



Agent and Object Technology Lab
Dipartimento di Ingegneria dell'Informazione
Università degli Studi di Parma



Software Engineering

Requirements Engineering

Prof. Agostino Poggi

- ◆ It may range from a high-level abstract statement of a service or of a system constraint to a detailed mathematical functional specification
- ◆ This is inevitable as requirements may serve a dual function
 - May be the basis for a bid for a contract: therefore must be open to interpretation
 - May be the basis for the contract itself: therefore must be defined in detail
- ◆ Both these statements may be called requirements

- ◆ Requirements engineering is the process of establishing
 - The services that the customer requires from a system
 - The constraints under which it operates and is developed
- ◆ Goal of the requirements engineering is to gather and analyze the descriptions of the system services and constraints

- ◆ Many people have difficulty understanding the difference between scope, requirements and design
 - Scope demonstrates the needs of the organization, and is documented in a vision and scope document
 - Requirements document the behavior of the software that will satisfy those needs
 - Design shows how those requirements will be implemented technically

- ♦ In principle, requirements should state **what** the system should do and the design should describe **how** it does this
- ♦ In practice, requirements and design are inseparable
 - A system architecture may be designed to structure the requirements
 - The system may interoperate with other systems that generate design requirements
 - The use of a specific design may be a domain requirement

- ◆ Use case analysis
 - Mostly focused on writing text and the simple use of overview context diagrams is often enough
 - Use cases are just a part of functional requirements describing the interactions inside the system and between the system and its users and providers
- ◆ Structural analysis – domain modeling
 - Finding the “real-world” objects involved in the use cases and creating class diagrams to represent them

- ◆ Behavioral analysis
 - Creating activity diagrams and sequence diagrams to capture use case details
 - Activity diagrams for business workflow
 - Sequence diagrams for reactive behavior (also with timing)
 - Possibly creating state charts to capture external reactive behavior of the system and other domain objects

- ◆ System customers
 - Help in their specification and read them to check whether they satisfy their needs
 - Help in specifying of changes in the requirements
- ◆ Managers
 - Use them to plan a bid for the realization of the system
 - Use them to plan the system development process

- ◆ System engineers
 - Use them to understand what system must be developed
- ◆ System test engineers
 - Use them to develop the validation tests for the system
- ◆ System maintenance engineers
 - Use them to understand the system and the relationships between its parts

- ◆ On the basis of the type of the system feature
 - Functional requirements
 - Non-functional requirements
 - Domain requirements
- ◆ On the basis of their static / dynamic nature
 - Enduring requirements
 - Volatile requirements
- ◆ On the basis of their audience
 - User requirements
 - System requirements

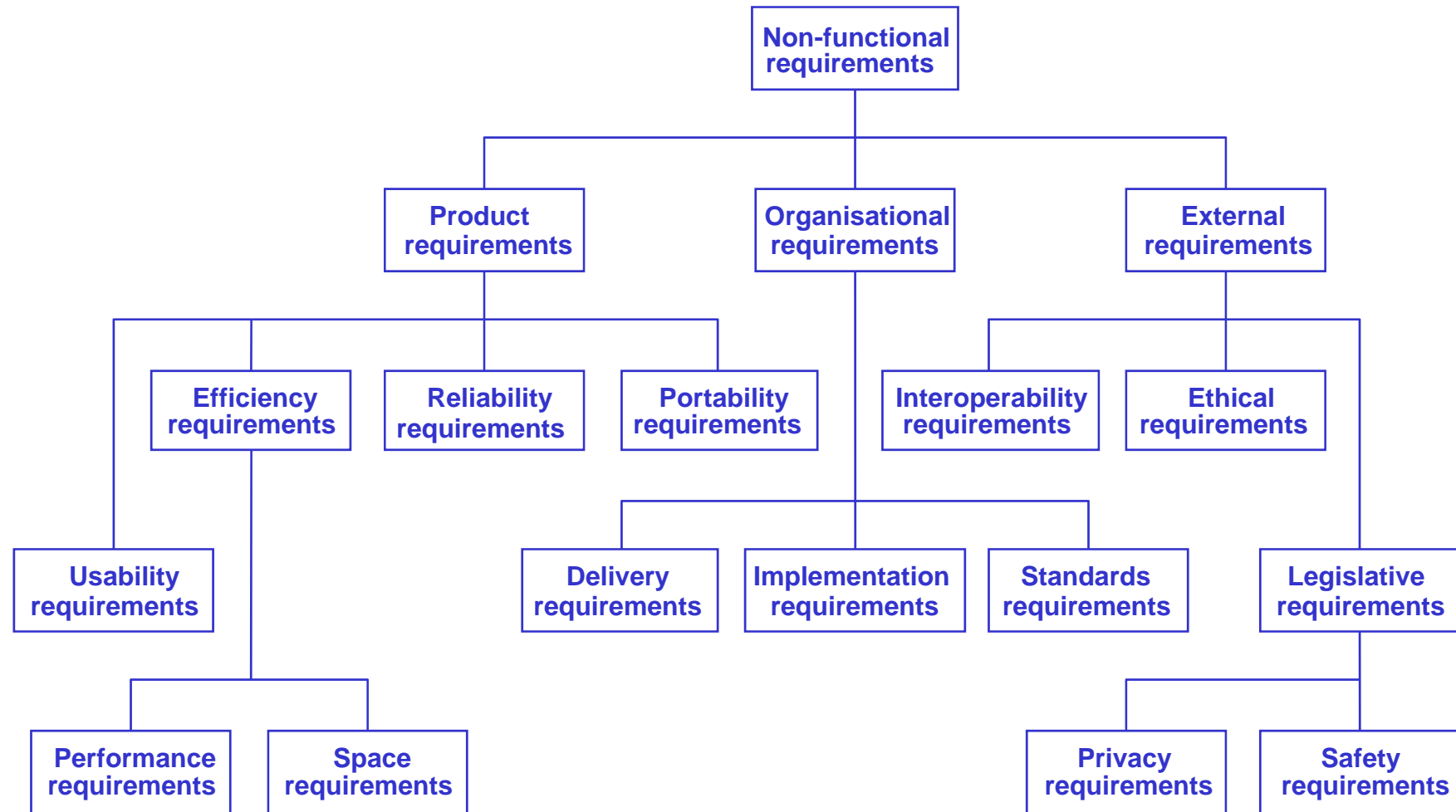
- ◆ Capture the intended behavior of the system
 - This behavior may be expressed as services, tasks or functions the system is required to perform

- ◆ Describe how the system should react to particular inputs and how the system should behave in particular situations
 - Describe functionality or system services

- ◆ Constraints on the services or functions offered by the system such as timing constraints, constraints on the development process, standards, etc.
- ◆ Specify criteria that can be used to judge the operation of a system, rather than specific behaviors
- ◆ Constrains the design and the implementation of the system, but does not describe a service that the system should provide

- ◆ Product requirements
 - Requirements which specify that the delivered product must behave in a particular way
 - E.g., execution speed, reliability, etc.
- ◆ Organizational requirements
 - Requirements which are a consequence of organizational policies and procedures
 - E.g., process standards used, implementation requirements, etc.
- ◆ External requirements
 - Requirements which arise from factors which are external to the system and its development process
 - E.g., interoperability requirements, legislative requirements, etc.

Non-Functional Requirements Classification



- ◆ Non-functional requirements may be very difficult to state precisely and imprecise requirements may be difficult to verify
- ◆ Goal
 - A general intention of the user such as “ease of use”
- ◆ Verifiable non-functional requirement
 - A statement using some measure that can be objectively tested
- ◆ Goals are helpful to developers as they convey the intentions of the system users

- ◆ A goal
 - The system should be easy to use by experienced controllers and should be organized in such a way that user errors are minimized

- ◆ A verifiable non-functional requirement
 - Experienced controllers shall be able to use all the system functions after a total of two hours training. After this training, the average number of errors made by experienced users shall not exceed two per day

- ◆ Speed: processed transaction per second, user event response time, screen refresh time
- ◆ Size: Kbytes, number of RAM chips
- ◆ Ease to use: training time, number of help frames
- ◆ Reliability: mean time to failure, probability of unavailability
- ◆ Robustness: time to restart after failure, percentage of events causing failure, probability of data corruption on failure
- ◆ Portability: percentage of target dependent statement, number of target systems

- ◆ Requirements that come from the application domain of the system and that reflect characteristics of that domain
- ◆ Can be either functional or non-functional that constraints existing requirements or define specific computations
 - If domain requirements are not satisfied, the system may be unworkable

- ◆ Stable requirements derived from the core activity of the customer organization
- ◆ For example, a hospital will always have doctors, nurses, etc.
- ◆ They may be derived from domain models

- ◆ Requirements which change during development or when the system is in use
- ◆ For example, in a hospital, requirements derived from health-care policy
- ◆ They can be divided in mutable, emergent, consequential and compatibility requirements

- ◆ Mutable requirements

- Requirements that change because of changes to the environment in which the organization is operating
- For example, in hospital systems, the funding of patient care may change and thus require different treatment information to be collected

- ◆ Emergent requirements

- Requirements that emerge as the customer's understanding of the system develops during the system development
- The design process may reveal new emergent requirements

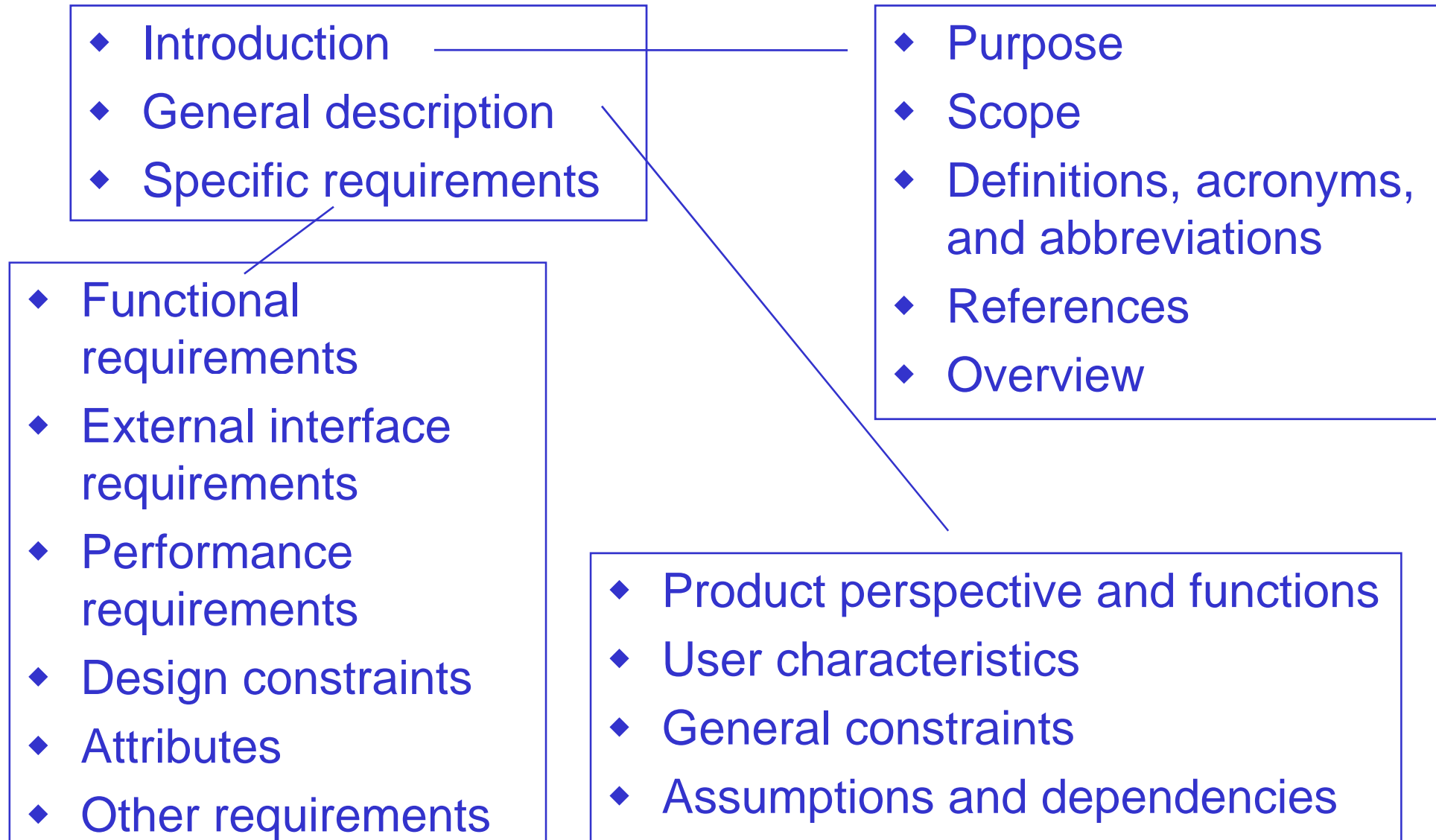
- ◆ Consequential requirements
 - Requirements that result from the introduction of the computer system
 - Introducing the computer system may change the organizations processes and open up new ways of working which generate new system requirements
- ◆ Compatibility requirements
 - Requirements that depend on the particular systems or business processes within an organization
 - As these change, the compatibility requirements on the commissioned or delivered system may also have to evolve

- ◆ Description of the system services and its operational constraints that is understandable by system users who don't have technical knowledge
- ◆ Written mainly for customers
 - Client managers
 - System end-users
 - Client engineering
 - Contractor manager
 - System architects
- ◆ User requirements are defined using natural language, tables and diagrams

