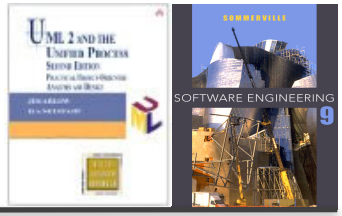


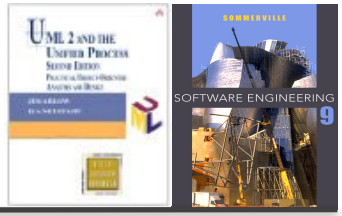
Lecture 4

OBJECT ORIENTED ANALYSIS

PB007 Software Engineering I
Faculty of Informatics, Masaryk University

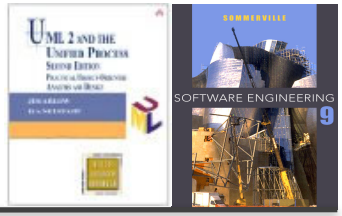
Fall 2016

Outline



- ✧ UML Objects and classes [Lecture 3]
- ✧ Finding analysis classes [Lecture 3]
- ✧ Relationships between objects and classes
  - Links
  - Associations
  - Dependencies
- ✧ Inheritance and polymorphism

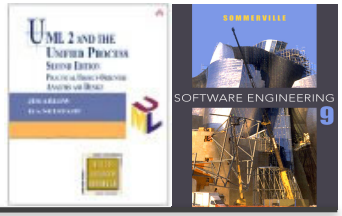
- ✧ UML State diagram



Relationships Between Objects and Classes

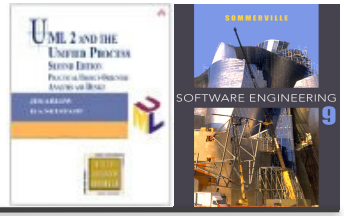
Lecture 4/Part 1

What is a link?

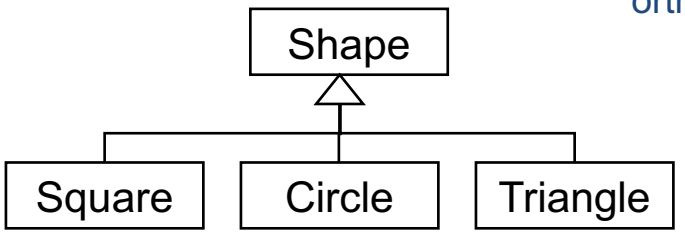


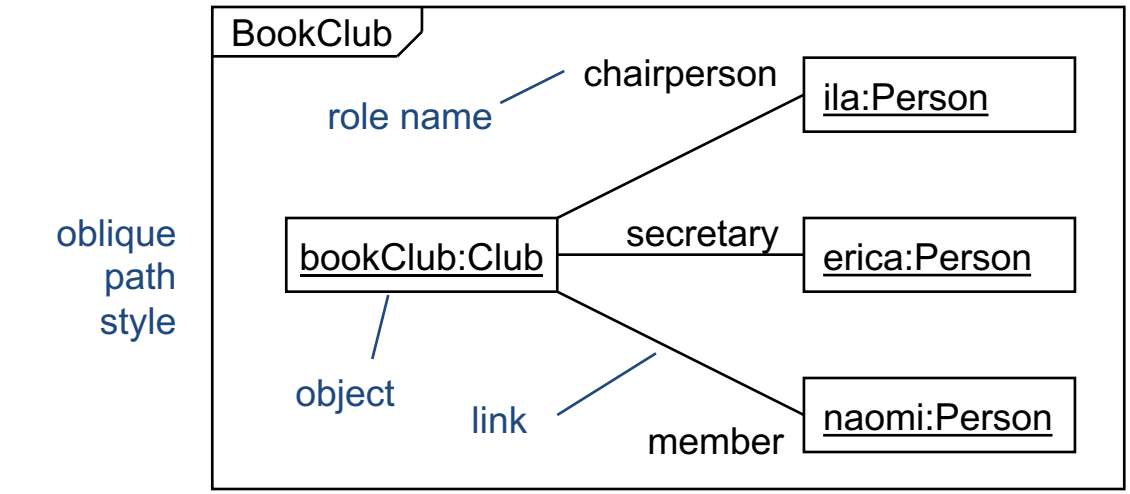
- Links are connections between objects
  - Think of a link as a **telephone line** connecting you and a friend. You can send messages back and forth using this link
- Links are the way that objects communicate
  - Objects **send messages to each other** via links
  - Messages **invoke operations**
- OO programming languages implement links as object references or pointers
  - When an object has a stored reference to another object, we say that there is a **link** between the objects

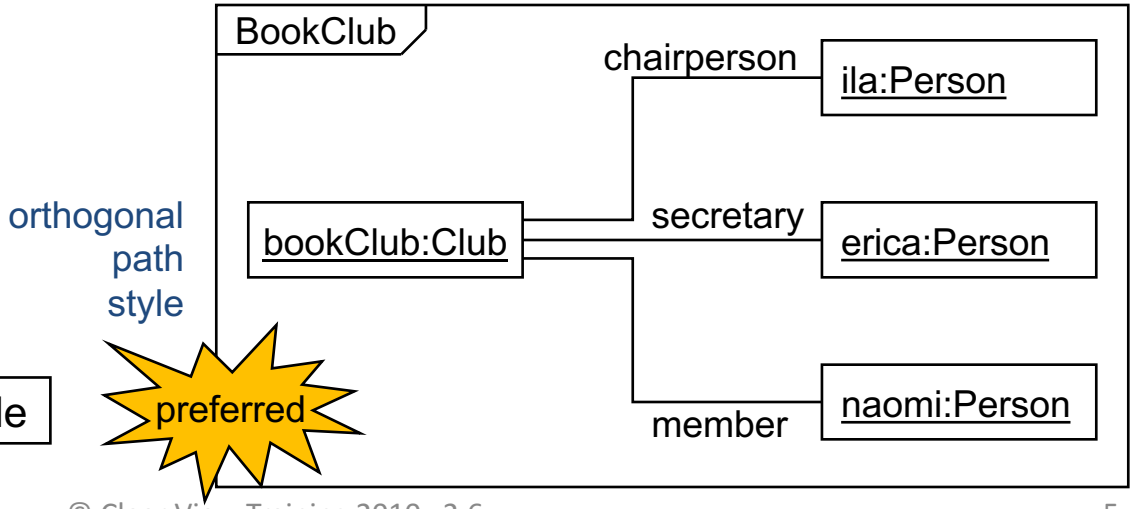
Object diagrams



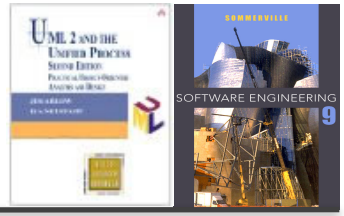
- Paths in UML diagrams can be drawn as orthogonal, oblique or curved lines
- We can combine paths into a tree if each path has **the same properties**

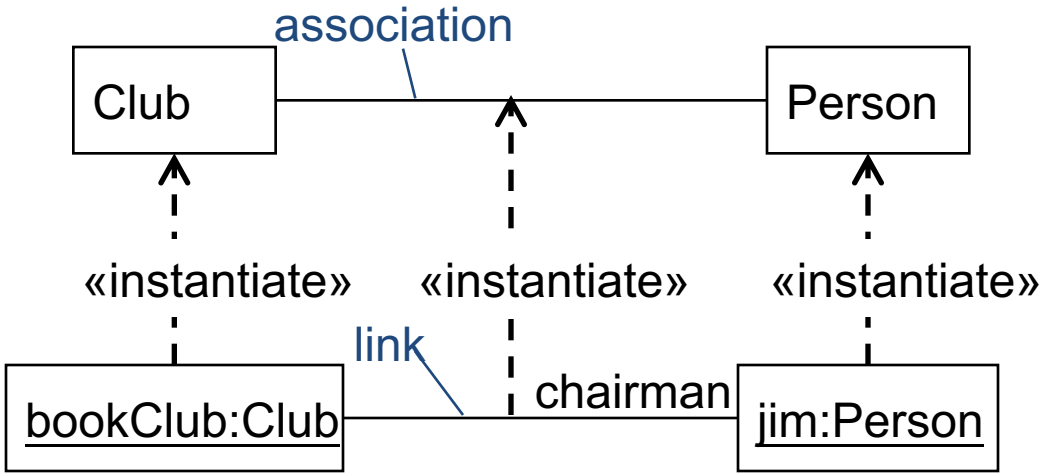


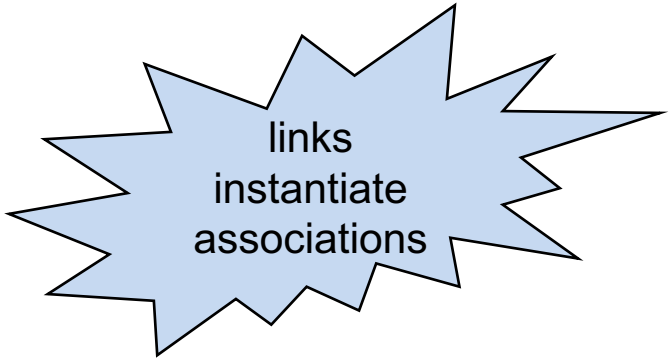




What is an association?

