

Module –II:

Chapter 5: System Modeling

Topics covered

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

System modeling

- ✧ System modeling is the process of developing abstract models of a system, with each model presenting a different view or perspective of that system.
- ✧ System modeling has now come to mean representing a system using some kind of graphical notation, which is now almost always based on notations in the Unified Modeling Language (UML).
- ✧ System modelling helps the analyst to understand the functionality of the system and models are used to communicate with customers.

Existing and planned system models

- ✧ Models of the existing system are used during requirements engineering. They help clarify what the existing system does and can be used as a basis for discussing its strengths and weaknesses. These then lead to requirements for the new system.
- ✧ Models of the new system are used during requirements engineering to help explain the proposed requirements to other system stakeholders. Engineers use these models to discuss design proposals and to document the system for implementation.
- ✧ In a model-driven engineering process, it is possible to generate a complete or partial system implementation from the system model.

System perspectives

- ✧ An external perspective, where you model the context or environment of the system.
- ✧ An interaction perspective, where you model the interactions between a system and its environment, or between the components of a system.
- ✧ A structural perspective, where you model the organization of a system or the structure of the data that is processed by the system.
- ✧ A behavioral perspective, where you model the dynamic behavior of the system and how it responds to events.

UML diagram types

- ✧ Activity diagrams, which show the activities involved in a process or in data processing .
- ✧ Use case diagrams, which show the interactions between a system and its environment.
- ✧ Sequence diagrams, which show interactions between actors and the system and between system components.

- ✧ Class diagrams, which show the object classes in the system and the associations between these classes.
- ✧ State diagrams, which show how the system reacts to internal and external events.

Use of graphical models

- ✧ As a means of facilitating discussion about an existing or proposed system
 - Incomplete and incorrect models are OK as their role is to support discussion.
- ✧ As a way of documenting an existing system
 - Models should be an accurate representation of the system but need not be complete.
- ✧ As a detailed system description that can be used to generate a system implementation
 - Models have to be both correct and complete.

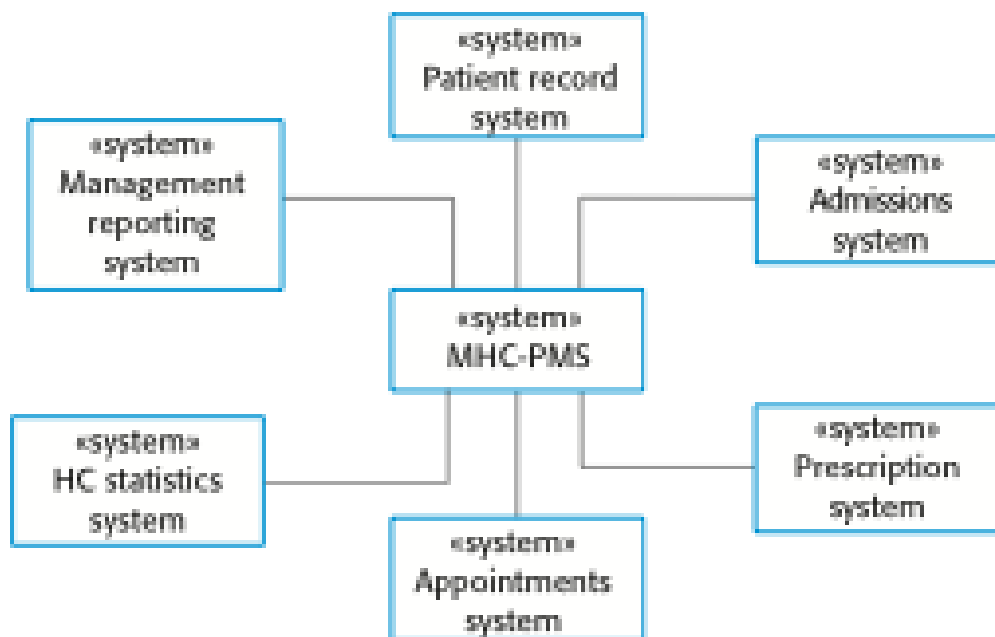
Context models

- ✧ Context models are used to illustrate the operational context of a system - they show what lies outside the system boundaries.
- ✧ Social and organisational concerns may affect the decision on where to position system boundaries.
- ✧ Architectural models show the system and its relationship with other systems.

System boundaries

- ✧ System boundaries are established to define what is inside and what is outside the system.
 - They show other systems that are used or depend on the system being developed.
- ✧ The position of the system boundary has a profound effect on the system requirements.
- ✧ Defining a system boundary is a political judgment
 - There may be pressures to develop system boundaries that increase / decrease the influence or workload of different parts of an organization.

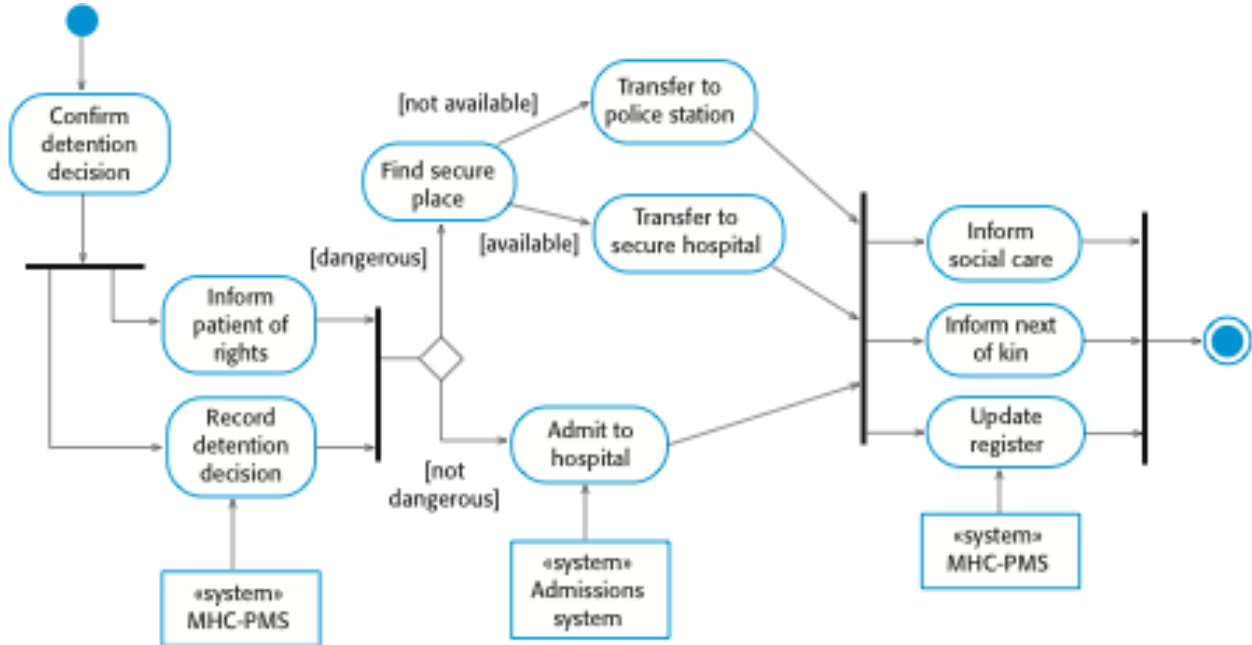
The context of the MHC-PMS



Process perspective

- ✧ Context models simply show the other systems in the environment, not how the system being developed is used in that environment.
- ✧ Process models reveal how the system being developed is used in broader business processes.
- ✧ UML activity diagrams may be used to define business process models.

Process model of involuntary detention



Interaction models

- ✧ Modeling user interaction is important as it helps to identify user requirements.
- ✧ Modeling system-to-system interaction highlights the communication problems that may arise.
- ✧ Modeling component interaction helps us understand if a proposed system structure is likely to deliver the required system performance and dependability.
- ✧ Use case diagrams and sequence diagrams may be used for interaction modelling.

Use case modeling

- ✧ Use cases were developed originally to support requirements elicitation and now incorporated into the UML.
- ✧ Each use case represents a discrete task that involves external interaction with a system.
- ✧ Actors in a use case may be people or other systems.
- ✧ Represented diagrammatically to provide an overview of the use case and in a more detailed textual form.