- ◆ More detailed specifications of user requirements
- ◆ Written for both client and contractor
 - System end-users
 - Client engineering
 - System architects
 - Software developers
- ◆ Can act as a contract between client and contractor
- ◆ System requirements may be expressed using system models

- ◆ Is a document that clearly specifies the system requirements as identified during the requirements process
- ◆ Should include both a definition and a specification of requirements
- ◆ Should describe what the system should do rather than how it should do it (It is not a design document)
- ◆ This document is called:
 - System Specification if it deals with hardware and software
 - Software Requirements Specification (SRS) if it deals only with software

- ◆ There are standards such as IEEE 830 which dictate the requirements for an SRS conforming to that standard
- ◆ A standard template for software requirements specifications may be used within organizations to aid in the production of consistent and complete requirements documents
 - SRS standards or templates may help to provide structure and consistency
 - SRS standards or templates may also impede the effective specification of requirements



- ◆ Use a layered format that provides increasing detail as the layers deepen
- ◆ Use consistent graphical notation and apply textual terms consistently
- ◆ Be sure to define all acronyms
- ◆ Be sure to include a table of contents and, if possible, an index and/or glossary
- ◆ Write in a simple, unambiguous style
- ◆ Always put yourself in the reader's position

- ◆ Problems arise when requirements are not precisely stated
- ◆ Ambiguous requirements may be interpreted in different ways by developers and users
- ◆ Consider the term appropriate viewers:
 - User intention: special purpose viewer for each different document type
 - Developer interpretation: provide a text viewer that shows the contents of the document

- ◆ In principle requirements should be both complete and consistent
 - Complete: they should include descriptions of all facilities required
 - Consistent: there should be no conflicts or contradictions in the descriptions of the system facilities
- ◆ In practice, it is very difficult or impossible to produce a complete and consistent requirements document

◆ Understandability

- Some requirements may be expressed in the language of the application domain
 - This is often not understood by software engineers developing the system
- Some requirements may be expressed in the language of developers
 - This is often not understood by customers of the system

◆ Implicitness

- Domain specialists understand the area so well that they do not think of making the domain requirements explicit
- Development specialists may consider that some technical solutions implicitly follows the requirements

- ◆ Conflicts between different non-functional requirements are common in complex systems
- ◆ Consider some requirements of a spacecraft system:
 - To minimize weight, the number of separate chips in the system should be minimized
 - To minimize power consumption, lower power chips should be used
 - However, using low power chips may mean that more chips have to be used

- ◆ Lack of clarity
 - Precision is difficult without making the document difficult to read
- ◆ Requirements confusion
 - Functional and non-functional requirements tend to be mixed-up
- ◆ Requirements amalgamation
 - Several different requirements may be expressed together

- ◆ Ambiguity

- The readers and writers of the requirement must interpret the same words in the same way, but natural language is naturally ambiguous so this is very difficult

- ◆ Over-flexibility

- The same thing may be said in a number of different ways in the specification

- ◆ Lack of modularization

- Natural language structures are inadequate to structure system requirements

- ◆ Invent a standard format and use it for all requirements
- ◆ Use language in a consistent way:
 - Same syntax for the description of the requirements
 - Same terms for the same type of requirements
- ◆ Use text highlighting to identify key parts of the requirement
- ◆ Avoid the use of computer jargon

◆ Behaviors/Constraints:

- **Shall:** system has to do it 100% of the time unless specifically excepted
- **Should:** desirable that system does it whenever reasonable to do so
- **Can:** system can do something, but no particular incentive to implement

◆ User Actions:

- **Must:** user has to do this (same as “shall”, except for user, not computer)
- **May:** user can exhibit this behavior, but does not have to

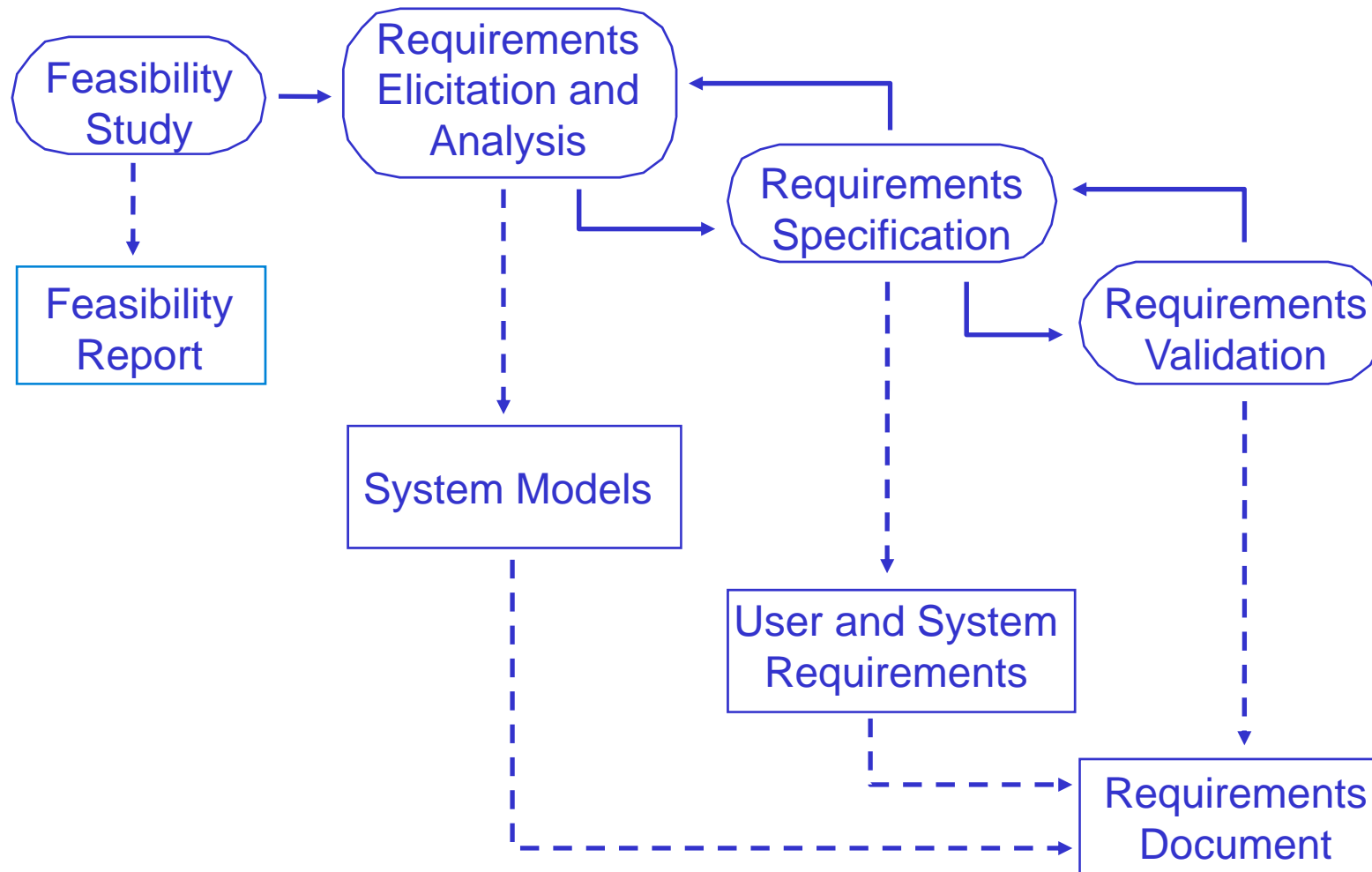
- ◆ Environment:

- **Will:** designer can count on environment being this way
- **Might:** designer has to accommodate situation, but can't count on it

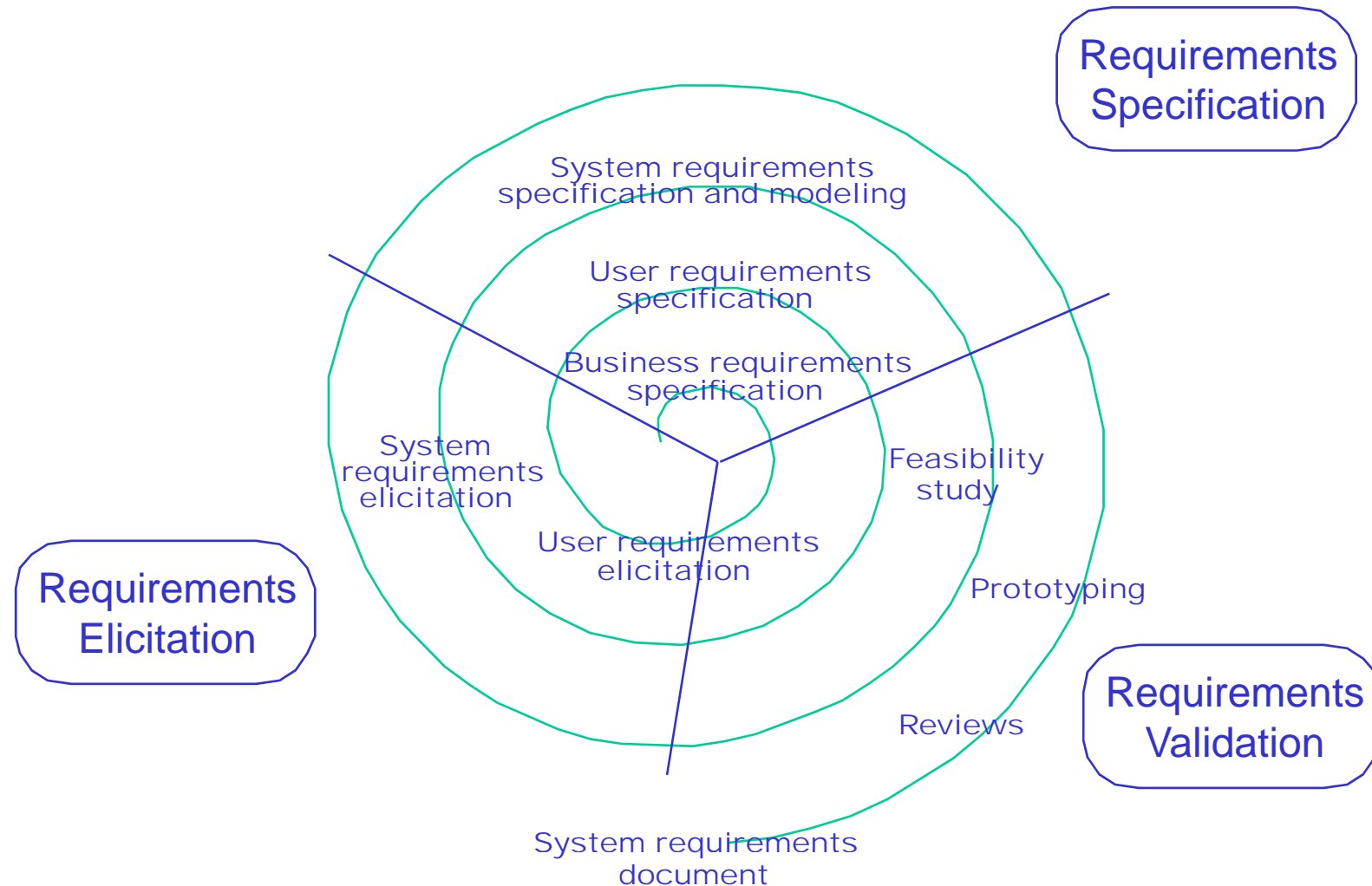
- ◆ Change risk:

- **Expected to:** this area is likely to changed
- **Could:** this area is something that could change, but might not

- ♦ The processes used for requirements engineering vary widely depending on:
 - The application domain
 - The people involved
 - The organization developing the requirements
- ♦ However, there are a number of generic activities common to all processes:
 - Requirements elicitation
 - Requirements analysis
 - Requirements validation
 - Requirements management



Requirements Engineering Process



- ◆ User involvement
- ◆ Clear statement of requirements
- ◆ Proper planning
- ◆ Realistic expectations
- ◆ Smaller project milestones
- ◆ Clear vision and objectives
- ◆ Hard working and focused staff

- ◆ A feasibility study decides whether or not the proposed system is worthwhile
- ◆ A short focused study that checks
 - If the system contributes to organisational objectives
 - If the system can be engineered using current technology and within budget
 - If the system can be integrated with other systems that are used

- ◆ Based on information assessment (what is required), information collection and report writing
- ◆ Questions for people in the organisation
 - What if the system wasn't implemented?
 - What are current process problems?
 - How will the proposed system help?
 - What will be the integration problems?
 - Is new technology needed? What skills?
 - What facilities must be supported by the proposed system?

- ◆ Identify relevant sources of requirements (usually customer)
- ◆ Determine what information is needed
- ◆ Analyze the gathered information, looking for implications, inconsistencies, or unresolved issues
- ◆ Confirm your understanding of the requirements with the source
- ◆ Synthesize appropriate statements of the requirements

- ◆ The customer fully explore and fully understand their requirements
- ◆ The customers are able to separate their wants from their needs
- ◆ The customers are able to understand the capabilities and limitations of computer technology
- ◆ The customers understand the alternative solutions and impact of each alternative
- ◆ The customers understand the impact of the requirements on the developer and themselves

- ♦ The developers are solving the right problem
- ♦ The developers have confidence that the system to be delivered is feasible to build
- ♦ The developers have the trust and confidence of the customer
- ♦ The developers gain domain knowledge of the system

- ♦ The customer probably will be dissatisfied
- ♦ The customer and developer have to cope with constantly changing requirements
- ♦ The developer is solving the wrong problem
- ♦ The developer has a difficult time building the system

- ◆ Sampling
 - Process of collecting a representative sample of documents, forms, and records
- ◆ Observation of the work environment
 - A fact-finding technique where the systems analyst either participates in or watches a person in to learn about the system
- ◆ Questionnaire
 - A special-purpose document that allows the analyst to collect information and opinions from respondents
- ◆ Interviews
 - A fact-finding technique whereby the systems analysts collect information from individuals through face-to-face interaction

- ♦ Organization chart
- ♦ Memos and other documents that describe the problem
- ♦ Documentation and standard operating procedures for current system
- ♦ Manual and computerized screens and reports
- ♦ Samples of databases
- ♦ Etc.

