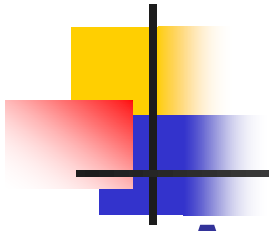
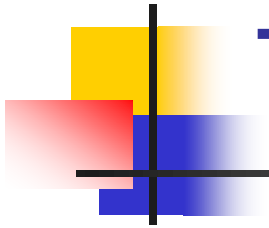


Aspect-oriented Software Development



Topics covered

- **The separation of concerns**
- **Aspects, join points and pointcuts**
- **Software engineering with aspects**

The separation of concerns

- The principle of separation of concerns states that software should be organized so that each program element does one thing and one thing only.
- Each program element should therefore be understandable without reference to other elements.
- Program abstractions (subroutines, procedures, objects, etc.) support the separation of concerns.

Example : Security concern

- Consider the problem of enforcing a security policy in some application.
- By its nature, security cuts across many of the natural units of modularity of the application.
- Moreover, the security policy must be uniformly applied to any additions as the application evolves.
- And the security policy that is being applied might itself evolve.
- Capturing concerns like a security policy in a disciplined way is difficult in a traditional programming language.

crosscutting concerns

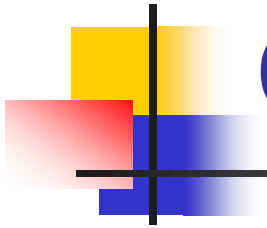
- Concerns like security cut across the natural units of modularity.
- For object-oriented programming languages, the natural unit of modularity is the class.
- But in object-oriented programming languages, crosscutting concerns are not easily turned into classes precisely because they cut across classes,
- and so these aren't reusable, they can't be refined or inherited, they are spread through out the program in an undisciplined way,
- in short, they are difficult to work with.

Aspect-oriented programming <> Object-oriented programming

- Aspect-oriented programming is a way of modularizing crosscutting concerns much
- Object-oriented programming is a way of modularizing common concerns.

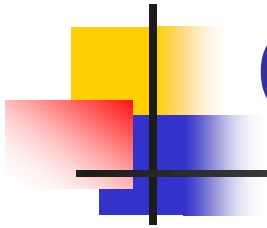
Aspect-oriented software development

- An approach to software development based around a new type of abstraction - an aspect.
- Used in conjunction with other approaches - normally object-oriented software engineering.
- Aspects encapsulate functionality that cross-cuts and co-exists with other functionality.
- Aspects include a definition of where they should be included in a program as well as code implementing the cross-cutting concern.



Concerns

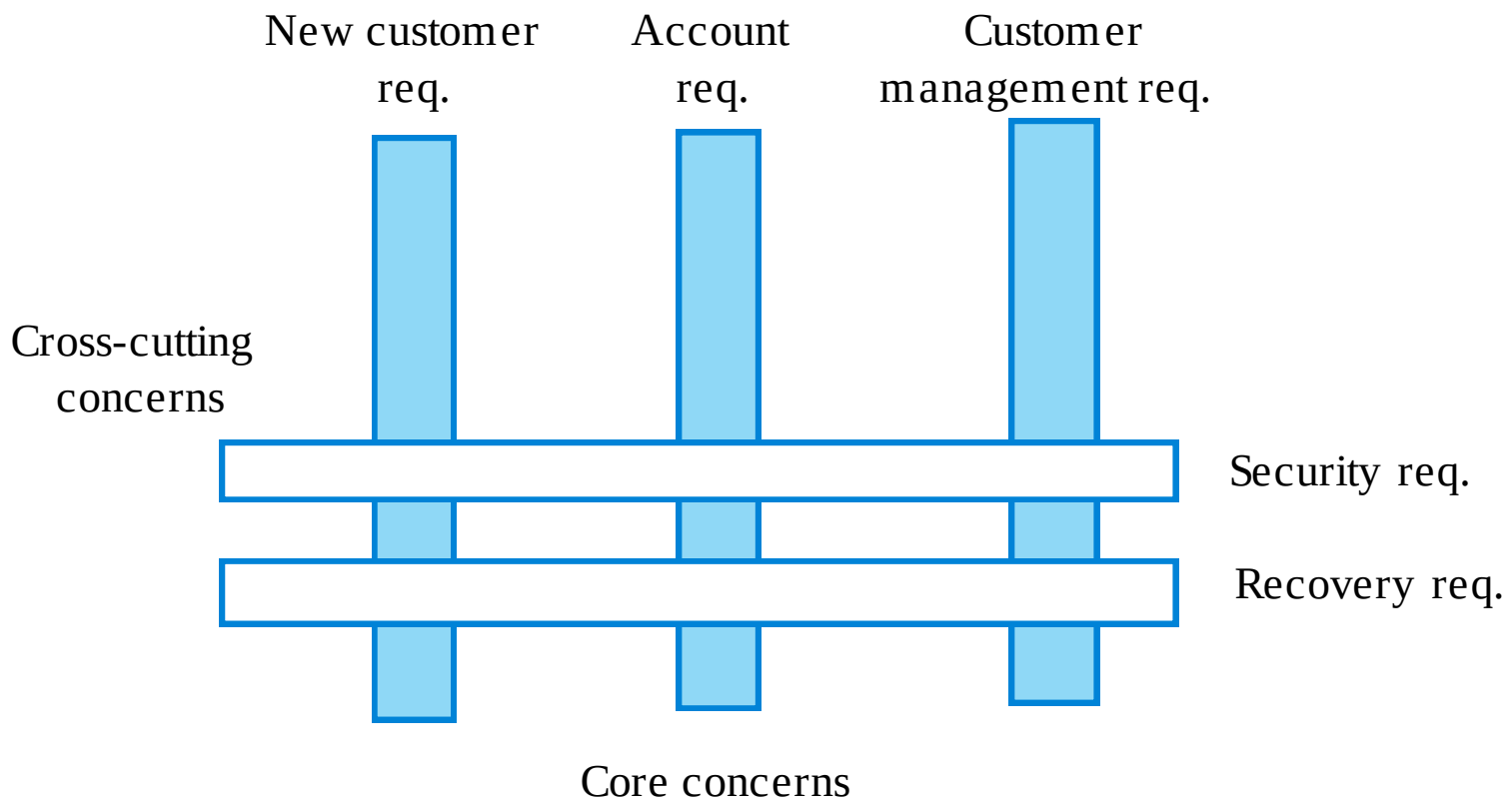
- Concerns are not program issues but reflect the system requirements and the priorities of the system stakeholders.
  - Examples of concerns are performance, security, specific functionality, etc.
- By reflecting the separation of concerns in a program, there is clear traceability from requirements to implementation.
- Core concerns are the functional concerns that relate to the primary purpose of a system; secondary concerns are functional concerns that reflect non-functional and QoS requirements.