Transfer-data use case

- ✧ A use case in the MHC-PMS:

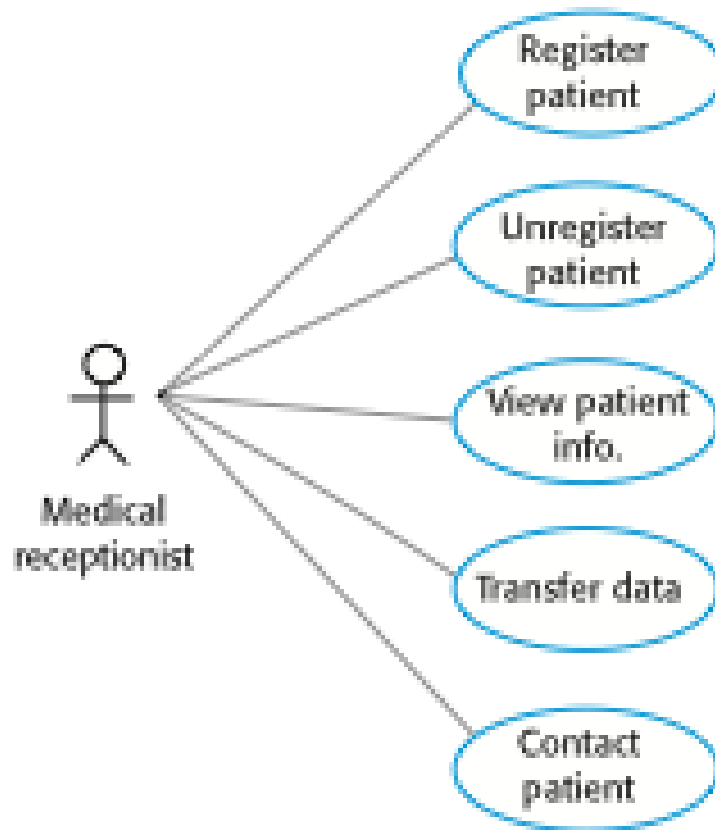


Tabular description of the 'Transfer data' use-case

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.

Use cases in the MHC-PMS involving the role 'Medical Receptionist':

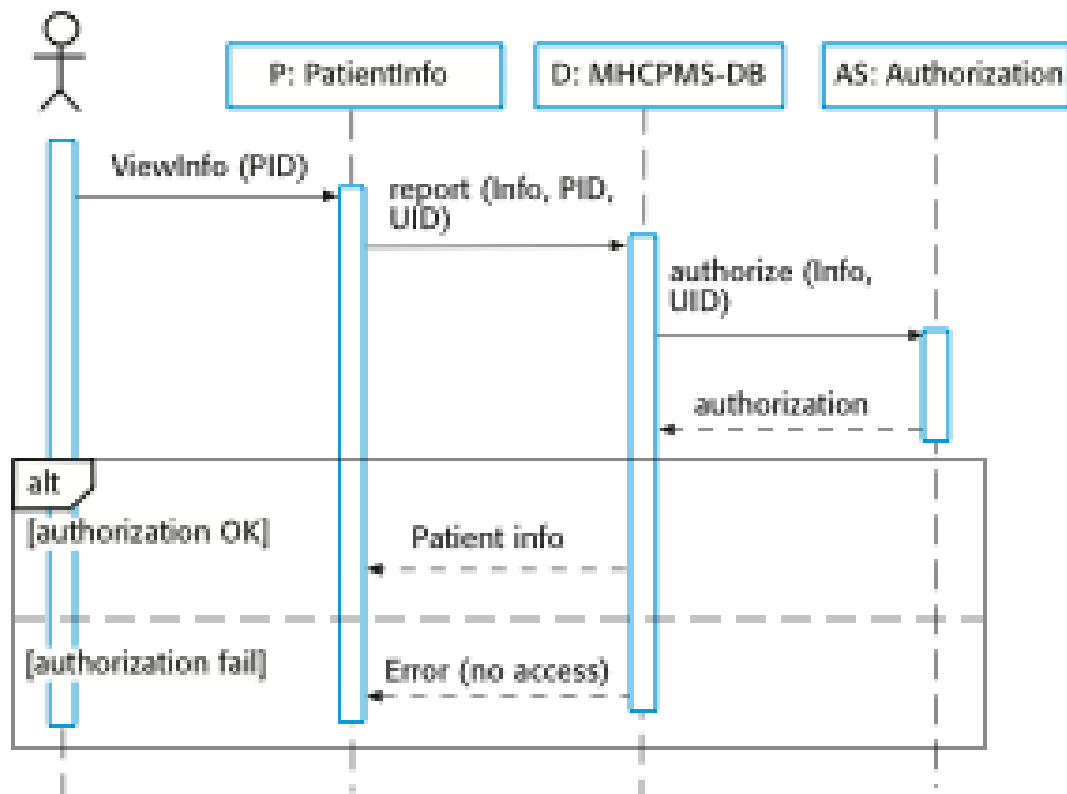


Sequence diagrams

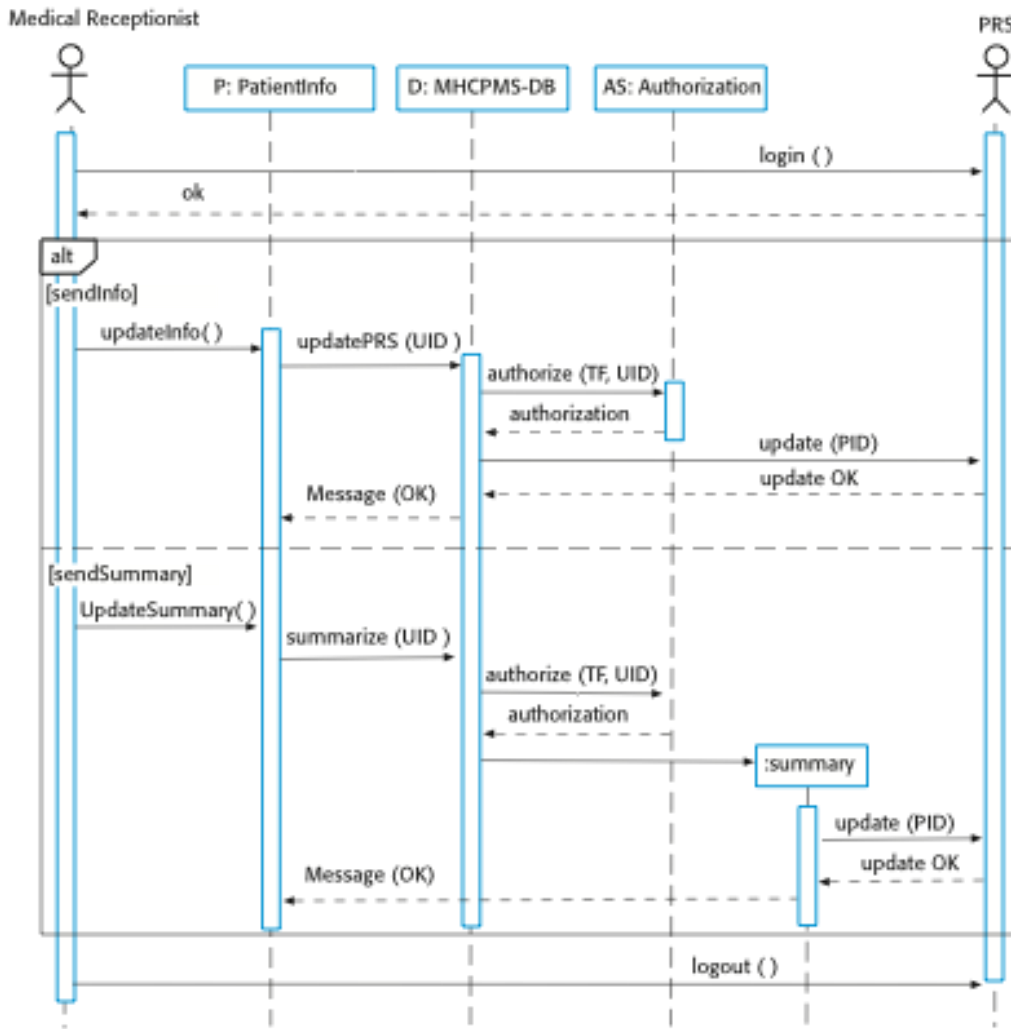
- ✧ Sequence diagrams are part of the UML and are used to model the interactions between the actors and the objects within a system.
- ✧ A sequence diagram shows the sequence of interactions that take place during a particular use case or use case instance.
- ✧ The objects and actors involved are listed along the top of the diagram, with a dotted line drawn vertically from these.
- ✧ Interactions between objects are indicated by annotated arrows.

Sequence diagram for View patient information:

Medical Receptionist



Sequence diagram for Transfer Data:



Structural models

- ✧ Structural models of software display the organization of a system in terms of the components that make up that system and their relationships.
- ✧ Structural models may be static models, which show the structure of the system design, or dynamic models, which show the organization of the system when it is executing.
- ✧ You create structural models of a system when you are discussing and designing the system architecture.