- ◆ Randomization

- A sampling technique characterized by having no predetermined pattern or plan for selecting sample data

- ◆ Stratification

- A systematic sampling technique that attempts to reduce the variance of the estimates by spreading out the sampling
- For example, choosing documents or records by formula and by avoiding very high or low estimates

- ◆ Determine the who, what, where, when, why, and how of the observation
- ◆ Obtain permission from appropriate supervisors or managers
- ◆ Inform those who will be observed of the purpose of the observation
- ◆ Keep a low profile

- ♦ Take notes during or immediately following the observation
- ♦ Review observation notes with appropriate individuals
- ♦ Don't interrupt the individuals at work
- ♦ Don't focus heavily on trivial activities
- ♦ Don't make assumptions

- ♦ Data gathered can be very reliable
- ♦ Can see exactly what is being done in complex tasks
- ♦ Relatively inexpensive compared with other techniques
- ♦ Can do work measurements

- ◆ People may perform differently when being observed
- ◆ Work observed may not be representative of normal conditions
- ◆ Timing can be inconvenient
- ◆ Interruptions
- ◆ Some tasks not always performed in the same way
- ◆ May observe wrong way of doing things

- ◆ Free-format questionnaire

- A questionnaire designed to offer the respondent greater latitude in the answer
- A question is asked, and the respondent records the answer in the space provided after the question

- ◆ Fixed-format questionnaire

- A questionnaire containing questions that require selecting an answer from predefined available responses

- ◆ Determine what facts and opinions must be collected and from whom you should get them
- ◆ Don't get carried away
- ◆ Based on the facts and opinions sought, determine whether free- or fixed-format questions will produce the best answers
- ◆ Write the questions
- ◆ Test the questions on a small sample of respondents
- ◆ Duplicate and distribute the questionnaire

- ◆ Unstructured interview
 - An interview that is conducted with only a general goal or subject in mind and with few, if any, specific questions
 - The interviewer counts on the interviewee to provide a framework and direct the conversation
- ◆ Structured interview
 - An interview in which the interviewer has a specific set of questions to ask of the interviewee

- ◆ Open-ended question
 - A question that allows the interviewee to respond in any way that seems appropriate
- ◆ Closed-ended question
 - A question that restricts answers to either specific choices or short, direct responses
- ◆ Often the open-ended and closed-ended are mixed

- ◆ Select interviewees
 - Learn about individual prior to the interview
- ◆ Prepare for the interview
 - Interview guide is a checklist of questions
- ◆ Conduct the interview
 - Establish rapport
 - Summarize the problem
 - Offer an incentive for participation / ask the interviewee for assistance
- ◆ Follow up on the interview
 - Memo that summarizes the interview
 - Thank you!

- ◆ Types of questions to avoid
 - Loaded questions
 - Leading questions
 - Biased questions
- ◆ Interview question guidelines
 - Use clear and concise language
 - Don't include your opinion as part of the question
 - Avoid long or complex questions
 - Avoid threatening questions
 - Don't use "you" when you mean a group of people

Do's

- ◆ Be courteous
- ◆ Listen carefully
- ◆ Maintain control
- ◆ Probe
- ◆ Observe mannerisms and nonverbal communication
- ◆ Be patient
- ◆ Keep interviewee at ease
- ◆ Maintain self-control

Don'ts

- ◆ Continue an interview unnecessarily
- ◆ Assume an answer is finished or leading nowhere
- ◆ Reveal verbal and non verbal clues
- ◆ Using jargon
- ◆ Reveal your personal biases
- ◆ Talk instead of listen
- ◆ Assume anything about the topic and the interviewee

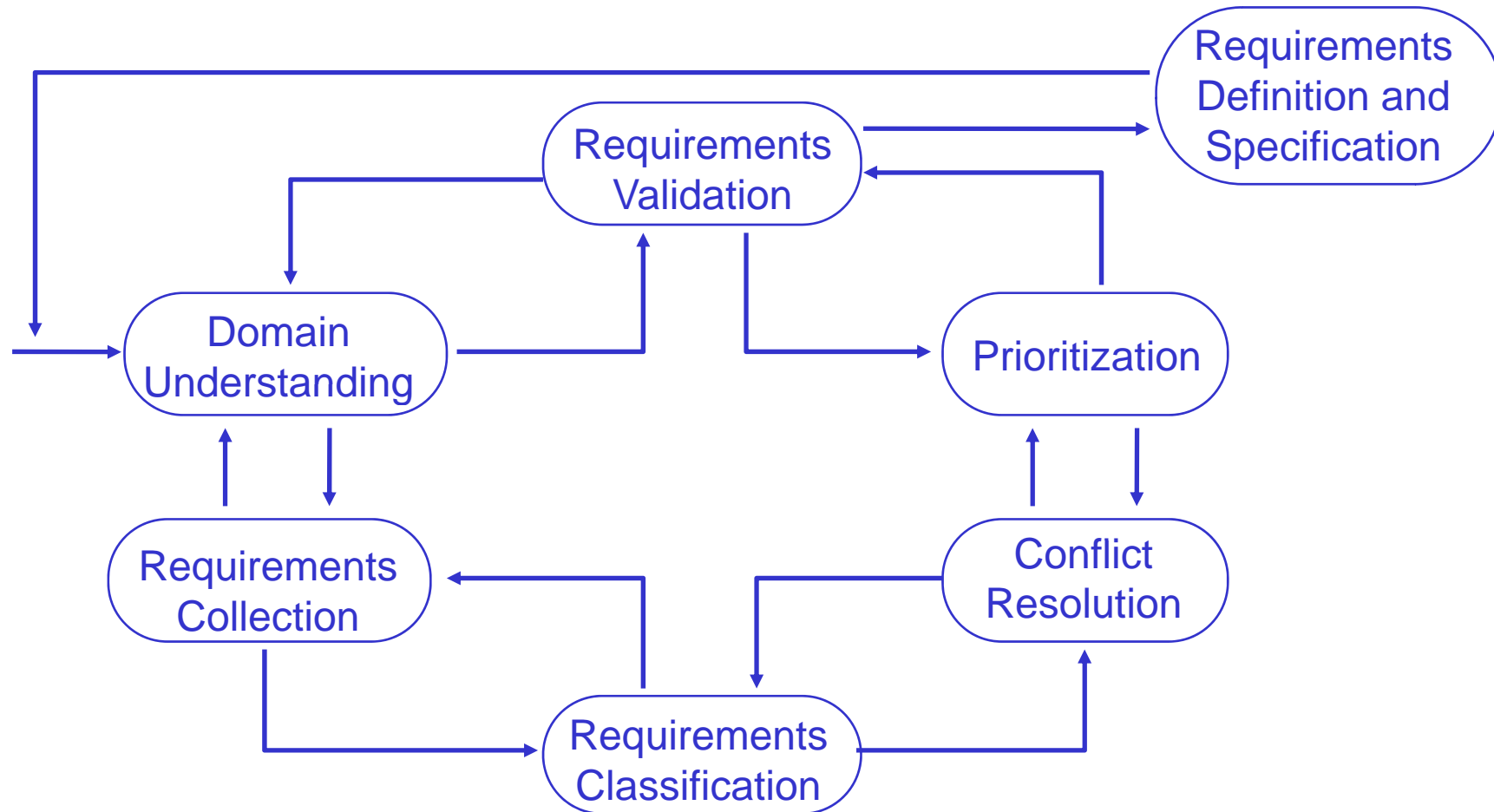
- ◆ Find, verify, clarify facts
 - About what stakeholders do
 - About how stakeholders might interact with the system
- ◆ Generate enthusiasm
- ◆ Get the end-user involved
- ◆ Solicit ideas and opinions

- ♦ Interviews are not good for understanding domain requirements
 - Requirements engineers cannot understand specific domain terminology
 - Some domain knowledge is so familiar that people find it hard to articulate or think that it isn't worth articulating

- ◆ Refines and structures the requirements to facilitate understanding (by developers), reuse, maintenance, etc.
- ◆ Yields a more precise and formal specification of requirements and defines the analysis model
 - Refine the informal description of the requirements
 - Convert the informal descriptions to flow diagrams

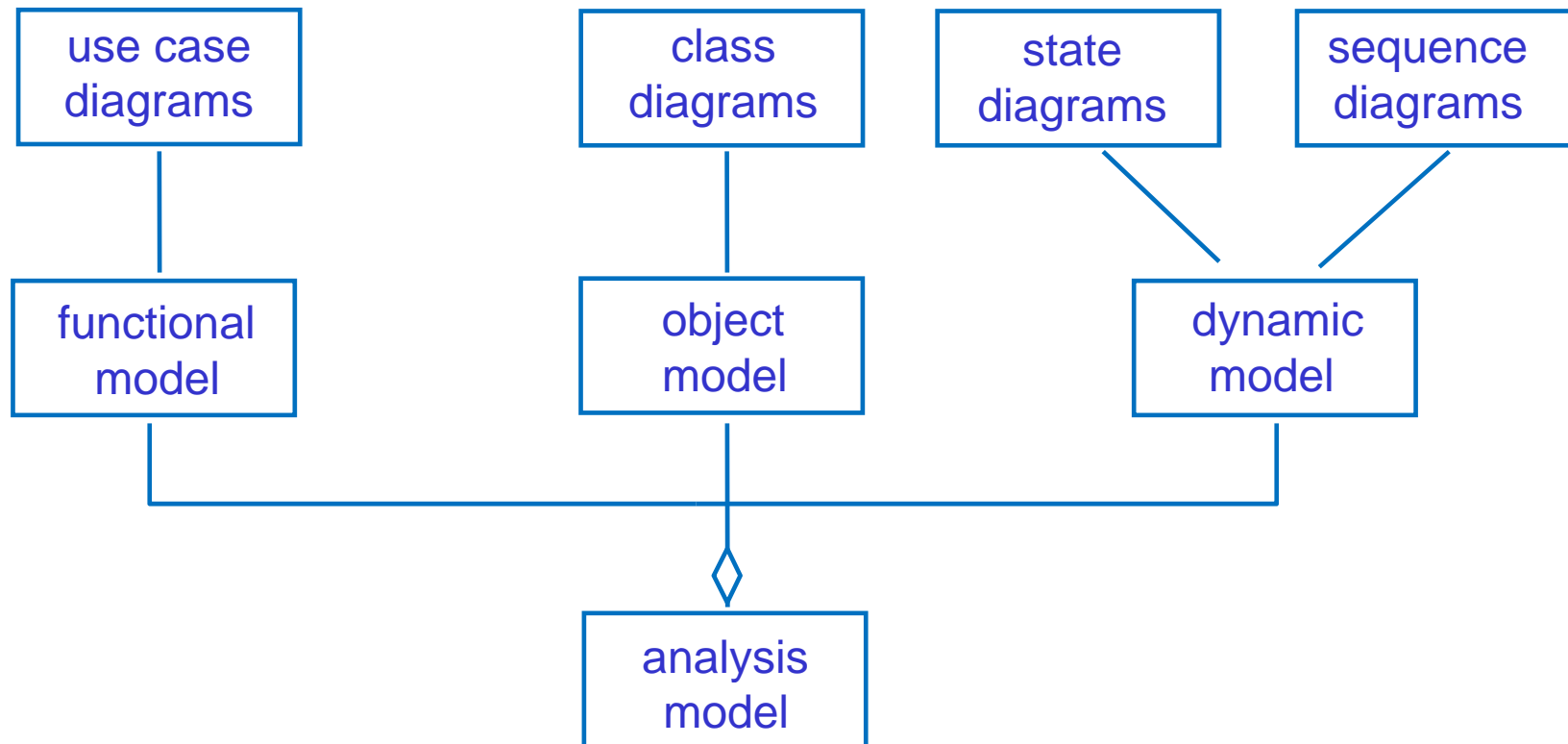
- ◆ Stakeholders don't know what they really want
- ◆ Stakeholders express requirements in their own terms
- ◆ Different stakeholders may have conflicting requirements
- ◆ Organizational and political factors may influence the system requirements
- ◆ The requirements may change during the analysis
 - New stakeholders may emerge and the business environment change

Requirements Analysis Process



- ◆ The analysis model makes abstractions
 - It is not a design model
 - It is a platform (language, OS, ...) independent model
- ◆ A structured analysis model is based on the functions to be realized by the system
- ◆ An object-oriented analysis model is based on the use cases and on the representation of the real objects and concepts of the system domain

Object-Oriented Analysis Model



- ♦ An analysis model is represented by an analysis system that is the top-level package of the model
- ♦ An analysis system may contain subsystems or analysis packages
- ♦ Within the analysis model, use cases are realized by analysis classes and interaction diagrams
- ♦ Analysis classes represent an abstraction of classes (and possibly entire subsystems) of the system to be implemented
- ♦ interaction diagrams describe dynamics of the system

- ◆ Use cases, stated simply, allow description of sequences of events that, taken together, lead to a system doing something useful
- ◆ A use case is simply a description (a story) of users and systems interacting in a typical fashion to go through the various paths or parts of a business process or automated process
- ◆ Use cases describe the interaction between a primary actor, the initiator of the interaction, and the system itself, through a sequence of simple steps

