

Chapter 8

■ Understanding Requirements

Slide Set to accompany

Software Engineering: A Practitioner's Approach, 8/e

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Requirements Engineering: Introduction

- Flawed arguments which can lead to a failed software project
 - Building software is compelling that **many software developers want to jump right in before they have a clear understanding** of what is needed
 - Things will become clear as they build
 - Project stakeholders will be able to understand need only after examining early iterations of the software
 - Things change so rapidly that any attempt to understand requirements in detail is a waste of time
 - The bottom line is producing a working program, and that all else is secondary

Requirements Engineering

- The broad spectrum of tasks and techniques that lead to an understanding of requirements
- Establishes a solid base for design and construction
- Without it, the resulting software has a high probability of not meeting customer's needs
- A major software engineering action that begins during the communication activity and continues into the modeling activity

Requirements Engineering: Bridge to design & construction

- What is the starting point?
 - At **the feet of the project stakeholders**
 - Business need is defined, user scenarios are described, functions and features are delineated, project constraints are identified
 - With **a broader system definition**
 - Software is but one component of the larger system domain
- Allows you to examine the context of the software word to be performed
 - The specific needs that design and construction must address; the priorities that guide the order in which word is to be completed; the information, functions, and behaviors that will have a profound impact on the resultant design

Requirements Engineering-I

- **Inception**—ask a set of questions that establish ...
 - basic understanding of the problem
 - the people who want a solution
 - the nature of the solution that is desired, and
 - the effectiveness of preliminary communication and collaboration between the customer and the developer
- **Elicitation**—elicit requirements from all stakeholders
- **Elaboration**—create an analysis model that identifies data, function and behavioral requirements
- **Negotiation**—agree on a deliverable system that is realistic for developers and customers

Requirements Engineering-II

- **Specification**—can be any one (or more) of the following:
 - A written document
 - A set of models
 - A formal mathematical
 - A collection of user scenarios (use-cases)
 - A prototype
- **Validation**—a review mechanism that looks for
 - errors in content or interpretation
 - areas where clarification may be required
 - missing information
 - inconsistencies (a major problem when large products or systems are engineered)
 - conflicting or unrealistic (unachievable) requirements.
- **Requirements management**

Inception

- How does a software project get started?
- Is there a single event that becomes the catalyst for a new computer-based system or product
- Or does the need evolve over time?
 - ➔ No definitive answers to these questions ...
- In general, most projects begin when a business need is identified or a potential new market or service is discovered
- Stakeholders from the business community
 - Define a business case for the idea
 - Try to identify the breadth and depth of the market
 - Do a rough feasibility analysis
 - Identify a working description of the project's scope

Inception

- Establish the following:
 - a basic understanding of the problem
 - the people who want a solution
 - the nature of the solution that is desired, and
 - the effectiveness of preliminary communication and collaboration between the customer and the developer

Elicitation

- It certainly seems simple enough by doing ...
 - Ask the customer, the users, and others
 - What the objectives for the system or product are, what is to be accomplished, how the system or product fits into the needs of the business, and finally, how the system or product is to be used on a day-to-day basis

➔ But it isn't simple. It is very hard!

Elicitation

- To establish business goals
 - An important part of elicitation
 - Engage stakeholders and encourage them to share their goals honestly
 - Once the goals have been captured, a prioritization mechanism should be established, and a design rationale for a potential architecture can be created

Elicitation: Three Problems

[Christel and Kang '92]

- Problems of scope
 - Occur when the boundary of the system is ill-defined or the customers and users specify unnecessary technical detail that may confuse
- Problems of understanding
 - Occur when customers and users are not completely sure of what is needed, don't have a full understanding of the problem domain, or they have trouble communicating needs, or they specify requirements that conflict with the needs of other customers and users ..
- Problems of volatility
 - Occur when the requirements change over time

➔ To overcome these problems, the requirements-gathering activity should be done in an organized manner

Elaboration

- The information obtained from the customer during inception and elicitation is expanded and refined
- Focuses on developing a refined requirements model that identifies various aspects of software function, behavior, and information
- It is driven by the creation and refinement of user scenarios that describe how the end user will interact with the system
 - Each user scenario is parsed to extract analysis classes
 - The attributes of each analysis class are defined
 - The services that are required by each class are identified
 - The relationship and collaboration b/w classes are identified
 - A variety of supplementary diagrams are produced

Negotiation

- Common problems
 - Customers and users can ask for more than can be achieved, given limited business resources
 - Different customers or users can propose conflicting requirements, arguing that their version is “essential for our special needs”
- Negotiation
 - Reconciles these conflicts
 - Customers, users, and other stakeholders are asked to rank requirements and then discuss conflicts in priority\
 - Prioritizes requirements, accesses their cost and risk, and addresses internal conflicts → Towards an iterative approach

