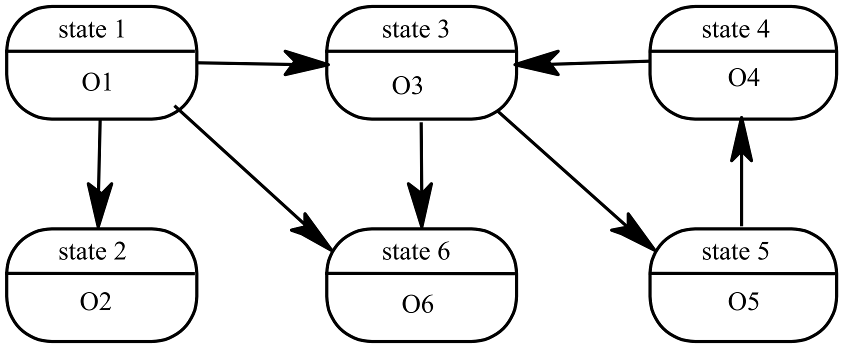
Object-oriented Design

- Designing systems using self-contained objects and object classes

Characteristics of OOD

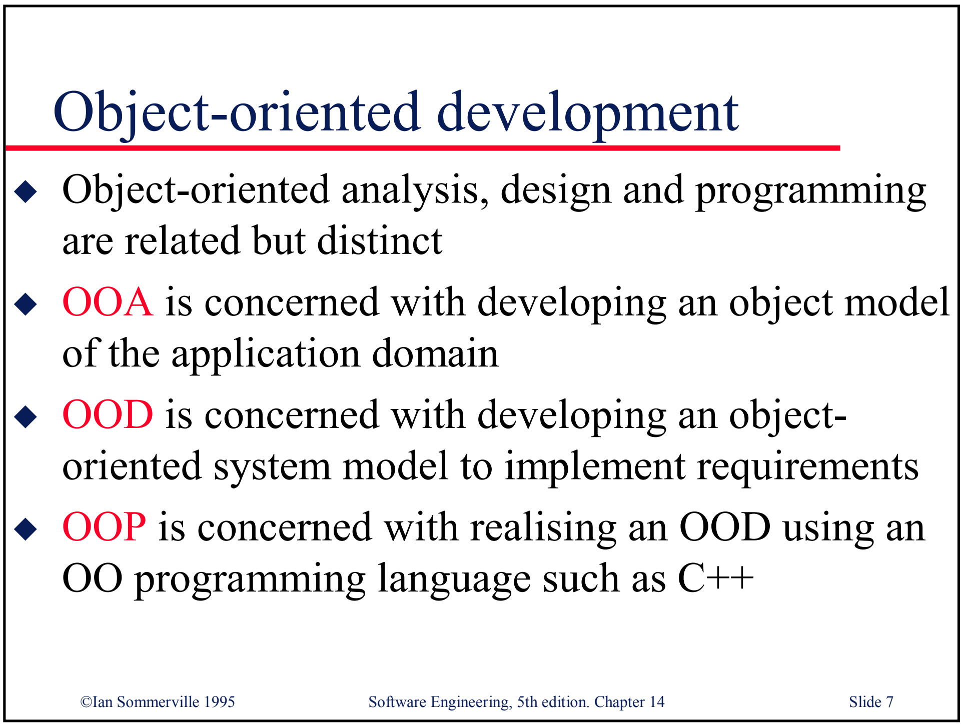
- Objects are abstractions of real-world or system entities and manage themselves
- Objects are independent and encapsulate state and representation information.
- System functionality is expressed in terms of object services
- Shared data areas are eliminated. Objects communicate by message passing
- Objects may be distributed and may execute sequentially or in parallel