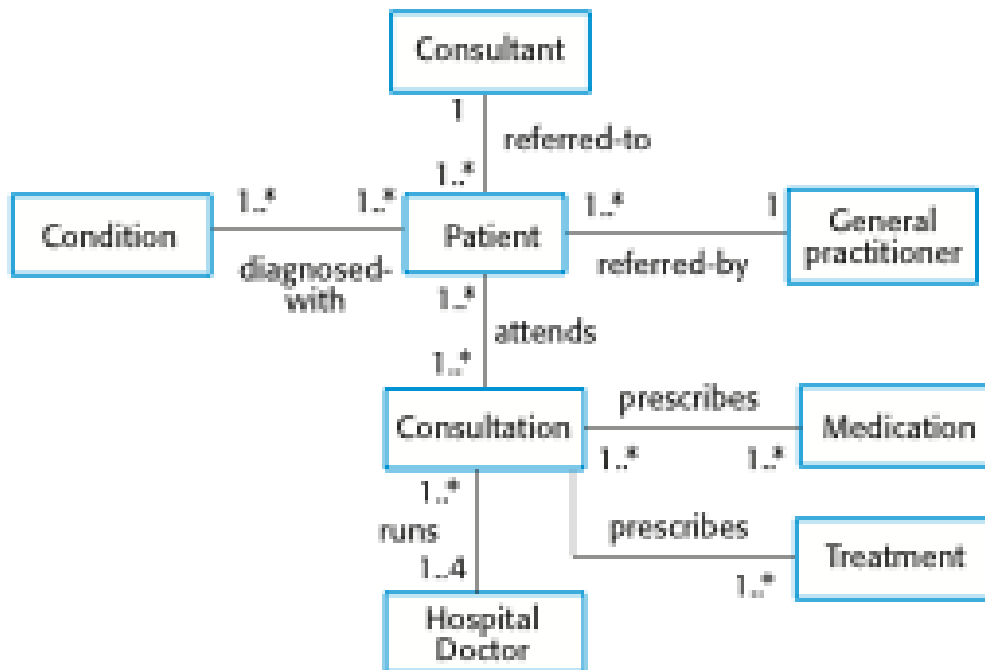
Class diagrams

- ✧ Class diagrams are used when developing an object-oriented system model to show the classes in a system and the associations between these classes.
- ✧ An object class can be thought of as a general definition of one kind of system object.
- ✧ An association is a link between classes that indicates that there is some relationship between these classes.
- ✧ When you are developing models during the early stages of the software engineering process, objects represent something in the real world, such as a patient, a prescription, doctor, etc.

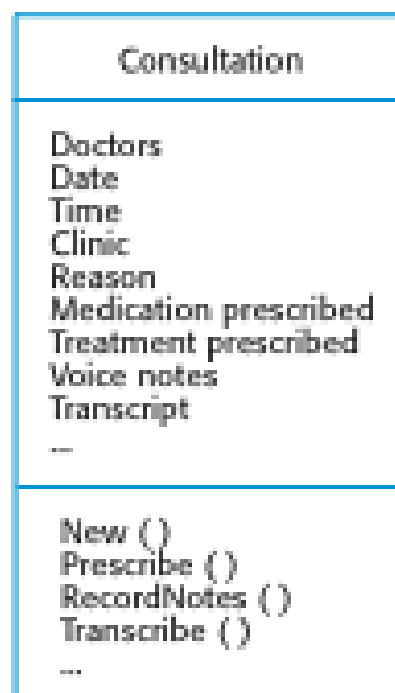
UML classes and association:



Classes and associations in the MHC-PMS:



The Consultation class:

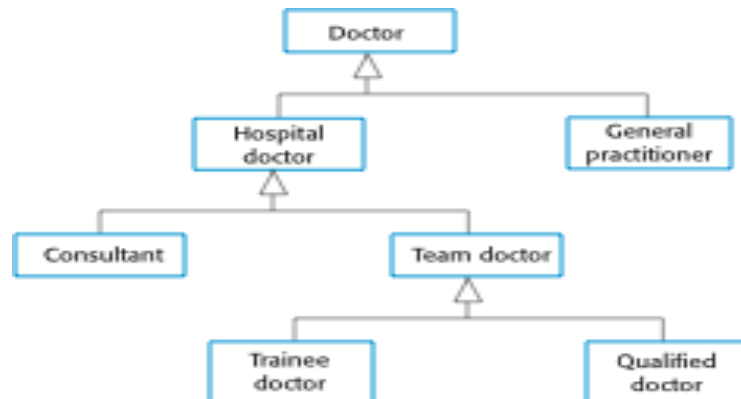


Generalization

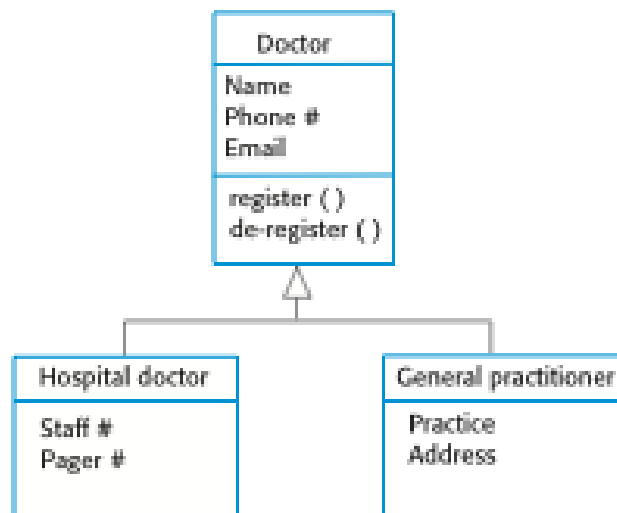
- ✧ Generalization is an everyday technique that we use to manage complexity.
- ✧ Rather than learn the detailed characteristics of every entity that we experience, we place these entities in more general classes (animals, cars, houses, etc.) and learn the characteristics of these classes.
- ✧ This allows us to infer that different members of these classes have some common characteristics e.g. squirrels and rats are rodents.

- ✧ In modeling systems, it is often useful to examine the classes in a system to see if there is scope for generalization. If changes are proposed, then you do not have to look at all classes in the system to see if they are affected by the change.
- ✧ In object-oriented languages, such as Java, generalization is implemented using the class inheritance mechanisms built into the language.
- ✧ In a generalization, the attributes and operations associated with higher-level classes are also associated with the lower-level classes.
- ✧ The lower-level classes are subclasses inherit the attributes and operations from their superclasses. These lower-level classes then add more specific attributes and operations.

A generalization hierarchy



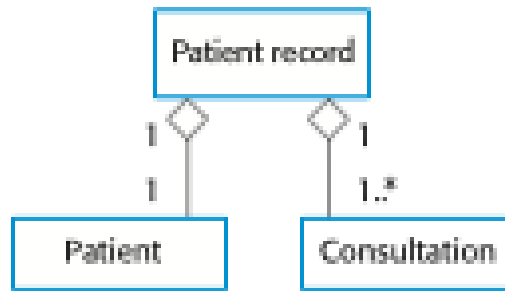
A generalization hierarchy with added detail



Object class aggregation models

- ✧ An aggregation model shows how classes that are collections are composed of other classes.
- ✧ Aggregation models are similar to the part-of relationship in semantic data models.

The aggregation association:



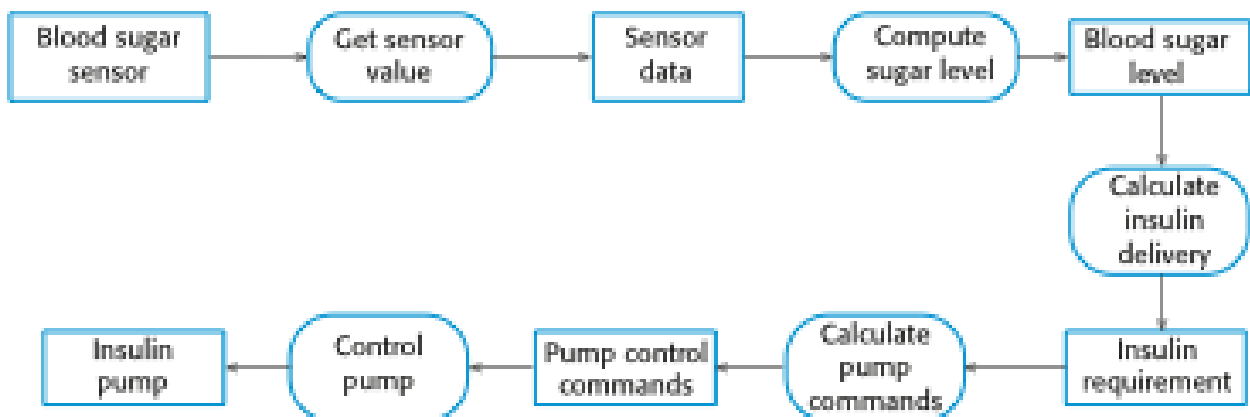
Behavioral models

- ✧ Behavioral models are models of the dynamic behavior of a system as it is executing. They show what happens or what is supposed to happen when a system responds to a stimulus from its environment.
- ✧ You can think of these stimuli as being of two types:
 - **Data:** Some data arrives that has to be processed by the system.
 - **Events:** Some event happens that triggers system processing. Events may have associated data, although this is not always the case.