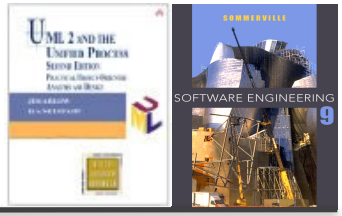


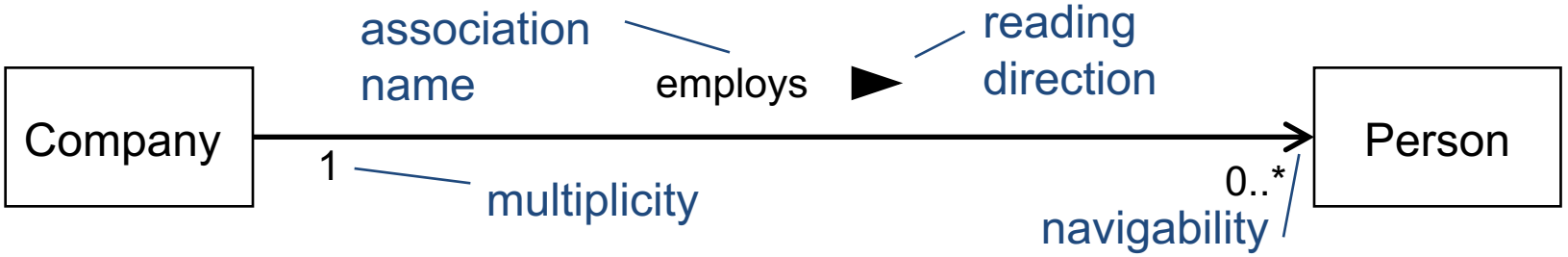


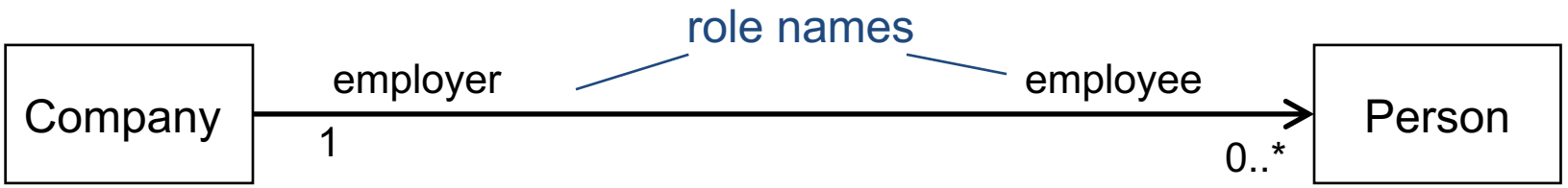


- Associations are relationships between classes
- Associations between classes indicate that there **may be** links between objects of those classes, while links indicates that there **must be** associations
- Can there be a communication between objects of two classes that have no association between them?

Association syntax



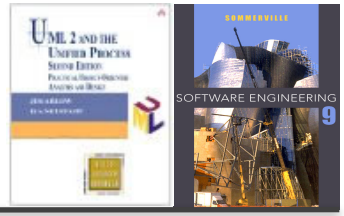




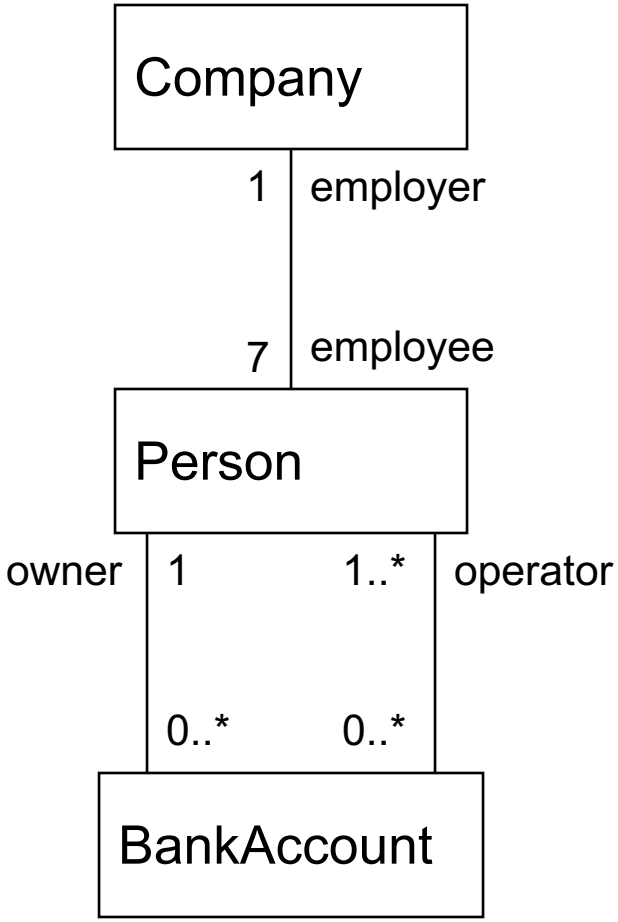
- An association can have **role names** OR an **association name**
- **Multiplicity** is a constraint that specifies the number of objects that can participate in a relationship at any point in time
  - If multiplicity is not explicitly stated in the model then it is undecided – *there is no default multiplicity*

multiplicity: min..max	
0..1	zero or 1
1	exactly 1
0..*	zero or more
1..*	1 or more
1..6	1 to 6

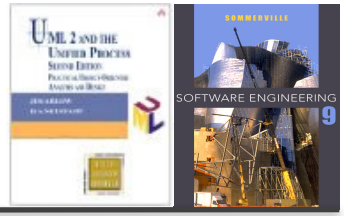
Multiplicity exercise

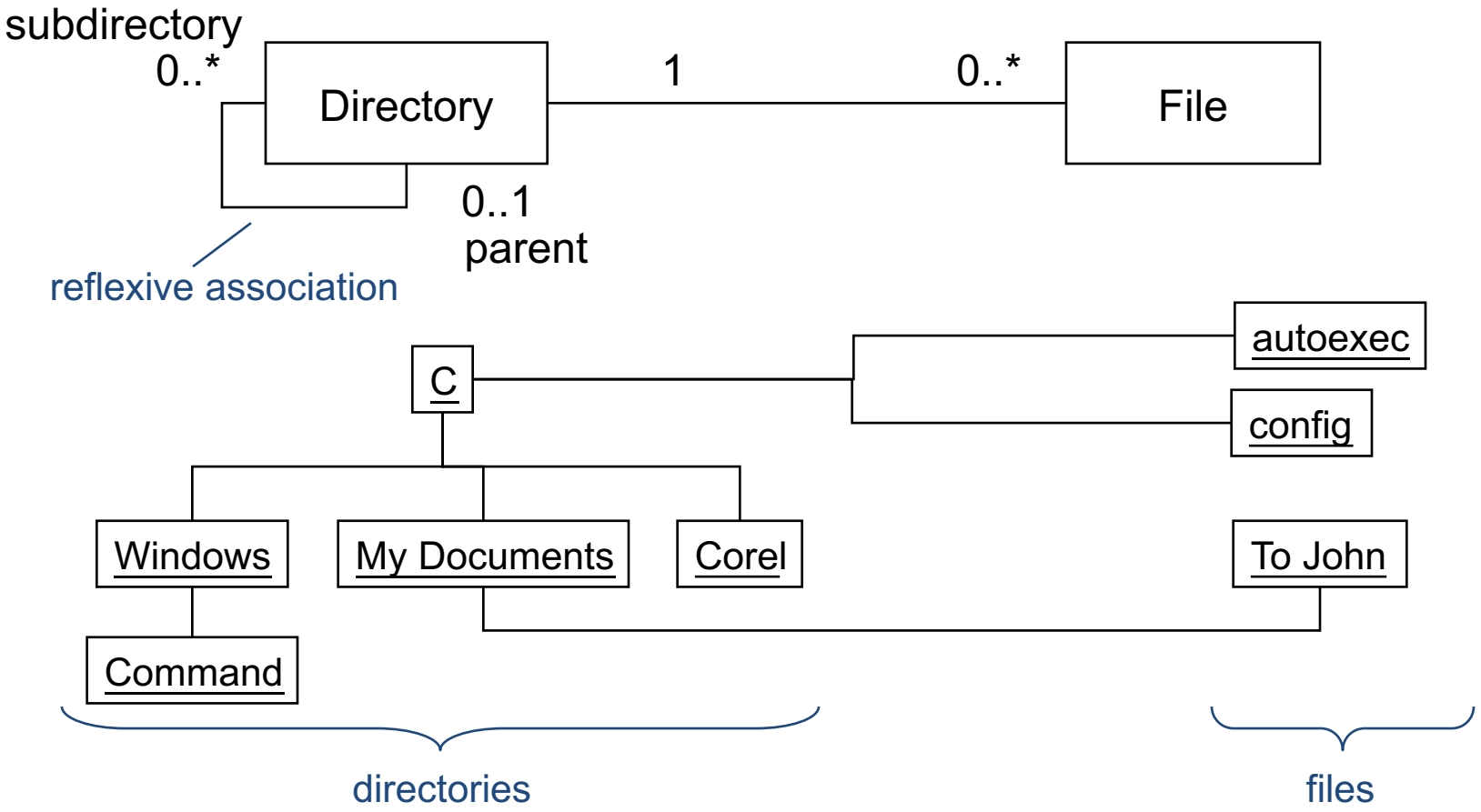


- How many
  - Employees can a Company have?
  - Employers can a Person have?
  - Owners can a BankAccount have?
  - Operators can a BankAccount have?
  - BankAccounts can a Person have?
  - BankAccounts can a Person operate?



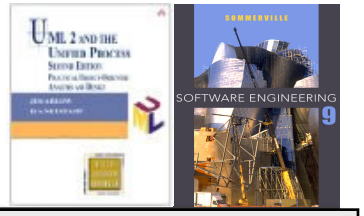
Reflexive associations: file system example

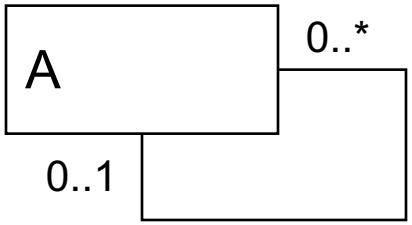
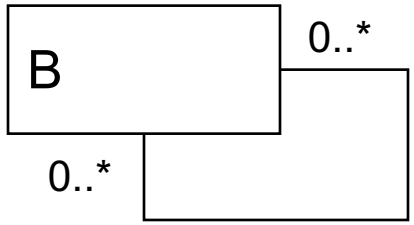
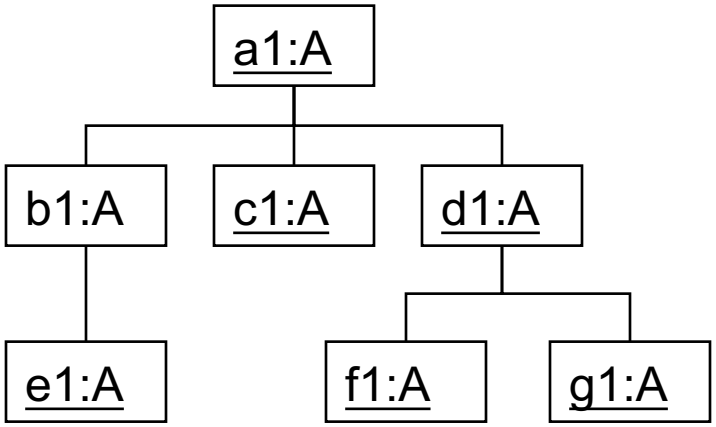
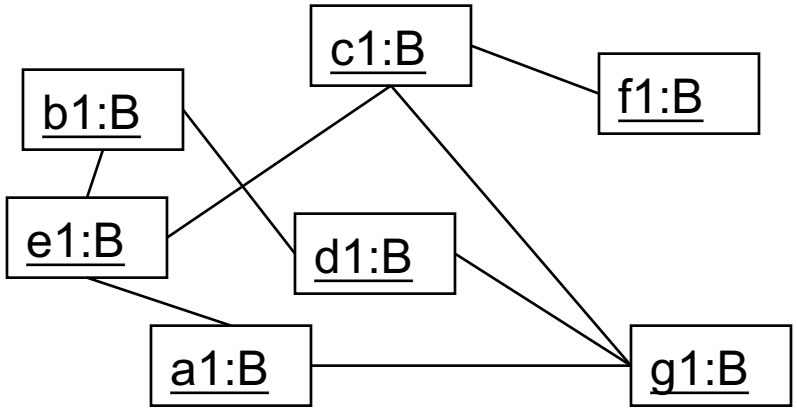




