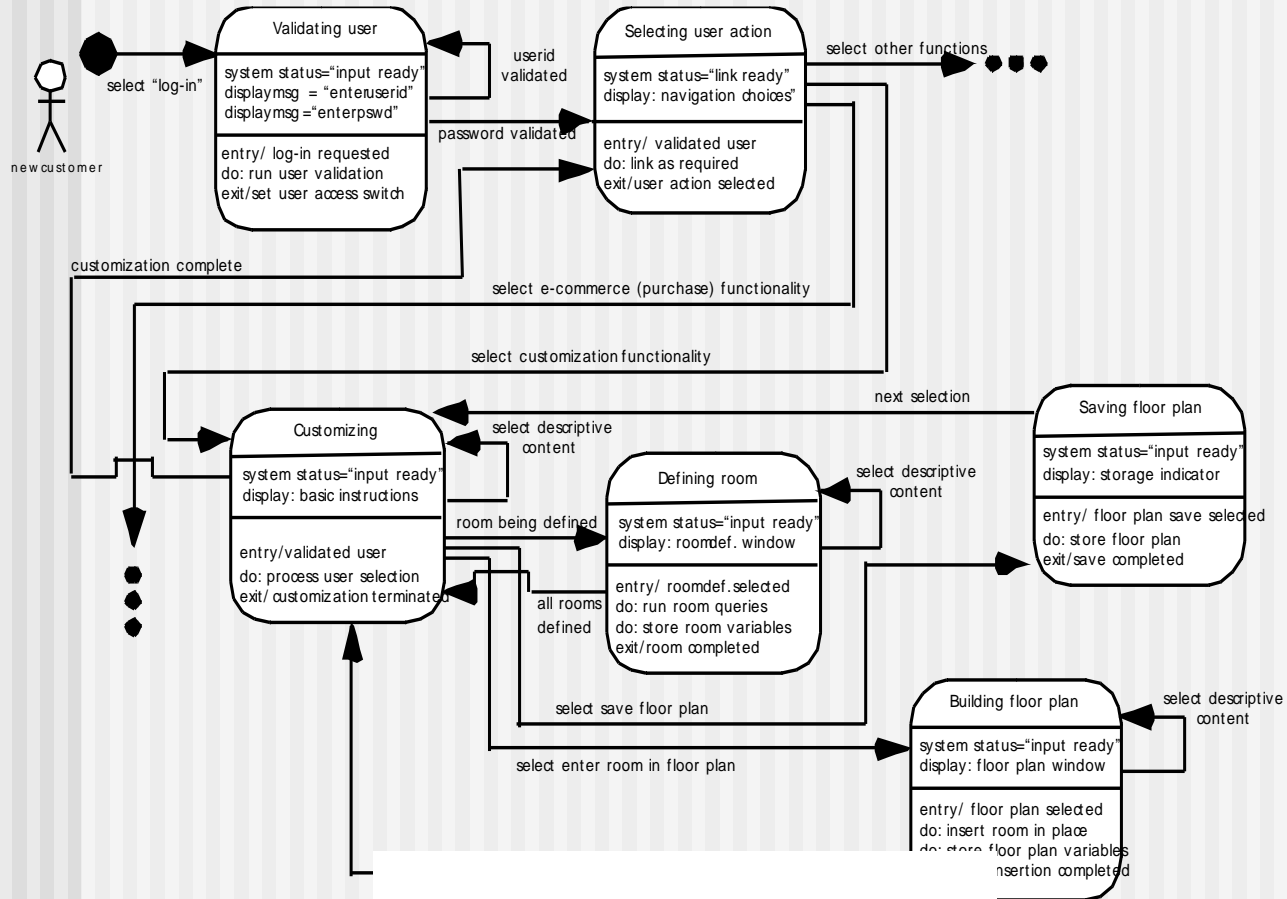
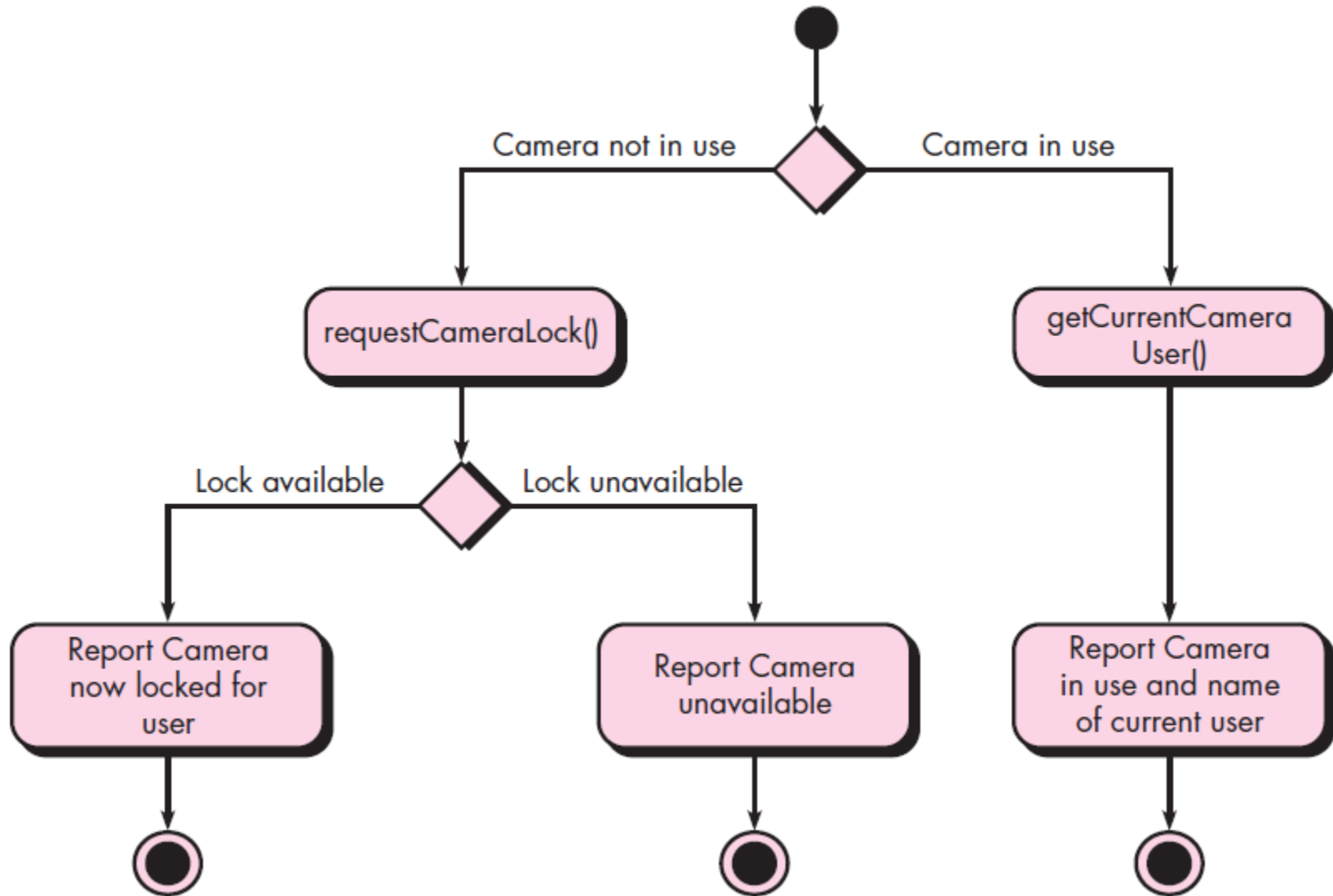