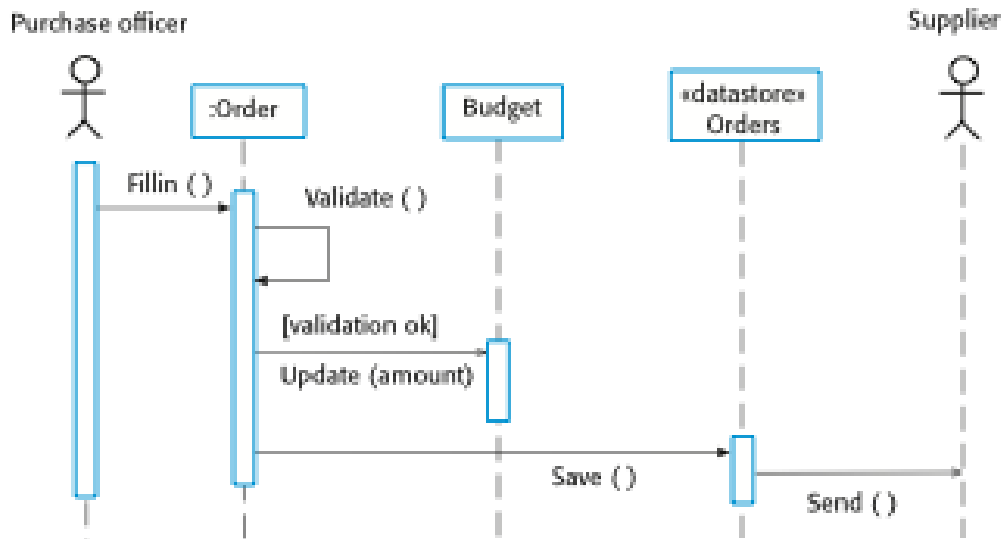
Data-driven modeling

- ✧ Many business systems are data-processing systems that are primarily driven by data. They are controlled by the data input to the system, with relatively little external event processing.
- ✧ Data-driven models show the sequence of actions involved in processing input data and generating an associated output.
- ✧ They are particularly useful during the analysis of requirements as they can be used to show end-to-end processing in a system.

An activity model of the insulin pump's operation



Order processing:



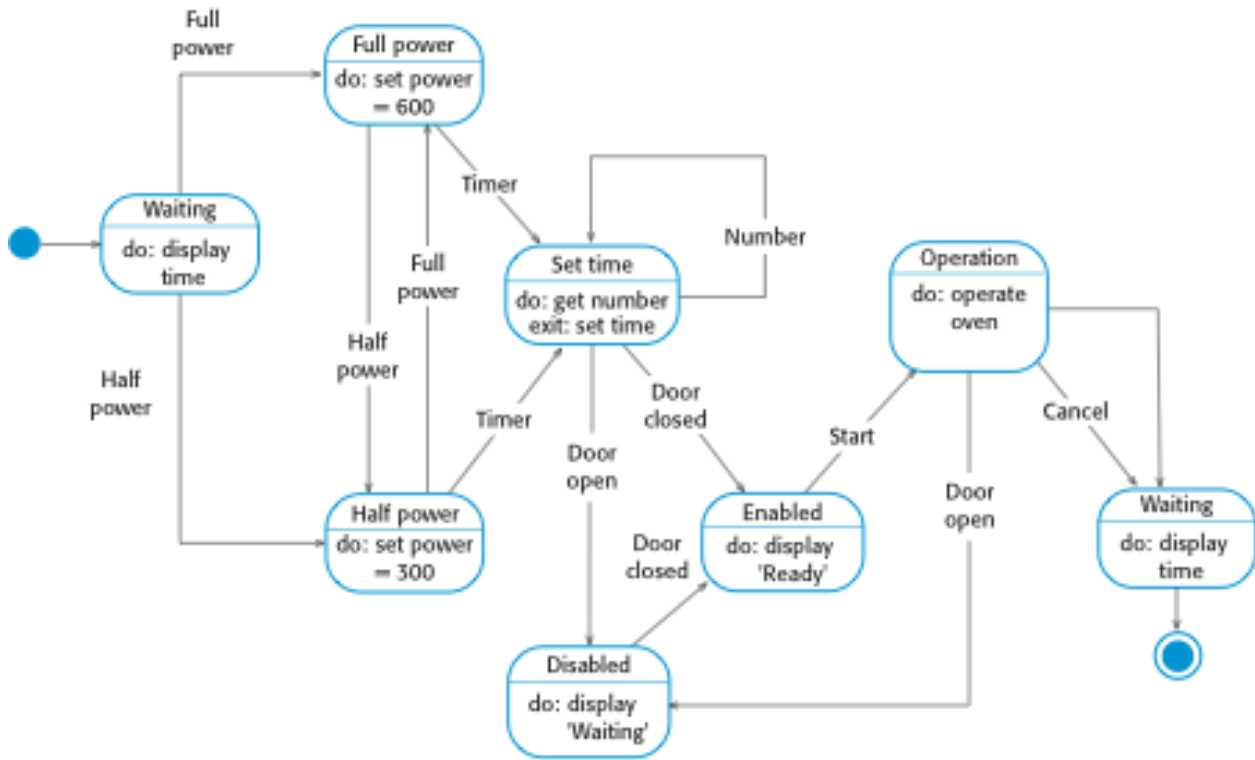
Event-driven modeling

- ✧ Real-time systems are often event-driven, with minimal data processing. For example, a landline phone switching system responds to events such as ‘receiver off hook’ by generating a dial tone.
- ✧ Event-driven modeling shows how a system responds to external and internal events.
- ✧ It is based on the assumption that a system has a finite number of states and that events (stimuli) may cause a transition from one state to another.

State machine models

- ✧ These model the behaviour of the system in response to external and internal events.
- ✧ They show the system’s responses to stimuli so are often used for modelling real-time systems.
- ✧ State machine models show system states as nodes and events as arcs between these nodes. When an event occurs, the system moves from one state to another.
- ✧ State charts are an integral part of the UML and are used to represent state machine models.

State diagram of a microwave oven



States and stimuli for the microwave oven (a)

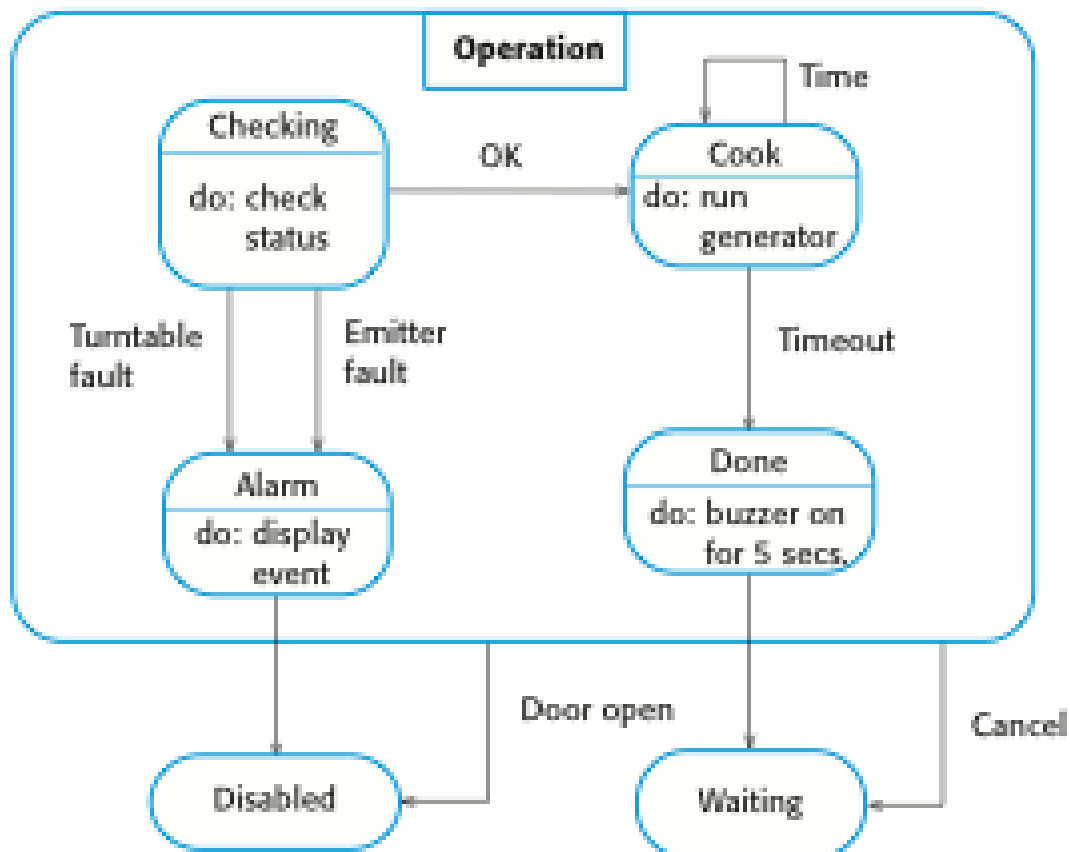
State	Description
Waiting	The oven is waiting for input. The display shows the current time.
Half power	The oven power is set to 300 watts. The display shows 'Half power'.
Full power	The oven power is set to 600 watts. The display shows 'Full power'.
Set time	The cooking time is set to the user's input value. The display shows the cooking time selected and is updated as the time is set.
Disabled	Oven operation is disabled for safety. Interior oven light is on. Display shows 'Not ready'.
Enabled	Oven operation is enabled. Interior oven light is off. Display shows 'Ready to cook'.
Operation	Oven in operation. Interior oven light is on. Display shows the timer countdown. On completion of cooking, the buzzer is sounded for five seconds. Oven light is on. Display shows 'Cooking complete' while buzzer is sounding.