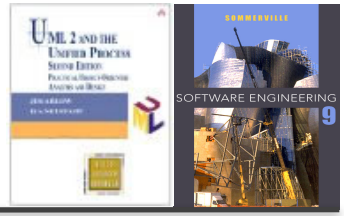
- If ToJohn was a directory, would it still conform to the class diagram?

Hierarchies and networks



hierarchy	network
	
	
In an association hierarchy, each object has **zero or one** object directly above it.	In an association network, each object has **zero or many** objects directly above it.

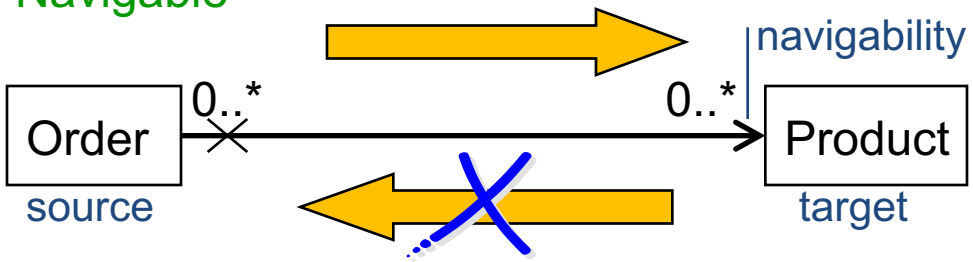
Navigability



- Navigability indicates that it is possible to traverse from an object of the **source** class to objects of the **target** class

An Order object stores a list of Products

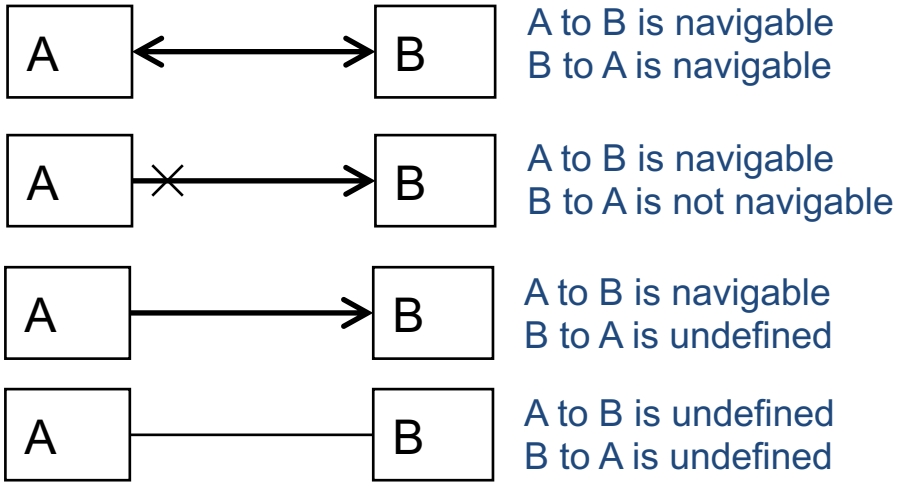
Navigable



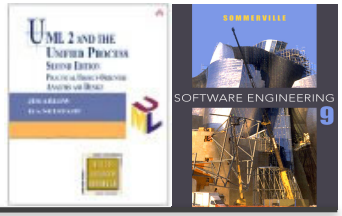
Not navigable

A Product object does not store a list of Orders

- Can there be a communication in a direction not supported by the navigability?
- Are some of the cases on the right equivalent?

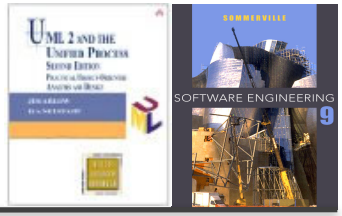


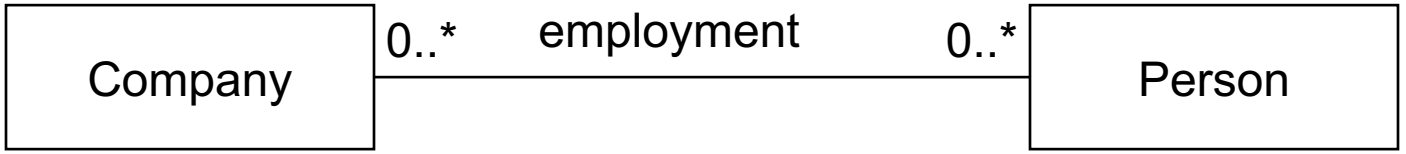
Associations and attributes



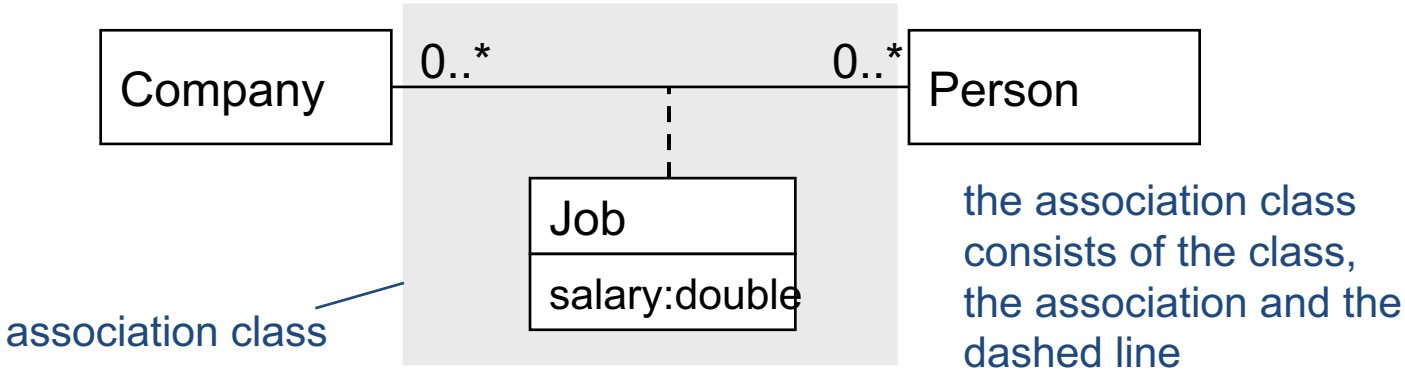
- An association is (through its role name) a **representation of an attribute**
- **Use associations when:**
  - The target class is an important part of the model
  - The target class is a class that you have designed yourself
- **Use attributes when:**
  - The target class is not important, e.g. a primitive type such as number, string
  - The target class is just an implementation detail such as a bought-in component or a library component e.g. Java.util.Vector (from the Java standard libraries)

Association classes

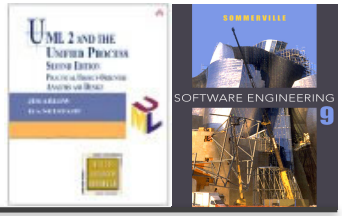




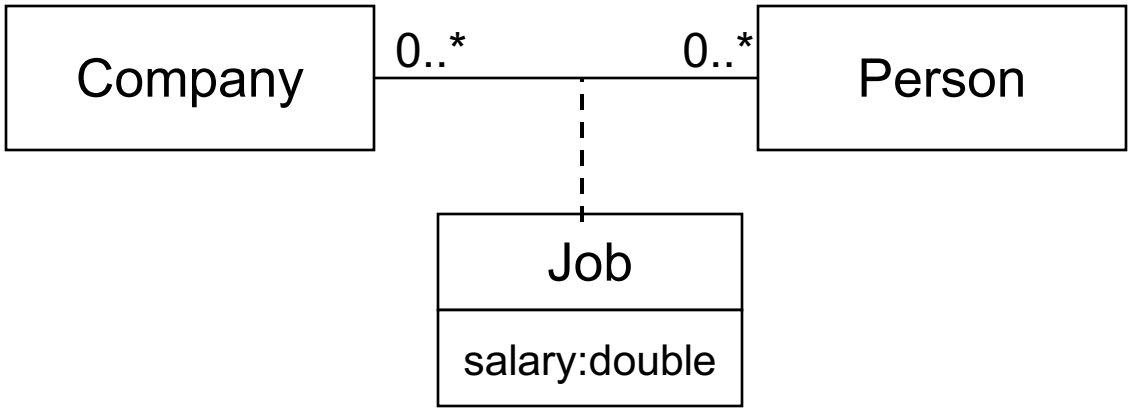
- Where do we record the Person's salary?
- We model the association itself as an association class. Exactly one instance of this class exists for each link between a Person and a Company.
- We can place the salary and any other attributes or operations which are really features of the association into this class