OOD structure



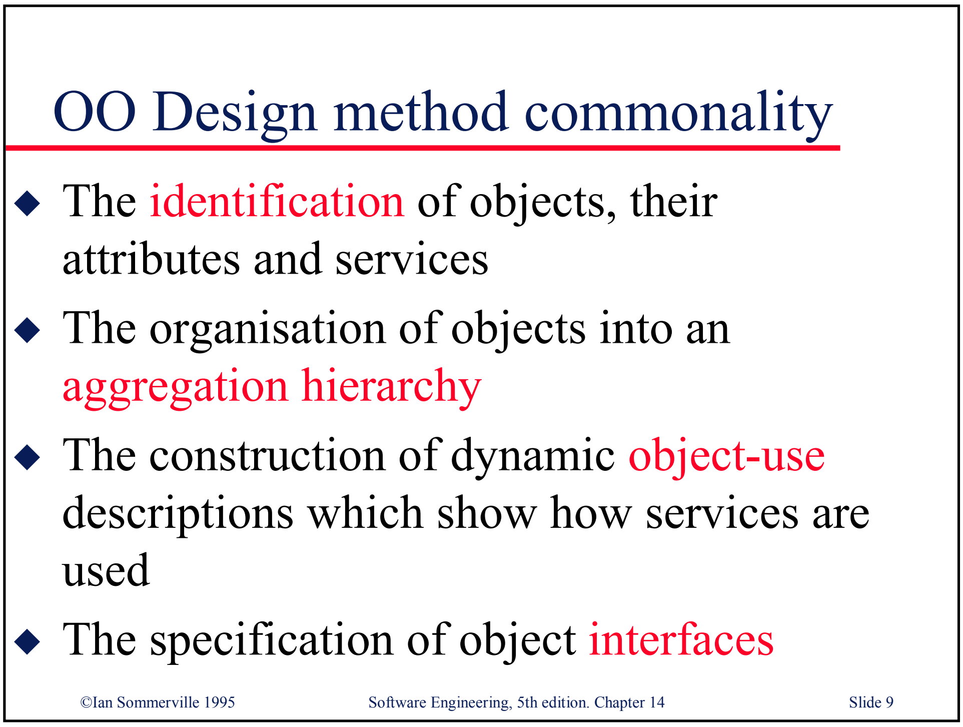
Advantages of OOD

- Easier maintenance. Objects may be understood as stand-alone entities
- Objects are appropriate reusable components
- For some systems, there may be an obvious mapping from real world entities to system objects



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 realising an OOD using an OO programming language such as C++



OO Design method commonality

- The identification of objects, their attributes and services
- The organisation of objects into an aggregation hierarchy
- The construction of dynamic object-use descriptions which show how services are used
- The specification of object interfaces

Objects, classes and inheritance

- **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

Objects

An **object** is an entity which 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.

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.

Message examples

- Call the printing service associated with lists to print the list L1

  List.Print (L1)

- Call the service associated with integer arrays which finds the maximum value of array XX. Return the result in Max_value

  IntArray.Max (XX, Max_value)

A mail message object class

- Replace with portrait slide

Interface design of mail message

```
package   Mail is
    type  MESSAGE  is private    ;
    -- Object operations
    procedure    Send (M: MESSAGE; Dest: DESTINATION) ;
    procedure    Present (M: MESSAGE; D: DEVICE) ;
    procedure    File (M: MESSAGE; File: FILENAME) ;
    procedure    Print (M: MESSAGE; D: DEVICE) ;

    -- Sender attribute
    function    Sender (M: MESSAGE)   return   MAIL_USER ;
    procedure    Put_sender (M:   in out   MESSAGE; Sender: MAIL_USER) ;
    -- Receiver attribute
    function    Receiver  (M: MESSAGE)   return   MAIL_USER ;
    procedure    Put_receiver (M:   in out   MESSAGE; Receiver: MAIL_USER) ;
    -- Access functions and Put operations for other attributes here
    ...
private
    -- The representation of the attributes is concealed by
    -- representing it as an access type. Details are inside the package body
    type  MAIL_MESSAGE_RECORD ;
    type  MESSAGE  is access      MAIL_MESSAGE_RECORD ;
end  Mail ;
```

Interface design of mail message

```
class Mail_message {
public:
        Mail_message () ;
        ~Mail_message () ;
        void Send () ;
        void File (char* filename) ;
        void Print (char* printer_name) ;
        void Present (char* device_name) ;
        char* Sender () ;
        void Put_sender (char* S) ;
        char* Receiver () ;
        void Put_receiver (char* R) ;
        // Other access and inspection functions here
private:
        char* sender, receiver, senderaddr, receiveraddr ;
        char* title, text ;
        date datesent, datereceived ;
} ;
```

Object definition

Ada

```
with  Mail ;
-- define an object of type mail message by declaring a
-- variable of the specified abstract data type
Office_memo: Mail.MESSAGE ;
-- Call an operation on mail message
Mail.Print (Office_memo, Laser_printer) ;
```

C++

```
-- define an object of type Mail_message
Mail_message Office_memo ;

// Call an operation on mail message
Office_memo.Print (“Laser_printer”) ;
```

Inheritance

- Objects are members of classes which define attribute types and operations
- Classes may be arranged in a class hierarchy where one class is derived from an existing class (super-class)
- A sub-class inherits the attributes and operations from its super class and may add new methods or attributes of its own

