System Modeling

Chapter 5

System Modeling
in the textbook

- Context models
- Interaction models
- Structural models
- Behavioral models
- Model-driven engineering

System Modeling

- System modeling is
  - the process of developing abstract representations of a system
  - each model presents a different perspective of that system.
- System models are **Abstract**
  - Not an alternate representation
  - Some details are left out

System Perspectives

Different perspectives presented by models:

- **external**: context or environment of *the system*
- **interaction**: between *the system* and its environment, or between components within *the system*
- **structural**: organization of *the system*, or structure of data
- **behavioral**: dynamic behavior, including how *the system* responds to events

System Modeling

- Notation used to represent the models:
  - Graphical (diagrams)
    - UML=Unified Modeling Language
  - Formal/mathematical (ch 12)
- Models of *the system* are used in:
  - Requirements development
    - clarification, discussion
  - Design process
    - represent plans for implementation
  - Model-driven engineering
- Precision and completeness: not always necessary

UML Diagrams

We'll discuss these UML Diagrams

- **Activity diagrams**: the activities in a process.
- **Use case diagrams**: interactions between a system and its environment.
- **Sequence diagrams**: interactions between actors and the system and components.
- **Class diagrams**: classes in the system and the associations between these classes.
- **State diagrams**: how the system reacts to events.

5.1 Context Models

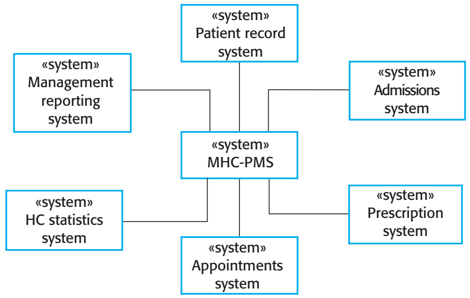
- Primarily an external perspective
  - shows how *the system* is situated or involved in its context
- Two sub-views within the perspective:
  - Static view: shows what other systems *the system* will interact with
  - Dynamic View: shows how *the system* is involved in business processes

Simple Context Model

Static view

- Used to define system boundaries
  - determines what is done by *the system*, and what will be done manually or by some other system
  - stakeholders must decide on this early
- Represented as a box and line diagram:
  - Boxes show each of the systems involved
  - Lines show interaction between systems
  - Technically NOT a UML diagram

Fig 5.1: The context of the MHC-PMS



Note: <<system>> is an example of a “stereotype” in UML
A mechanism to categorize an element in some way

Process Model

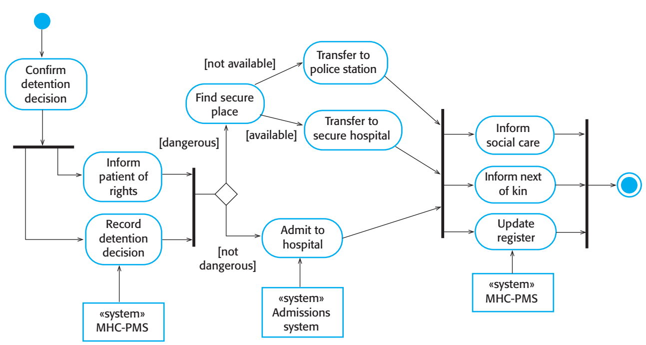
Dynamic view

- Shows how *the system* is used in business processes
- Represented as a UML Activity diagram
  - Shows activity and flow of control

filled circle: start
filled concentric circle: finish
rounded rectangles: activities
rectangles: other objects (the different systems in fig 5.2)
arrows: flow of work
diamonds: branch (and merge)
guards: condition under which flow is taken out of branch
solid bar: activity coordination/concurrency control (fork, join)

Fig 5.2: Process model of involuntary detention

Example of a UML Activity diagram



Note: This diagram is missing one branch and 2 merge diamonds

5.2 Interaction Models

- Model interactions
  - between *the system* and environment or users
  - between components within *the system*
- Uses:
  - user and system: developing requirements
  - system components: help to understand flow of control in an object oriented system
- Use Case Diagrams:
  - represent user-system interactions
- Sequence Diagrams:
  - represent interactions between components (and actors)