- ◆ Use cases should describe all possible interactions within and with the system
- ◆ Use cases are not mapped one-to-one to requirements
 - Each requirement must be covered by at least one use case
 - However, use cases may contain many requirements
- ◆ Use cases are described by combining:
 - Use case diagrams
 - Textual descriptions
 - Interaction diagrams (optional)
- ◆ Use cases are realized by identifying the actors and the interaction between the actors and the system

- ◆ Define system boundary to identify actors correctly
- ◆ Identify users and systems that depend on the system's primary and secondary functionalities
- ◆ Identify hardware and software platforms with which the system interacts
- ◆ Select entities that play distinctly different roles in the system
- ◆ Identify as actors external entities with common goals and direct interaction with the system
- ◆ Denote actors as nouns

- ◆ Business / Domain Use Cases
 - Interactions between users and the business (or domain)
- ◆ System Use Cases
 - Interactions between users and the system
 - One business use cases contains a set of system use cases
- ◆ To name the use cases, give it a verb name to show the action that must be performed
 - Describe a transaction completely
 - No description of user interface whatsoever

- ◆ Tasks to be performed by the user and the system
- ◆ Starting situation and states where it finishes
- ◆ Flow of information to the user and to the system
- ◆ Events that are conveyed to the user and to the system
- ◆ Normal flow of events
- ◆ What can go wrong
- ◆ Other concurrent activities

- ♦ Is described by few steps (up to 5), but most important provides a meaningful result to the end users
- ♦ Describes interactions and mechanisms not policies
- ♦ Excludes user or system interfaces implementation choices
- ♦ Is described by few (5 - 10) pages
- ♦ Has a single initiator actor
- ♦ Includes the major business exceptions and their handling

- ◆ Use cases can be ordered on the basis of their importance for the realization of the system
- ◆ Ordering depends on:
 - Significant impact on the architectural design
 - Include risk, time-critical or complex function
 - Involve significant research and/or new and risky technology
 - Represent primary line-of-business processes
 - Etc.
- ◆ Ranking is usually expressed with qualitative values:
 - E.g., high, medium, low
 - E.g., must have, essential, nice to have

- ◆ Define the start state and the preconditions
- ◆ Define when the use case starts
- ◆ Define the order of activity in the main flow of events
- ◆ Define any alternative flows of events
- ◆ Define any exceptional flows of events
- ◆ Define any post conditions and the end state
- ◆ Mention the actors involved with this use case, and any use cases used or extended by this use case
- ◆ Mention the related interaction diagrams
- ◆ Mention any design issues as an appendix

Use Case ID:			
Use Case Name:			
Created By:		Last Updated By:	
Date Created:		Date Last Updated:	
Actors:			
Description:			
Trigger:			
Preconditions:			
Postconditions:			
Normal Flow:			
Alternative Flows:			
Exceptions:			
Includes:			
Priority:			
Frequency of Use:			
Business Rules:			
Special Requirements:			
Assumptions:			
Notes and Issues:			

Use Case	<i>Use case identifier and reference number and modification history</i>
Description	<i>Goal to be achieved by use case and sources for requirement</i>
Actors	<i>List of actors involved in use case</i>
Assumptions	<i>Conditions that must be true to terminate successfully</i>
Steps	<i>Interactions between actor and system necessary to achieve goal</i>
Variations (optional)	<i>Any variations in the steps</i>
Non-Functional (optional)	<i>List of non-functional requirements that the use case must meet.</i>
Issues	<i>List of issues that remain to be resolved</i>

Use Case	2. Repairing_Cellular_Network history created 1/5/98 Derek Coleman, modified 5/5/98.
Description	Operator rectifies a report by changing parameters of a cell. sources [Operating Manual 1993], [Jones 1998].
Assumptions	Changes to network are always successful when applied to a network.
Actors	Operator (primary) Cellular network Field maintenance engineer
Steps	<ol style="list-style-type: none"> 1. Operator notified of network problem. 2. Operator starts repair session. 3. REPEAT <ol style="list-style-type: none"> 3.1. Operator runs network diagnosis application. 3.2 Operator identifies cells to be changed and their new parameter values. 3.3 IN PARALLEL <ol style="list-style-type: none"> 3.3.1 Maintenance engineer tests network cells 3.3.2 Maintenance engineer sends fault reports.
Variations	UNTIL no more reports of problems 4. Operator closes repair session.
Non-Functional	#1. System may detect fault and notify operator or Field maintenance engineer may report fault to Operator. Performance Mean: time to repair network fault must be less than 3 hours. Fault Tolerance: A repair session must be able to tolerate failure of Operator's console.
Issues	What are the modes of communication between field maintenance engineer and operator?

- ◆ Try to describe use cases without thinking about in what way they will be implemented
- ◆ Be as narrative as possible
- ◆ State success scenarios
- ◆ Introduce all the possible scenarios of a use cases
- ◆ Agree on a “format style” for use case description

- ◆ Name a use case starting with a verb in order to emphasize that it is a process
 - E.g., Buy Items, Enter an order, Reduce inventory, etc.
- ◆ Document exception handling or branching
 - E.g., when a “buy item” fails, then ...
 - E.g., when a “credit card approval ” fails, then ...
- ◆ Do not represent individual steps as use cases
 - E.g., define a use case for the operation: printing a receipt

- ♦ Tutors in the organization are assigned courses to teach according to the area that they specialize in and their availability
- ♦ The organization publishes and maintains a calendar of the different courses and the assigns tutors every year
- ♦ There is a group of course administrators in the organization who manage the courses including course content, assigning courses to tutors, and defining the course schedule

- ◆ Courses shall be assigned to the tutors only by course administrators
- ◆ Courses information topics and contents shall be managed only by course administrators
- ◆ Tutors information shall be managed only by course administrators and by corresponding tutor
- ◆ Course calendar shall be visualized by course administrators, tutors, and students

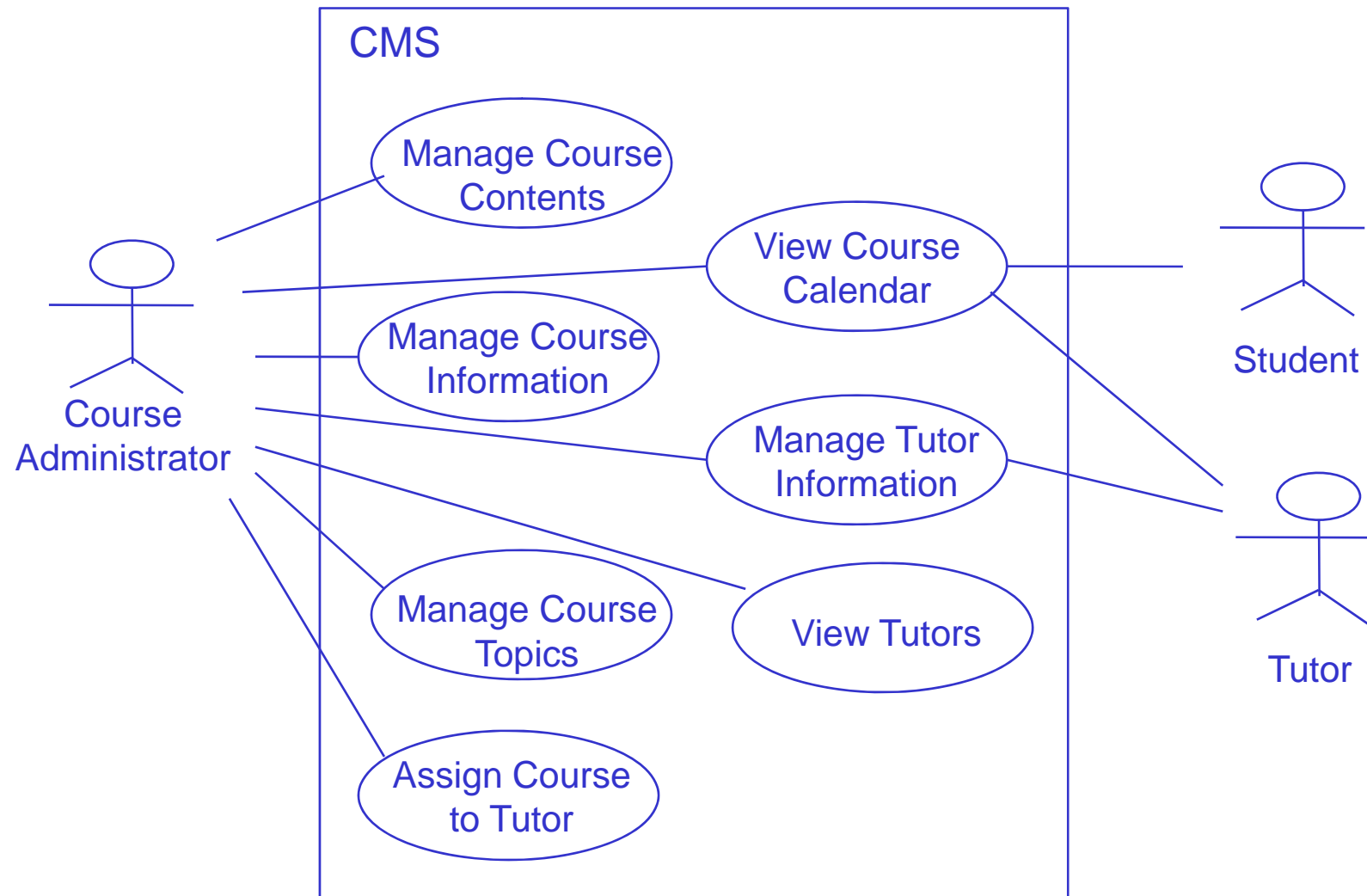
- ♦ **Courses** and **topics** that make up courses
- ♦ **Tutors** that teach courses
- ♦ **Course administrators** who manage the assignment of courses to tutors
- ♦ **Calendars** (course schedules) that are generated as a result of the work performed by the course administrators
- ♦ **Students** who refer to calendars (course schedules) to decide which courses they wish to take up for study

- ◆ Actors

- Tutor, student, course administrator

- ◆ Use Cases

- Manage courses: view courses, manage course topics and manage course information
- Manage tutors: view course calendar, view tutors, manage tutor information, and assign courses to tutors



◆ Playlist Support

- Download prebuilt playlist, create playlist, add songs to playlist, reorder playlist, delete song from playlist, calculate cost, check song availability

◆ Payment Support

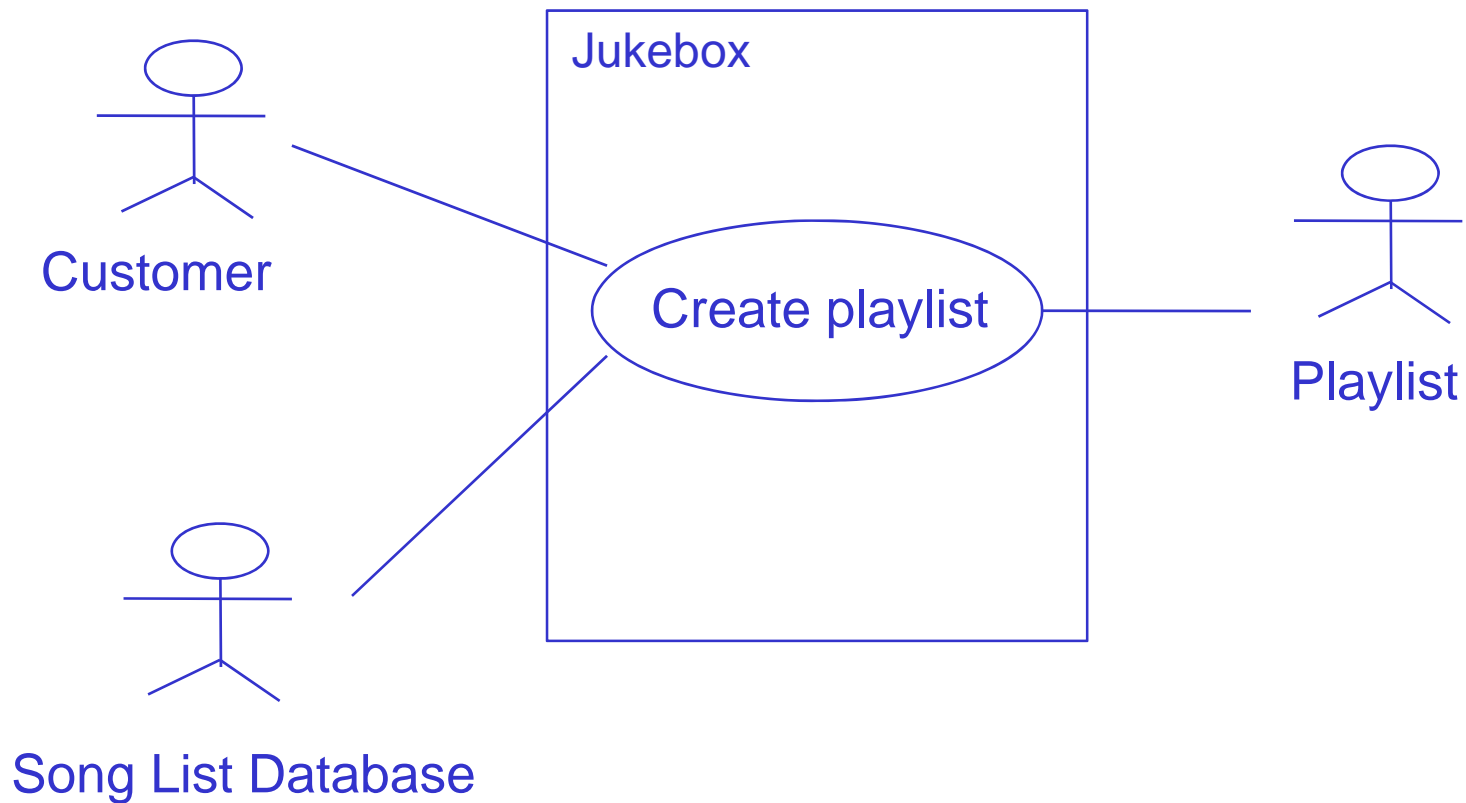
- Display payment options, payment by cash, payment by cell phone, payment by credit card