A class or type hierarchy

- Replace with portrait slide

Multiple inheritance

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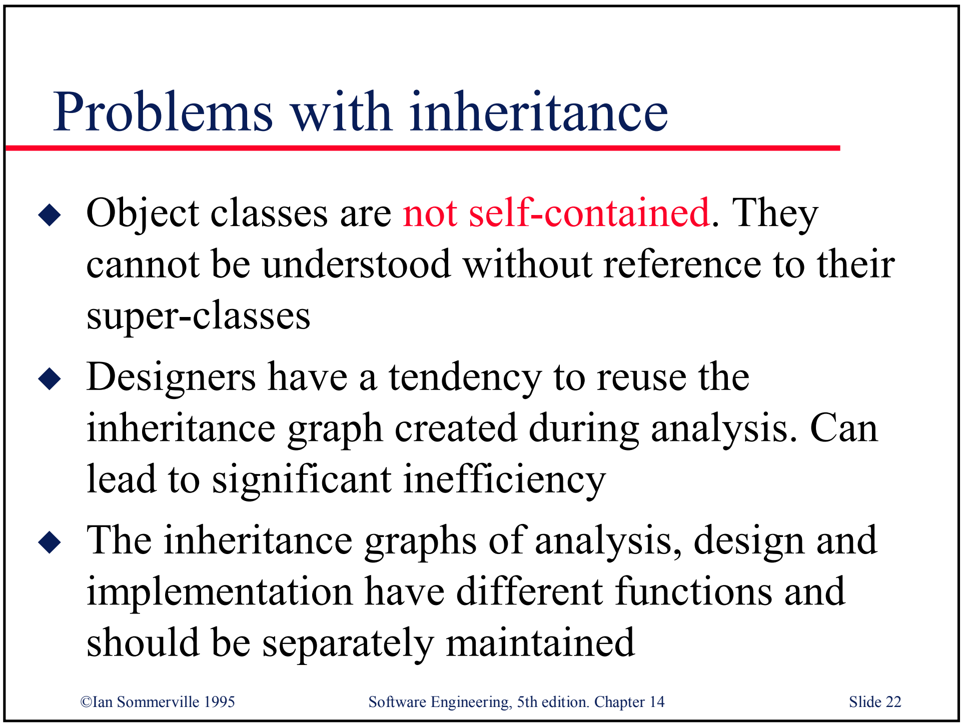
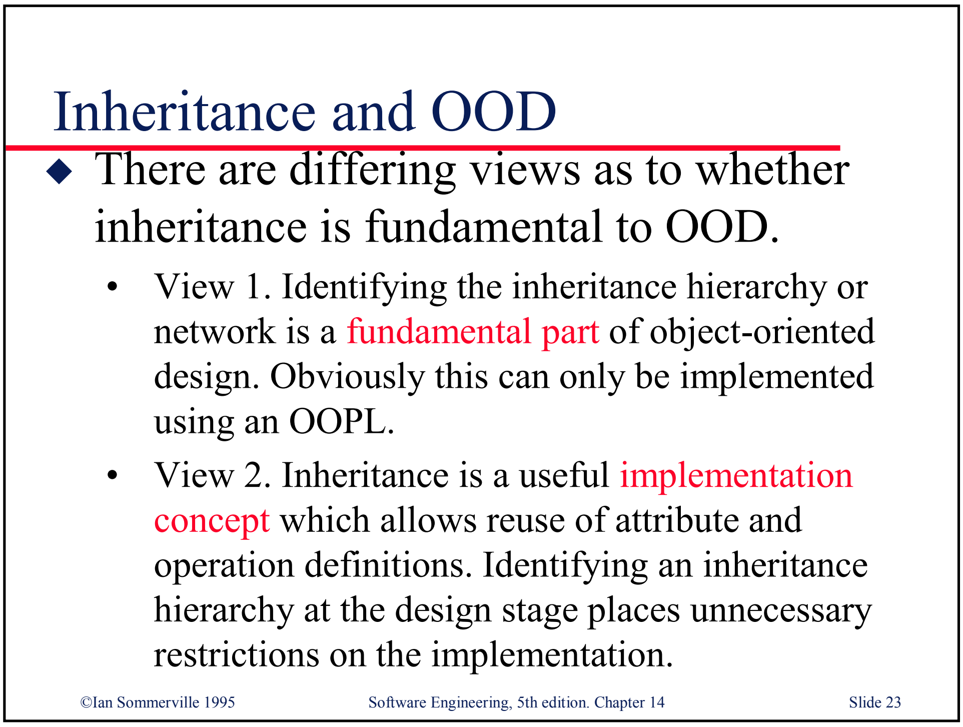
Advantages of inheritance

- 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 organisational knowledge about domains and systems



Problems with inheritance

- 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



Inheritance and OOD

- There are differing views as to whether inheritance is fundamental to OOD.
  - View 1. Identifying the inheritance hierarchy or network is a fundamental part of object-oriented design. Obviously this can only be implemented using an OOPL.
  - View 2. Inheritance is a useful implementation concept which allows reuse of attribute and operation definitions. Identifying an inheritance hierarchy at the design stage places unnecessary restrictions on the implementation.

Object identification

- Identifying objects 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 method)
- Base the identification on tangible things in the application domain
- Use a behavioural approach and identify objects based on what participates in what behaviour
- Use a scenario-based analysis. Used in the ObjectOry method

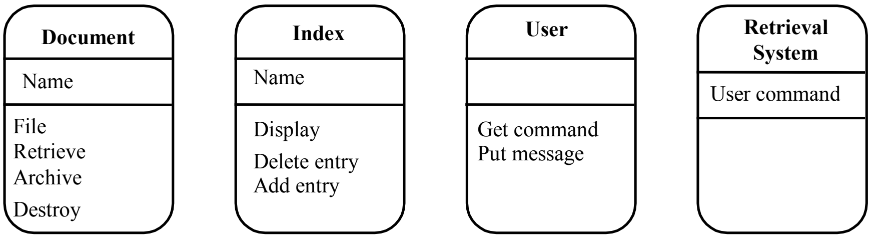
An office information system

The Office Information **Retrieval System** (OIRS) is an automatic file clerk which can *file* **documents** under some name in one or more **indexes**, *retrieve* **documents**, *display* and *maintain* **document indexes**, *archive* documents and *destroy* **documents.** The **system** is activated by a request from the **user** and always *returns* a message to the **user** indicating the success or failure of the request.