States and stimuli for the microwave oven (b)

Stimulus	Description
Half power	The user has pressed the half-power button.
Full power	The user has pressed the full-power button.

Timer	The user has pressed one of the timer buttons.
Number	The user has pressed a numeric key.
Door open	The oven door switch is not closed.
Door closed	The oven door switch is closed.
Start	The user has pressed the Start button.
Cancel	The user has pressed the Cancel button.

Microwave oven operation:



Model-driven engineering

- ✧ Model-driven engineering (MDE) is an approach to software development where models rather than programs are the principal outputs of the development process.
- ✧ The programs that execute on a hardware/software platform are then generated automatically from the models.

Proponents of MDE argue that this raises the level of abstraction in software engineering so that engineers no longer have to be concerned with programming language details or the specifics of execution platforms

Usage of model-driven engineering

- ✧ Model-driven engineering is still at an early stage of development, and it is unclear whether or not it will have a significant effect on software engineering practice.
- ✧ Pros/ Advantages
 - Allows systems to be considered at higher levels of abstraction
 - Generating code automatically means that it is cheaper to adapt systems to new platforms.
- ✧ Cons/ Disadvantages
 - Models for abstraction and not necessarily right for implementation.
 - Savings from generating code may be outweighed by the costs of developing translators for new platforms.

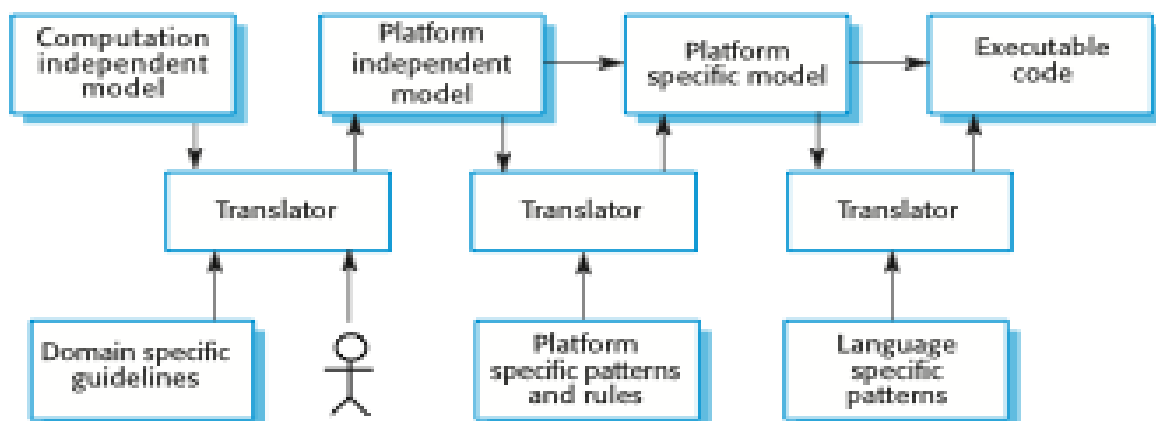
Model driven architecture

- ✧ Model-driven architecture (MDA) was the precursor of more general model-driven engineering
- ✧ MDA is a model-focused approach to software design and implementation that uses a subset of UML models to describe a system.
- ✧ Models at different levels of abstraction are created. From a high-level, platform independent model, it is possible, in principle, to generate a working program without manual intervention.

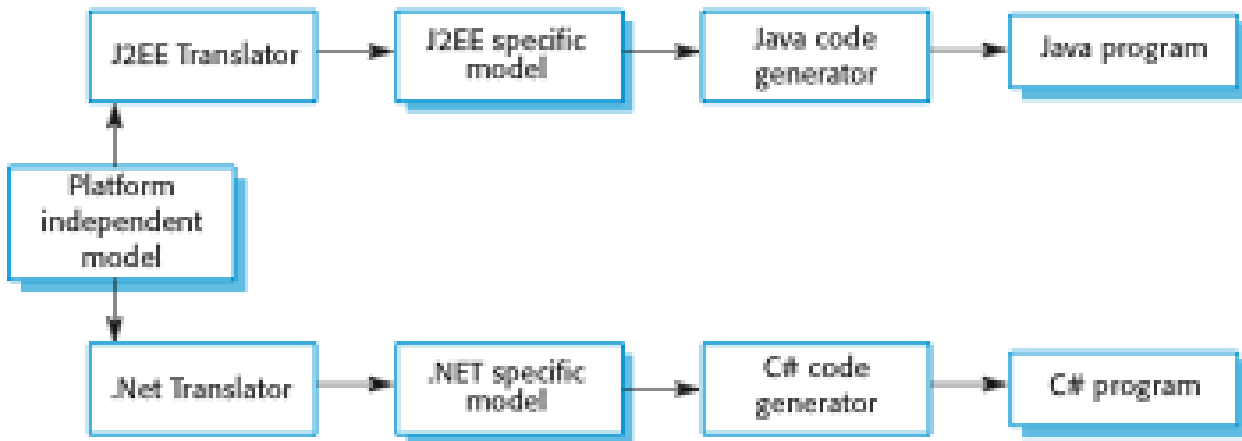
Types of model

- ✧ *A computation independent model (CIM)*
 - These model the important domain abstractions used in a system. CIMs are sometimes called domain models.
- ✧ *A platform independent model (PIM)*
 - These model the operation of the system without reference to its implementation. The PIM is usually described using UML models that show the static system structure and how it responds to external and internal events.
- ✧ *Platform specific models (PSM)*
 - These are transformations of the platform-independent model with a separate PSM for each application platform. In principle, there may be layers of PSM, with each layer adding some platform-specific detail.

MDA transformations



Multiple platform-specific models



Agile methods and MDA

- ✧ The developers of MDA claim that it is intended to support an iterative approach to development and so can be used within agile methods.
- ✧ The notion of extensive up-front modeling contradicts the fundamental ideas in the agile manifesto and I suspect that few agile developers feel comfortable with model-driven engineering.
- ✧ If transformations can be completely automated and a complete program generated from a PIM, then, in principle, MDA could be used in an agile development process as no separate coding would be required.

Executable UML

- ✧ The fundamental notion behind model-driven engineering is that completely automated transformation of models to code should be possible.
- ✧ This is possible using a subset of UML 2, called Executable UML or xUML.

Features of executable UML

- ✧ To create an executable subset of UML, the number of model types has therefore been dramatically reduced to these 3 key types:
 - Domain models that identify the principal concerns in a system. They are defined using UML class diagrams and include objects, attributes and associations.
 - Class models in which classes are defined, along with their attributes and operations.
 - State models in which a state diagram is associated with each class and is used to describe the life cycle of the class.
- ✧ The dynamic behaviour of the system may be specified declaratively using the object constraint language (OCL), or may be expressed using UML's action language.

Chapter 7: Design and Implementation

Topics covered

- Object-oriented design using the UML
- Design patterns
- Implementation issues
- Open source development

Design and implementation

- Software design and implementation is the stage in the software engineering process at which an executable software system is developed.
- Software design and implementation activities are invariably interleaved.
- Software design is a creative activity in which you identify software components and their relationships, based on a customer's requirements.
- Implementation is the process of realizing the design as a program.

Build or buy

- In a wide range of domains, it is now possible to buy off-the-shelf systems (COTS) that can be adapted and tailored to the users' requirements.
- For example, if you want to implement a medical records system, you can buy a package that is already used in hospitals. It can be cheaper and faster to use this approach rather than developing a system in a conventional programming language.
- When you develop an application in this way, the design process becomes concerned with how to use the configuration features of that system to deliver the system requirements.

An object-oriented design process

- Structured object-oriented design processes involve developing a number of different system models.
- They require a lot of effort for development and maintenance of these models and, for small systems, this may not be cost-effective.
- However, for large systems developed by different groups design models are an important communication mechanism.