Cross-cutting concerns

- Cross-cutting concerns are concerns whose implementation cuts across a number of program components.
- This results in problems when changes to the concern have to be made - the code to be changed is not localised but is in different places across the system.
- Cross cutting concerns lead to tangling and scattering.

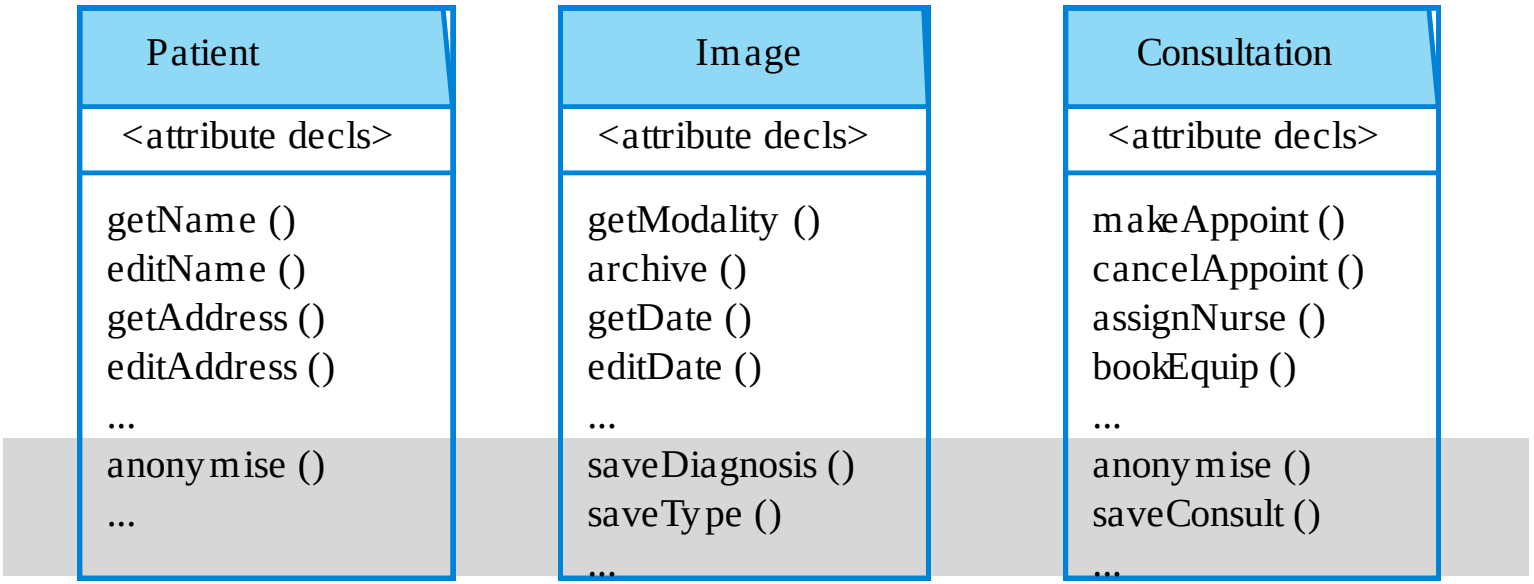
Cross-cutting concerns



Tangling

```
synchronized void put (SensorRecord rec ) throws InterruptedException
    {
        if ( numberOfEntries == bufsize)
            wait () ;
        store [back] = new SensorRecord (rec.sensorId, rec.sensorVal) ;
        back = back + 1 ;
        if (back == bufsize)
            back = 0 ;
        numberOfEntries= numberOfEntries + 1 ;
        notify() ;
    } // put
```