Objects and operations

- Nouns in the description give pointers to objects in the system
- Verbs give pointers to operations associated with objects
- Approach assumes that the designer has a common sense knowledge of the application domain as not all objects and services are likely to be mentioned in the description

Preliminary object identification



Document

Name

File
Retrieve
Archive
Destroy

Index

Name

Display
Delete entry
Add entry

User

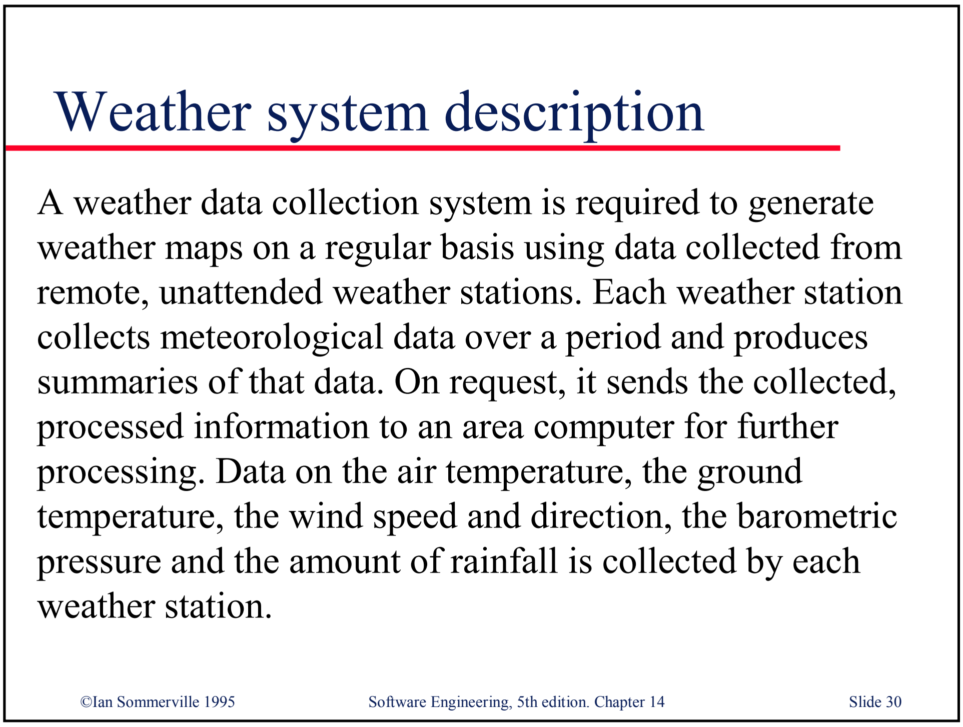
Get command
Put message

Retrieval System

User command

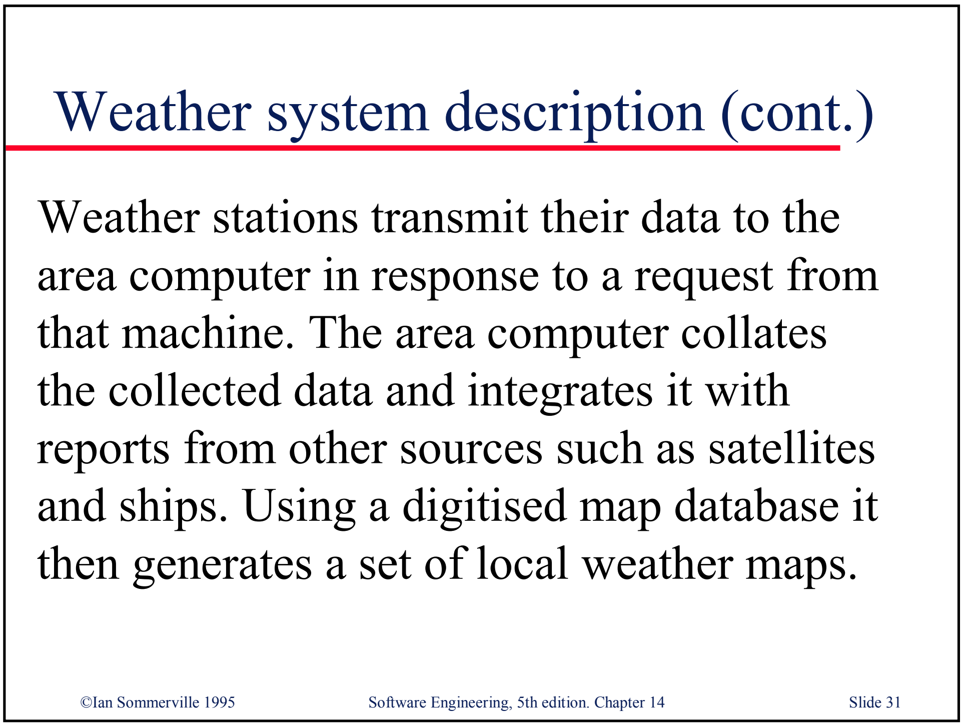
A weather mapping system

- Takes data from several remote weather stations which perform local data processing
- The data is transmitted to an area computer for further processing and integration with other weather reports
- Weather maps are generated by the area computer by combining the weather data with a map database