Specification

- Different things to different people
- It can be a written document; a set of graphical models; a formal mathematical model; a collection of usage scenarios; a prototype; any combination of these
- **Standard template**
 - Suggested by some researchers
 - Standard template should be developed and used for a specification,
 - They argue that standard template leads to requirements that are presented in a consistent and therefore more understandable manner
 - ➔ Keeping **flexibility** sometimes is necessary

Specification

- The formality and format of a specification varies with the size and the complexity of the software to be built
 - For large systems, a written document, combining natural language description and graphical models may be the best approach
 - For small systems, usage scenarios may be all that required

Validation

- The work products of requirements engineering are assessed **for quality**
- Examines the specification to ensure that ..
 - All software requirements have been stated unambiguously
 - Inconsistencies, omissions, and errors have been detected and corrected
 - The work products conform to the standards established for the process, the project, and the product

Validation

- Technical review
 - The primary requirements validation mechanism
 - Review team is organized, which includes
 - Software engineers, customers, users, and other stakeholders
 - Look for the errors in content or interpretation, areas where clarification may be required, missing information, inconsistencies, conflicting requirements, or unrealistic requirements

Validation: Requirement representation problem

- Example requirements
 - R1) The software should be user friendly
 - R2) The probability of a successful unauthorized database intrusion should be less than 0.0001

- R1: Too vague. To validate it, it must be quantified or qualified in some manner
- R2: An intrusion testing will be difficult and time consuming. Is this level of security even warranted for the application? Can other complementary requirements associated with security replace the quantitative requirement noted?

Validation: Requirement representation problem

- [Glinz '09] Quality requirements need to be represented in a manner that delivers optimal value
- The more critical the quality requirement is, the greater the need to state it in quantifiable terms
- Less-critical quality requirements can be stated in general terms
- In some cases, a general quality requirement can be verified using a qualitative technique
- Quality requirements can be verified using a combination of qualitative and quantitative assessment

Requirement Management

- Motivation: Requirements over time
 - Requirements for computer-based systems change
 - The desire to change requirements persists throughout the life of the system
- Requirement management: A set of activities that help the project team identify, control, and track requirements and changes to requirements at any time as the project proceeds
 - These activities are identical to the software configuration management (SCM) technique

Inception: Establishing the Groundwork

- Situation: Customer or end users may be located in a different city or country, may have only a vague idea, with limited technical knowledge or limited time to interact with the requirement engineers
- What are the steps to get the project started in a way that will keep it moving forward toward a successful solution?

Establishing the Groundwork

- Step1) Identify stakeholders
 - Stakeholder: Anyone who benefits in a direct or indirect way from the system which is being developed [Sommerville '97]
 - Business operations managers, product managers
 - Marketing people, internal and external customers, end users, consultants, product engineers, software engineers, support and maintenance engineers, ...
 - Each stakeholder has a different view of the system, achieves different benefits when getting the successful system, or is open to different risk for the failure
 - “who else do you think I should talk to?”

Establishing the Groundwork

- Step2) Recognizing multiple viewpoints
 - The requirements of the system will be explored from many different point of view
 - The marketing group → functions and features that will excite the potential market
 - Business managers → a feature set that can be built within budget and that will meet defined market windows
 - End users → Features that are familiar to them and easy to learn and use
 - Software engineers → functions that are invisible to nontechnical stakeholders but that enable an infrastructure that supports more marketable functions and features
 - Support engineers → maintainability of the software

Establishing the Groundwork

- Step2) Recognizing multiple viewpoints
 - After collecting information from multiple viewpoints, emerging requirements may be inconsistent or may conflict with one another
 - Several things that can make it hard to elicit requirements
 - Project goals are unclear
 - Stakeholders' priorities differ
 - People have unspoken assumptions
 - Stakeholders interpret meanings differently
 - Requirements are stated in a way that make them difficult to verify

- ➔ These problems need to be eliminated or reduced

Establishing the Groundwork

- Step3) Working toward collaboration
 - Collaboration does not necessarily mean that requirements are defined by committee
 - In many cases, stakeholders collaborate by providing their view of requirements, but a strong “project champion” (a business manager or a senior technologist) may make the final decision about which requirements make the cut

Establishing the Groundwork

- Step4) Asking the first questions
 - Questions asked at the inception should be **context free**
 - Focuses on the customer and other stakeholders, the overall project goals and benefits
 - Context-free questions may be
 - Who is behind the request for this work?
 - Who will use the solution?
 - What will be the economic benefit of a successful solution
 - Is there another source for the solution that you need?