Scattering


Patient
<attribute decls>
getName ()
editName ()
getAddress ()
editAddress ()
...
anonymise ()
...
Image
<attribute decls>
getModality ()
archive ()
getDate ()
editDate ()
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saveDiagnosis ()
saveType ()
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Consultation
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assignNurse ()
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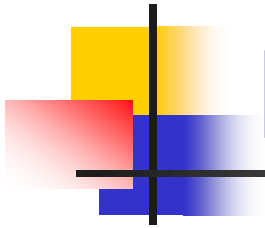
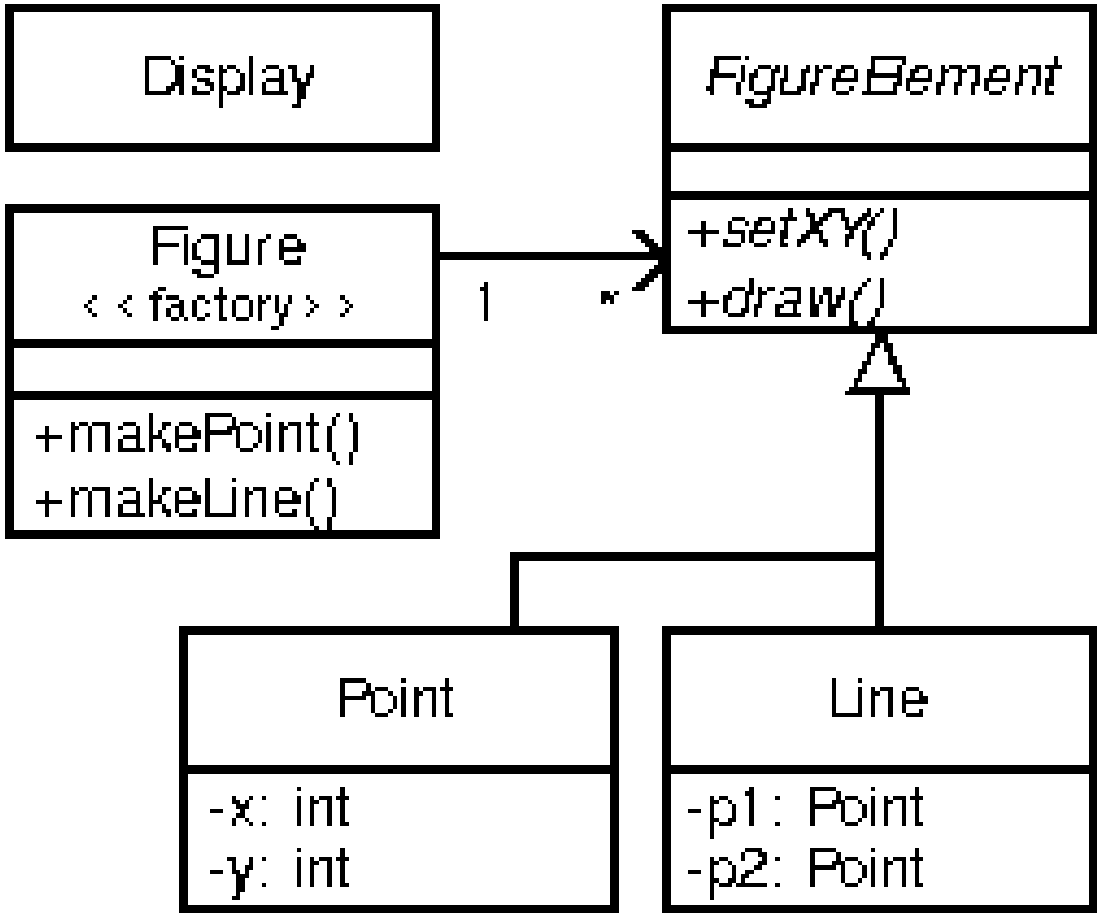
Aspects, join points and pointcuts

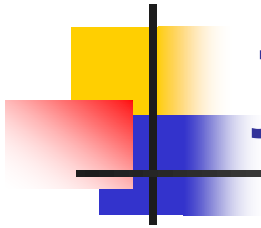


- An **aspect** is an abstraction which implements a concern. It includes information where it should be included in a program.
- A **join point** is a place in a program where an aspect may be included (woven).
- A **pointcut** defines where (at which join points) the aspect will be included in the program.

Aspects, join points and pointcuts



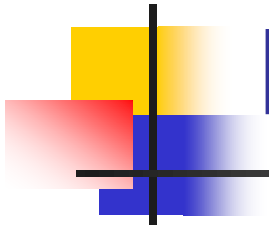
join points and pointcuts



- Each method call at runtime is a different join point, even if it comes from the same call expression in the program.
- pointcuts identifies the specific events with which advice should be associated.
  - Examples of contexts where advice can be woven into a program
    - Before the execution of a specific method
    - After the normal or exceptional return from a method
    - When a field in an object is modified

join point model

- Call events
  - Calls to a method or constructor
- Execution events
  - Execution of a method or constructor
- Initialisation events
  - Class or object initialisation
- Data events
  - Accessing or updating a field
- Exception events
  - The handling of an exception

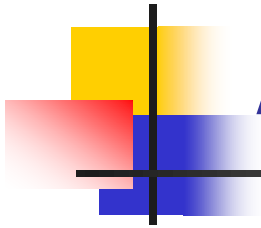


Pointcuts

- call(void Point.setX(int))
- call(void Point.setX(int)) || call(void Point.setY(int))
- call(void FigureElement.setXY(int,int)) ||
  call(void Point.setX(int)) ||
  call(void Point.setY(int)) ||
  call(void Line.setP1(Point)) ||
  call(void Line.setP2(Point));

join points and pointcuts

- pointcut move():
  call(void FigureElement.setXY(int,int)) ||
  call(void Point.setX(int)) ||
  call(void Point.setY(int)) ||
  call(void Line.setP1(Point)) ||
  call(void Line.setP2(Point));
- call(void Figure.make*(..))
- call(public * Figure.* (..))



Advice

- before(): move() {
  System.out.println("about to move");
  }

- after() returning: move() {
  System.out.println("just successfully moved");
  }

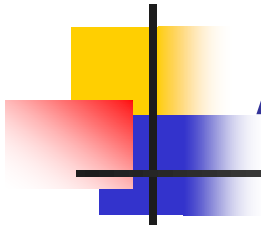
Aspect-Example

```
aspect PointBoundsChecking {
    pointcut setX(int x):
        (call(void FigureElement.setXY(int, int)) && args(x, *))
        || (call(void Point.setX(int)) && args(x));

    pointcut setY(int y):
        (call(void FigureElement.setXY(int, int)) && args(*, y))
        || (call(void Point.setY(int)) && args(y));

    before(int x): setX(x) {
        if ( x < MIN_X || x > MAX_X )
            throw new IllegalArgumentException("x is out of bounds.");
    }
    before(int y): setY(y) {
        if ( y < MIN_Y || y > MAX_Y )
            throw new IllegalArgumentException("y is out of bounds.");
    }
}
```

Advice

- pointcut setXY(FigureElement fe, int x, int y):
  call(void FigureElement.setXY(int, int))
  && target(fe)
  && args(x, y);

- after(FigureElement fe, int x, int y) returning:
  setXY(fe, x, y) {
  System.out.println(fe + " moved to (" + x + ", " + y + ").");
  }