Weather system description

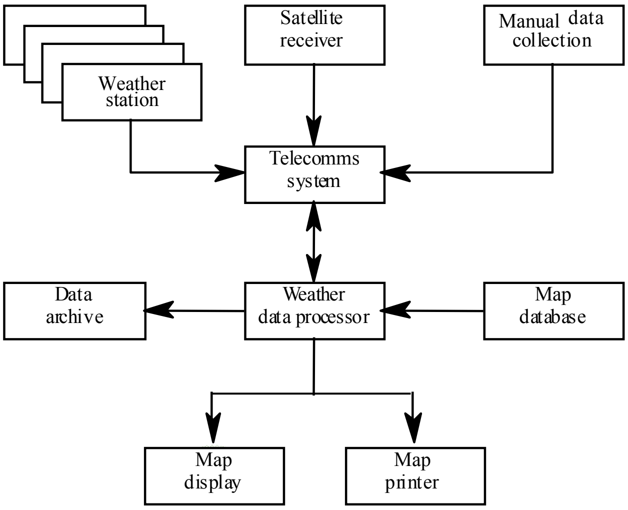
A weather data collection system is required to generate weather maps on a regular basis using data collected from remote, unattended weather stations. Each weather station collects meteorological data over a period and produces summaries of that data. On request, it sends the collected, processed information to an area computer for further processing. Data on the air temperature, the ground temperature, the wind speed and direction, the barometric pressure and the amount of rainfall is collected by each weather station.



Weather system description (cont.)

Weather stations transmit their data to the area computer in response to a request from that machine. The area computer collates the collected data and integrates it with reports from other sources such as satellites and ships. Using a digitised map database it then generates a set of local weather maps.

System architecture



Principal abstract objects

- Weather station
  - Package of instruments which collects data, performs some processing and transmits the data for further processing
- Map database
  - Database of survey information which allows maps to be generated at different scales
- Weather map
  - A representation of an area with superimposed, summarized weather information
- Weather data
  - Used to produce the map and is archived for future processing

Weather station description

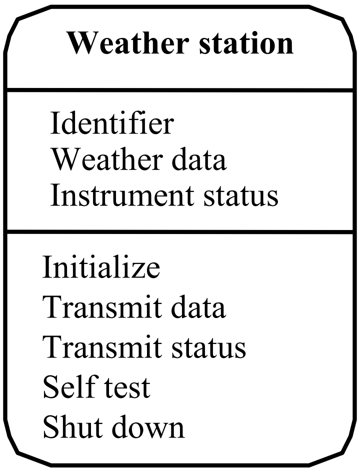
A weather station is a package of software controlled instruments which collects data, performs some data processing and transmits this data for further processing. The instruments include air and ground thermometers, an anemometer, a wind vane, a barometer and a rain gauge. Data is collected every five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

When a command is issued to transmit the weather data, the weather station processes and summarises the collected data. The summarised data is transmitted to the mapping computer when a request is received.

Weather station objects

- ◆ Identified objects
  - Air and ground thermometers, anemometer, wind vane, barometer, rain gauge. The package of instruments may also be an object
- ◆ Identified operations
  - Collect data, Perform data processing and Transmit Data
- ◆ Identified attributes
  - Summarized data
- ◆ This description is refined using domain knowledge e.g. a weather station must have a unique identifier

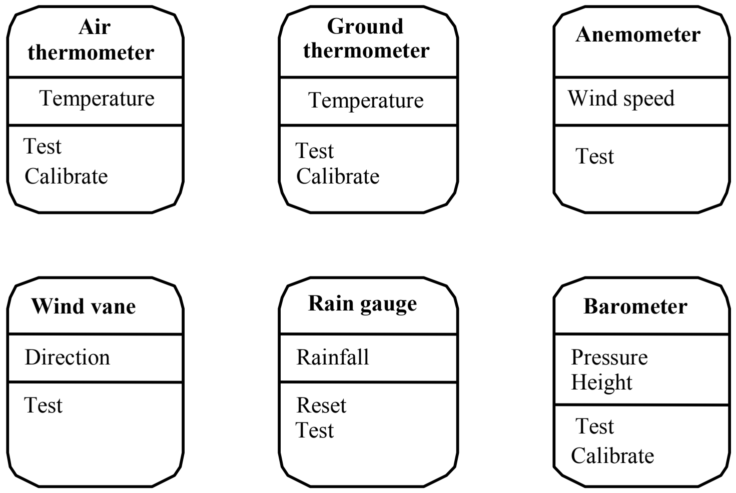
Weather station class



Hardware object design

- Hardware objects correspond directly to sensors or actuators connected to the system
- They conceal the details of the hardware control, e.g. buffer address, masking bit pattern etc.
- Hardware changes can often be introduced by hardware object re-implementation

