

# Software Engineering

## Object-Oriented Design

Based on Software Engineering, 7<sup>th</sup> Edition by Ian Sommerville

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### Objectives

- To explain how a software design may be represented as a set of interacting objects that manage their own state and operations
- To describe the activities in the object-oriented design process
- To introduce various models that can be used to describe an object-oriented design
- To show how the UML may be used to represent these models

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## Object-oriented development

- Object-oriented analysis, design and programming are related but distinct.
- OOA is concerned with developing an object model of the application domain.
- OOD is concerned with developing an object-oriented system model to implement requirements.
- OOP is concerned with realizing an OOD using an OO programming language such as Java or C++.

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## Object-oriented design

- Objects are abstractions of real-world or system entities and manage themselves.
- Objects are independent and encapsulate state and representation information.
- System functionality is expressed in terms of object services.
- Shared data areas are eliminated. Objects communicate by message passing.
- Objects may be distributed and may execute sequentially or in parallel.
- Advantages
  - Easier maintenance. Objects may be understood as stand-alone entities.
  - Objects are potentially reusable components.
  - For some systems, there may be an obvious mapping from real world entities to system objects.

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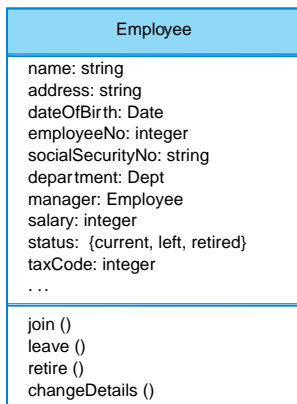
## Objects and object classes

- Objects are entities in a software system which represent instances of real-world and system entities.
- Object classes are templates for objects. They may be used to create objects.
- Object classes may inherit attributes and services from other object classes.
- *An **object** is an entity that has a state and a defined set of operations which operate on that state. The state is represented as a set of object attributes. The operations associated with the object provide services to other objects (clients) which request these services when some computation is required.*
- *Objects are created according to some **object class** definition. An object class definition serves as a template for objects. It includes declarations of all the attributes and services which should be associated with an object of that class.*

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## The Unified Modeling Language

- Several different notations for describing object-oriented designs were proposed in the 1980s and 1990s.
- The Unified Modeling Language is an integration of these notations.
- It describes notations for a number of different models that may be produced during OO analysis and design.
- It is now a *de facto* standard for OO modeling.



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## Object communication

- Conceptually, objects communicate by message passing.
- Messages
  - The name of the service requested by the calling object;
  - Copies of the information required to execute the service and the name of a holder for the result of the service.
- In practice, messages are often implemented by procedure calls
  - Name = procedure name;
  - Information = parameter list.

```
// Call a method associated with a buffer  
// object that returns the next value  
// in the buffer
```

```
v = circularBuffer.Get () ;
```

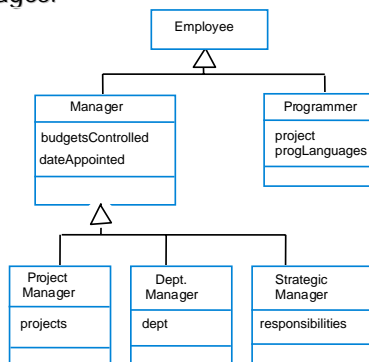
```
// Call the method associated with a  
// thermostat object that sets the  
// temperature to be maintained
```

```
thermostat.setTemp (20) ;
```

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## Generalization and inheritance

- Objects are members of classes that define attribute types and operations.
- Classes may be arranged in a class hierarchy where one class (a super-class) is a generalization of one or more other classes (sub-classes).
- A sub-class inherits the attributes and operations from its super class and may add new methods or attributes of its own.
- Generalization in the UML is implemented as inheritance in OO programming languages.



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## Inheritance

### Advantages

- It is an abstraction mechanism which may be used to classify entities.
- It is a reuse mechanism at both the design and the programming level.
- The inheritance graph is a source of organizational knowledge about domains and systems.

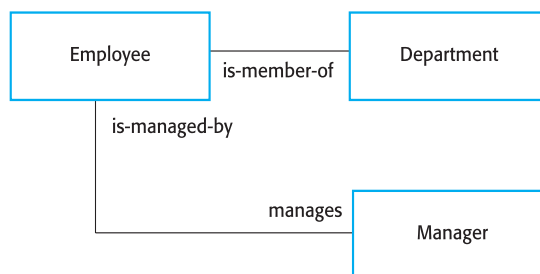
### Problems

- Object classes are not self-contained. they cannot be understood without reference to their super-classes.
- Designers have a tendency to reuse the inheritance graph created during analysis. Can lead to significant inefficiency.
- The inheritance graphs of analysis, design and implementation have different functions and should be separately maintained.