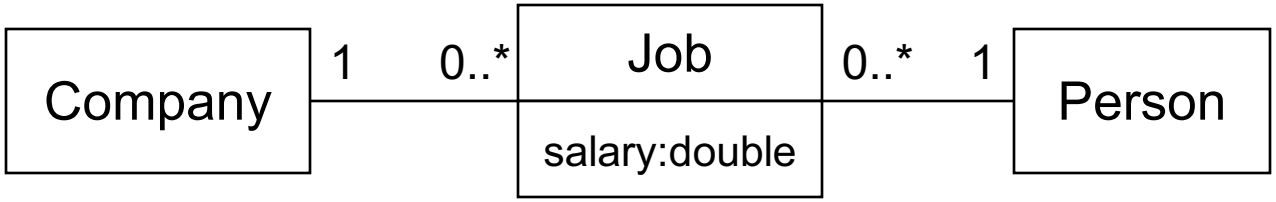
Using association classes



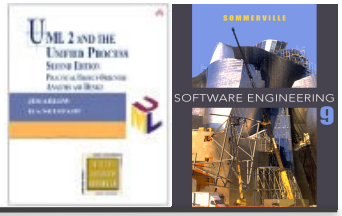
If we use an association class, then a particular Person can have only **one** Job with a particular Company



If, however a particular Person can have **multiple** jobs with the same Company, then we must use a reified association

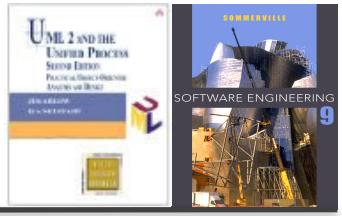


Dependencies

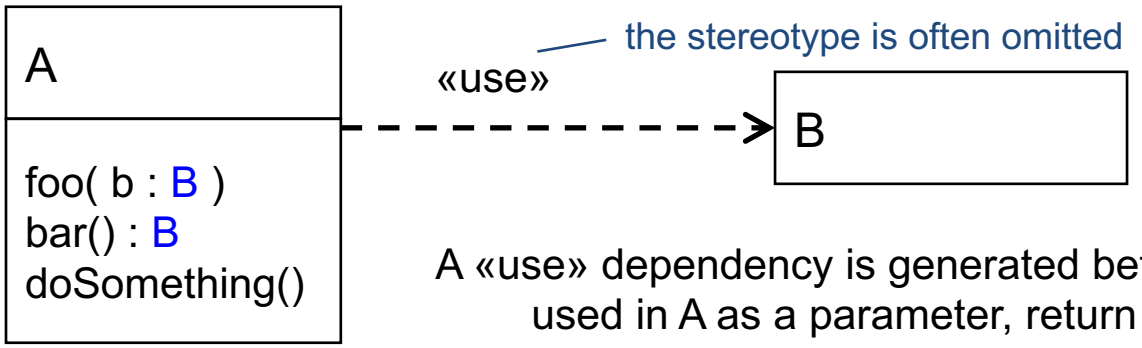


- "A dependency is a relationship between two elements where a change to one element (the supplier) may affect or supply information needed by the other element (the client)".
  - In other words, the client **depends** in some way on the supplier
  - Weaker type of relationship than **association**
  - Can there be both association and dependency between two classes?
- Three types of dependency:
  - **Usage** - the client uses some of the services made available by the supplier to implement its own behavior – this is the most commonly used type of dependency
  - **Abstraction** - a shift in the level of abstraction. The supplier is more abstract than the client
  - **Permission** - the supplier grants some sort of permission for the client to access its contents – this is a way for the supplier to control and limit access to its contents

Usage dependencies



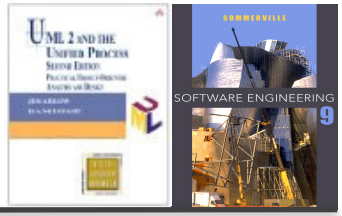
- Stereotypes
  - **«use»** - the client makes use of the supplier to implement its behaviour
  - **«call»** - the client operation invokes the supplier operation
  - **«parameter»** - the supplier is a parameter of the client operation
  - **«send»** - the client (an operation) sends the supplier (a signal) to some unspecified target
  - **«instantiate»** - the client is an instance of the supplier




```
A :: doSomething() {
   B myB = new B();
}
```

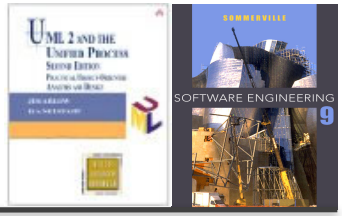
A «use» dependency is generated between A and B when B is used in A as a parameter, return value or inside method body

Abstraction and permission dependencies

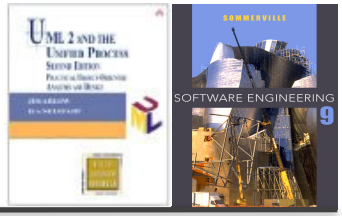


- Abstraction dependencies
  - **«trace»** - the client and the supplier represent the same concept but at different points in development
  - **«substitute»** - the client may be substituted for the supplier at runtime. The client and supplier must realize a common contract. Use in environments that *don't* support specialization/generalization
  - **«refine»** - the client represents a fuller specification of the supplier
  - **«derive»** - the client may be derived from the supplier. The client is logically redundant, but may appear for implementation reasons
- Permission dependencies
  - **«access»** the public contents of the supplier package are added as private elements to the namespace of the client package
  - **«import»** the public contents of the supplier package are added as public elements to the namespace of the client package
  - **«permit»** the client element has access to the supplier element despite the declared visibility of the supplier

Key points



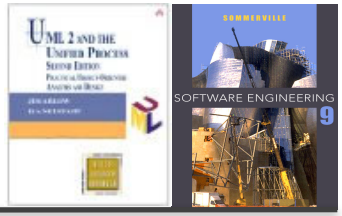
- ✧ Links – relationships between objects
- ✧ Associations – relationships between classes
  - role names
  - multiplicity
  - navigability
  - association classes
- ✧ Dependencies – relationships between model elements
  - usage
  - abstraction
  - permission



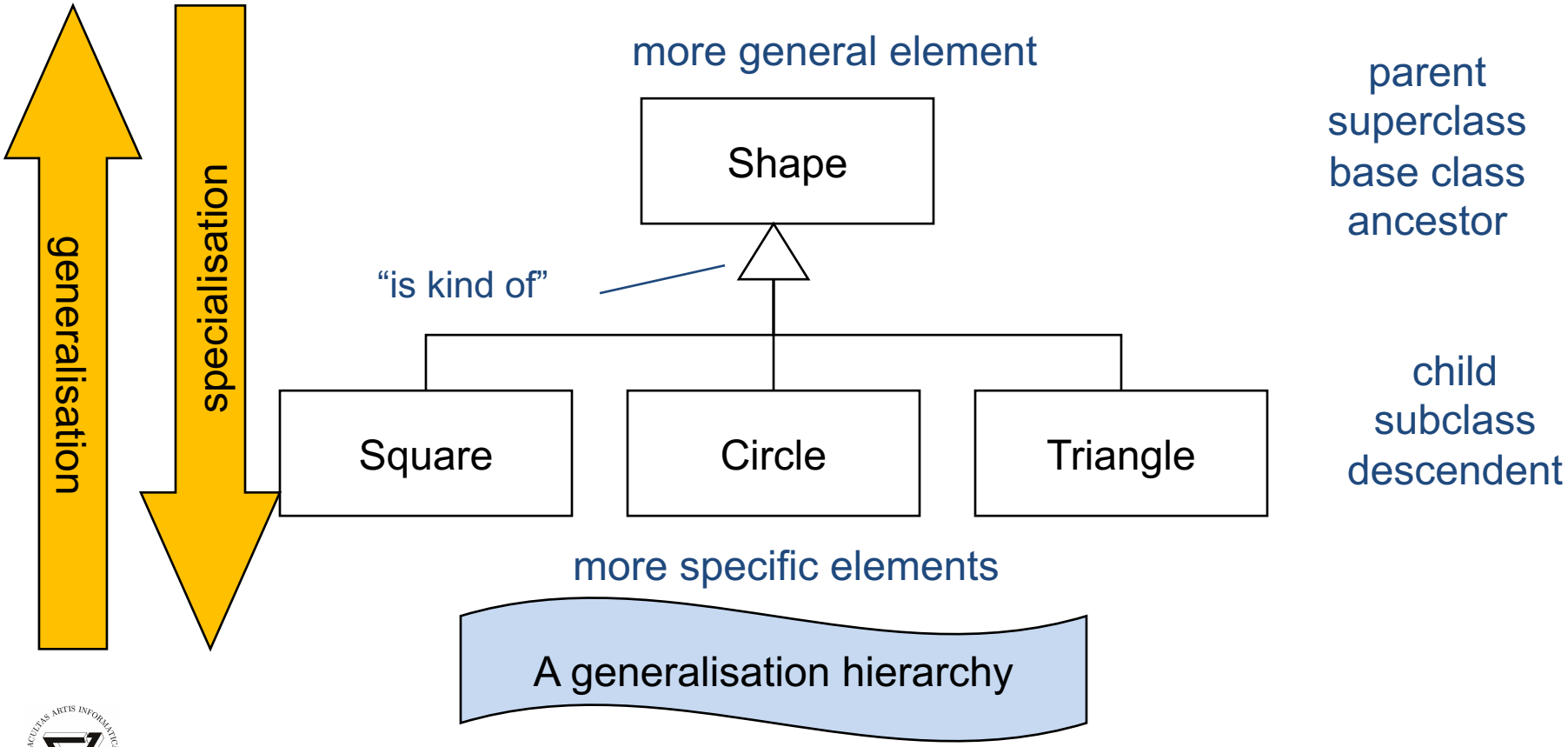
Inheritance and polymorphism

Lecture 4/Part 2

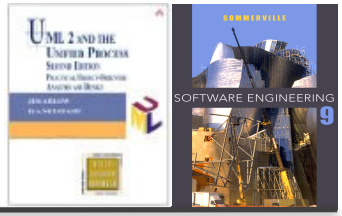
Generalisation



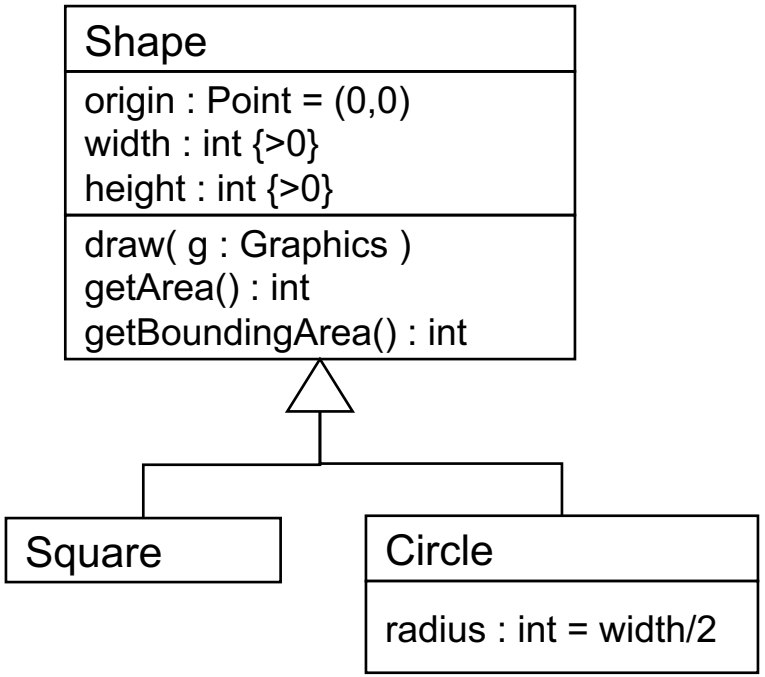
A relationship between a more general element and a more specific element (with more information)