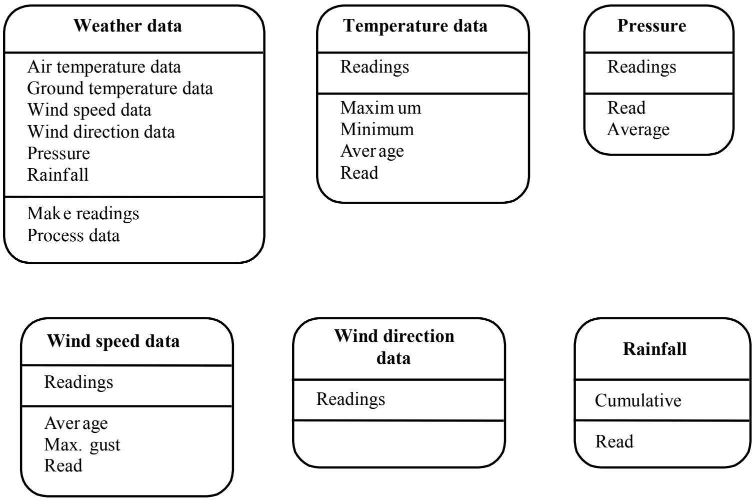
Hardware control objects



Data collected by weather station

- Air and ground temperature
  - Maximum, minimum and average
- Wind speed
  - Average speed, maximum gust speed
- Wind direction
  - Every 5 minutes during collection period
- Pressure
  - Average barometric pressure
- Rainfall
  - Cumulative rainfall

Weather data objects



Weather data

Air temperature data
Ground temperature data
Wind speed data
Wind direction data
Pressure
Rainfall

Make readings
Process data

Temperature data

Readings

Maximum
Minimum
Average
Read

Pressure

Readings

Read
Average

Wind speed data

Readings

Average
Max. gust
Read

Wind direction data

Readings

Rainfall

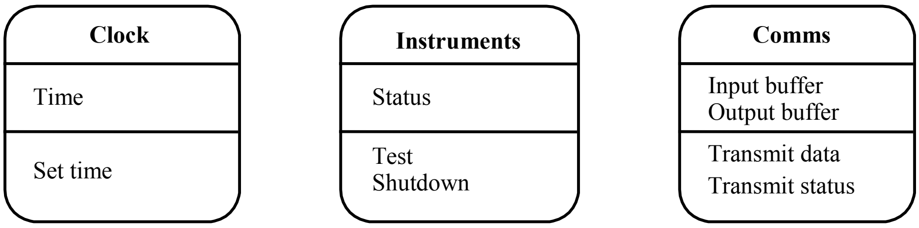
Cumulative

Read

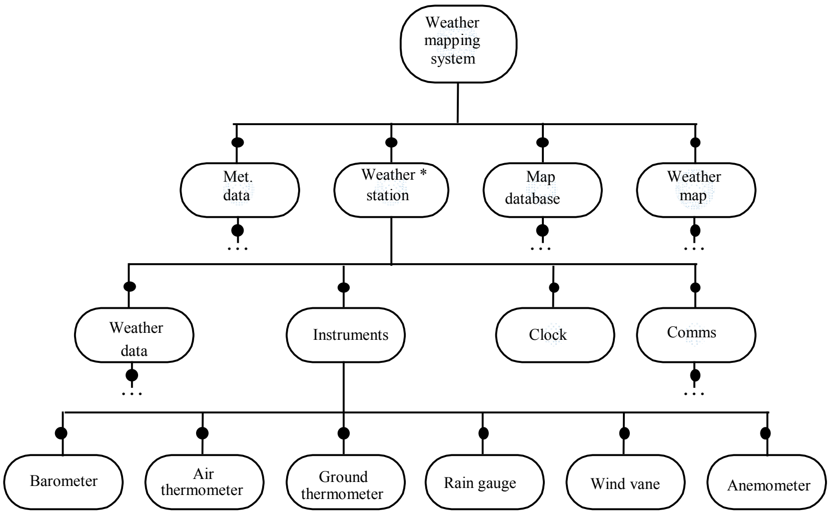
Weather data

- All weather data can be encapsulated in a single object. Logically, the weather station transmits a single object to the area computer
- The attributes of the weather data object are themselves objects
- The Process_data operation is initiated when weather information is to be transmitted. It computes the information required using raw collected data

Other weather station objects



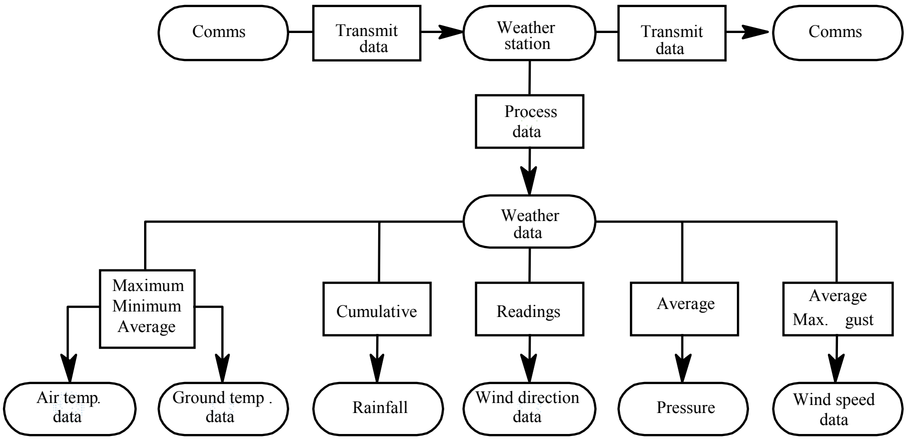
Object aggregation hierarchy



Static and dynamic system structure

- Object aggregation hierarchy diagrams show the static system structure. They illustrate objects and sub-objects. This is NOT the same as an inheritance hierarchy
- Object-service usage diagrams illustrate how objects use other objects. They show the messages passed (procedures called) between objects