- ➔ Help to identify all stakeholders & measurable benefit

Establishing the Groundwork

- Step4) Asking the first questions
 - How would you characterize “good” output that would be generated by a successful solution?
 - What problems will this solution address?
 - Can you show me the business environment in which the solution will be used?
 - Will special performance issues or constraints affect the way the solution is approached?
- ➔ enables you to gain a better understanding of the problem allows the customer to voice his or her perceptions about a solution

Establishing the Groundwork

- Step4) Asking the first questions
 - Are you the right person to answer these questions?
Are your answers “official”?
 - Are my questions relevant to the problem that you have?
 - Am I asking too many questions?
 - Can anyone else provide additive information?
 - Should I be asking you anything else?

- ➔ Focuses on the effectiveness of the communication activity itself

Establishing the Groundwork

- Nonfunctional requirement (NFR)
 - It can be described as a quality attribute, a performance attribute, a security attribute, or a general constraint on a system
 - **Quality function deployment (QFD)**
 - Attempts to translate unspoken customer needs or goals into system requirements
 - Two-phase approach to identify NFRs
 - 1) Establish a set of software engineering guidelines for the system to be built
 - 2) Develop a list of NFRs
 - Requirements that address usability, testability, security, or maintainability
 - Lists a simple table
 - NFRs as *column labels*
 - Software engineering guidelines as *row labels*

Establishing the Groundwork

■ Traceability

- A software engineering term that refers to documented links between software engineering work products (requirements and test cases)
 - **Traceability matrix**
 - The relationship b/w requirements and other software engineering works products
 - Rows: Labeled using requirement names
 - Columns: Labeled with the name of a software engineering work product (e.g., a design element or a test case)
 - A matrix cell: marked to indicate the presence of a link b/w the two
- It often can be used to ensure that the engineering work products have taken all requirements into account₃₀

Elicitation: Eliciting Requirements

- Also called Requirements gathering
- Combines elements of problem solving, elaboration, negotiation, and specification
- the goal is
 - to identify the problem
 - propose elements of the solution
 - negotiate different approaches, and
 - specify a preliminary set of solution requirements

Eliciting Requirements

- A product request is generated during inception
- Meetings are conducted and attended by both software engineers and customers
- Rules for preparation and participation are established
- An agenda is suggested
 - that is formal enough to cover all important points but informal enough to encourage the free flow of ideas
- A "facilitator" (can be a customer, a developer, or an outsider) controls the meeting
- A "definition mechanism" (can be work sheets, flip charts, or wall stickers or an electronic bulletin board, chat room or virtual forum) is used

Product Request: Example from SafeHome project

Our research indicates that the market for home management systems is growing at a rate of 40 percent per year. The first SafeHome function we bring to market should be the home security function. Most people are familiar with “alarm systems” so this would be an easy sell.

The home security function would protect against and/or recognize a variety of undesirable “situations” such as illegal entry, fire, flooding, carbon monoxide levels, and others. It’ll use our wireless sensors to detect each situation. It can be programmed by the homeowner, and will automatically telephone a monitoring agency when a situation is detected.

Eliciting Requirements: Reviewing the product request

- While reviewing the product request before the meeting,
- each attendee is asked to **make a list of objects that are part of the environment** that surrounds the system, **other objects that are to be produced by the system**, and **objects that are used by the system to perform its functions**.
- Each attendee is asked to **make another list of services** (processes or functions) that manipulate or interact with the objects.
- **Lists of constraints** (e.g., cost, size, business rules) and **performance criteria** (e.g., speed, accuracy) are also developed.

Eliciting Requirements: Mini-specification

- Stakeholders develop *mini-specifications* for entries on a list, when an object or service described on the list will require further explanation
- Each mini-specification is an elaboration of an object or service
- Example: the mini-spec for the SafeHome object Control Panel might be

The control panel is a wall-mounted unit that is approximately 9 5 inches in size. The control panel has wireless connectivity to sensors and a PC. User interaction occurs through a keypad containing 12 keys. A 3 3 inch LCD color display provides user feedback. Software provides interactive prompts, echo, and similar functions.

Eliciting Requirements:

Issues list for Mini-specification

- The mini-specs are presented to all stakeholders for discussion.
 - Additions, deletions, and further elaboration are made. In some cases, the development of mini-specs will uncover new objects, services, constraints, or performance requirements that will be added to the original lists.
 - During all discussions, the team may raise an issue that cannot be resolved during the meeting.
- An *issues list* is maintained so that these ideas will be acted on later.

Eliciting Requirements: Quality Function Deployment

- QFD is a quality management technique that translates the needs of the customer into technical requirements for software.
- QFD “concentrates on maximizing customer satisfaction from the software engineering process”
- QFS identifies three types of requirements
 - **Normal requirements:** The objectives and goals that are stated for a product or system during meetings with the customer.
 - **Expected requirements:** These requirements are implicit to the product or system and may be so fundamental that the customer does not explicitly state them. Their absence will be a cause for significant dissatisfaction.
 - **Exciting requirements:** These features go beyond the customer’s expectations and prove to be very satisfying when present.