Class inheritance



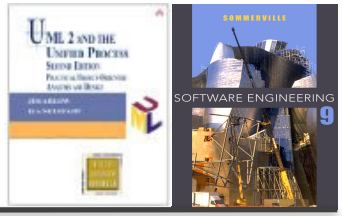
- Subclasses inherit **all** features of their superclasses:
  - attributes
  - operations
  - relationships
  - stereotypes, tags, constraints
- Subclasses can add new features
- Subclasses can override superclass operations
- We can use a subclass instance **anywhere** a superclass instance is expected

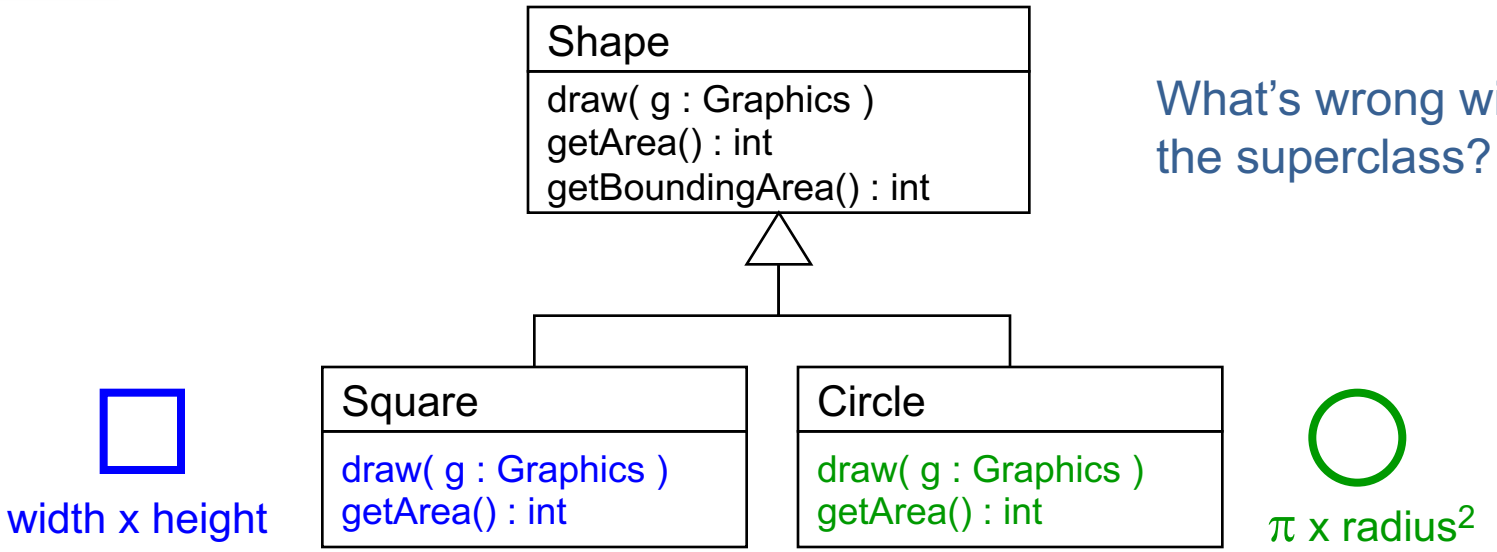


Substitutability Principle

What's wrong with these subclasses?

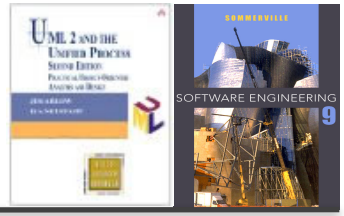
Overriding

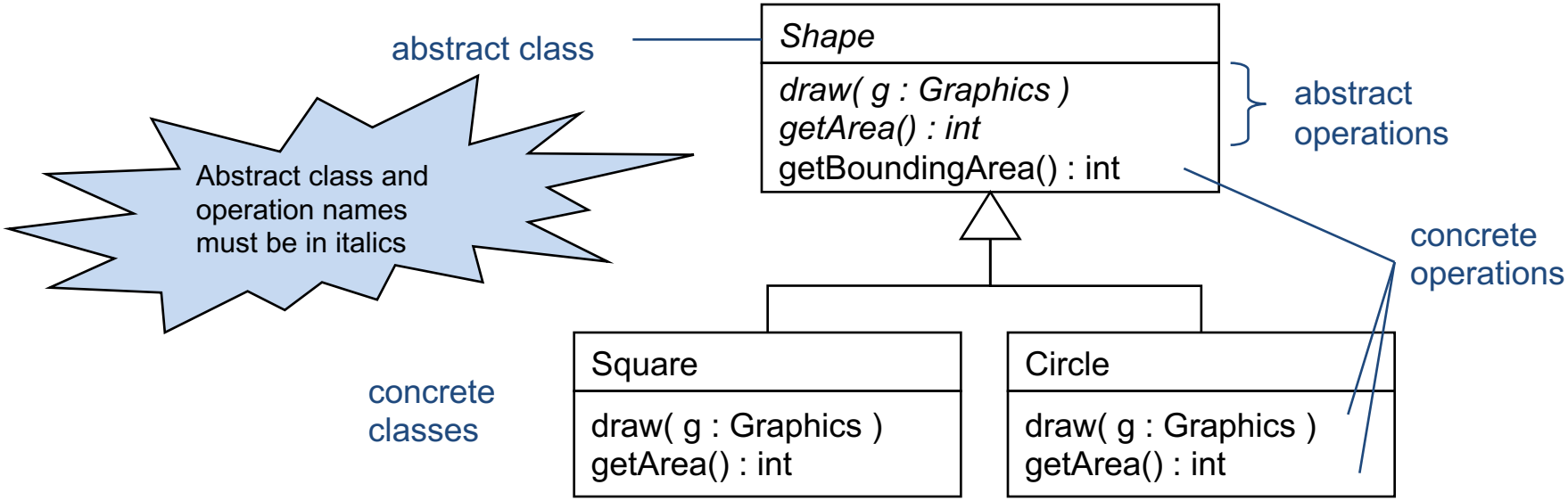




- Subclasses often need to **override** superclass behaviour
- To override a superclass operation, a subclass must provide an operation with the same signature
  - The operation signature is the operation name, return type and types of all the parameters

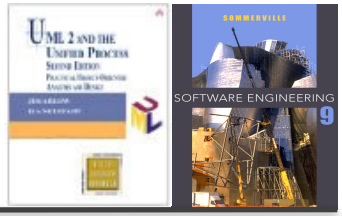
Abstract operations & classes



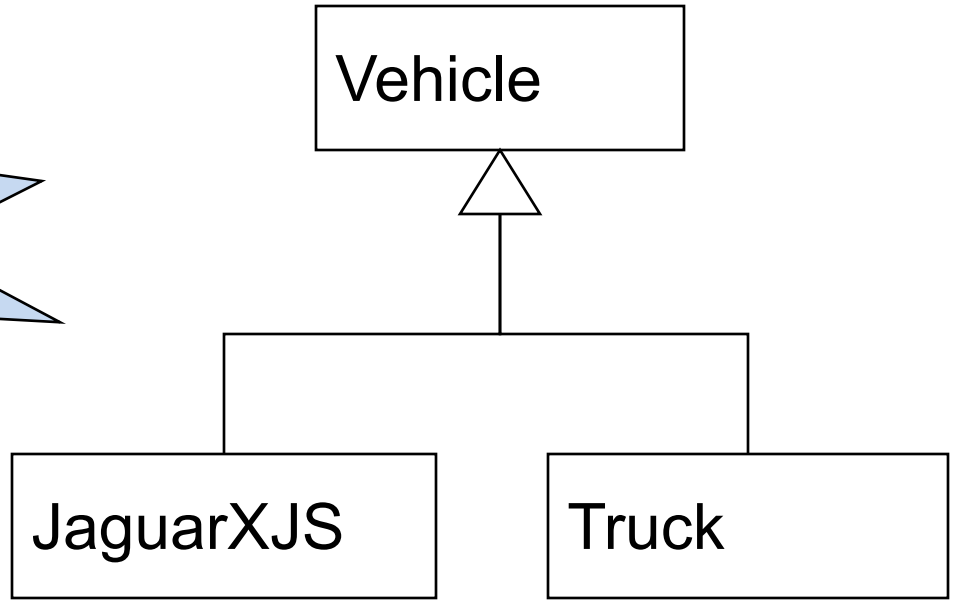


- We can't provide an implementation for *Shape :: draw(g : Graphics)* or for *Shape :: getArea() : int* because we don't know how to draw or calculate the area for a "shape"!
- Operations that lack an implementation are **abstract operations**
- A class with any abstract operations **can't be instantiated** and is therefore an **abstract class**

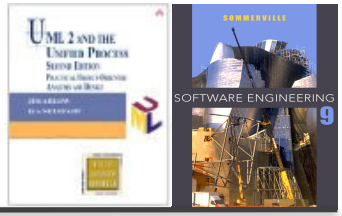
Exercise



what's wrong with this model?