Object interactions



Comms

Transmit data

Weather station

Transmit data

Comms

Process data

Weather data

Maximum Minimum Average

Cumulative

Readings

Average

Average Max. gust

Air temp. data

Ground temp . data

Rainfall

Wind direction data

Pressure

Wind speed data

Weather station object interactions

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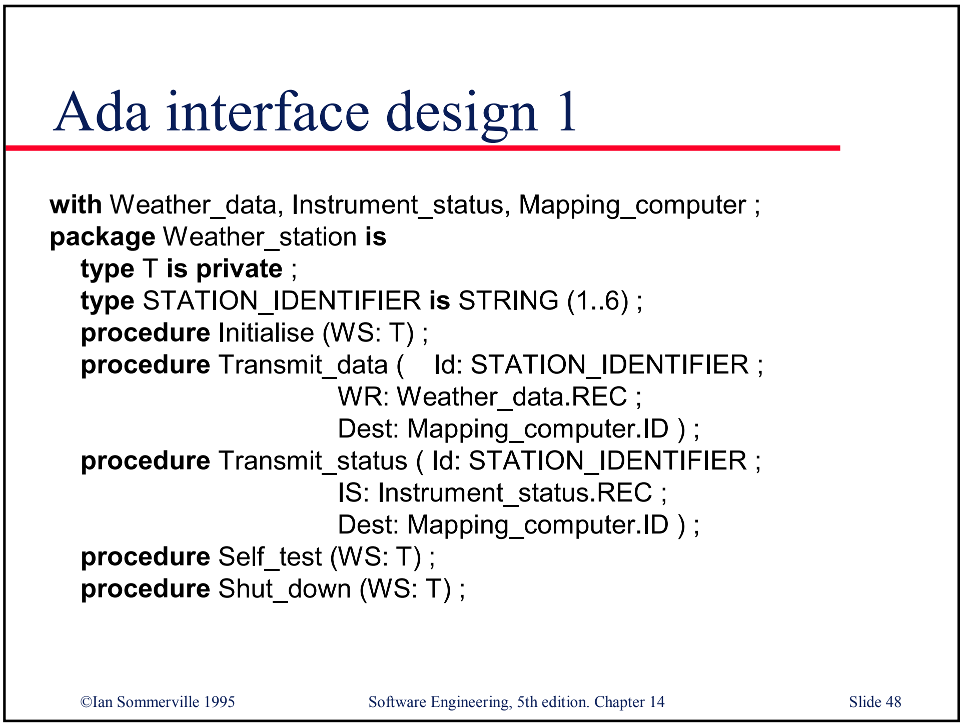
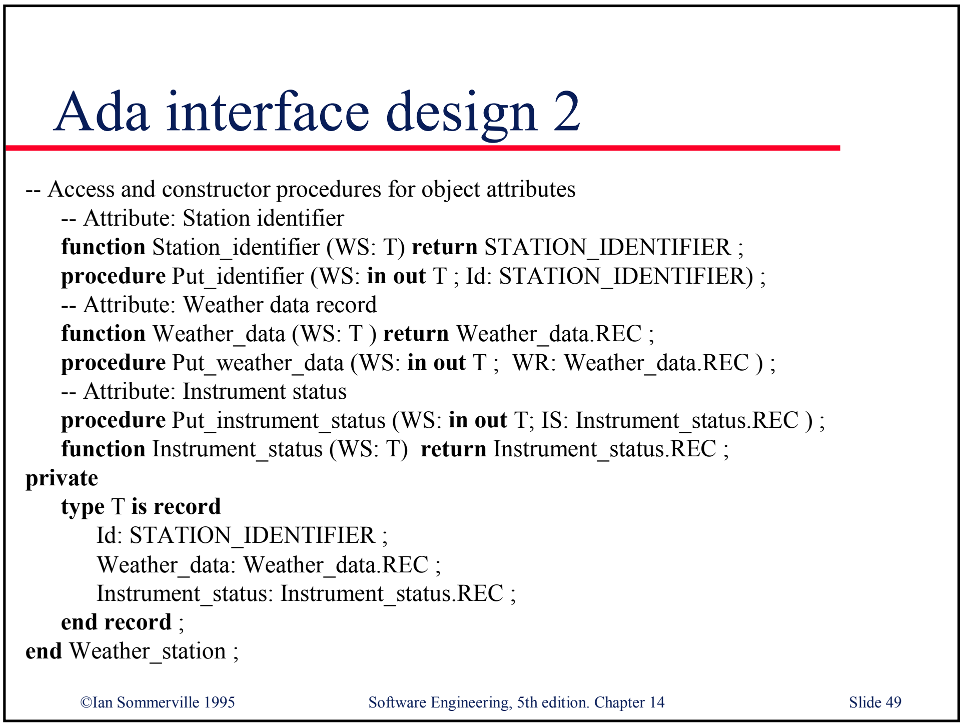
Object interface design