Eliciting Requirements: Quality Function Deployment

- Customer voice table
 - Based on customer interviews and observation, surveys, and examination of historical data (e.g., problem reports) as raw data for the requirements gathering activity.
 - These data are then translated into a table of requirements

Eliciting Requirements: Usage Scenarios

- Use cases
 - a set of scenarios created by developers and users that identify a thread of usage for the system to be constructed
 - provide a description of how the system will be used
 - It helps us to understand how these functions and features will be used by different classes of end users → allowing us to move into more technical software engineering activities

Elicitation Work Products

- A statement of need and feasibility
- A bounded statement of scope for the system or product.
- A list of customers, users, and other stakeholders who participated in requirements elicitation
- A description of the system's technical environment
- A list of requirements (preferably organized by function) and the domain constraints that apply to each
- A set of usage scenarios that provide insight into the use of the system or product under different operating conditions
- Any prototypes developed to better define requirements.

Agile Requirements Elicitation

- Users stores
 - Created by stakeholders for agile process
 - Each user story describes a simple system requirement written from the user's perspective
 - User stories can be written on small note cards, making it easy for developers to select and manage a subset of requirements to implement for the next product increment
 - Allows developers to shift their focus on communication with stakeholders with the selected requirements
 - Critics: A consideration of overall business goals and nonfunctional requirements is often lacking

Eliciting Requirements: Service-Oriented Methods

- Service-oriented method
 - Views a system as an aggregation of services
 - Service: As simple as providing a single function
- Requirements elicitation for service-oriented methods: focuses on **the definition of services to be rendered by an application**
- **Touchpoint**: represents an opportunity for the user to interact with the system to receive a desired service

Developing User Cases

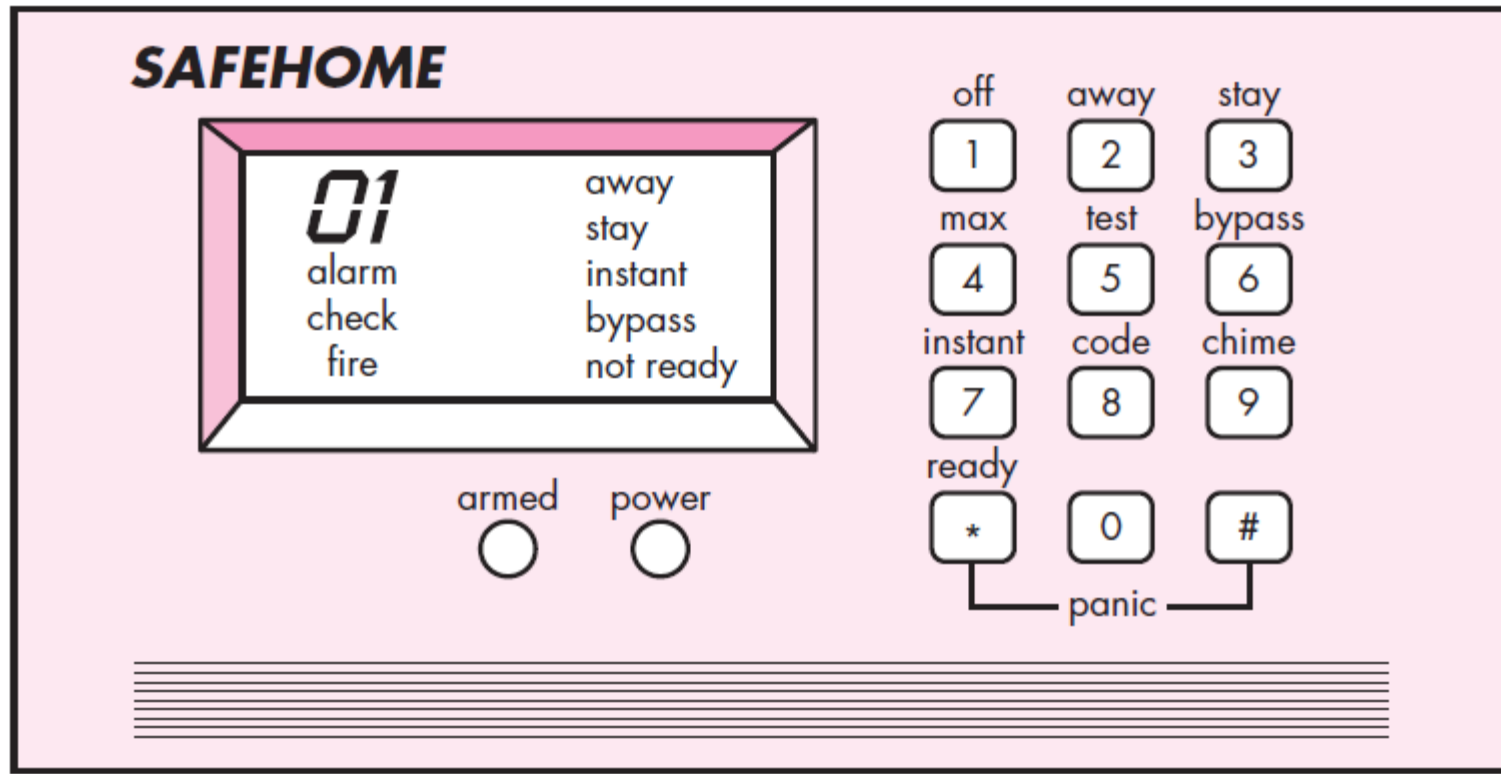
- User cases are defined from an actor's point of view
 - An actor is a role that people or devices play as they interact with the software
 - An actor is anything that communicates with the system or product and that is external to the system itself
 - Every actor has one or more goals when using the system
 - An actor and an end user are not necessarily the same thing
- Not all actors are identified during the first iteration
 - **Primary actors** are identified during the first iteration
 - Primary actors interact to achieve required system function and derive the intended benefit from the system. They work directly and frequently with the software
 - **Secondary actors** are identified as more is learned about the system
 - Support the system so that primary actors can do their work