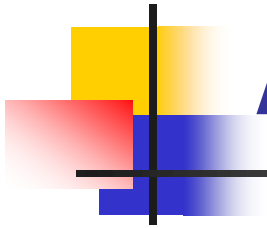


Aspect

```
aspect Logging {
    OutputStream logStream = System.err;

    before(): move() {
        logStream.println("about to move");
    }
}
```

An authentication aspect

```
aspect authentication
{
    before: call (public void update* (..))   // this is a pointcut
    {
        // this is the advice that should be executed when woven into
        // the executing system
        int tries = 0 ;
        string userPassword = Password.Get ( tries ) ;
        while (tries < 3 && userPassword != thisUser.password ( ) )
        {
            // allow 3 tries to get the password right
            tries = tries + 1 ;
            userPassword = Password.Get ( tries ) ;
        }
        if (userPassword != thisUser.password ( )) then
            //if password wrong, assume user has forgotten to logout
            System.Logout (thisUser.uid) ;
    }
} // authentication
```

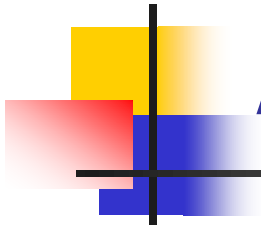


Aspect

```
aspect PointObserving {
    private Vector Point.observers = new Vector();
    public static void addObserver(Point p, Screen s) {
        p.observers.add(s);
    }
    public static void removeObserver(Point p, Screen s) {
        p.observers.remove(s);
    }

    pointcut changes(Point p): target(p) && call(void Point.set*(int));
    after(Point p): changes(p) {
        Iterator iter = p.observers.iterator();
        while ( iter.hasNext() ) {
            updateObserver(p, (Screen)iter.next());
        }
    }

    static void updateObserver(Point p, Screen s) {
        s.display(p);
    }
}
```

Aspect terminology

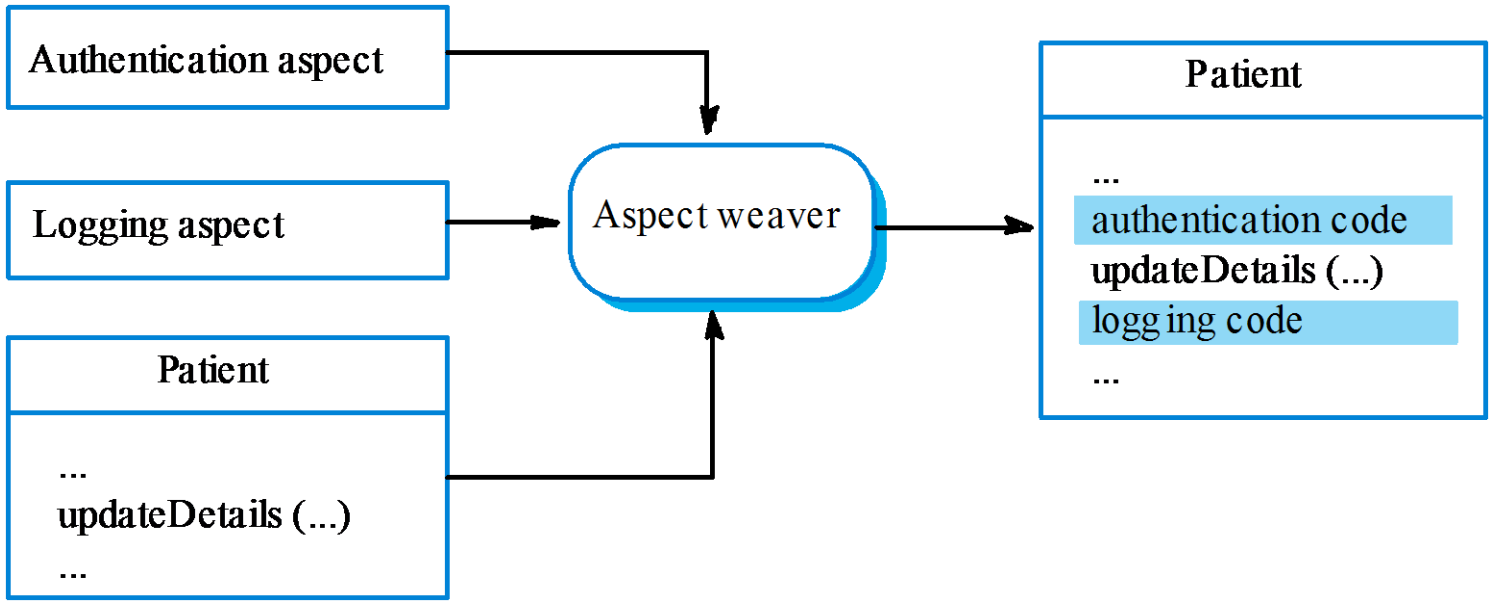
Term	Definition
advice	The code implementing a concern.
aspect	A program abstraction that defines a cross-cutting concern. It includes the definition of a pointcut and the advice associated with that concern.
join point	An event in an executing program where the advice associated with an aspect may be executed.
join point model	The set of events that may be referenced in a pointcut.
pointcut	A statement, included in an aspect, that defines the join points where the associated aspect advice should be executed.
weaving	The incorporation of advice code at the specified join points by an aspect weaver.