- Concerned with specifying the detail of the object interfaces. This means defining attribute types and the signatures and semantics of object operations
- Representation information should be avoided
- Precise specification is essential so a programming language description should be used



Ada interface design 1

```
with Weather_data, Instrument_status, Mapping_computer ;
package Weather_station is
   type T is private ;
   type STATION_IDENTIFIER is STRING (1..6) ;
   procedure Initialise (WS: T) ;
   procedure Transmit_data (    Id: STATION_IDENTIFIER ;
                               WR: Weather_data.REC ;
                               Dest: Mapping_computer.ID ) ;
   procedure Transmit_status ( Id: STATION_IDENTIFIER ;
                               IS: Instrument_status.REC ;
                               Dest: Mapping_computer.ID ) ;
   procedure Self_test (WS: T) ;
   procedure Shut_down (WS: T) ;
```



Ada interface design 2

```
-- Access and constructor procedures for object attributes
   -- Attribute: Station identifier
   function Station_identifier (WS: T) return STATION_IDENTIFIER ;
   procedure Put_identifier (WS: in out T ; Id: STATION_IDENTIFIER) ;
   -- Attribute: Weather data record
   function Weather_data (WS: T ) return Weather_data.REC ;
   procedure Put_weather_data (WS: in out T ;  WR: Weather_data.REC ) ;
   -- Attribute: Instrument status
   procedure Put_instrument_status (WS: in out T; IS: Instrument_status.REC ) ;
   function Instrument_status (WS: T)  return Instrument_status.REC ;
private
   type T is record
      Id: STATION_IDENTIFIER ;
      Weather_data: Weather_data.REC ;
      Instrument_status: Instrument_status.REC ;
   end record ;
end Weather_station ;
```

C++ interface design

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Java (少し違います 6th Editionより)

```
interface WeatherStation {
            public void Weather Station();
            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
```

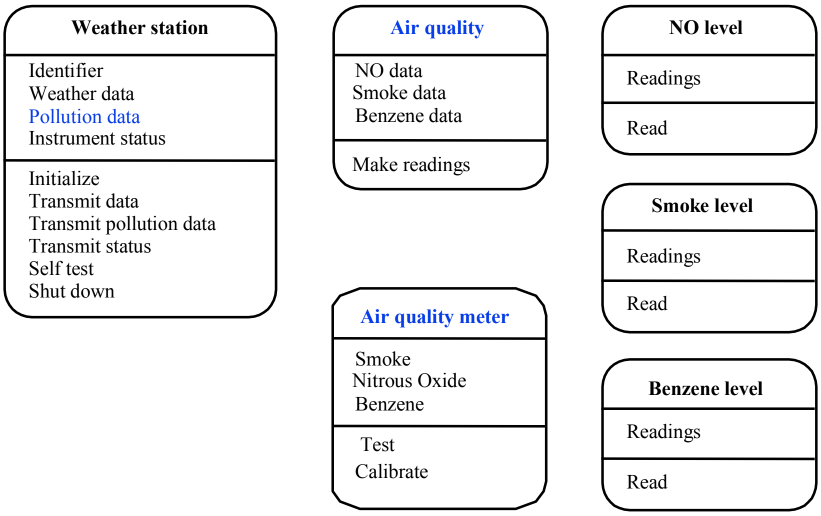
Design evolution

- Hiding information inside objects means that changes made to an object do not affect other objects in an unpredictable way
- Assume pollution monitoring facilities are to be added to weather stations. These sample the air and compute the amount of different pollutants in the atmosphere
- Pollution readings are transmitted with weather data

Changes required

- Add a Pollution record object.
- Add an operation Transmit pollution data to Weather station. Modify control software to collect pollution readings
- Add an Air quality sub-object to Pollution record at the same level as Pressure, Rainfall, etc.
- Add a hardware object Air quality meter
- Adding pollution data collection does NOT affect weather data collection in any way

Pollution monitoring objects



Weather station

Identifier
Weather data
Pollution data
Instrument status

Initialize
Transmit data
Transmit pollution data
Transmit status
Self test
Shut down

Air quality

NO data
Smoke data
Benzene data

Make readings

Air quality meter

Smoke
Nitrous Oxide
Benzene

Test
Calibrate

NO level

Readings

Read

Smoke level

Readings

Read

Benzene level

Readings

Read

Concurrent objects

- The nature of objects as self-contained entities make them suitable for concurrent implementation
- The message-passing model of object communication can be implemented directly if objects are running on separate processors in a distributed system

Object implementation

- C++ has no built-in concurrency constructs
- Ada’s concurrency constructs (tasks) may be used to implement concurrent objects
- Task types represent object classes, tasks represent object instances, task entries represent object operations.
- Task entries are called like procedures

Active and passive objects

- Passive objects.
  - The object is implemented as a parallel process (server) with entry points corresponding to object operations. If no calls are made to it, the object suspends itself
- Active objects
  - Objects are implemented as parallel processes and the internal object state may be changed by the object itself and not simply by external calls