Developing User Cases

- Jacobson [Jac92] suggests a number of questions for a use case
 - Who is the primary actor, the secondary actor(s)?
 - What are the actor's goals?
 - What preconditions should exist before the story begins?
 - What main tasks or functions are performed by the actor?
 - What exceptions might be considered as the story is described?
 - What variations in the actor's interaction are possible?
 - What system information will the actor acquire, produce, or change?
 - Will the actor have to inform the system about changes in the external environment?
 - What information does the actor desire from the system?
 - Does the actor wish to be informed about unexpected changes?

SafeHome Example

- SafeHome control panel



SafeHome Example:

Basic use case

1. The homeowner observes the *SafeHome* control panel to determine if the system is ready for input. If the system is not ready, a *not ready* message is displayed on the LCD display, and the homeowner must physically close windows or doors so that the *not ready* message disappears. [A *not ready* message implies that a sensor is open; i.e., that a door or window is open.]
2. 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.
3. The homeowner selects and keys in *stay* or *away* to activate the system. *Stay* activates only perimeter sensors (inside motion detecting sensors are deactivated). *Away* activates all sensors.
4. When activation occurs, a red alarm light can be observed by the homeowner.

Templates for detailed description of use cases [Cockburn '01]

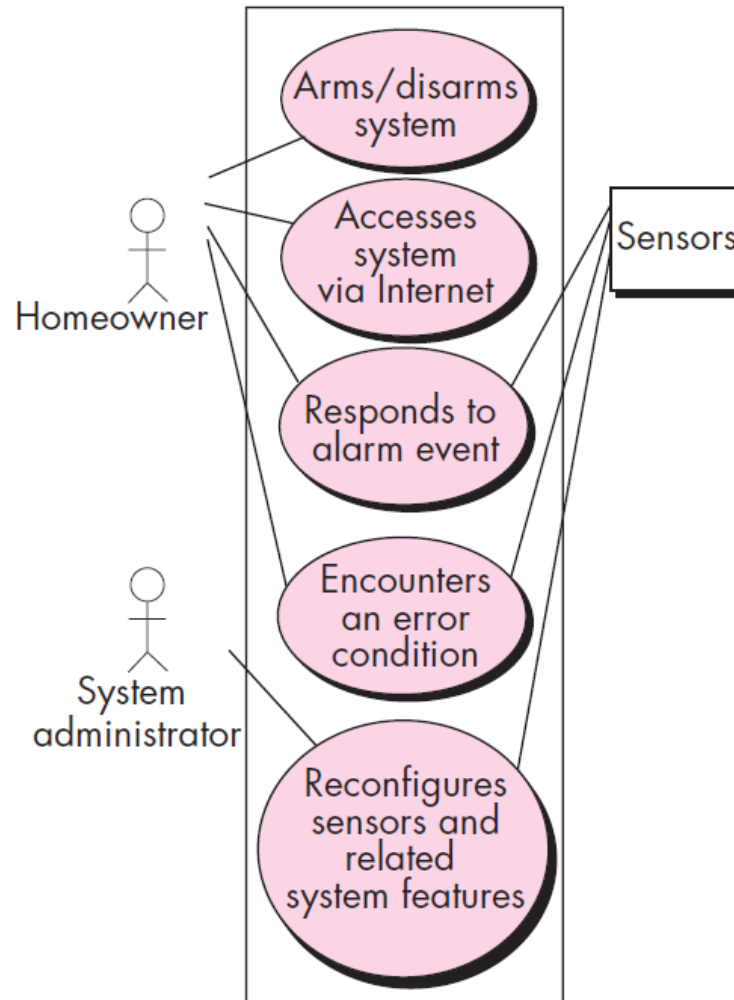
- Use case
- Primary actor
- Goal in context
- Preconditions
- Trigger
- Scenario
- Exceptions
- Priority
- When available
- Frequency of use
- Channel to actor
- Secondary actors
- Channels to secondary actors
- Open issues