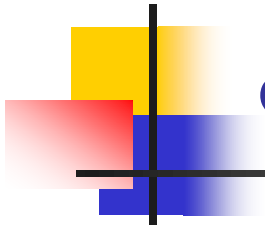
Aspect weaving

- Aspect weavers process source code and weave the aspects into the program at the specified pointcuts.
- Three approaches to aspect weaving
  - Source code pre-processing
  - Link-time weaving
  - Dynamic, execution-time weaving

Aspect weaving

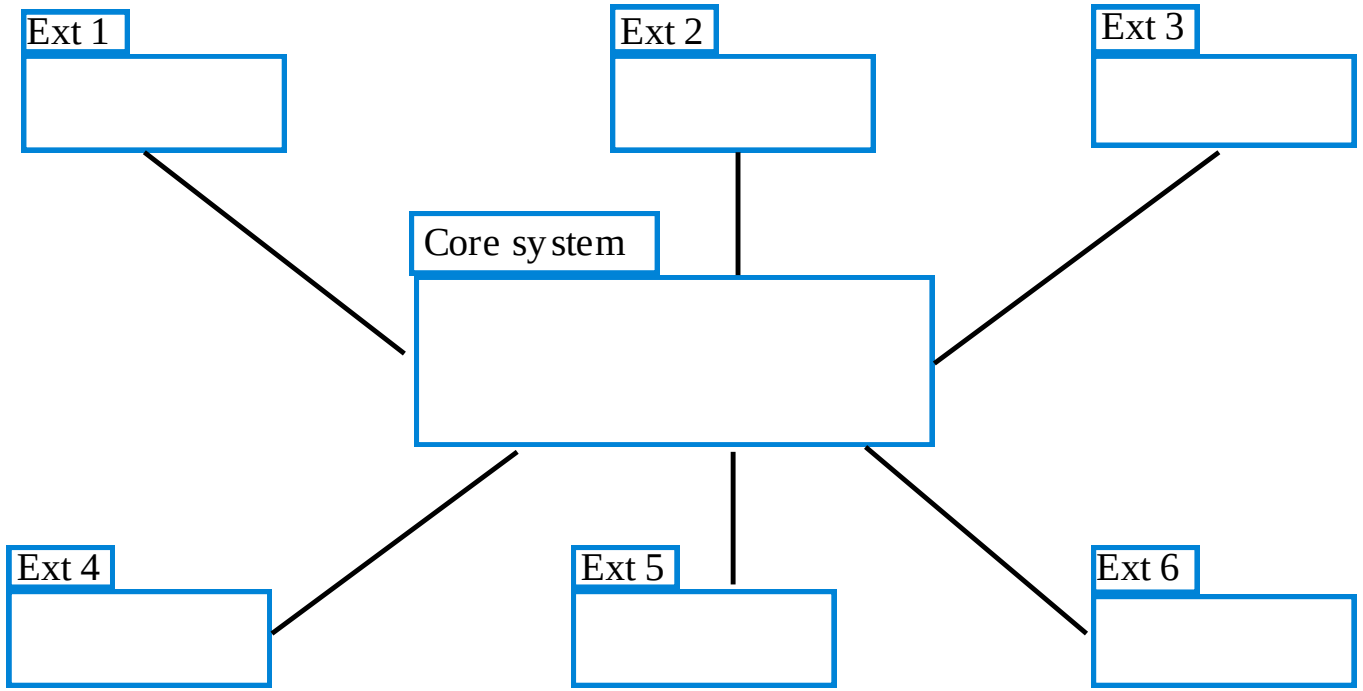


Software engineering with aspects



- Aspects were introduced as a programming concept but, as the notion of concerns comes from requirements, an aspect oriented approach can be adopted at all stages in the system development process.
- The architecture of an aspect-oriented system is based around a core system plus extensions.
- The core system implements the primary concerns. Extensions implement secondary and cross-cutting concerns.

Core system + extensions



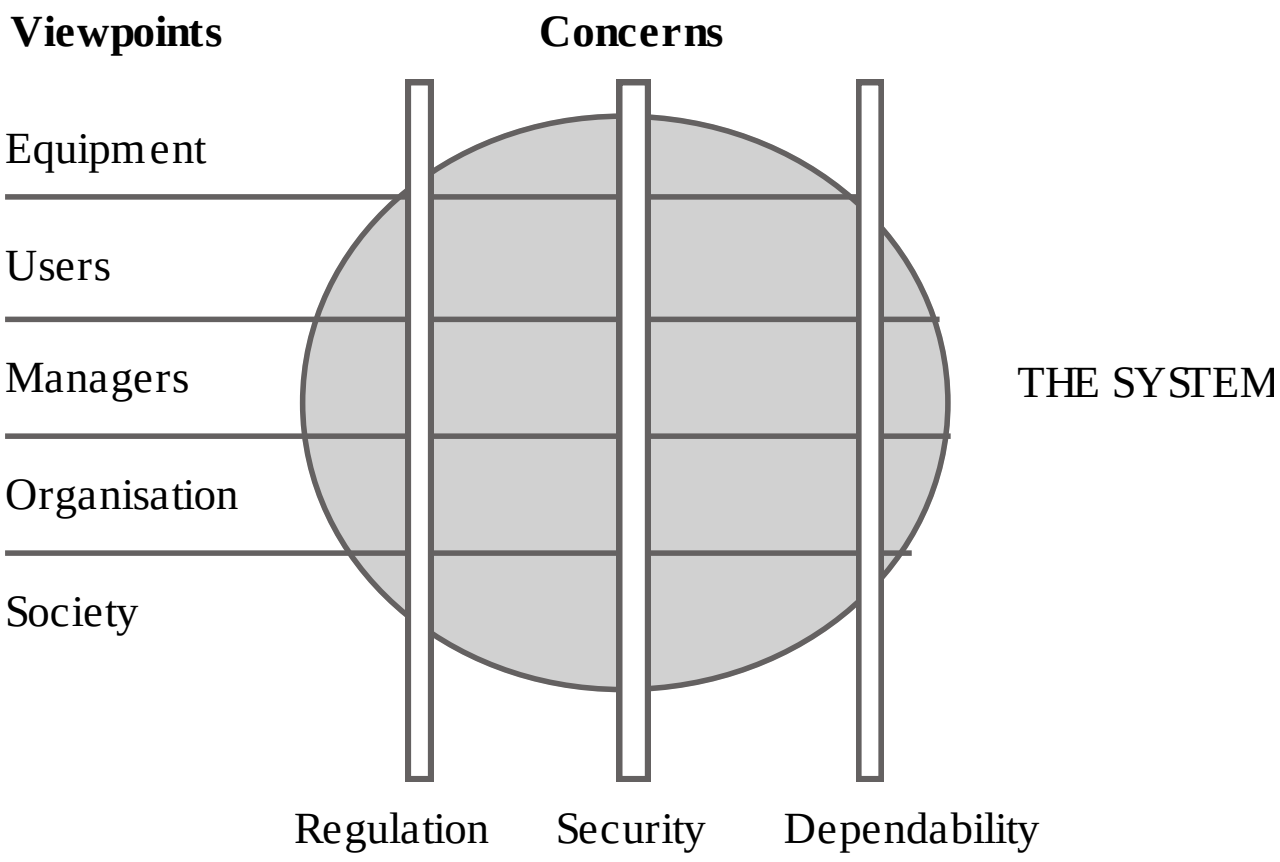
Types of extension

- Secondary functional extensions
  - Add extra functional capabilities to the core system
- Policy extensions
  - Add functional capabilities to support an organisational policy such as security
- QoS extensions
  - Add functional capabilities to help attain quality of service requirements
- Infrastructure extensions
  - Add functional capabilities to support the implementation of the system on some platform