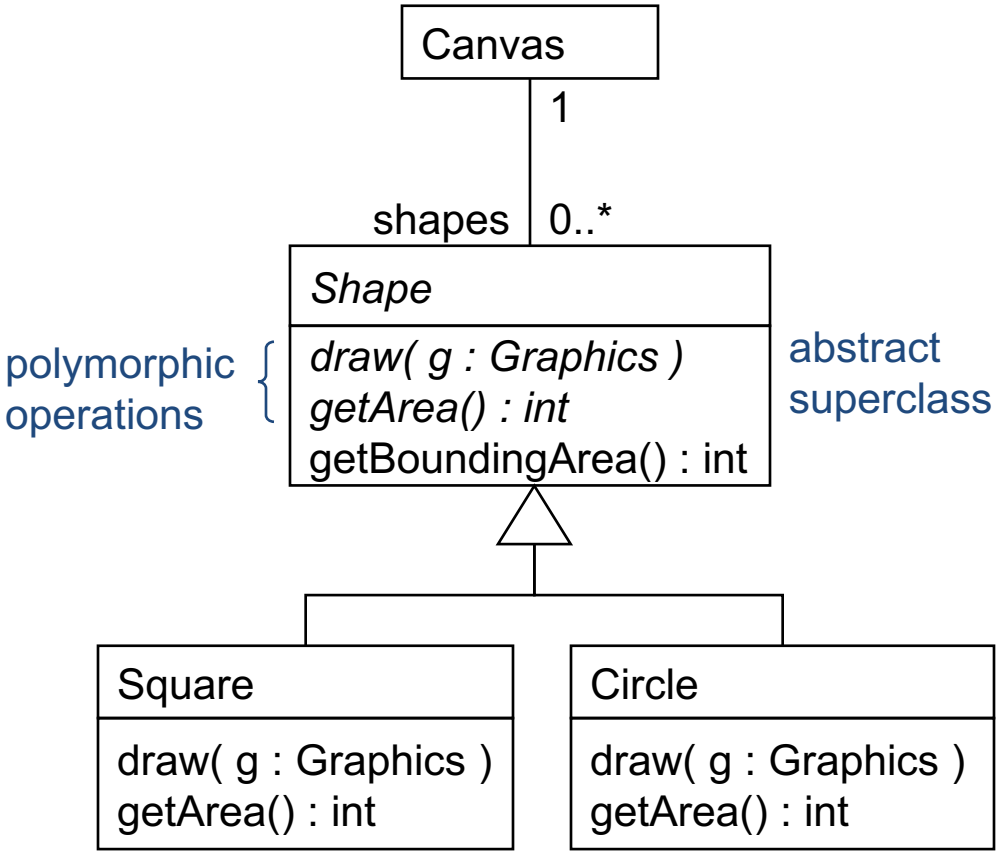


Polymorphism

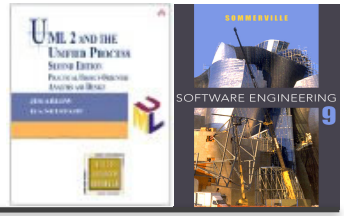


- Polymorphism = "many forms"
  - A polymorphic operation has many implementations
  - Square and Circle provide implementations for the polymorphic operations *Shape::draw()* and *Shape::getArea()*
- The operation in Shape superclass defines a contract for the subclasses.

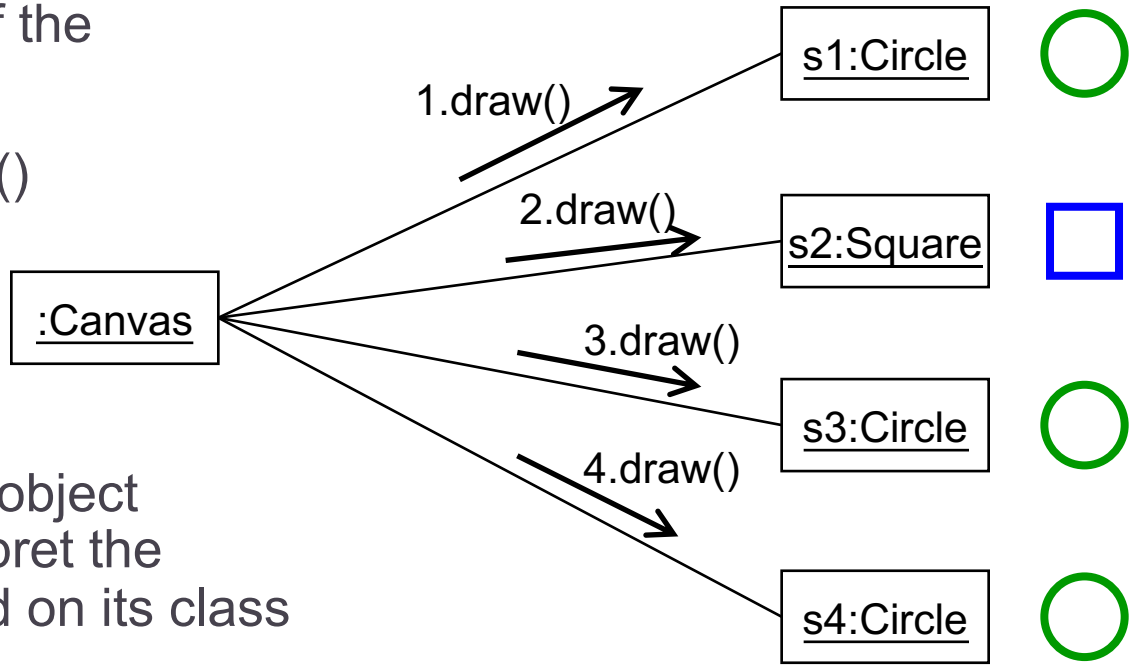
A Canvas object has a collection of *Shape* objects where each *Shape* may be a Square or a Circle



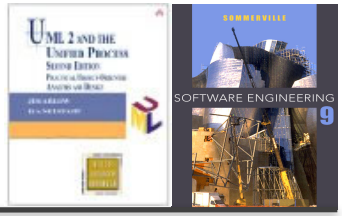
What happens?

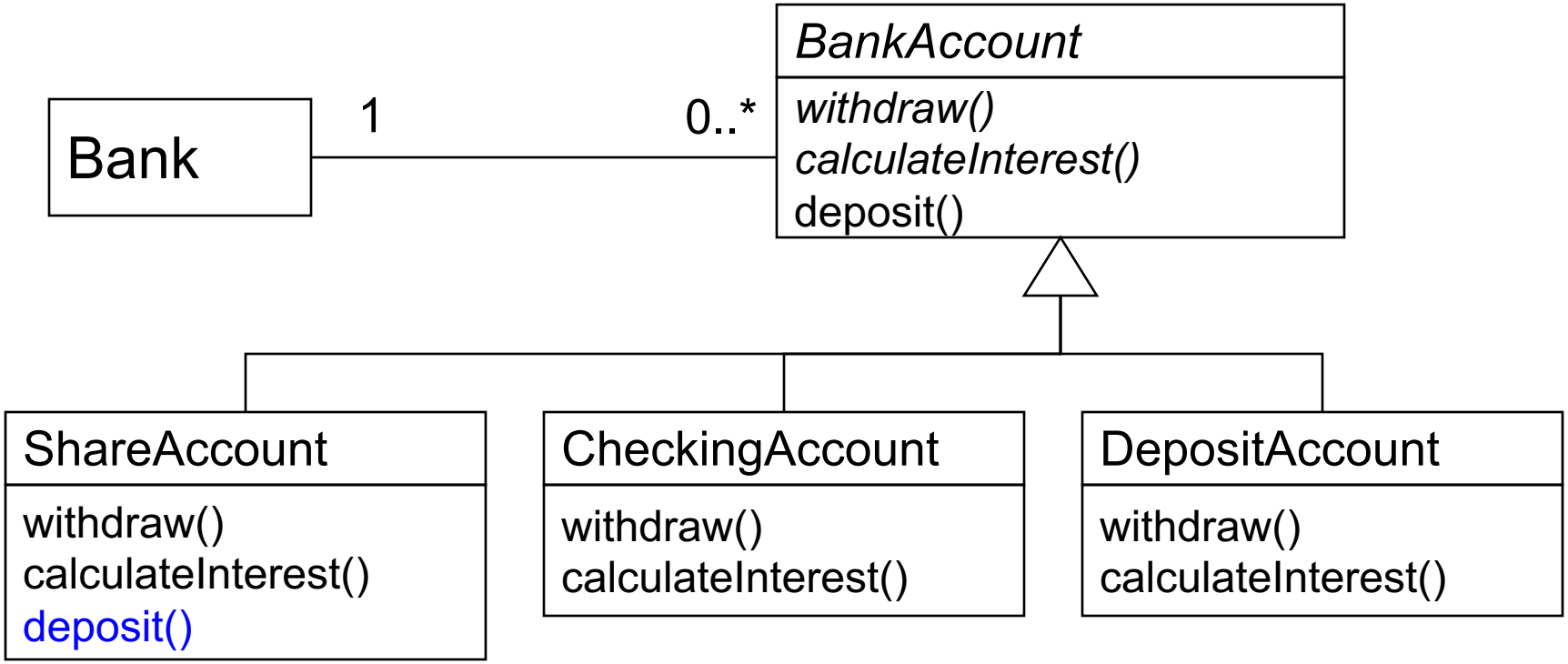


- Each class of object has its own implementation of the draw() operation
- On receipt of the draw() message, each object invokes the draw() operation specified by its class
- We can say that each object "decides" how to interpret the draw() message based on its class



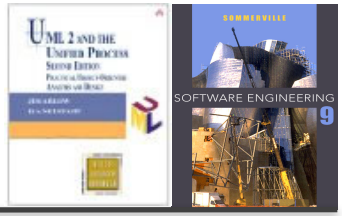
BankAccount example



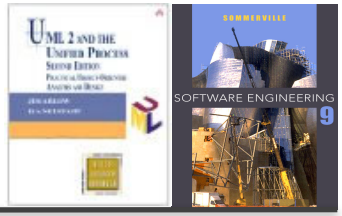


- We have overridden the deposit() operation even though it is **not** abstract.