◆ Playback Mechanism

- Load song, play song, display song information

- ◆ Payment by cash
 - Monitor cash input
 - Return proper change
 - Refund money
- ◆ Payment by cell phone
 - Display phone number to dial
- ◆ Load Song
 - Fetch song from local database
 - Fetch song from network

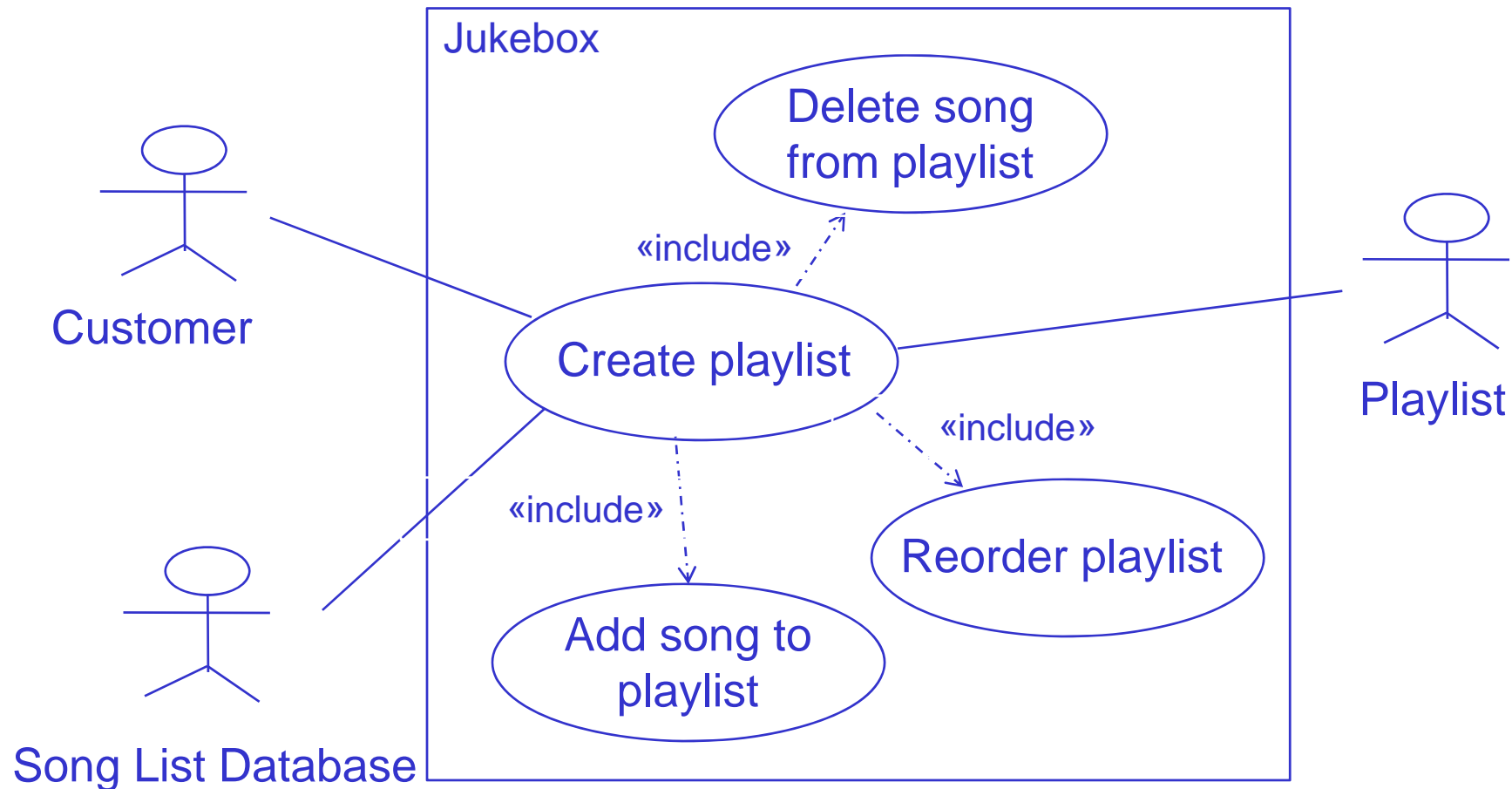
Create Playlist Use Case Diagram



Create Playlist Use Case Description

Property	Description	Use Case
Title	Create Playlist	
Goal	Allow the customer to create a playlist	
Scope	Playlist Support	
Level	Primary Task	
Precondition(s)	Access to a song list database must be available	
Postcondition(s)	Playlist has been created	
Primary Actor 1	Song List Database	
Primary Actor 2	Playlist	
Primary Actor 3	Customer	
Secondary Actor	None	
Trigger Event	Customer Chooses to Create a Playlist	
Step 1	Customer browses through song list database	
Exception 1.1	Timeout (Customer waited to long)	
Step 2	Customer selects songs to add to play list	Add Songs to Playlist
Step 3	List of songs in playlist is displayed	
Variation 3.1	Customer chooses to reorder playlist	Reorder Playlist
Variation 3.2	Customer chooses to delete songs from playlist	Delete Song from Playlist

Create Playlist Use Case Diagram



- ♦ Analysis classes are an abstraction of one or more real classes or subsystems of the to system to be realized
- ♦ Analysis classes handle functional requirements
 - Non-functional requirements are handled in architectural design
- ♦ Analysis classes are usually represented with class diagrams through the Boundary, Control and Entity stereotypes
 - The semantics of these stereotypes provides a consistent method of finding and analyzing such classes

- ◆ Provides a crisp abstraction of something from the problem domain (or solution) domain
- ◆ Embodies a small well defined set of responsibilities and carry them out well
- ◆ Provides clear separation of abstraction, specification, and implementation
- ◆ Is understandable and simple yet extendable and adaptable

- ◆ Noun verb analysis
- ◆ Use case driven
- ◆ Common class patterns
- ◆ CRC cards
- ◆ Mixed approach

- ◆ Set of heuristics for identifying classes, attributes and associations from a requirements specification
 - Nouns may identify: classes, attributes and instances
 - Verb phrases may identify: operations, relationships and constraints
- ◆ Relies on the completeness and correctness of the requirements document
- ◆ Quality depends on style of writing, often there are too many nouns

Text Component	Model Component	Example
proper noun	instance	Jim Smith
common noun	class	toy, doll
doing verb	method	buy, recommend
classifying verb	inheritance	is a
possessive verb	aggregation	has a
modal verb	constraint	must be
adjective	attribute	3 years old
transitive verb	method	enter
intransitive verb	method (event)	depends on

- ♦ Similar to the noun verb analysis, but centered on use cases
- ♦ Identifies objects, responsibilities of each object, and how these objects collaborate with other objects analyzing the different scenarios described in the use cases
- ♦ Relies on the completeness of use case models

- ◆ Derives classes from the generic classification theory of objects
 - Part of science that concerned with partitioning the world of objects into useful groups
- ◆ Provide useful guidance, but not offering a systematic process to find complete and reliable classes
- ◆ Too loosely bound to specific user requirements and possible misinterpretation of class name

- ◆ Concept class
 - E.g., reservation
- ◆ Event class
 - E.g., arrival
- ◆ Organization class
 - E.g., travelAgency
- ◆ People class
 - E.g., passenger
- ◆ Places class
 - E.g., TravelOffice

Bahrami(1999)

- ◆ Physical class
 - E.g., Airplane
- ◆ Business class
 - E.g., Reservation
- ◆ Logical class
 - E.g., FlightTimetable
- ◆ Application class
 - E.g., ReservationTrans
- ◆ Computer class
 - E.g., Index
- ◆ Behavioral class
 - E.g., ReservationCancel

Rumbaugh et. Al. (1999)

- ♦ An attractive way of interpreting, understanding and teaching about objects based on:
 - Three compartments cards:
 - Class name
 - Responsibilities of the class
 - Collaborators of the class
 - Animated brainstorming sessions
- ♦ CRC cards do not provide a systematic process to find complete and reliable classes
- ♦ CRC cards are a means for the validation of requirements identifying errors and omissions

- ♦ Initial classes come from domain knowledge
- ♦ Common class patterns approach to guide
- ♦ Noun phrase approach to add more classes
- ♦ Use case approach to verify
- ♦ CRC to brainstorm

- ♦ The library contains books and journals. It may have several copies of a given book. Some of the books are reserved for short-term loans only. All others may be borrowed by any library member for three weeks. Members of the library can normally borrow up to six items at a time, but members of staff may borrow up to 12 items at one time. Only members of staff may borrow journals
- ♦ The system must keep track of when books and journals are borrowed and returned and enforce the rules

- ♦ The **library** contains **books** and **journals**. It may have several **copies** of a given book. Some of the books are reserved for **short-term loans only**. All others may be borrowed by any library **member** for three **weeks**. Members of the library can normally borrow up to six **items** at a time, but **members of staff** may borrow up to 12 items at one time. Only members of staff may borrow journals.
- ♦ The **system** must keep track of when books and journals are borrowed and returned and enforce the **rules**.

- ♦ Library
- ♦ Book
- ♦ Journal
- ♦ Copy
- ♦ ShortTermLoan
- ♦ LibraryMember
- ♦ Week
- ♦ Item
- ♦ StaffMember
- ♦ System
- ♦ Rule

From Library System description to Classes, Relationships and Operations

Classes

- ◆ Library
- ◆ Book
- ◆ Journal
- ◆ Copy
- ◆ ShortTermLoan
- ◆ LibraryMember
- ◆ Week
- ◆ Item
- ◆ StaffMember
- ◆ System
- ◆ Rule

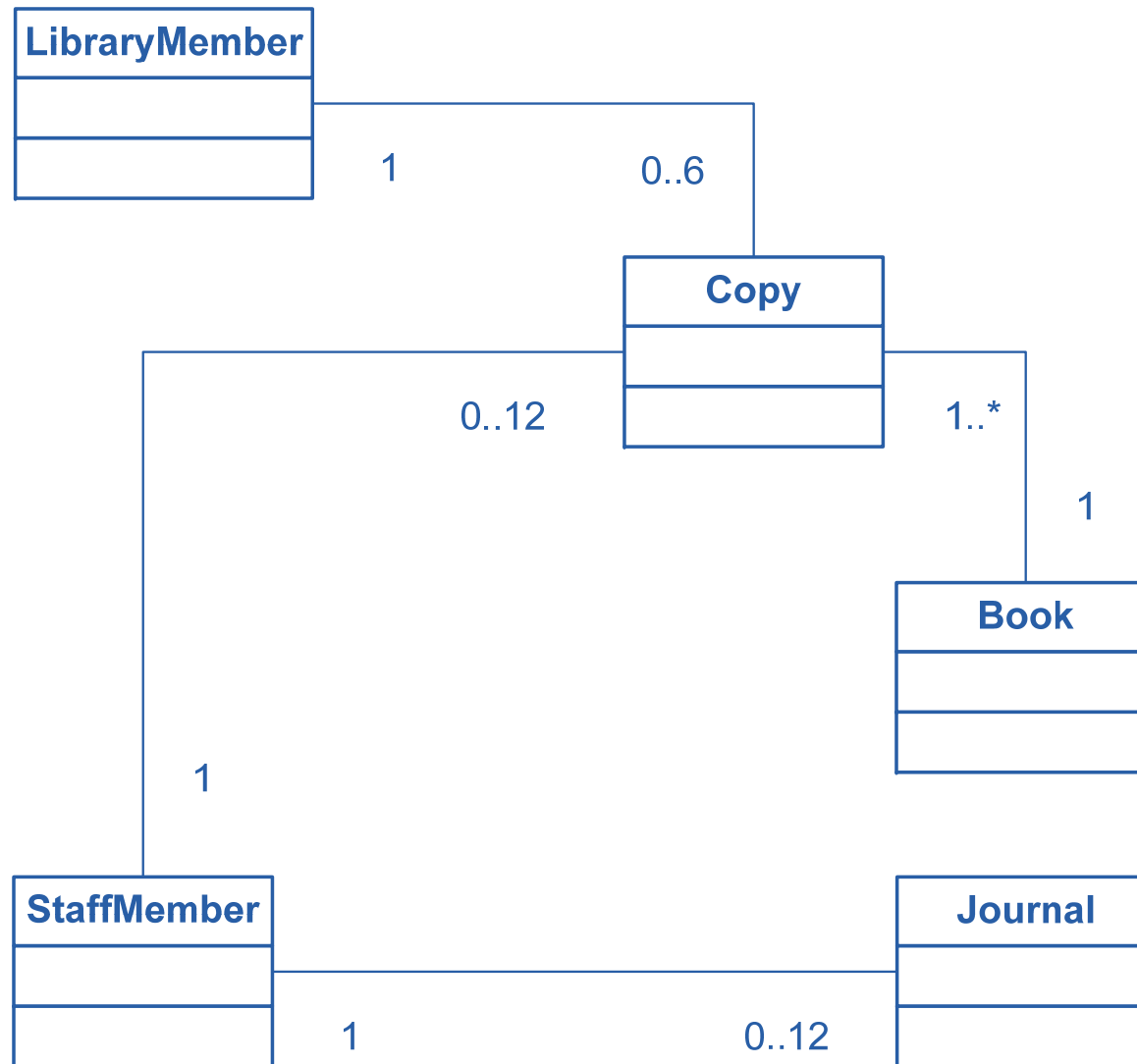
Relationships

- ◆ Book is an Item
- ◆ Journal is an Item
- ◆ Copy is a copy of a Book
- ◆ StaffMember is a LibraryMember