Concern-oriented requirements engineering

- An approach to requirements engineering that focuses on customer concerns is consistent with aspect-oriented software development.
- Viewpoints are a way to separate the concerns of different stakeholders.
- Viewpoints represent the requirements of related groups of stakeholders.
- Cross-cutting concerns are concerns that are identified by all viewpoints.

Viewpoints and Concerns



Viewpoints on an inventory system

1. **Emergency service users**

1.1 Find a specified type of equipment (e.g. heavy lifting gear)
1.2 View equipment available in a specified store
1.3 Check-out equipment
1.4 Check-in equipment
1.5 Arrange equipment to be transported to emergency
1.6 Submit damage report
1.7 Find store close to emergency

2. **Emergency planners**

2.1 Find a specified type of equipment
2.2 View equipment available in a specified location
2.3 Add and remove equipment from a store
2.4 Move equipment from one store to another
2.6 Order new equipment

3. **Maintenance staff**

3.1 Check-in/Check-out equipment for maintenance
3.2 View equipment available at each store
3.3 Find a specified type of equipment
3.4 View maintenance schedule for an equipment item
3.5 Complete maintenance record for an equipment item
3.6 Show all items in a store requiring maintenance

Availability requirements

AV.1 There shall be a 'hot standby' system available in a location that is geographically well-separated from the principal system.

Rationale: The emergency may affect the principal location of the system.

AV.1.1 All transactions shall be logged at the site of the principal system and at the remote standby site.

Rationale: This allows these transactions to be replayed and the system databases made consistent

AV.1.2 The system shall send status information to the emergency control room system every five minutes

Rationale: The operators of the control room system can switch to the hot standby if the principal system is unavailable.

Inventory system - core requirements

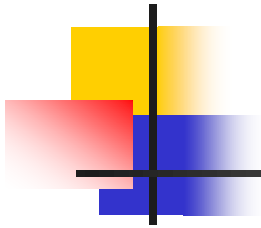
- C.1 The system shall allow authorised users to view the description of any item of equipment in the emergency services inventory.
- C.2 The system shall include a search facility to allow authorised users to search either individual inventories or the complete inventory for a specific item or type of equipment.

Inventory system - extension requirements

- E1.1 It shall be possible for authorised users to place orders with accredited suppliers for replacement items of equipment.
- E1.1.1 When an item of equipment is ordered, it should be allocated to a specific inventory and flagged in that inventory as ‘on order’.

Aspect-oriented design/programming

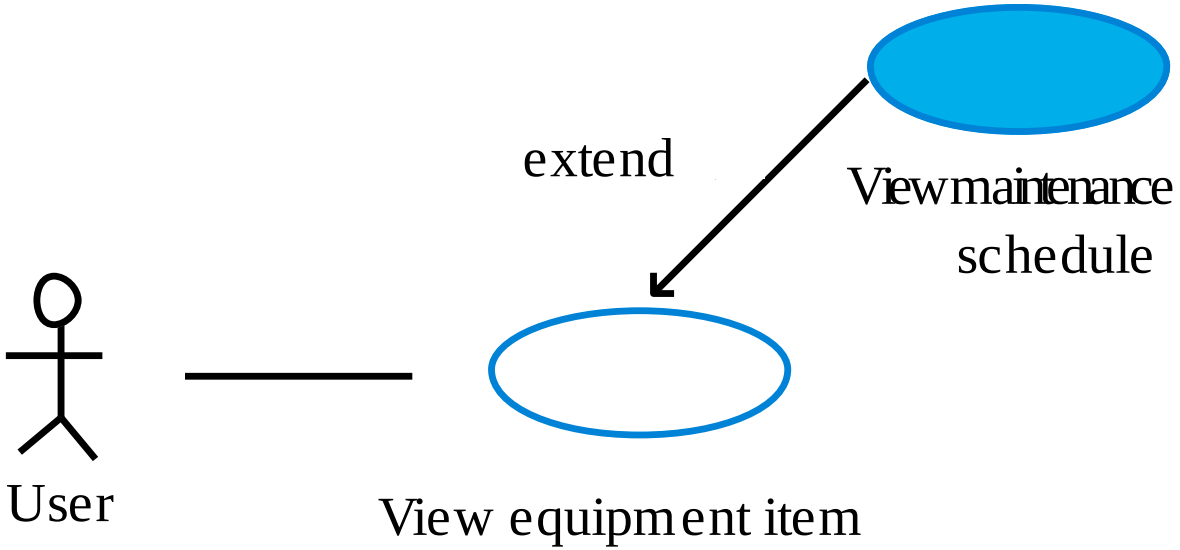
- Aspect-oriented design
  - The process of designing a system that makes use of aspects to implement the cross-cutting concerns and extensions that are identified during the requirements engineering process.
- Aspect-oriented programming
  - The implementation of an aspect-oriented design using an aspect-oriented programming language such as AspectJ.