Key points



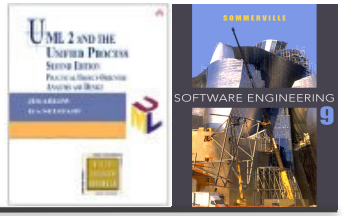
- ✧ Generalisation, specialisation, inheritance
- ✧ Subclasses
  - inherit all features from their parents including constraints and relationships
  - may add **new features**, constraints and relationships
  - may **override** superclass operations
- ✧ A class that can't be instantiated is an abstract class



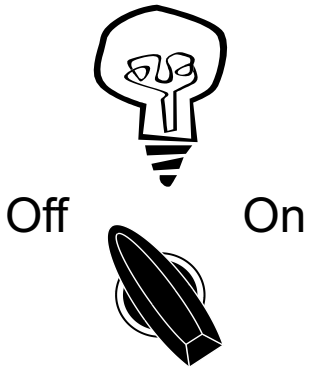
UML State Diagram

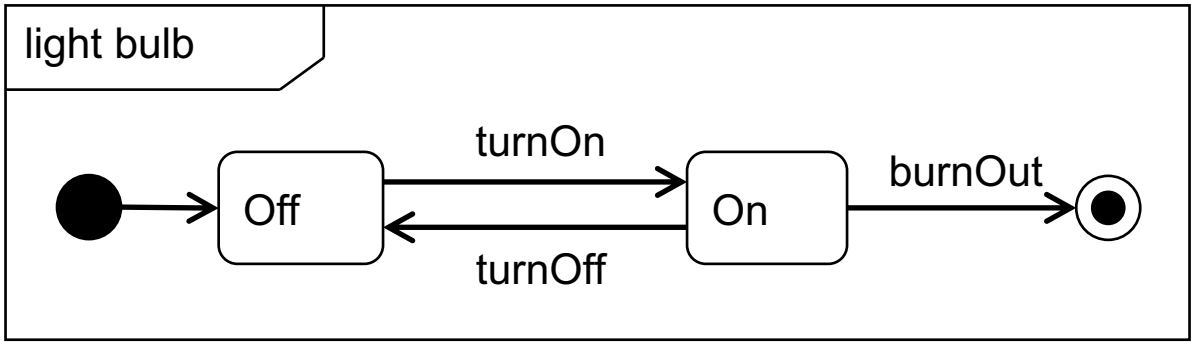
Lecture 4/Part 3

State machines

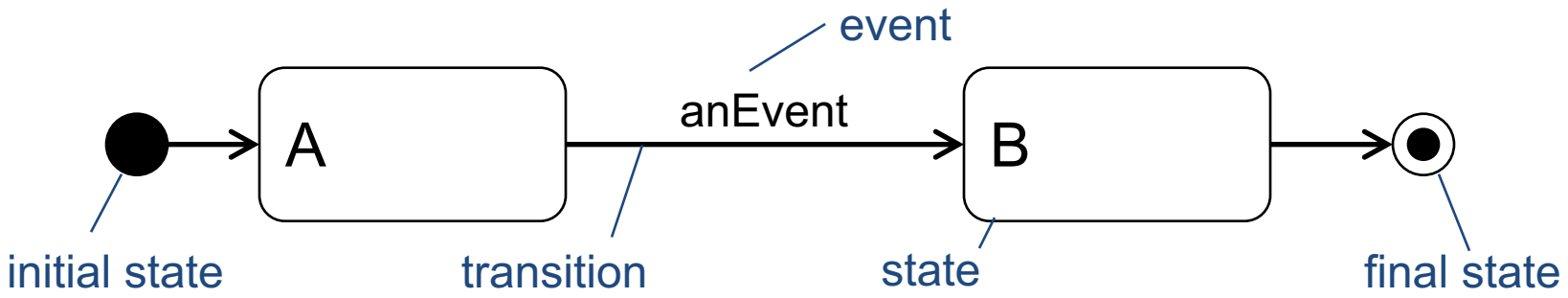


- Models life stages of a **single** model element – e.g. object, use case, module
- Every state machine exists in the context of a particular model element that:
  - Has a clear life history modelled as a progression of **states**, **transitions** and **events**
  - Responds to events dispatched from outside of the element
- There are two types of state machines:
  - **Behavioural state machines** - define the behaviour of a model element
  - **Protocol state machines** - model the protocol of a classifier
    - E.g. call conditions and call ordering of an interface that itself has no behaviour





Basic state machine syntax

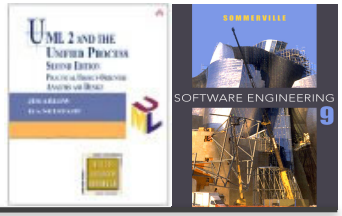


- State = a situation or condition during the life of an object
  - Determined at any point in time by the **values of its attributes**, the relationships to other objects, or the **activities** it is performing.
- Every state machine should have one initial state which indicates the first state of the sequence
- Unless the states cycle endlessly, state machines should have a final state which terminates its lifecycle

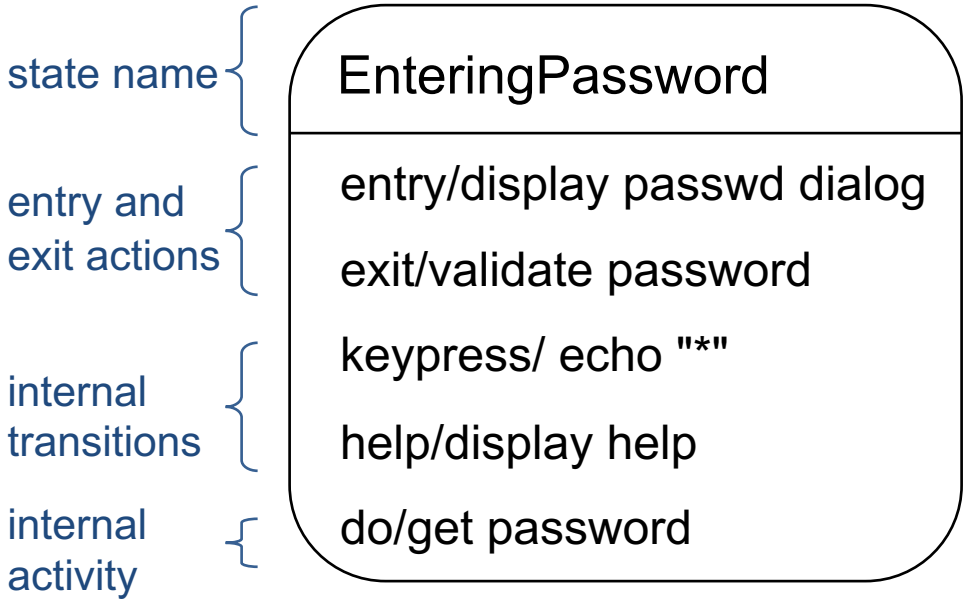
How many states?

Color
red : int green : int blue : int

State syntax

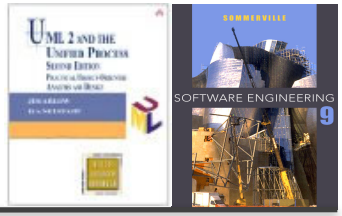


- Actions are **instantaneous** and **uninterruptible**
  - Entry actions occur immediately on state entry
  - Exit actions occur immediately on state leaving
- Internal transitions occur **within** the state. They do not fire transition to a new state
- Activities take a finite amount of time and are interruptible



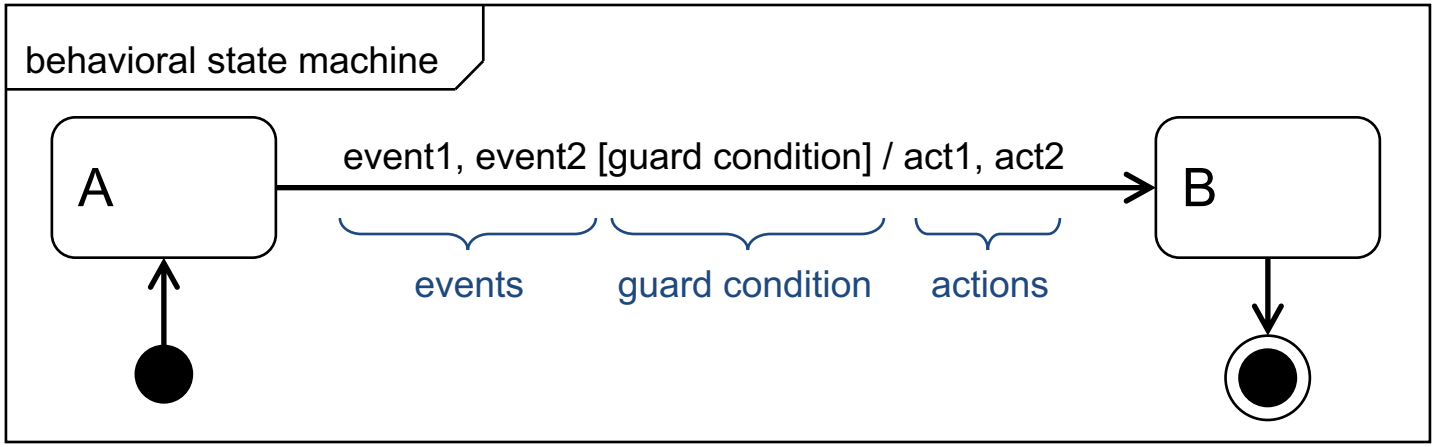
Action syntax: eventTrigger / action
Activity syntax: do / activity

Transitions



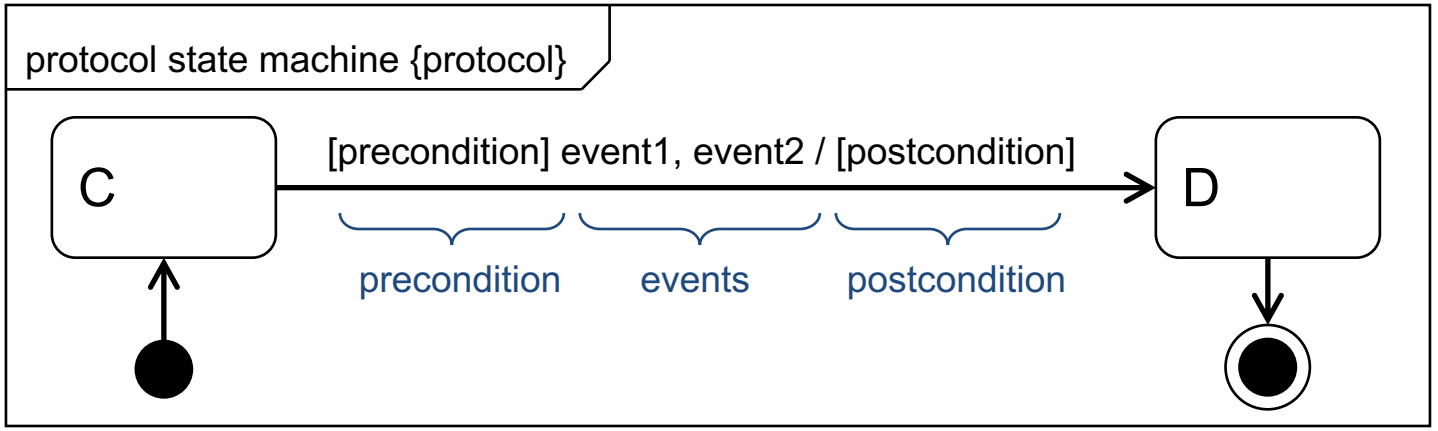
Behavioral state machine

Specifies object's reactions to events.