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## UML associations

- Objects and object classes participate in relationships with other objects and object classes.
- In the UML, a generalized relationship is indicated by an association.
- Associations may be annotated with information that describes the association.
- Associations are general but may indicate that an attribute of an object is an associated object or that a method relies on an associated object.



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## An object-oriented design process

- Structured 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 essential communication mechanism.
- Key activities without being tied to any proprietary process such as the RUP
  - 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.

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## Example: Weather system description

A **weather mapping system** is required to generate weather maps on a regular basis using data collected from remote, unattended weather stations and other data sources such as weather observers, balloons and satellites. Weather stations transmit their data to the area computer in response to a request from that machine.

The area computer system validates the collected data and integrates it with the data from different sources. The integrated data is archived and, using data from this archive and a digitized map database a set of local weather maps is created. Maps may be printed for distribution on a special-purpose map printer or may be displayed in a number of different formats.

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## System context and models of use

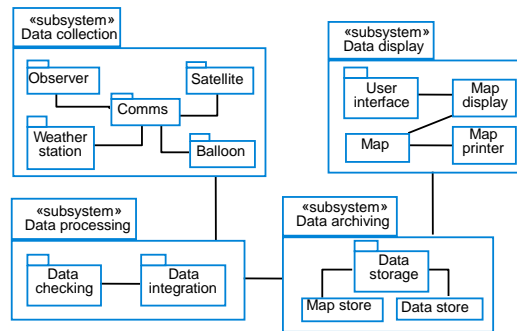
- Develop an understanding of the relationships between the software being designed and its external environment
- System context
  - A static model that describes other systems in the environment. Use a subsystem model to show other systems.
- Model of system use
  - A dynamic model that describes how the system interacts with its environment. Use use-cases to show interactions

Data display layer where objects are concerned with preparing and presenting the data in a human-readable form

Data archiving layer where objects are concerned with storing the data for future processing

Data processing layer where objects are concerned with checking and integrating the collected data

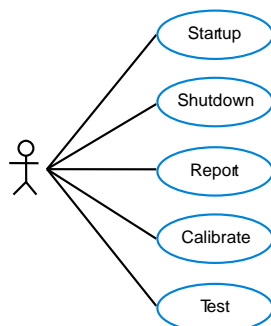
Data collection layer where objects are concerned with acquiring data from remote sources



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## Use-case models

- Use-case models are used to represent each interaction with the system.
- A use-case model shows the system features as ellipses and the interacting entity as a stick figure.

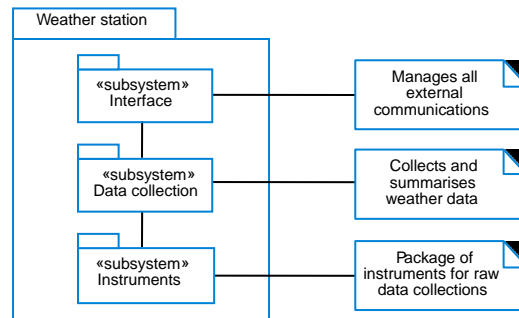


<b>System</b>	Weather station
<b>Use-case</b>	Report
<b>Actors</b>	Weather data collection system, Weather station
<b>Data</b>	The weather station sends a summary of the weather data that has been collected from the instruments in the collection period to the weather data collection system. The data 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 5 minute intervals.
<b>Stimulus</b>	The weather data collection system establishes a modem link with the weather station and requests transmission of the data.
<b>Response</b>	The summarised data is sent to the weather data collection system
<b>Comments</b>	Weather stations are usually asked to report once per hour but this frequency may differ from one station to the other and may be modified in future.

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## Architectural design

- Once interactions between the system and its environment have been understood, you use this information for designing the system architecture.
- A layered architecture as discussed in Chapter 11 is appropriate for the weather station
  - Interface layer for handling communications;
  - Data collection layer for managing instruments;
  - Instruments layer for collecting data.
- There should normally be no more than 7 entities in an architectural model.



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## Object identification

- Identifying objects (or object classes) is the most 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 identification
  - Use a grammatical approach based on a natural language description of the system (used in Hood OOD method).
  - Base the identification on tangible things in the application domain.
  - Use a behavioral approach and identify objects based on what participates in what behavior.
  - Use a scenario-based analysis. The objects, attributes and methods in each scenario are identified.

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## Example: Weather station description

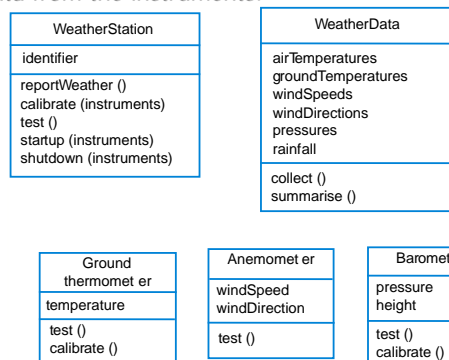
A **weather station** is a package of software controlled instruments which collects data, performs some data processing and transmits this data for further processing. The instruments include air and ground thermometers, an anemometer, a wind vane, a barometer and a rain gauge. Data is collected periodically.