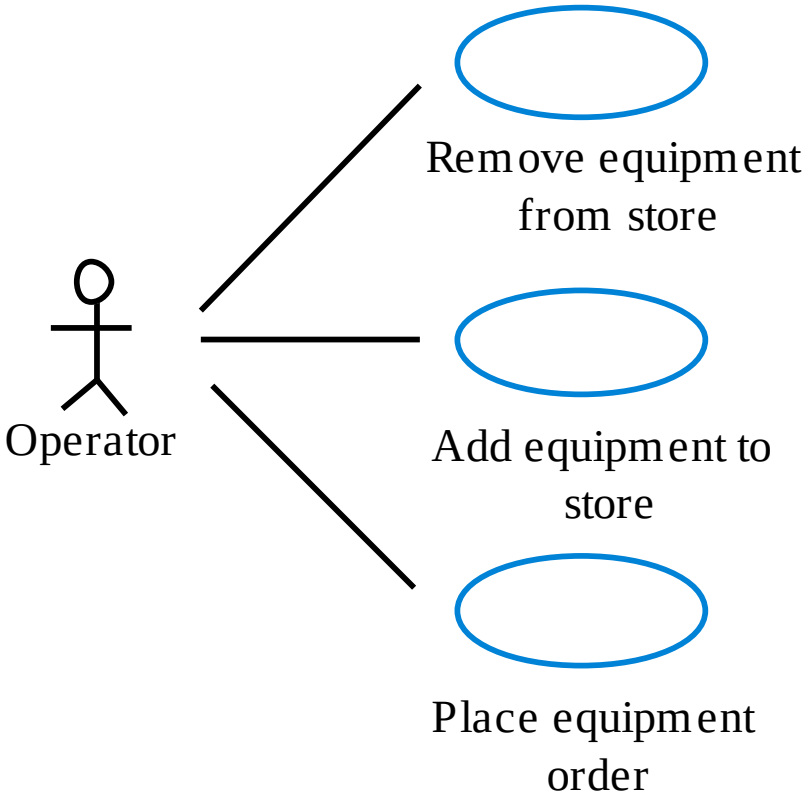
Use-cases

- A use-case approach can serve as a basis for aspect-oriented software engineering.
- Each use case represents an aspect.
  - Extension use cases naturally fit the core + extensions architectural model of a system
- Jacobsen and Ng develop these ideas of using use-cases by introducing new concepts such as use-case slices and use case modules.