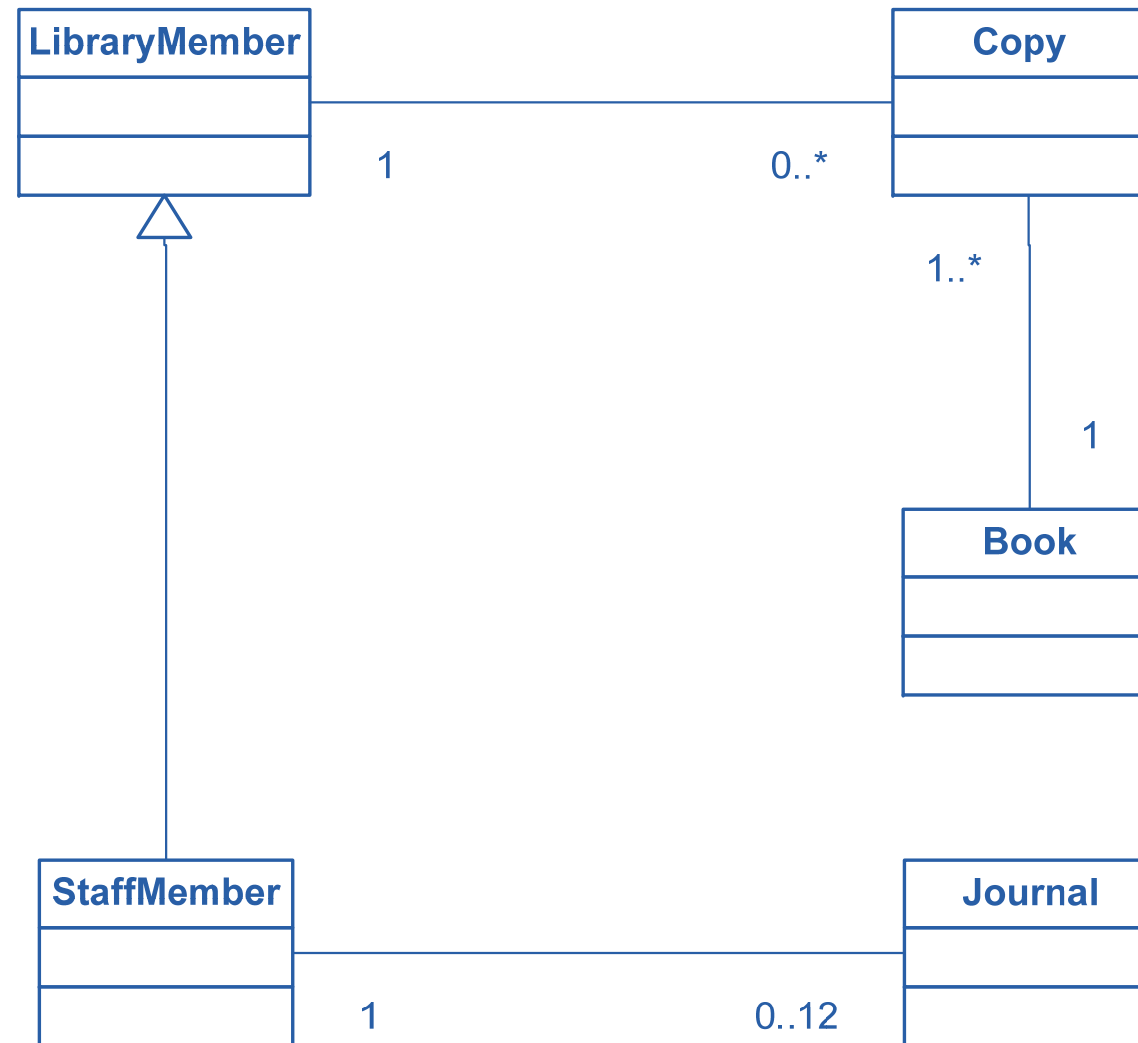
Operations

- ◆ LibraryMember borrows Copy
- ◆ LibraryMember returns Copy
- ◆ StaffMember borrows Journal
- ◆ StaffMember returns Journal

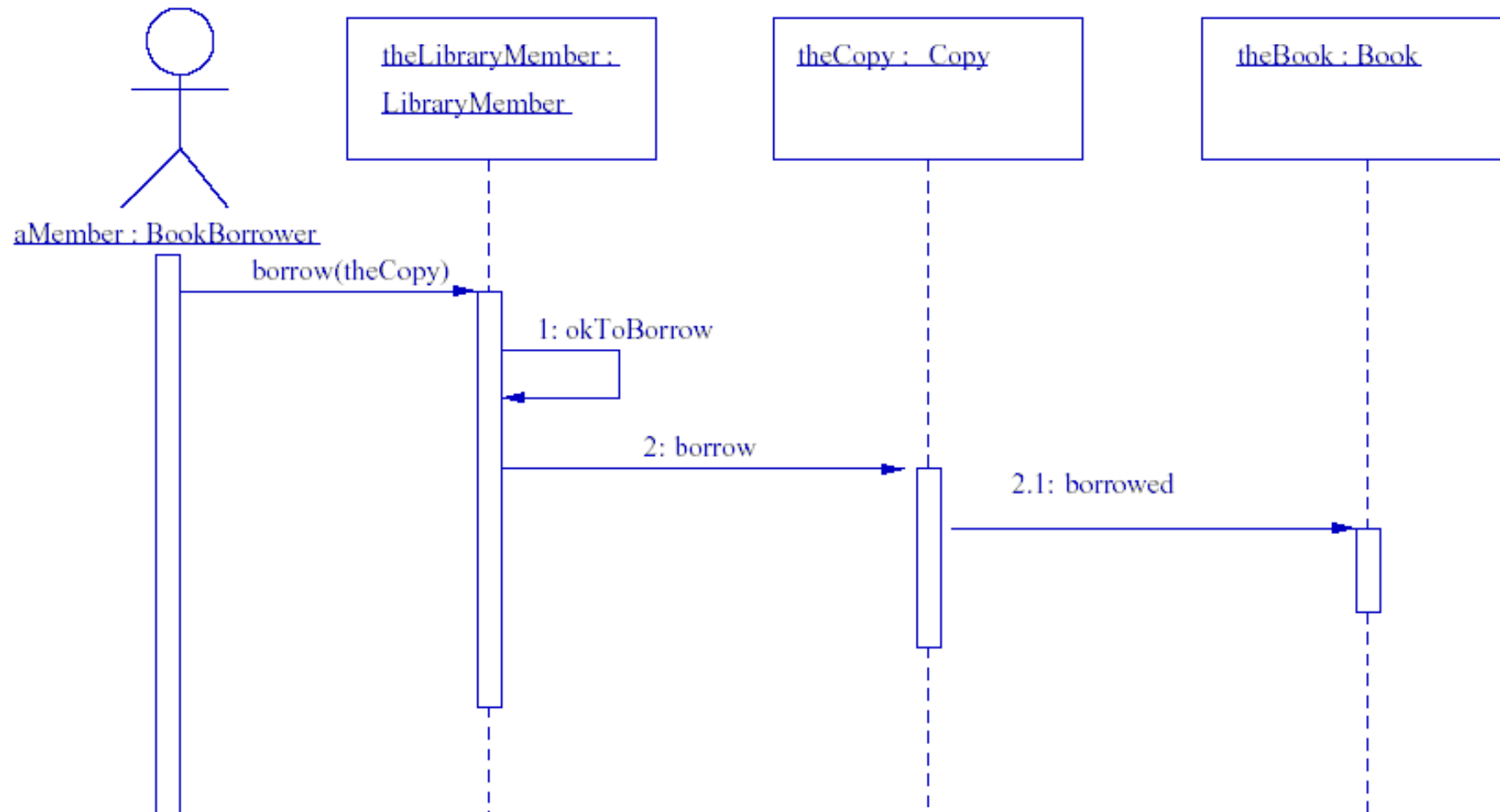
Library System Class Diagram



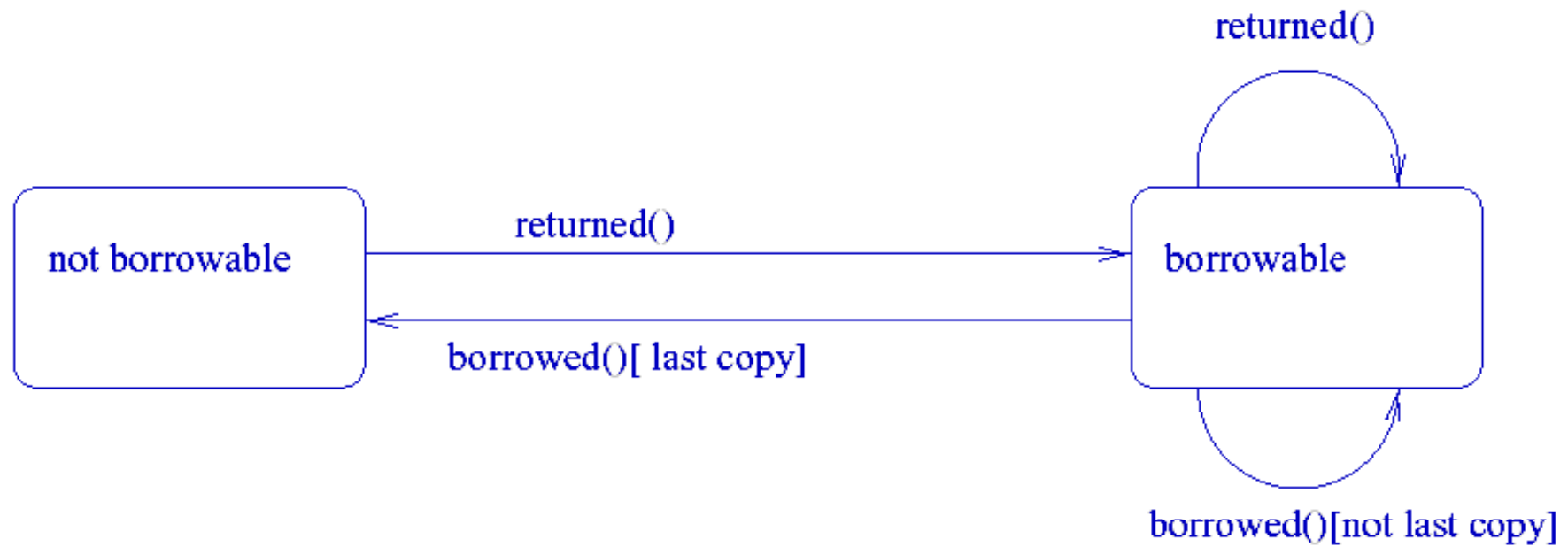
Library System Class Diagram



Library Member Borrows a Book Copy Sequence Diagram



Book Class State Diagram



From Create Playlist Use Case to Classes and Operations

Functional Requirements

- ♦ Customer browses through song list database
- ♦ Customer selects songs to add to play list
- ♦ List of songs in playlist is displayed
- ♦ Customer chooses to reorder playlist
- ♦ Customer chooses to delete songs from playlist