5.2.1 Use Case Modeling

- Main purpose: requirements elicitation + analysis
- Overview of one discrete user/system interaction
  - Focused on one goal of the actor
- Use Case Diagram components:
  - **stick figure:** actor (user or system)
  - **ellipse:** named interaction (verb-noun)
  - **line:** indicates involvement in interaction
- Diagram is supplemented with further details
  - simple textual description or
  - structured description (form/template/table) or
  - sequence diagram(s)

Fig 5.3: Transfer data use case

Example of a UML Use case diagram

Note: arrows are not part of UML, but shows direction of data flow

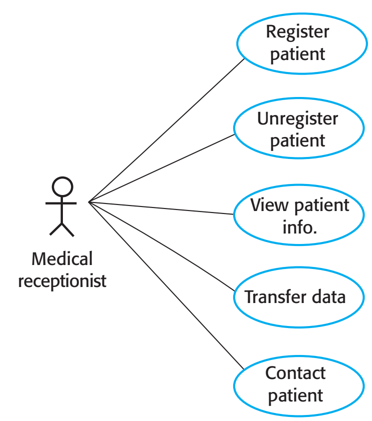
Note: primary actor on left, supporting actor on right

Fig 5.4: Tabular description of Transfer data use case

MHC-PMS: Transfer data	
Actors	Medical receptionist, patient records system (PRS)
Description	A receptionist may transfer data from the MHC-PMS to a general patient record database that is maintained by a health authority. The information transferred may either be updated personal information (address, phone number, etc.) or a summary of the patient's diagnosis and treatment.
Data	Patient's personal information, treatment summary
Stimulus	User command issued by medical receptionist
Response	Confirmation that PRS has been updated
Comments	The receptionist must have appropriate security permissions to access the patient information and the PRS.

Fig 5.5: Use cases involving Medical Receptionist

A composite use case diagram:
all interactions involving a given actor



5.2.2 Sequence Diagram

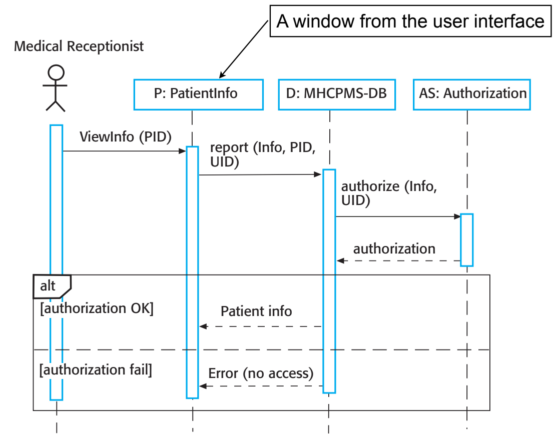
- Models the interactions between actors and objects within *the system* in some detail
- Can be used to show the sequence of interactions in a given use case
- Diagram notes:

Read sequence from top to bottom

objects and actors: listed across top with dotted lines going down
boxes on dotted line: lifetime of object (in this interaction)
dotted arrows between lines from objects: interactions, messages
annotations on arrows: calls to objects with parameters, return values
box named alt with conditions in brackets: for branching/alternatives

Fig 5.6: View patient information

Example of a UML Sequence diagram



PID: patient ID
UID: user ID
Info: kind of info to be returned

Sequence Diagram Uses

- Requirements Development:
  - To document/discuss requirements
  - These diagrams must leave out detail
    - so as not to constrain developers
  - For example:

  Minimal sequence diagram: only two components: user and system
  Use to show **sequence** of interactions between user and system
- Design/Implementation:
  - Details are required:
  - Messages must match objects' methods
  - Include parameters in method calls between objects
  - Source of the parameters

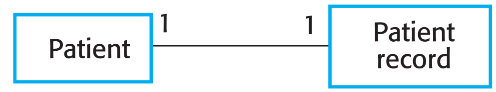
5.3 Structural Models

- Display the organization of *the system* in terms of its components and relationships
- Static Models
  - shows the structure of the system
- Dynamic Models
  - shows organization of system when it is executing (processes/threads)
  - (won't be discussing these)

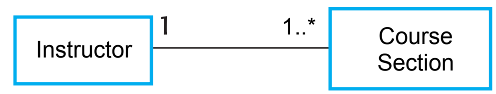
5.3.2 UML Class Diagrams

- Static model
- Shows classes and associations between them
- Uses:
  - developing requirements: model real-world objects
  - during design phase: add implementation objects
- Simple class diagrams:
  - **Box** represents a class (with a name)
  - **Lines** show associated between classes (name optional)
  - **Number** at each end to show how many objects can be involved in the association (multiplicity)

Fig 5.8: UML Classes and association



Two classes and one association
(a one-to-**one** relationship)



Two classes and one association
(a one-to-**many** relationship)

How many instructors does a Course Section have?