Process stages

There are a variety of different object-oriented design processes that depend on the organization using the process. Common activities in these processes include:

- Define the context and modes of use of the system;
- Design the system architecture;
- Identify the principal system objects;
- Develop design models;
- Specify object interfaces.
- Process illustrated here using a design for a wilderness weather station.

System context and interactions

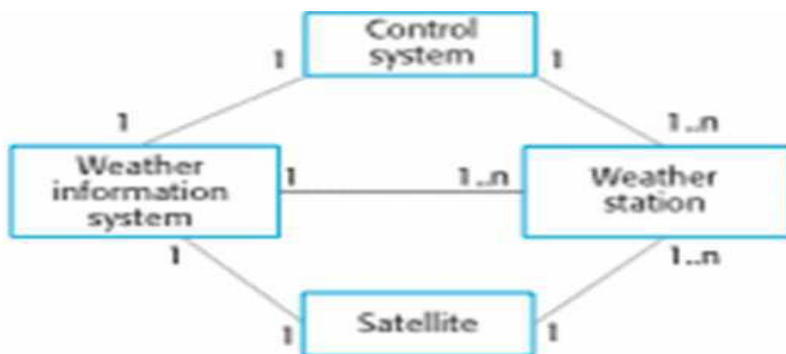
- Understanding the relationships between the software that is being designed and its external environment is essential for deciding how to provide the required system functionality and how to structure the system to communicate with its environment.

- Understanding of the context also lets you establish the boundaries of the system. Setting the system boundaries helps you decide what features are implemented in the system being designed and what features are in other associated systems.

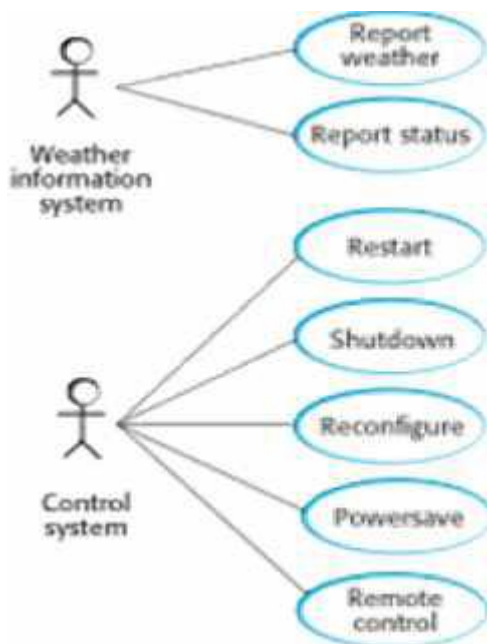
Context and interaction models

- A system context model is a structural model that demonstrates the other systems in the environment of the system being developed.
- An interaction model is a dynamic model that shows how the system interacts with its environment as it is used.

System context for the weather station:



Weather station use cases:



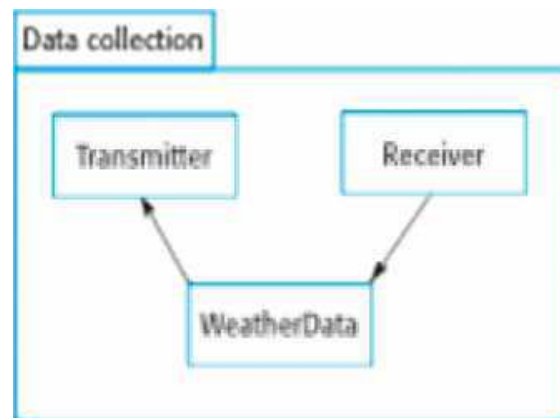
Use case description: Report weather:

System	Weather station
Use case	Report weather
Actors	Weather information system, Weather station
Description	The weather station sends a summary of the weather data that has been collected from the instruments in the collection period to the weather information system. The data sent are the maximum, minimum, and average ground and air temperatures; the maximum, minimum, and average air pressures; the maximum, minimum, and average wind speeds; the total rainfall; and the wind direction as sampled at five-minute intervals.
Stimulus	The weather information system establishes a satellite communication link with the weather station and requests transmission of the data.
Response	The summarized data is sent to the weather information system.
Comments	Weather stations are usually asked to report once per hour but this frequency may differ from one station to another and may be modified in the future.

Architectural design

- Once interactions between the system and its environment have been understood, you use this information for designing the system architecture.
- You identify the major components that make up the system and their interactions, and then may organize the components using an architectural pattern such as a layered or client-server model.
- The weather station is composed of independent subsystems that communicate by broadcasting messages on a common infrastructure.

Architecture of data collection system:



Object class identification

- Identifying object classes is often a difficult part of object oriented design.
- There is no 'magic formula' for object identification. It relies on the skill, experience and domain knowledge of system designers.
- Object identification is an iterative process. You are unlikely to get it right first time.

Approaches to object class identification

1. Use a grammatical approach based on a natural language description of the system. Objects and attributes are Nouns; operations or services are verbs.
2. Use tangible entities (things) in the application domain such as aircraft, roles such as manager or doctor, events such as requests, interactions such as meetings, etc.
3. Use a scenario-based analysis where various scenarios of system use are identified and analyzed.

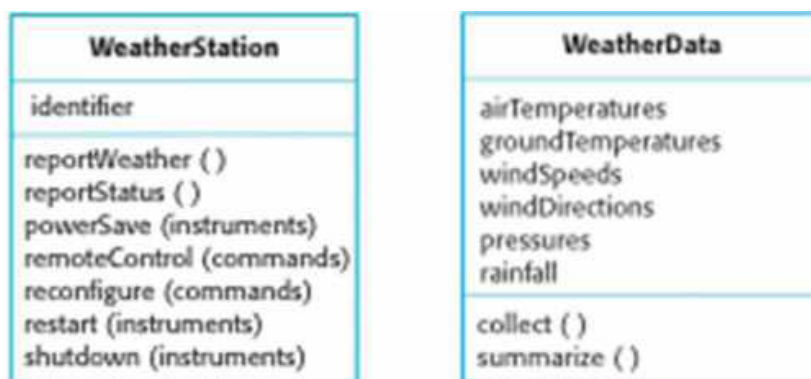
Weather station description

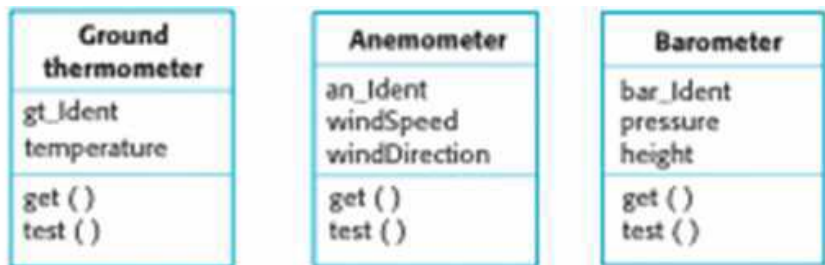
- A weather station is a package of software controlled instruments which collects data, performs some data processing and transmits this data for further processing. The instruments include air and ground thermometers, an anemometer, a wind vane, a barometer and a rain gauge. Data is collected periodically.
- When a command is issued to transmit the weather data, the weather station processes and summarizes the collected data. The summarized data is transmitted to the mapping computer when a request is received.

Weather station object classes

- Object class identification in the weather station system may be based on the tangible hardware and data in the system.
- Ground thermometer, Anemometer, Barometer are Application domain objects.
- Weather station and Weather data objects have been identified from system description and the scenario (use case) description.
- Weather station object class provides basic interface of the weather station to its environment. It therefore reflects the interactions identified in the use-case model.
- Weather data object class is responsible processing the report weather command. It sends summarized data from the weather station instruments to the weather information system
- Ground thermometer, Anemometer and Barometer object classes are directly related to instruments in the system.

Weather station objects:





1.4 Design models

- Design models show the objects and object classes and relationships between these entities.
- Static models describe the static structure of the system in terms of object classes and relationships.
- Dynamic models describe the dynamic interactions between objects.

Examples of design models

- Subsystem models that show logical groupings of objects into coherent subsystems.
- Sequence models that show the sequence of object interactions.
- State machine models that show how individual objects change their state in response to events.
- Other models include use-case models, aggregation models, generalization models, etc.