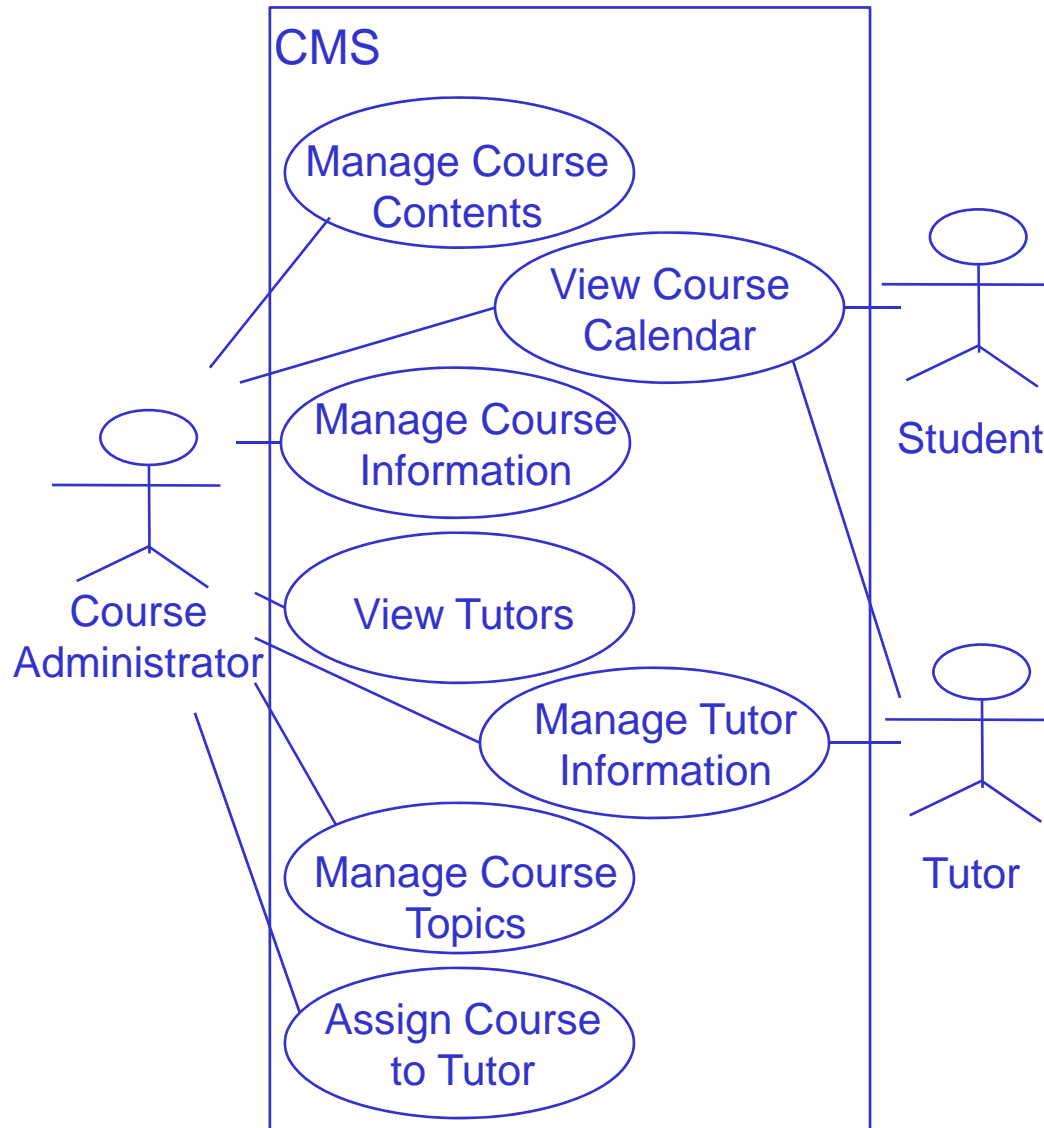
Classes

- ♦ SongListDatabase
- ♦ Song
- ♦ Playlist

Operations

- ♦ Playlist.add
- ♦ Playlist.list
- ♦ Playlist.order
- ♦ Playlist.remove

From CMS Top Use Case Diagram to Classes and Methods



- ◆ CourseAdministrator
- ◆ Tutor
- ◆ Student
- ◆ Course
- ◆ CourseCalendar
- ◆ Topic

Classes

- ◆ viewCourses
- ◆ manageCourseInformation
- ◆ viewCourseCalendar
- ◆ viewTopics
- ◆ manageTopic
- ◆ viewTutors
- ◆ manageTutorInformation
- ◆ assignTutorToCourse

Operations

Course Operations

- ◆ viewAllCourses
- ◆ viewCourse
- ◆ createCourse
- ◆ modifyCourse
- ◆ removeCourse

Tutor Operations

- ◆ viewTutor
- ◆ createTutor
- ◆ modifyTutor
- ◆ removeTutor

Topic Operations

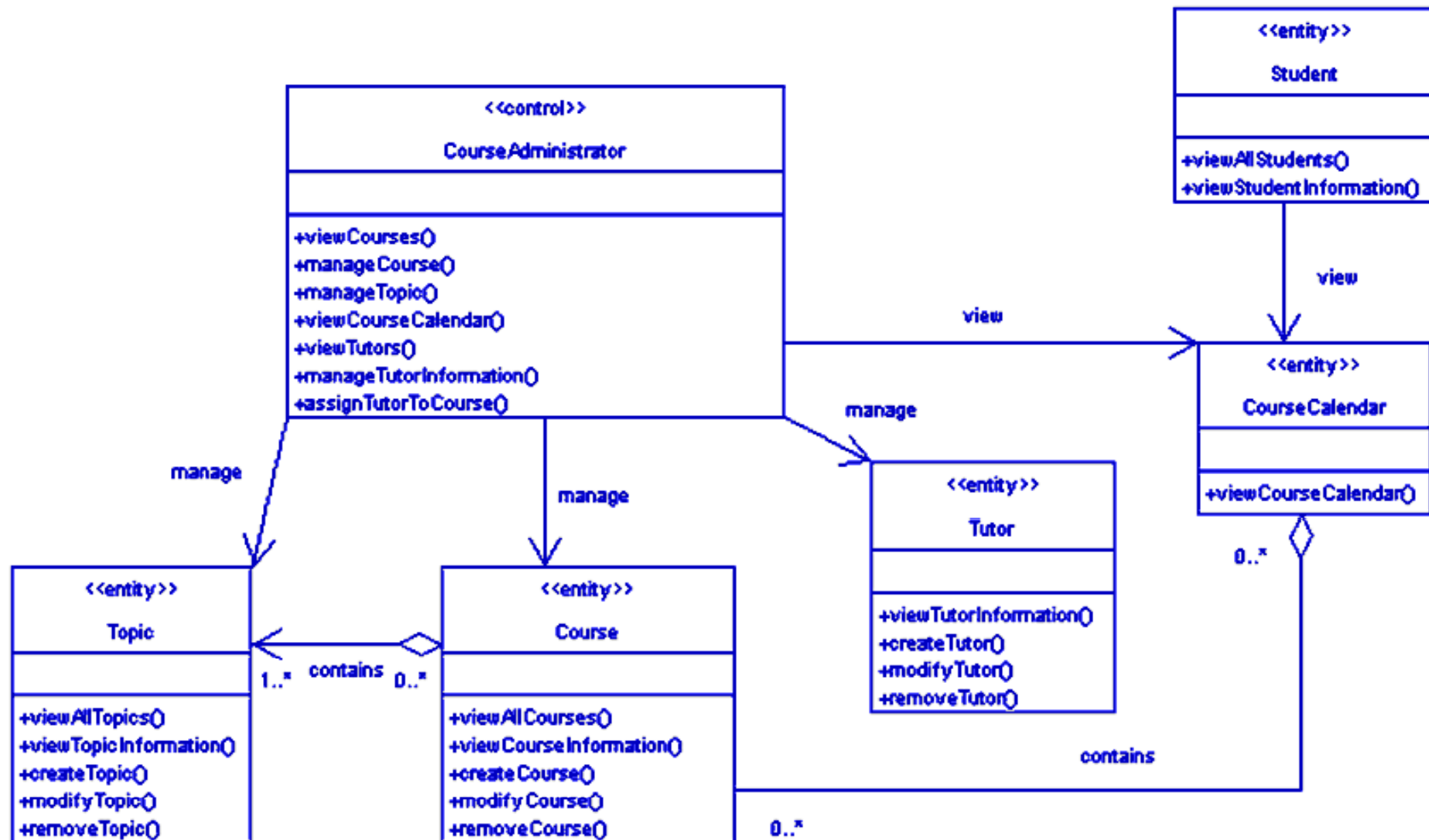
- ◆ viewAllTopics
- ◆ viewTopic
- ◆ createTopic
- ◆ modifyTopic
- ◆ removeTopic

Course Calendar Operations

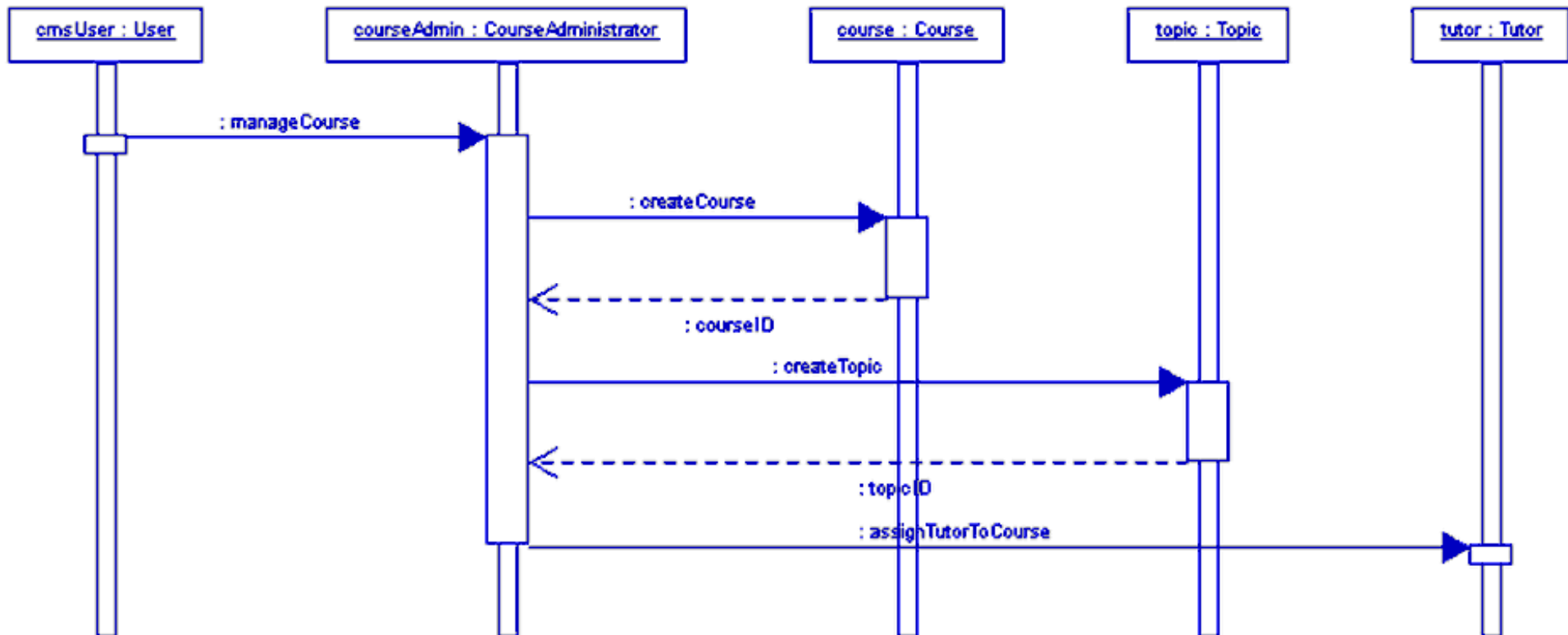
- ◆ viewCourseCalendar

Student Operations

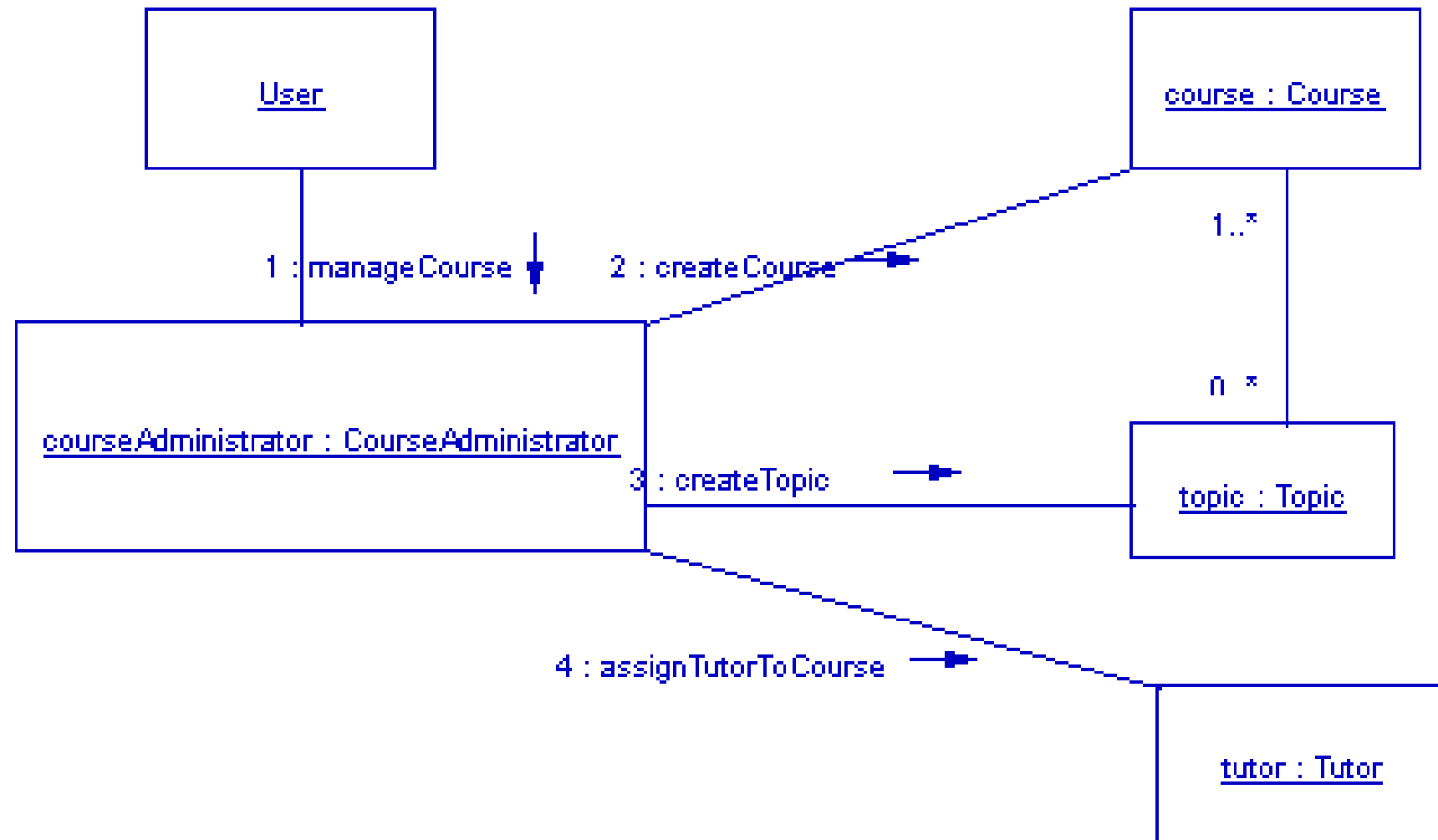
- ◆ viewAllStudents
- ◆ viewStudentInformation