Figure 18.6 Partial state diagram for **new customer** interaction

The Functional Model

- The functional model addresses two processing elements of the WebApp
 - (1) **user observable functionality** that is delivered by the app to end-users
 - (2) the **operations contained within analysis classes** that implement behaviors associated with the class.
- An **activity diagram** can be used to represent processing flow

Activity Diagram



The Configuration Model

- In some cases, the configuration model is nothing more than a list of server-side and client-side attributes.
- However, for more complex WebApps, a variety of configuration complexities (e.g., distributing load among multiple servers, caching architectures, remote databases, multiple servers serving various objects on the same Web page) may have an impact on analysis and design.
- The UML *deployment diagram* can be used in situations in which complex configuration architectures must be considered.

Navigation Modeling

- In most mobile applications that reside on smartphone platforms, navigation is generally constrained to relatively simple button lists and icon-based menus
 - Navigation modeling is relatively simple
- For WebApps, navigation modeling is more complex and often considers how each user category will navigate from one WebApp element to another.
 - ➔ You should focus on overall navigation requirements

Navigation Modeling- Questions for WebApp

- Should certain elements be easier to reach (require fewer navigation steps) than others? What is the priority for presentation?
- Should certain elements be emphasized to force users to navigate in their direction?
- How should navigation errors be handled?
- Should navigation to related groups of elements be given priority over navigation to a specific element.
- Should navigation be accomplished via links, via search-based access, or by some other means?
- Should certain elements be presented to users based on the context of previous navigation actions?
- Should a navigation log be maintained for users?

Navigation Modeling- Questions for WebApp

- Should a full navigation map or menu (as opposed to a single “back” link or directed pointer) be available at every point in a user’s interaction?
- Should navigation design be driven by the most commonly expected user behaviors or by the perceived importance of the defined WebApp elements?
- Can a user “store” his previous navigation through the WebApp to expedite future usage?
- For which user category should optimal navigation be designed?
- How should links external to the WebApp be handled? overlaying the existing browser window? as a new browser window? as a separate frame?

Summary

- Behavioral modeling depicts dynamic behavior. The behavioral model uses input from scenario-based and class-based elements to represent the states of analysis classes and the system as a whole.
- Analysis patterns enable a software engineer to use existing domain knowledge to facilitate the creation of a requirements model.
- Requirements modeling for mobile applications and WebApp can use most, if not all, of the modeling elements discussed in this book.