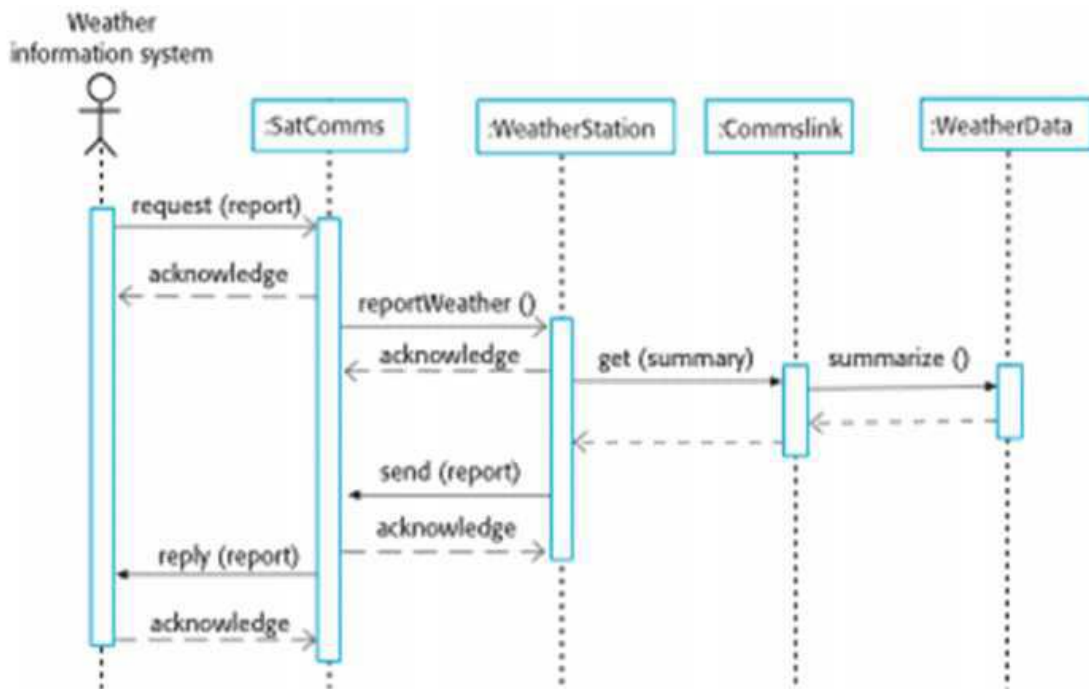
Subsystem models

- Shows how the design is organized into logically related groups of objects.
- In the UML, these are shown using packages - an encapsulation construct. This is a logical model. The actual organization of objects in the system may be different.

Sequence models

- Sequence models show the sequence of object interactions that take place
- Objects are arranged horizontally across the top;
- Time is represented vertically so models are read top to bottom;
- Interactions are represented by labeled arrows; Different styles of arrow represent different types of interaction;
- A thin rectangle in an object lifeline represents the time when the object is the controlling object in the system.

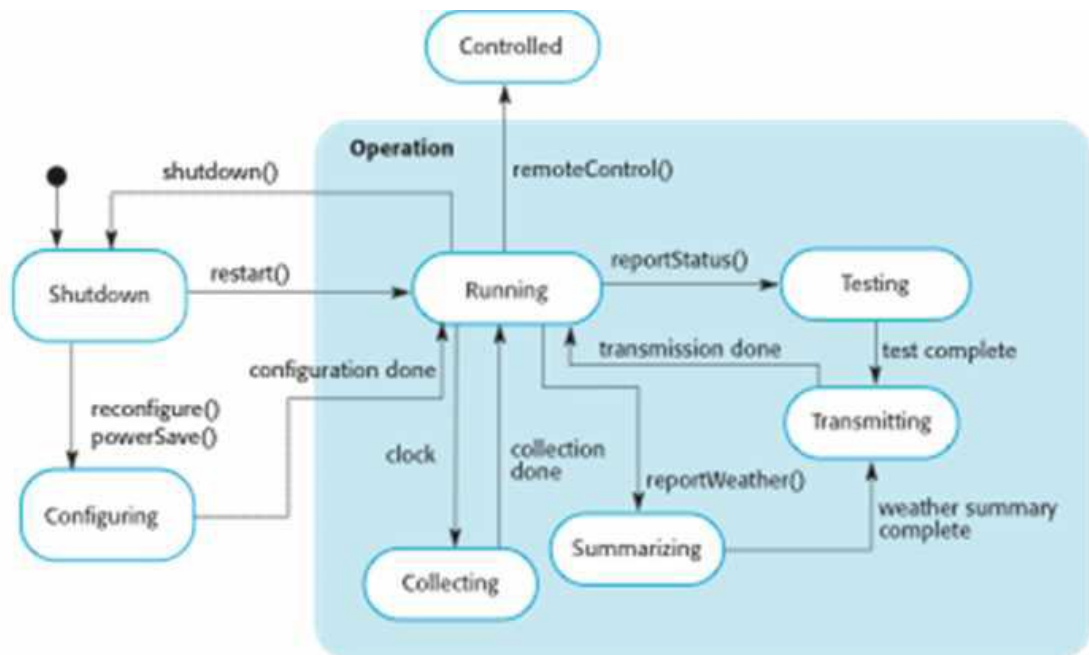
Sequence diagram describing data collection:



State diagrams

- State diagrams are used to show how objects respond to different service requests and the state transitions triggered by these requests.
- State diagrams are useful high-level models of a system or an object’s run-time behavior.
- You don’t usually need a state diagram for all of the objects in the system. Many of the objects in a system are relatively simple and a state model adds unnecessary detail to the design.

Weather station state diagram:



1.5 Interface specification

- Object interfaces have to be specified so that the objects and other components can be designed in parallel.
- Designers should avoid designing the interface representation but should hide this in the object itself.
- Objects may have several interfaces which are viewpoints on the methods provided.
- The UML uses class diagrams for interface specification but Java may also be used.

Weather station interfaces



Design patterns

- A design pattern is a way of reusing abstract knowledge about a problem and its solution.
- A pattern is a description of the problem and the essence of its solution.
- It should be sufficiently abstract to be reused in different settings.
- Pattern descriptions usually make use of object-oriented characteristics such as inheritance and polymorphism.

Pattern elements

- Name
- A meaningful pattern identifier.
- Problem description.
- Solution description.
- Not a concrete design but a template for a design solution that can be instantiated in different ways.
- Consequences
- The results and trade-offs of applying the pattern.

The Observer pattern

- Name
- Observer.
- Description
- Separates the display of object state from the object itself.
- Problem description
- Used when multiple displays of state are needed.
- Solution description
- See slide with UML description.

- Consequences
- Optimisations to enhance display performance are impractical.

Pattern name	Observer
Description	Separates the display of the state of an object from the object itself and allows alternative displays to be provided. When the object state changes, all displays are automatically notified and updated to reflect the change.
Problem description	<p>In many situations, you have to provide multiple displays of state information, such as a graphical display and a tabular display. Not all of these may be known when the information is specified. All alternative presentations should support interaction and, when the state is changed, all displays must be updated.</p> <p>This pattern may be used in all situations where more than one display format for state information is required and where it is not necessary for the object that maintains the state information to know about the specific display formats used.</p>

Pattern name	Observer
Solution description	<p>This involves two abstract objects, Subject and Observer, and two concrete objects, ConcreteSubject and ConcreteObject, which inherit the attributes of the related abstract objects. The abstract objects include general operations that are applicable in all situations. The state to be displayed is maintained in ConcreteSubject, which inherits operations from Subject allowing it to add and remove Observers (each observer corresponds to a display) and to issue a notification when the state has changed.</p> <p>The ConcreteObserver maintains a copy of the state of ConcreteSubject and implements the Update() interface of Observer that allows these copies to be kept in step. The ConcreteObserver automatically displays the state and reflects changes whenever the state is updated.</p>
Consequences	<p>The subject only knows the abstract Observer and does not know details of the concrete class. Therefore there is minimal coupling between these objects. Because of this lack of knowledge, optimizations that enhance display performance are impractical. Changes to the subject may cause a set of linked updates to observers to be generated, some of which may not be necessary.</p>

Figure: The Observer pattern (2)