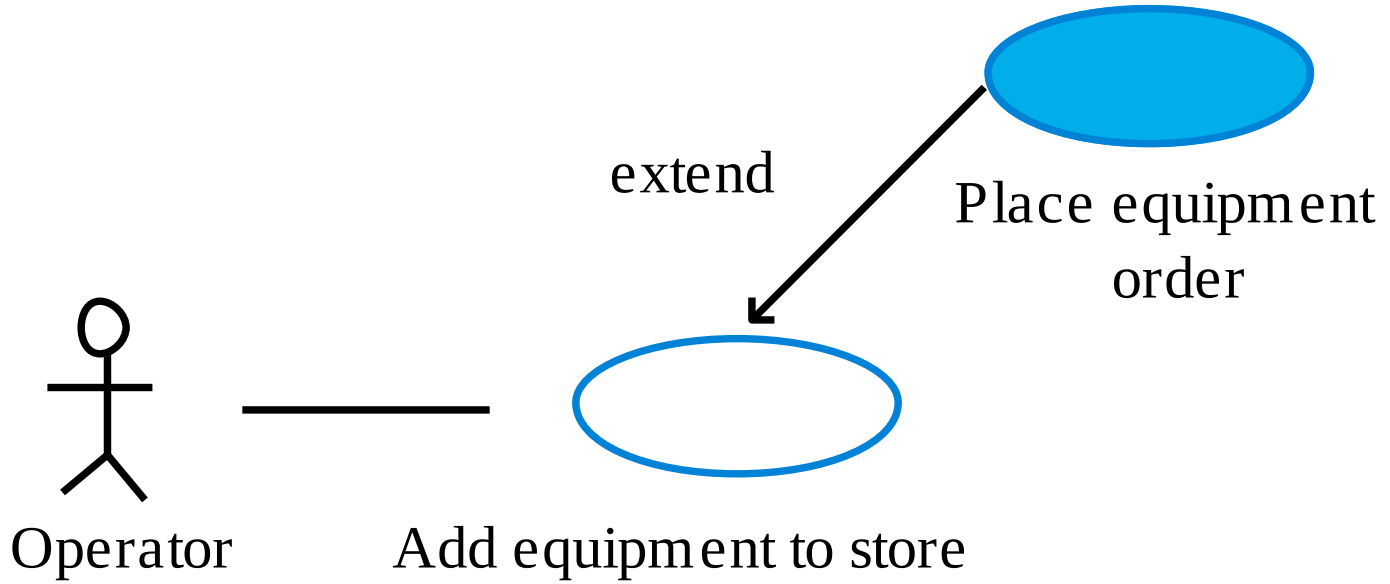
An extension use case



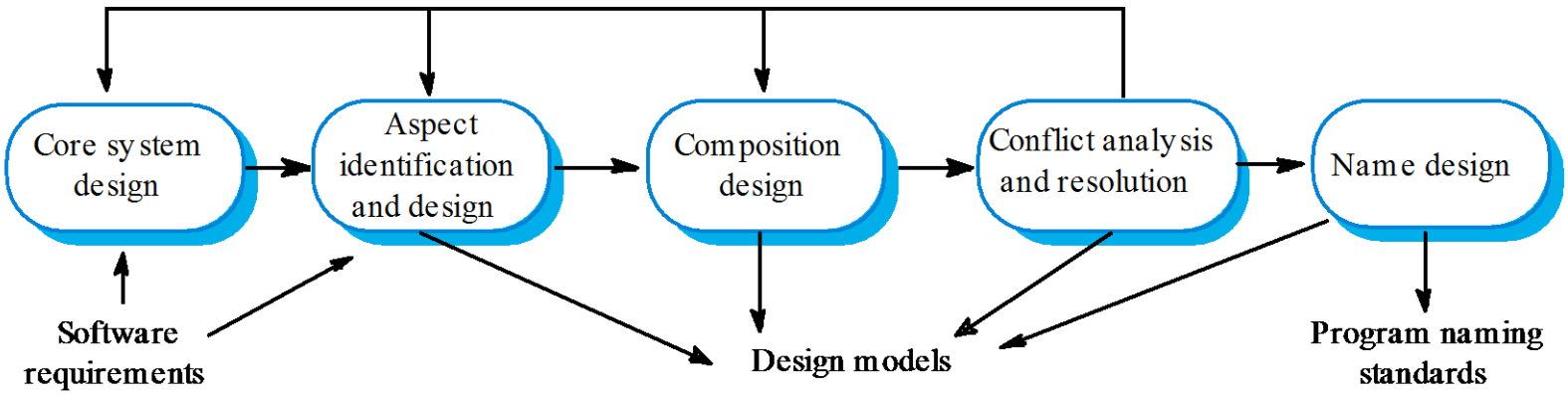
Inventory use cases



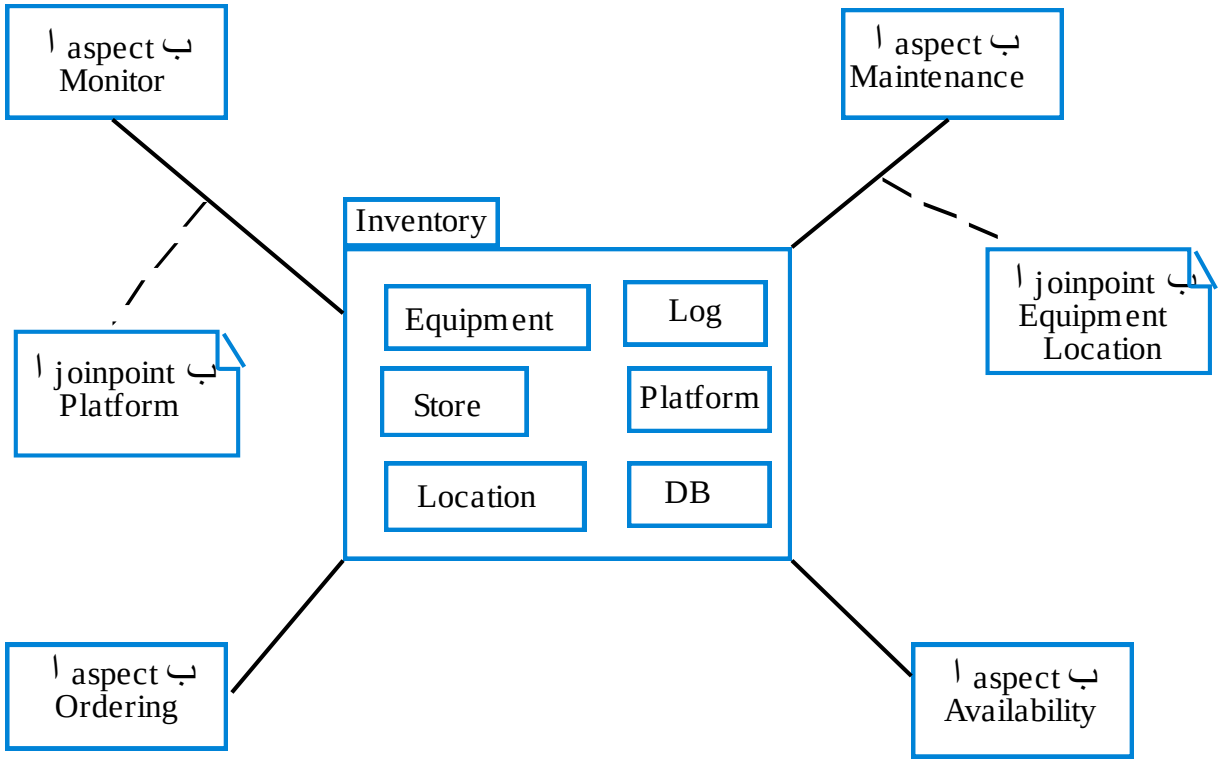
Inventory extension use-case



An AOSD process



An aspect-oriented design model



Verification and validation

- The process of demonstrating that a program meets it specification (verification) and meets the real needs of its stakeholders (validation)
- Like any other systems,aspect-oriented systems can be tested as black-boxes using the specification to derive the tests
- However, program inspections and 'white-box' testing that relies on the program source code is problematic.
- Aspects also introduce additional testing problems

Testing problems with aspects

- How should aspects be specified so that tests can be derived?
- How can aspects be tested independently of the base system?
- How can aspect interference be tested?
- How can tests be designed so that all join points are executed and appropriate aspect tests applied?

Program inspection problems

- To inspect a program (in a conventional language) effectively, you should be able to read it from right to left and top to bottom.
- Aspects make this impossible as the program is a web rather than a sequential document. You can’t tell from the source code where an aspect will be woven and executed.
- Flattening an aspect-oriented program for reading is practically impossible.

White box testing

- The aim of white box testing is to use source code knowledge to design tests that provide some level of program coverage e.g. each logical branch in a program should be executed at least once.
- Aspect problems
  - How can source code knowledge be used to derive tests?
  - What exactly does test coverage mean?

Aspect problems

- Deriving a program flow graph of a program with aspects is impossible. It is therefore difficult to design tests systematically that ensure that all combinations of base code and aspects are executed.
- What does test coverage mean?
  - Code of each aspect executed once?
  - Code of each aspect exeucted once at each join point where aspect woven?
  - ???

Key points

- The key benefit of an aspect-oriented approach is that it supports the separation of concerns.
- Tangling occurs when a module implements several requirements; Scattering occurs when the implementation of a single concern is spread across several components.
- Systems may be designed as a core system with extensions to implement secondary concerns.

Key points

- To identify concerns, you may use a viewpoint-oriented approach to requirements engineering.
- The transition from requirements to design may be made using use-cases where each use-case represents a stakeholder concern.
- The problems of inspecting and deriving tests for aspect-oriented programs are a significant barrier to the adoption of AOSD.