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.

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## Weather station object classes

- Ground thermometer, Anemometer, Barometer
  - Application domain objects that are 'hardware' objects related to the instruments in the system.
- Weather station
  - The basic interface of the weather station to its environment. It therefore reflects the interactions identified in the use-case model.
- Weather data
  - Encapsulates the summarized data from the instruments.



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## Further objects and object refinement

- Use domain knowledge to identify more objects and operations
  - Weather stations should have a unique identifier;
  - Weather stations are remotely situated so instrument failures have to be reported automatically. Therefore attributes and operations for self-checking are required.
- Active or passive objects
  - In this case, objects are passive and collect data on request rather than autonomously. This introduces flexibility at the expense of controller processing time.

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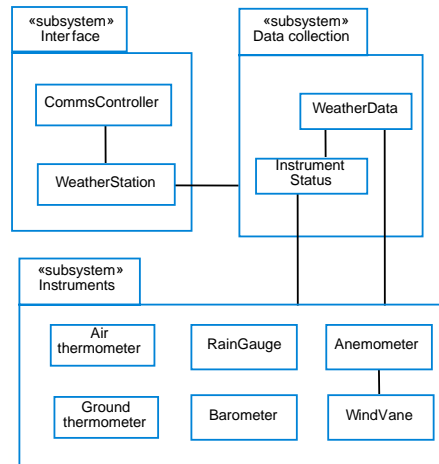
## Design models

- 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:
  - Sub-system 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.

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## Subsystem models

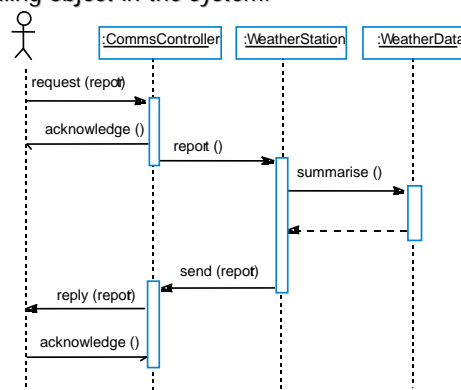
- Shows how the design is organized into logically related groups of objects.
- In the UML, these are shown using packages - an encapsulation construct. This is a logical model. The actual organization of objects in the system may be different.



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## Sequence models

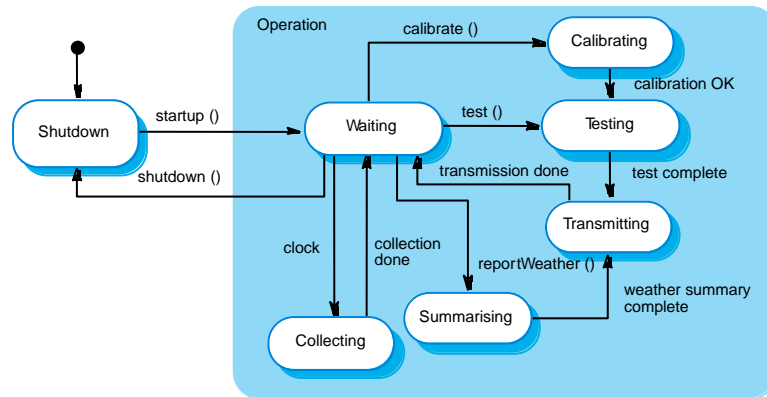
- Sequence models show the sequence of object interactions that take place
  - Objects are arranged horizontally across the top;
  - Time is represented vertically so models are read top to bottom;
  - Interactions are represented by labeled arrows, Different styles of arrow represent different types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



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## Statecharts

- Show how objects respond to different service requests and the state transitions triggered by these requests
  - If object state is Shutdown then it responds to a Startup() message;
  - In the waiting state the object is waiting for further messages;
  - If reportWeather () then system moves to summarizing state;
  - If calibrate () the system moves to a calibrating state;
  - A collecting state is entered when a clock signal is received.



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## Object 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.

```
interface WeatherStation {
    public void WeatherStation ();
    public void startup ();
    public void startup (Instrument i);
    public void shutdown ();
    public void shutdown (Instrument i);
    public void reportWeather ();
    public void test ();
    public void test (Instrument i);
    public void calibrate (Instrument i);
    public int getID ();
} //WeatherStation
```

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## Key points

- OOD is an approach to design so that design components have their own private state and operations.
- Objects should have constructor and inspection operations. They provide services to other objects.
- Objects may be implemented sequentially or concurrently.
- The Unified Modeling Language provides different notations for defining different object models.
- A range of different models may be produced during an object-oriented design process. These include static and dynamic system models.
- Object interfaces should be defined precisely using e.g. a programming language like Java.
- Object-oriented design potentially simplifies system evolution.