SafeHome Example:

Detailed description of use cases

- **Use case:** *InitiateMonitoring*
- **Primary actor:** Homeowner.
- **Goal in context:** To set the system to monitor sensors when the homeowner leaves the house or remains inside.
- **Preconditions:** System has been programmed for a password and to recognize various sensors.
- **Trigger:** The homeowner decides to “set” the system, i.e., to turn on the alarm functions.
- **Scenario:**
 1. Homeowner: observes control panel
 2. Homeowner: enters password
 3. Homeowner: selects “stay” or “away”
 4. Homeowner: observes read alarm light to indicate that *SafeHome* has been armed
- ...

SafeHome Example: Use case diagram



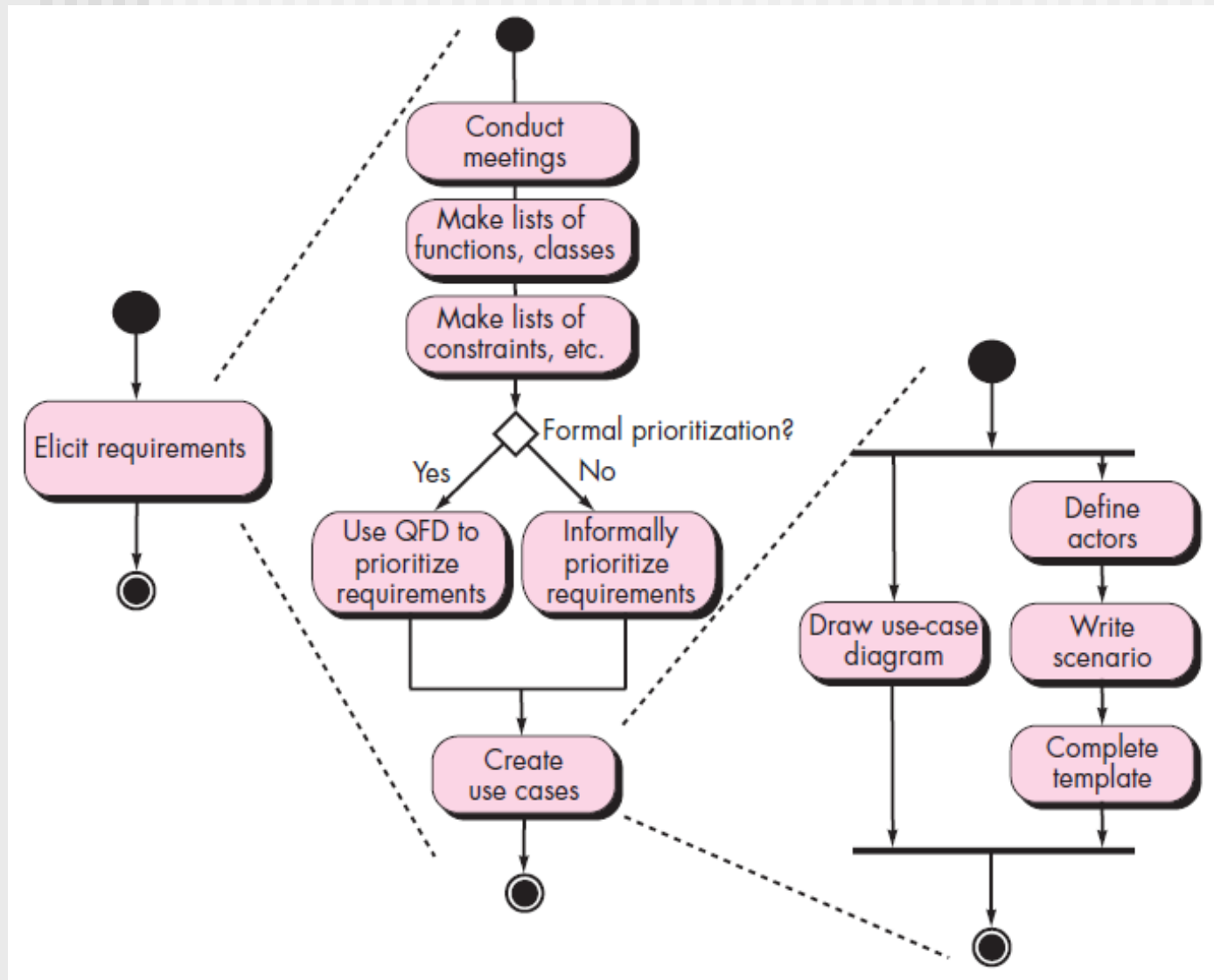
Elaboration: Building the Analysis Model