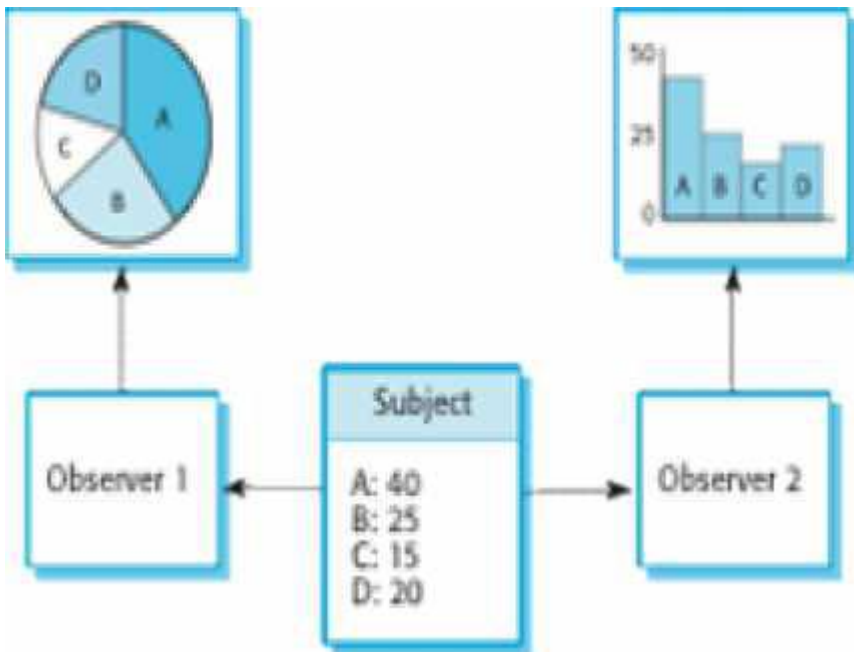


Figure: Multiple displays using the Observer pattern

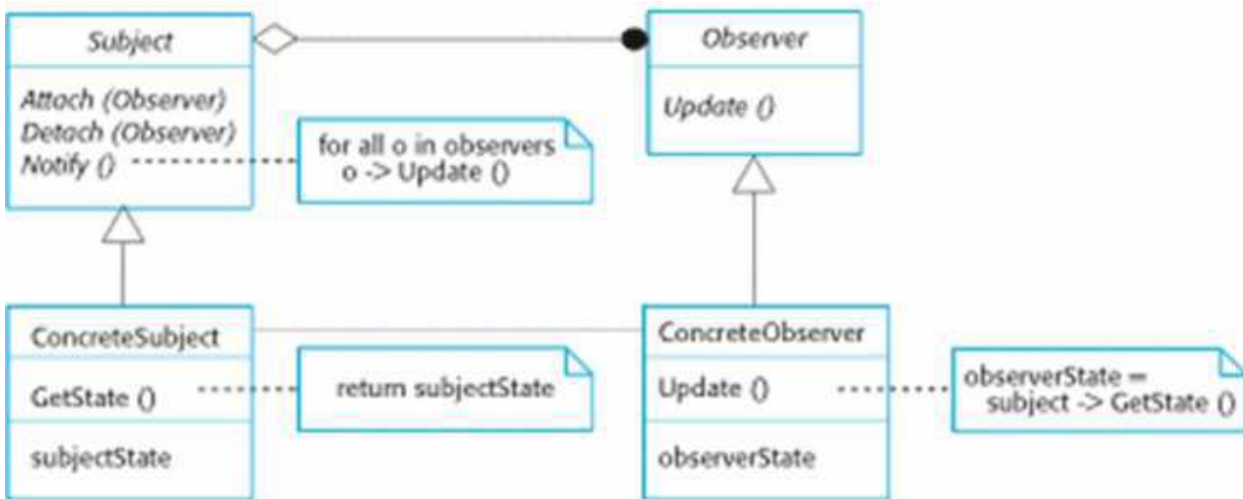


Figure: A UML model of the Observer pattern

Design problems

- To use patterns in your design, you need to recognize that any design problem you are facing may have an associated pattern that can be applied.
- Tell several objects that the state of some other object has changed (Observer pattern).
- Tidy up the interfaces to a number of related objects that have often been developed incrementally (Façade pattern).
- Provide a standard way of accessing the elements in a collection, irrespective of how that collection is implemented (Iterator pattern).
- Allow for the possibility of extending the functionality of an existing class at run-time (Decorator pattern).

Implementation issues

- Focus here is not on programming, although this is obviously important, but on other implementation issues that are often not covered in programming texts:
- Reuse Most modern software is constructed by reusing existing components or systems. When you are developing software, you should make as much use as possible of existing code.

- Configuration management During the development process, you have to keep track of the many different versions of each software component in a configuration management system.
- Host-target development Production software does not usually execute on the same computer as the software development environment. Rather, you develop it on one computer (the host system) and execute it on a separate computer (the target system).

Reuse

- From the 1960s to the 1990s, most new software was developed from scratch, by writing all code in a high-level programming language.
- The only significant reuse of software was the reuse of functions and objects in programming language libraries.
- Costs and schedule pressure mean that this approach became increasingly unviable, especially for commercial and Internet-based systems.
- An approach to development based around the reuse of existing software emerged and is now generally used for business and scientific software.

Reuse levels

- The abstraction level
- At this level, you don't reuse software directly but use knowledge of successful abstractions in the design of your software.
- The object level
- At this level, you directly reuse objects from a library rather than writing the code yourself.
- The component level
- Components are collections of objects and object classes that you reuse in application systems.
- The system level
- At this level, you reuse entire application systems.

Reuse costs

- The costs of the time spent in looking for software to reuse and assessing whether or not it meets your needs.
- Where applicable, the costs of buying the reusable software. For large off-the-shelf systems, these costs can be very high.
- The costs of adapting and configuring the reusable software components or systems to reflect the requirements of the system that you are developing.
- The costs of integrating reusable software elements with each other (if you are using software from different sources) and with the new code that you have developed.

Configuration management

- Configuration management is the name given to the general process of managing a changing software system.

- The aim of configuration management is to support the system integration process so that all developers can access the project code and documents in a controlled way, find out what changes have been made, and compile and link components to create a system.

Configuration management activities

- Version management, where support is provided to keep track of the different versions of software components. Version management systems include facilities to coordinate development by several programmers.
- System integration, where support is provided to help developers define what versions of components are used to create each version of a system. This description is then used to build a system automatically by compiling and linking the required components.
- Problem tracking, where support is provided to allow users to report bugs and other problems, and to allow all developers to see who is working on these problems and when they are fixed.

Host-target development

- Most software is developed on one computer (the host), but runs on a separate machine (the target).
- More generally, we can talk about a development platform and an execution platform.
- A platform is more than just hardware.
- It includes the installed operating system plus other supporting software such as a database management system or, for development platforms, an interactive development environment.
- Development platform usually has different installed software than execution platform; these platforms may have different architectures.

Development platform tools

- An integrated compiler and syntax-directed editing system that allows you to create, edit and compile code.
- A language debugging system.
- Graphical editing tools, such as tools to edit UML models.
- Testing tools, such as Junit that can automatically run a set of tests on a new version of a program.
- Project support tools that help you organize the code for different development projects.

Integrated development environments (IDEs)

- Software development tools are often grouped to create an integrated development environment (IDE).
- An IDE is a set of software tools that supports different aspects of software development, within some common framework and user interface.
- IDEs are created to support development in a specific programming language such as Java. The language IDE may be developed specially, or may be an instantiation of a general-purpose IDE, with specific language-support tools.

Component/system deployment factors

- If a component is designed for a specific hardware architecture, or relies on some other software system, it must obviously be deployed on a platform that provides the required hardware and software support.
- High availability systems may require components to be deployed on more than one platform. This means that, in the event of platform failure, an alternative implementation of the component is available.
- If there is a high level of communications traffic between components, it usually makes sense to deploy them on the same platform or on platforms that are physically close to one other. This reduces the delay between the time a message is sent by one component and received by another.

Open source development

- Open source development is an approach to software development in which the source code of a software system is published and volunteers are invited to participate in the development process
- Its roots are in the Free Software Foundation (www.fsf.org), which advocates that source code should not be proprietary but rather should always be available for users to examine and modify as they wish.
- Open source software extended this idea by using the Internet to recruit a much larger population of volunteer developers. Many of them are also users of the code.

Open source systems

- The best-known open source product is, of course, the Linux operating system which is widely used as a server system and, increasingly, as a desktop environment.
- Other important open source products are Java, the Apache web server and the MySQL database management system.

Open source issues

- Should the product that is being developed make use of open source components?
- Should an open source approach be used for the software's development?

Open source business

- More and more product companies are using an open source approach to development.
- Their business model is not reliant on selling a software product but on selling support for that product.
- They believe that involving the open source community will allow software to be developed more cheaply, more quickly and will create a community of users for the software.

Open source licensing

- A fundamental principle of open-source development is that source code should be freely available, this does not mean that anyone can do as they wish with that code.
- Legally, the developer of the code (either a company or an individual) still owns the code. They can place restrictions on how it is used by including legally binding conditions in an open source software license.
- Some open source developers believe that if an open source component is used to develop a new system, then that system should also be open source.
- Others are willing to allow their code to be used without this restriction. The developed systems may be proprietary and sold as closed source systems.

License models

- The GNU General Public License (GPL). This is a so-called 'reciprocal' license that means that if you use open source software that is licensed under the GPL license, then you must make that software open source.
- The GNU Lesser General Public License (LGPL) is a variant of the GPL license where you can write components that link to open source code without having to publish the source of these components.
- The Berkley Standard Distribution (BSD) License. This is a nonreciprocal license, which means you are not obliged to re-publish any changes or modifications made to open source code. You can include the code in proprietary systems that are sold.

License management

- Establish a system for maintaining information about open-source components that are downloaded and used.
- Be aware of the different types of licenses and understand how a component is licensed before it is used.
- Be aware of evolution pathways for components.
- Educate people about open source.
- Have auditing systems in place.
- Participate in the open source community.