Manage Course Sequence Diagram



Manage Course Communication Diagram



- ◆ The process of establishing and justifying the belief that the requirements as documented correspond to what the client organization, the users and the other stakeholders really want
- ◆ Two important issues:
 - Completeness
 - Cost
- ◆ Ideally, validation process should continue as long as necessary, but budget and deadlines constrain it

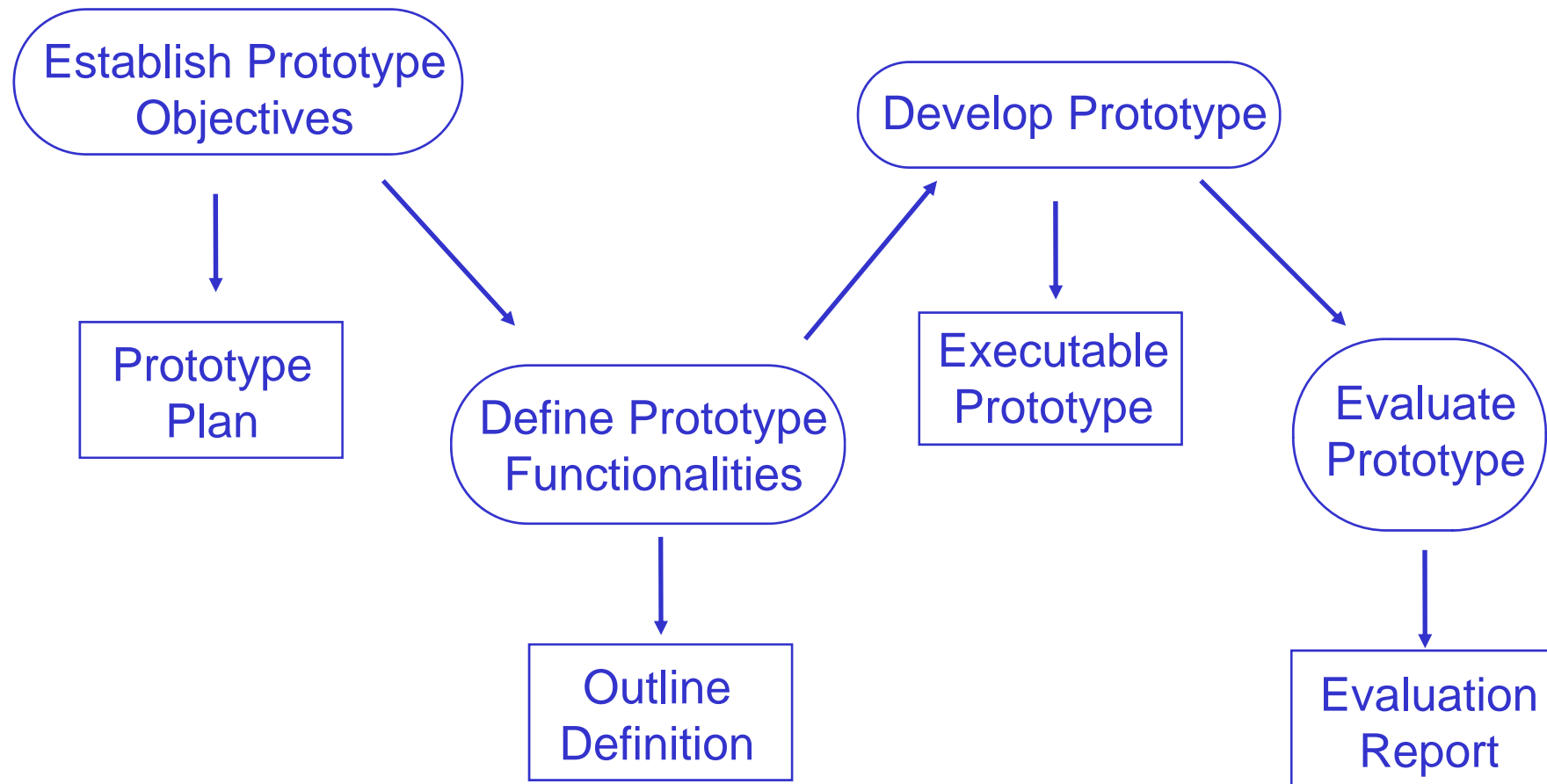
- ◆ Validity
 - Does the system provide the functions which best support customer's needs?
- ◆ Consistency
 - Are there any requirements conflicts?
- ◆ Completeness
 - Are all functions required by the customer included?
- ◆ Realism
 - Can the requirements be implemented given available budget and technology?
- ◆ Verifiability
 - Can the requirements be checked?

- ◆ Requirements review
 - Systematic manual analysis of the requirements
- ◆ Prototyping
 - Using an executable model of the system to check requirements
- ◆ Test-case generation
 - Developing tests for requirements to check testability

- ◆ Regular reviews should be held while the requirements definition is being formulated
- ◆ Both client and contractor staff should be involved in reviews
- ◆ Reviews may be formal (with completed documents) or informal
 - Good communications between developers, customers and users can resolve problems at an early stage

- ◆ Verifiability
 - Is the requirement realistically testable?
- ◆ Comprehensibility
 - Is the requirement properly understood?
- ◆ Traceability
 - Is the origin of the requirement clearly stated?
- ◆ Adaptability
 - Can the requirement be changed without a large impact on other requirements?

- ◆ A prototype is an initial version of a system used to demonstrate concepts and try out design options
- ◆ A prototype can be used in:
 - The requirements engineering process to help with requirements elicitation and validation
 - In design processes to explore options and develop a UI design
 - In the testing process to run back-to-back tests (i.e., prototype versus real system)
- ◆ A prototype should be discarded after development as it is not a good basis for a production system



- ◆ Inputs to activity: use-case model, detailed use-case descriptions, supplementary requirements, glossary (or business/domain model)
 - Actor interacts by viewing and manipulating elements that represent attributes of use cases
 - Assure each use case is accessible to the actors through the user interface
 - Assure well-integrated, easy-to-use, consistent, navigable user interfaces
 - Analyze usability; don't be fooled by wording of use case
- ◆ Build physical prototype to validate UI and the use cases

- ◆ Improved system usability
- ◆ A closer match to users' real needs
- ◆ Improved design quality
- ◆ Improved maintainability
- ◆ Reduced development effort

- ◆ Developing tests for requirements to check testability
 - Test cases are defined for each requirement, or shall statement
 - Tests are executed manually or automatically through specific test automation tool
- ◆ Tests difficult to implement reveal potential difficulty of implementing requirements

- ◆ Requirements management is the process of managing changing requirements during the requirements engineering process and system development
- ◆ Requirements are inevitably incomplete and inconsistent:
 - The priority of requirements from different viewpoints changes during the development process
 - Customers may specify requirements from a business perspective that conflict with end-user requirements
 - The business and technical environment of the system changes during its development

- ◆ Keep project within costs, within budget, and to meet customers needs
- ◆ Estimate cost of system based on requirements
- ◆ Control the volatility of the requirements
- ◆ Manage the requirements configuration of the system
- ◆ Negotiate requirement changes
- ◆ Re-estimate cost of the system when requirements change

- ◆ Requirements identification
 - How requirements are individually identified
- ◆ A change management process
 - The process followed when analyzing a requirements change
- ◆ Traceability policies
 - The amount of information about requirements relationships that is maintained
- ◆ CASE tool support
 - The tool support required to help manage requirements change

- ◆ Should apply to all proposed changes to the requirements
- ◆ Based on three main steps:
 - Problem analysis
 - Discuss requirements problem and propose change
 - Change analysis and costing
 - Assess effects of change on other requirements
 - Change implementation
 - Modify requirements document and other documents to reflect change

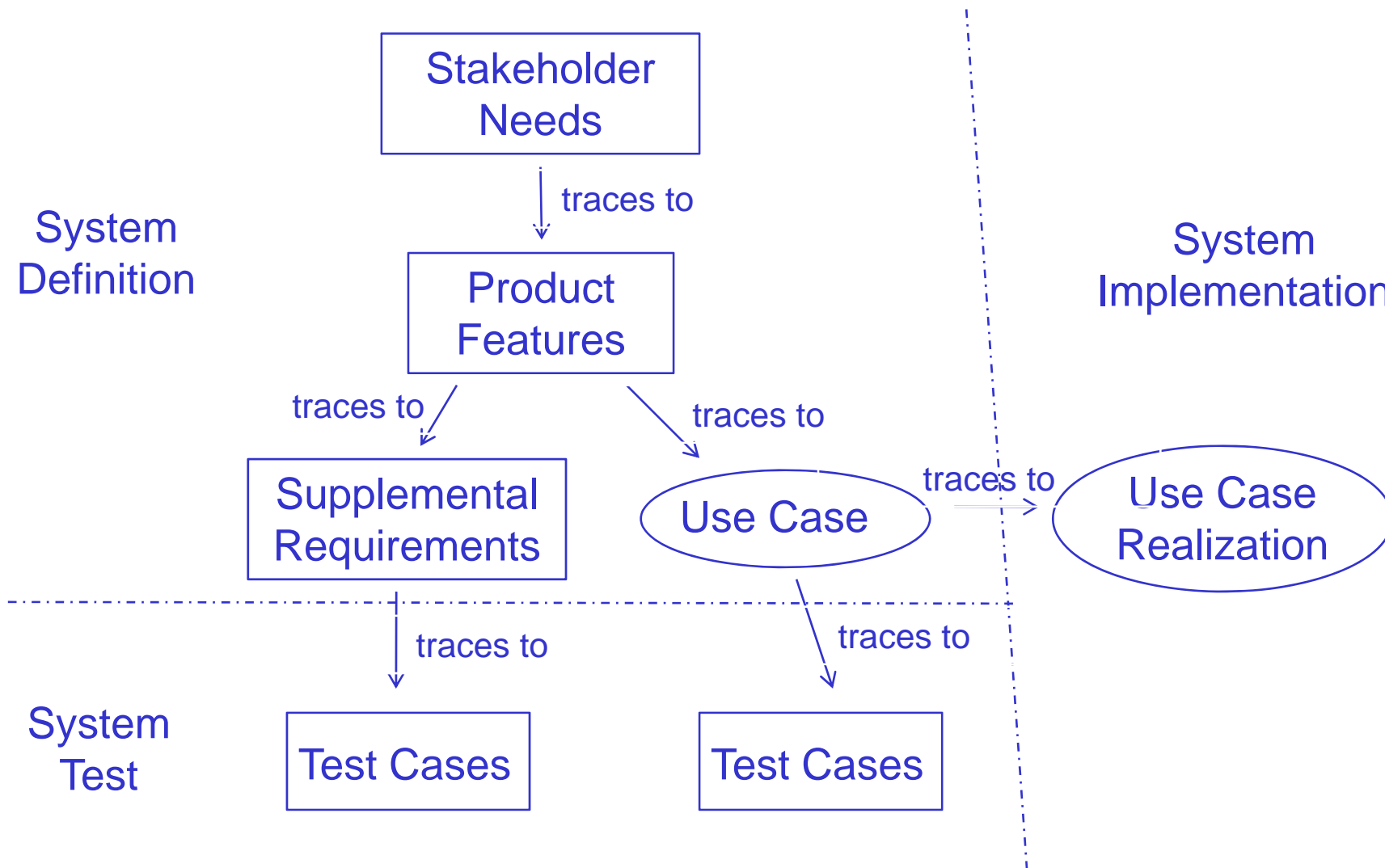
- ◆ Requirements storage
 - Requirements should be managed in a secure, managed data store
- ◆ Change management
 - The process of change management is a workflow process whose stages can be defined and information flow between these stages partially automated
- ◆ Traceability management
 - Automated retrieval of the links between requirements

- ◆ The degree to which a relationship can be established between two or more products of the development process, especially products having a predecessor-successor or master-subordinate relationship to one another
 - For example, the degree to which the requirements and design of a given software component match
- ◆ The ability to trace requirements artifacts through the stages of specification, architecture, design, implementation, and testing is a significant factor in assuring a quality software implementation

- ♦ Tracing user needs to product features
- ♦ Tracing features to use cases
- ♦ Tracing features to supplementary requirements
- ♦ Tracing requirements to implementation
- ♦ Tracing use cases to use-case realizations

- ◆ Tracing from the use-case realization into implementation
- ◆ Tracing supplementary requirements into implementation
- ◆ Tracing from requirements to test
- ◆ Tracing from use case to test case

Generalized Traceability Hierarchy



	Feature 1	Feature 2	...	Feature n
Need #1	X			
Need #2		X		X
Need ...		X	X	
Need #m				X

	Use case 1	Use case 2	...	Use case n
Feature #1	X			X
Feature #2		X		X
Feature ...			X	
Feature #m		X		X

Use Case	Scenario Number	... Test Case Id
Use Case #1	1	1.1
	2	2.1
	3	3.1
	4	4.1
	4	4.2
	4	4.3
	5	5.1
	6	6.1
	7	7.1
	7	7.2
	8	8.1
Use Case #2	1	1.1

- ◆ Lack of understanding of the domain or the real problem
 - Do domain analysis and prototyping
- ◆ Requirements change rapidly
 - Perform incremental development, build flexibility into the design, do regular reviews
- ◆ Attempting to do too much
 - Document the problem boundaries at an early stage, carefully estimate the time

- ◆ It may be hard to reconcile conflicting sets of requirements
 - Brainstorming, competing prototypes

- ◆ It is hard to state requirements precisely
 - Break requirements down into simple sentences and review them carefully, look for potential ambiguity, make early prototypes