- The analysis model
 - To provide a description of the required informational, functional, and behavioral domains for a computer-based system.
 - The model changes dynamically as you learn more about the system to be built
 - The analysis model is **a snapshot of requirements at any given time**. It is expected to change.
- The most common elements to be developed
 - Scenario-based elements
 - Class-based elements
 - Behavioral elements

Analysis model: Scenario-based elements

- The system is described from the user's point of view using a **scenario-based approach**
 - E.g.) basic use cases and their corresponding use-case diagrams evolve into more **elaborate template-based use cases**.
- Represented by **activity diagram**
- Often the first part of the model that is developed.
- They serve as input for the creation of other modeling elements.

Scenario-based elements

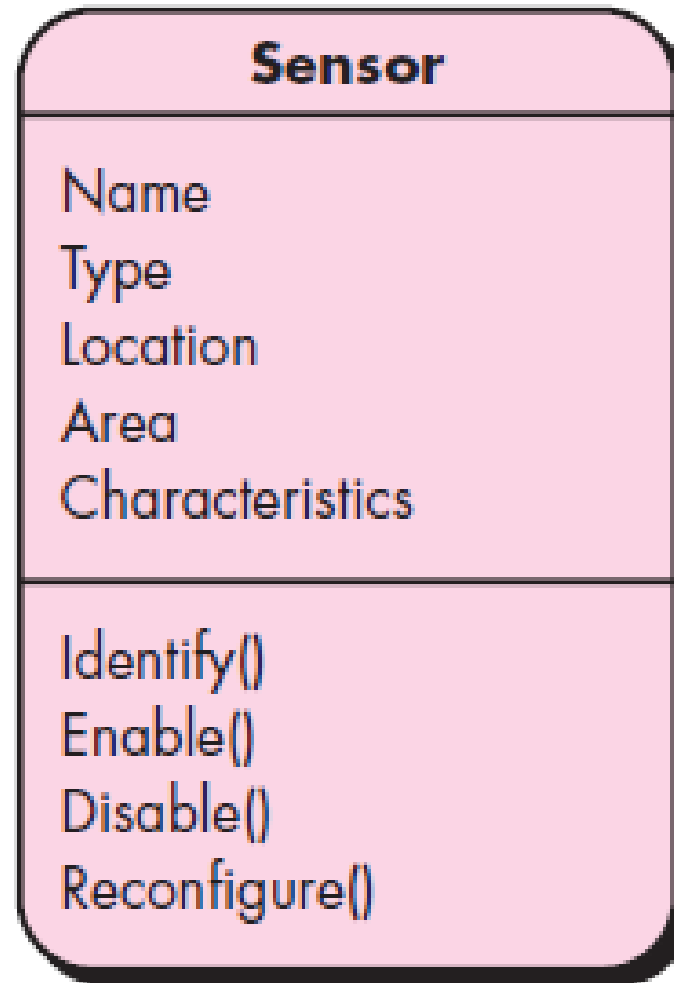


UML activity diagram for eliciting requirements and representing them using use cases.

Analysis model: Class-based elements

- Each usage scenario implies a set of objects that are manipulated as an actor interacts with the system.
- These objects are categorized into classes
- Represented by **class diagram**