Fig 5.9: Classes and associations in the MHC-PMS

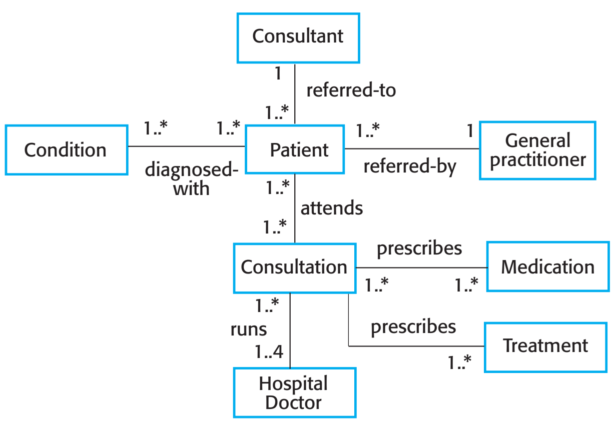
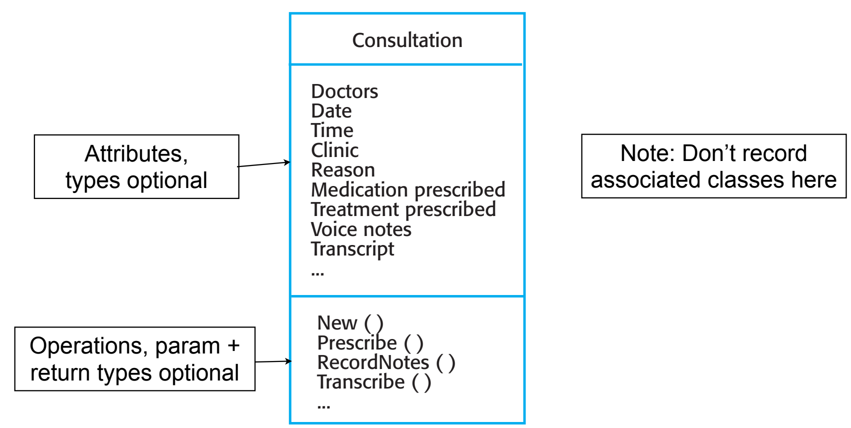


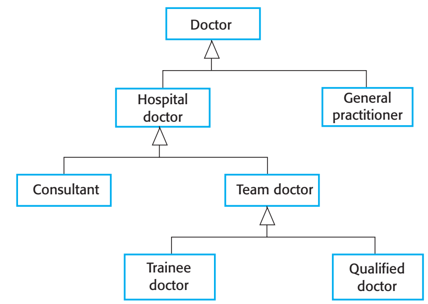
Fig 5.10: Consultation class, in more detail



5.3.2 Generalization

- Act of identifying commonality among concepts, defining:
  - a general concept (superclass)
  - specialized concept(s) (subclasses).
- Example: University personnel
  - Faculty, Staff, Students (graduate, undergrad)
  - All university personnel have ID numbers
  - All students have majors
- Common attributes are stored in superclass only
  - avoids duplication
  - changes affecting how ID number is implemented happens in University personnel class only

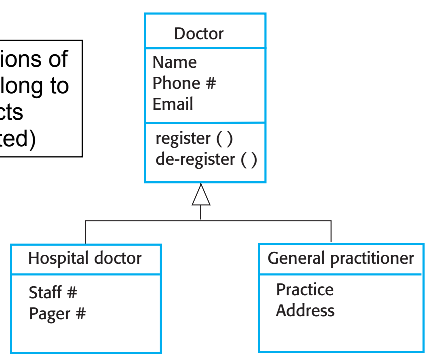
Fig 5.11: Generalization hierarchy



Arrow points to superclass

Fig 5.12: Generalization with added detail

Attributes + operations of superclass also belong to subclass objects (they are inherited)