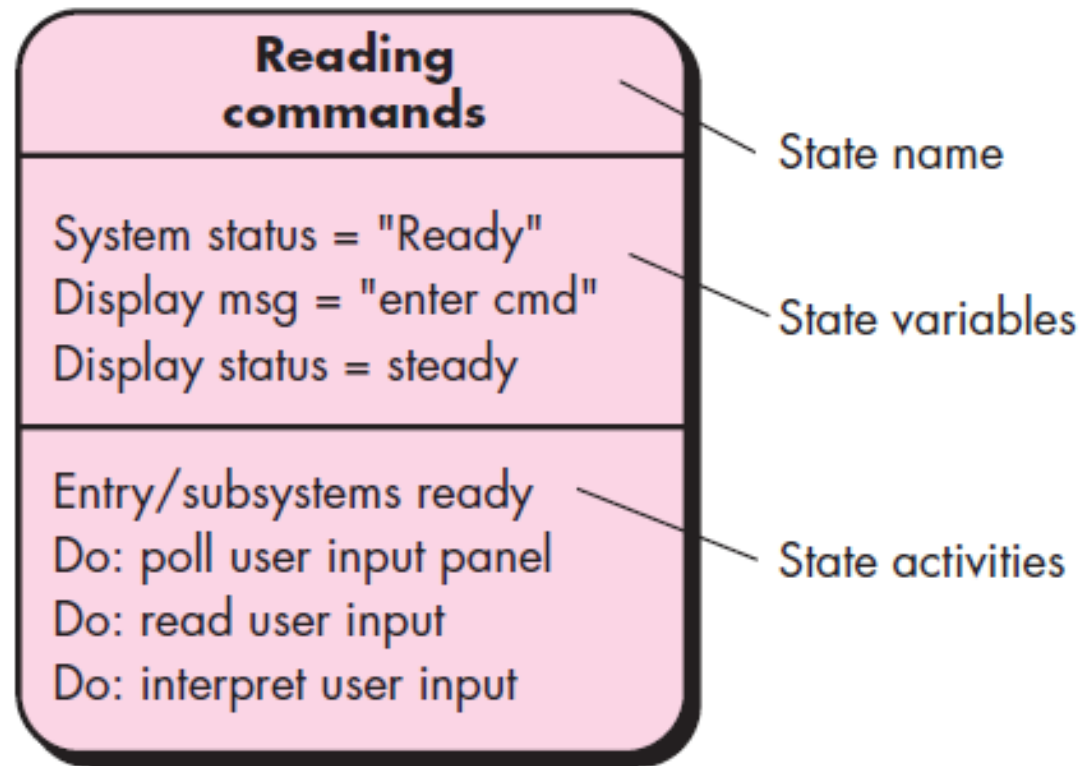
Class-based elements



Analysis model: Behavioral-based elements

- The behavior of a computer-based system can have a profound effect on the design that is chosen and the implementation approach that is applied.
- The *state diagram* is one method for representing the behavior of a system

Behavioral-based elements



Analysis Patterns

- Certain problems reoccur across all projects within a specific application domain
- These *analysis patterns* suggest solutions (e.g., a class, a function, a behavior) within the application domain that can be reused when modeling many applications.

Negotiating Requirements

In an ideal case, the inception, elicitation, and elaboration tasks determine customer requirements in sufficient detail to proceed to subsequent software engineering activities. Unfortunately, this rarely happens.

■ Goal

- To develop a project plan that meets stakeholder needs while at the same time reflecting the real-world constraints (e.g., time, people, budget) that have been placed on the software team.
- The best negotiations strive for a “win-win” result
- A set of negotiation activities
 - **Identify the key stakeholders**
 - These are the people who will be involved in the negotiation
 - **Determine each of the stakeholders “win conditions”**
 - Win conditions are not always obvious
 - **Negotiate**
 - Work toward a set of requirements that lead to “win-win”

Requirements Monitoring

■ Motivation

- Incremental development is commonplace. Use cases, new test cases are developed for each increment

■ Requirements monitoring

- Extremely useful when incremental development is used
- Five tasks
 - 1) **Distributed debugging**
 - 2) **Run-time verification**: whether software matches its specification
 - 3) **Run-time validation**: whether the evolving software meets user goals
 - 4) **Business activity monitoring**: whether a system satisfies business goal
 - 5) **Evolution and codesign**: Provides information to stakeholders as the system evolves

Validating Requirements

- As each element of the requirements model is created, it is **examined** for inconsistency, omissions, and ambiguity.
- The requirements represented by the model are **prioritized by** the stakeholders and **grouped** within requirements packages that will be implemented as software increments.

Validating Requirements: Review of Analysis Models

- Is **each requirement consistent** with the overall objective for the system/product?
- **Have all requirements been specified at the proper level of abstraction?** That is, do some requirements provide a level of technical detail that is inappropriate at this stage?
- Is the requirement really necessary or does it represent an add-on feature that may not be essential to the objective of the system?
- Is each requirement **bounded and unambiguous**?
- Does each requirement have attribution? That is, is a source (generally, a specific individual) noted for each requirement?
- Do any requirements conflict with other requirements?

Validating Requirements - II

- Is each requirement achievable in the technical environment that will house the system or product?
- Is each requirement testable, once implemented?
- Does the requirements model properly reflect the information, function and behavior of the system to be built.
- Has the requirements model been “partitioned” in a way that exposes progressively more detailed information about the system.
- Have requirements patterns been used to simplify the requirements model. Have all patterns been properly validated? Are all patterns consistent with customer requirements?

Summary

- Requirements engineering
 - Establish a solid foundation for design and construction
 - Occurs during the communication and modeling activities
 - Seven distinct functions—inception, elicitation, elaboration, negotiation, specification, validation, and management
- Project inception
 - stakeholders establish basic problem requirements, define overriding project constraints, and address major features and functions
- Elicitation
 - Requirements gathering activity that makes use of facilitated meetings, QFD, and the development of usage scenarios
 - The information obtained at inception is refined and expanded
- Elaboration
 - Further expands requirements in a model
 - a collection of scenario-based, class-based, and behavioral elements.