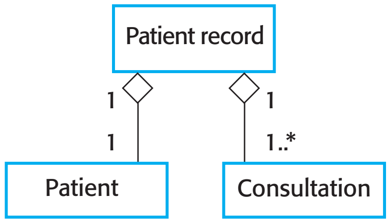


Subclass adds more specific attributes + operations

5.3.3 Aggregation

- When objects are composed of separate parts
  - ex: a (university) class is composed of a faculty member and several students
- UML: aggregation is a special kind of association
  - diamond at end of line closest to “whole” class
- When implemented, the composite usually has instance variables for each “part” object

Fig 5.13: Aggregation association



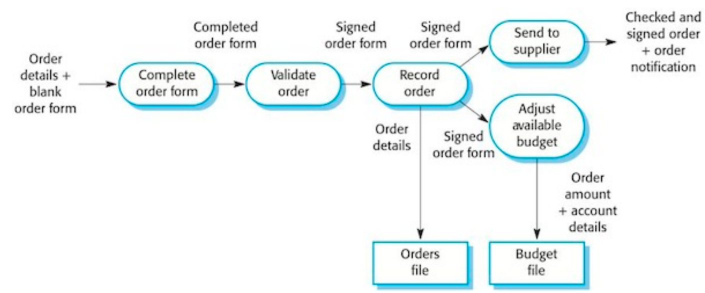
5.4 Behavioral models

- Represent dynamic behavior of *the system* as it is executing
- More of an "internal" view of *the system*
- Sequences of Actions:
  - UML Activity diagrams (process, flow of actions)
  - UML Sequence diagrams (sequence of interactions)
  - **Data-flow diagrams (DFD)**
- States of an object or system, with transitions
  - **UML state diagrams**

5.4.1 Data-flow diagram

- Many systems are data-processing systems, primarily driven by data.
- DFD illustrates how data is processed by the system in terms of inputs and outputs.
  Text
  - One of the first graphical software models (not UML)
- Models sequence of actions in a process
  - sequence of functions, each with input and output data
  - functional or procedural -oriented (not objects)
- Useful during requirements analysis:
  - simple and intuitive, users can validate proposed system

Example Data Flow Diagram: Order Processing



Oval: functional processing
Rectangle: data store
Labeled arrow: data (input/output) and movement

5.4.2 UML State diagrams

- Describes
  - all the states an (object or component or system) can get into
  - how state changes in response to events (transitions)
- Useful when object/component/system is changed by events (real time and embedded systems, etc.)
- Components of a state diagram
  - **Rounded rectangles:** system states
    - includes what action to **do** in that state
  - **Labelled arrow:** stimuli to force transition between states
    - **optional guard**: transition allowed only when guard is true
    - **unlabeled arrow:** transition occurs automatically when action is complete

Fig 5.16
State diagram of a microwave oven

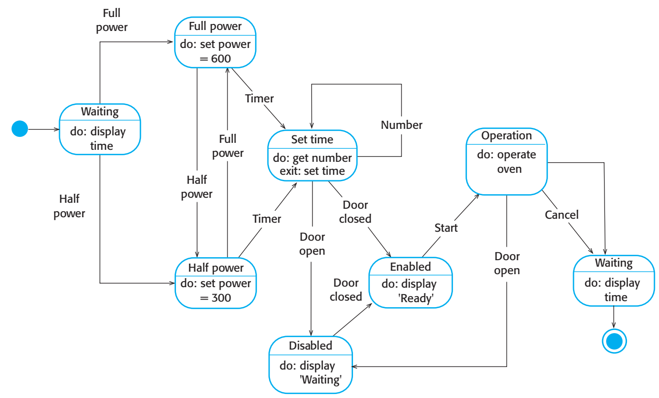


Diagram is missing (at least) one arrow

5.5 Model Driven Engineering (MDE)

- An approach to software development where models (rather than programs) are the principal outputs of the development process.
  - Developers generate programs automatically from the models.
  - Developers test and debug models rather than programs
- Models are often extensions of UML models
- Some problems:
  - Models are inherently too abstract to be a basis for the implementation.
  - Not enough good tools supporting model compilation and debugging yet.