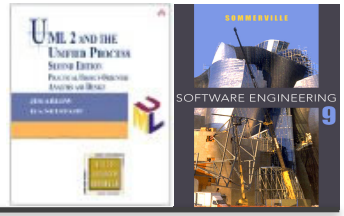


Protocol state machine

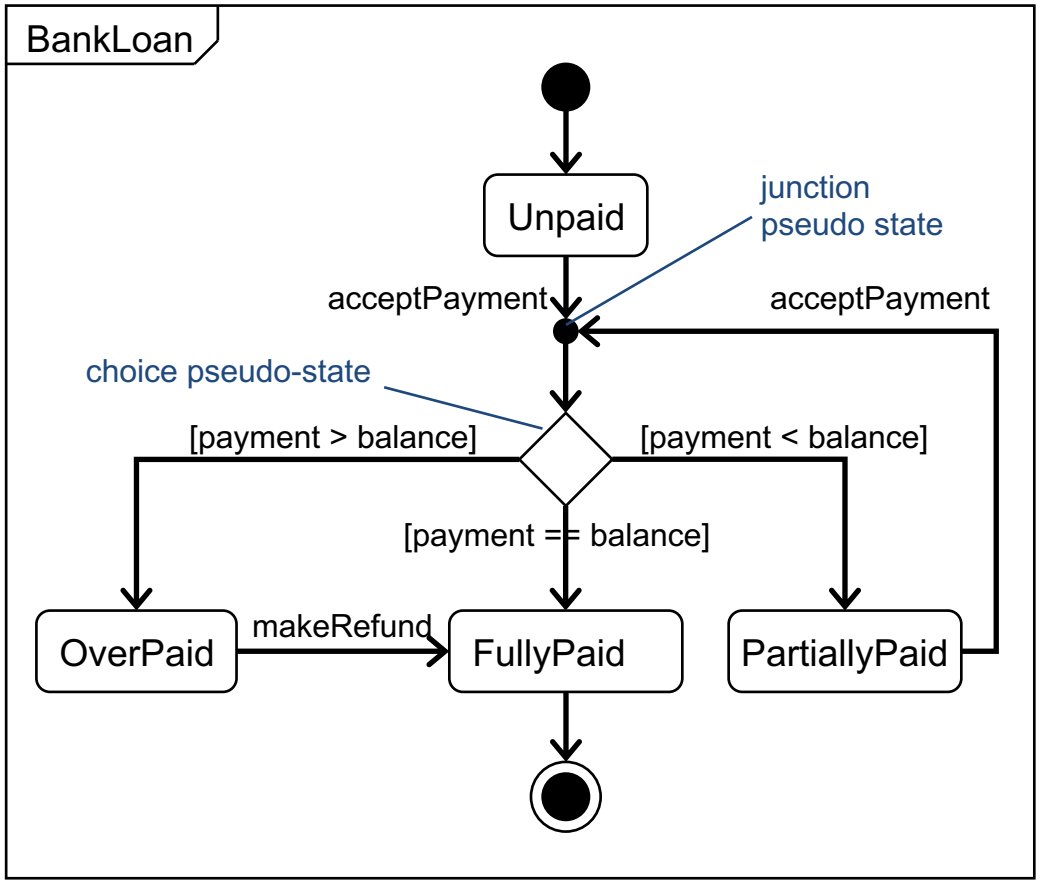
Specifies legal sequences of events.



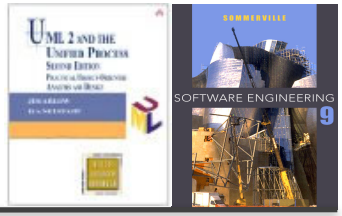
Choice and junction pseudo states



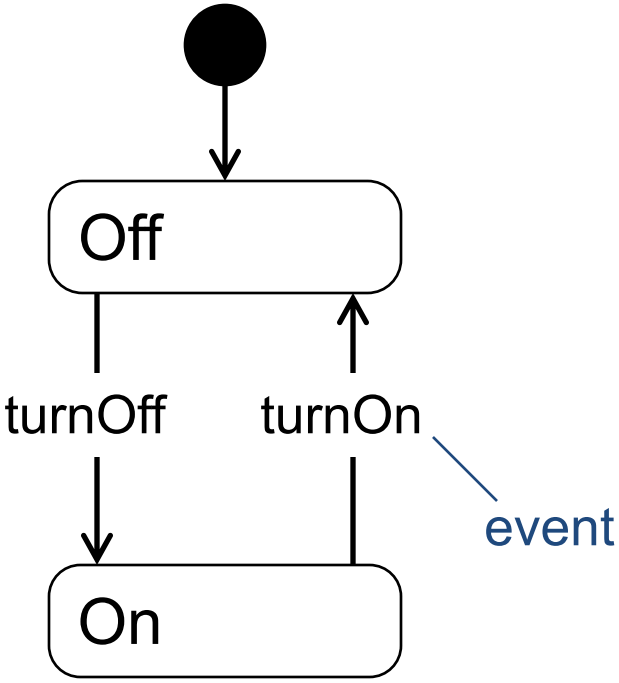
- **Choice pseudo state** directs its single incoming transition to one of its outgoing transitions
  - Each outgoing transition must have a mutually exclusive guard condition
  - Equivalent to two outgoing transitions from one state
- **Junction pseudo state** connects multiple incoming transitions into one (or more) transitions.
  - When there are more outgoing transitions, they must have guard conditions



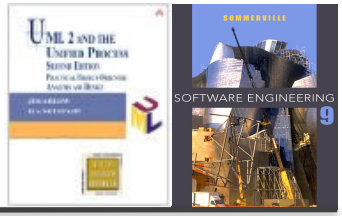
Events



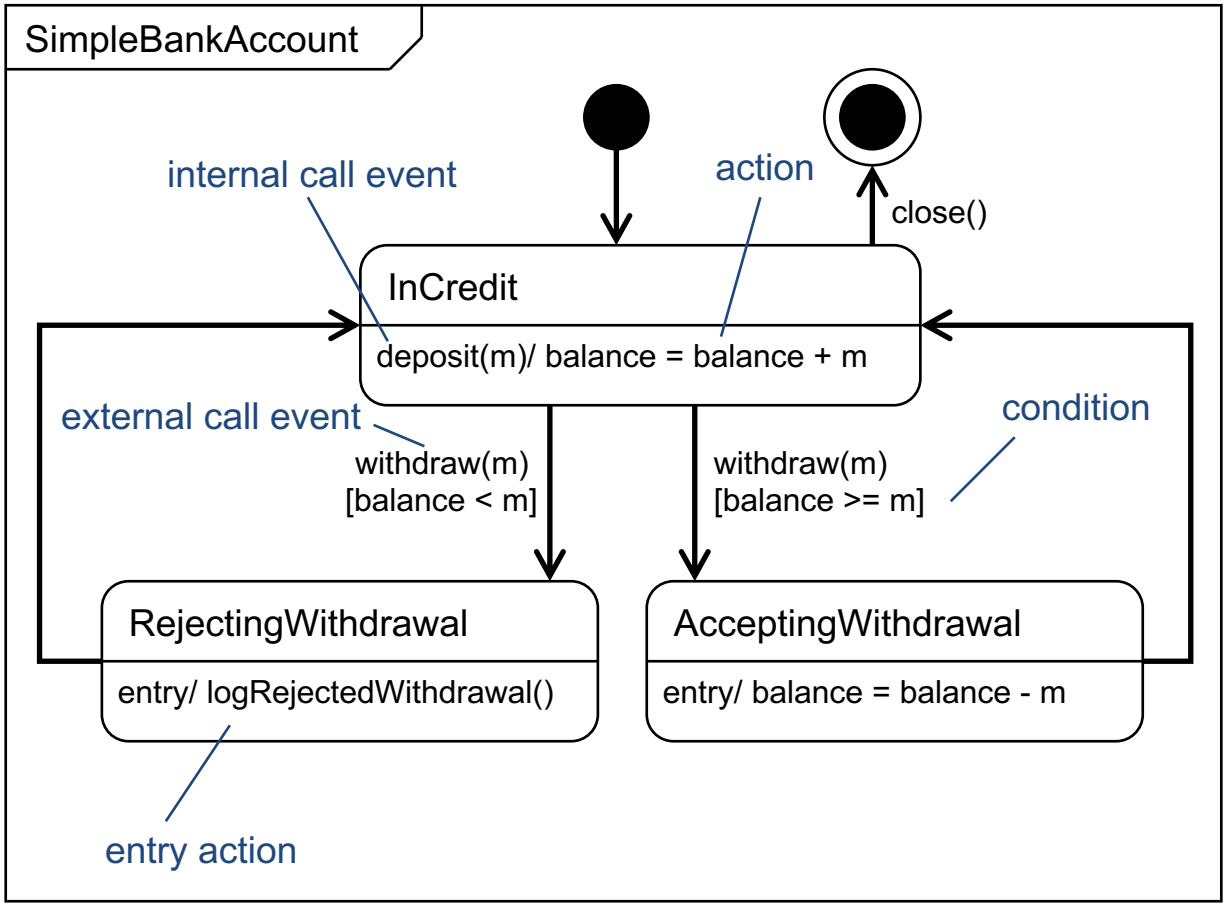
- "The specification of a noteworthy occurrence that has location in time and space"
- Events trigger transitions in state machines
- Events can be shown externally, on transitions, or internally within states (internal transitions)
- There are four types of event:
  - Call event
  - Signal event
  - Change event
  - Time event



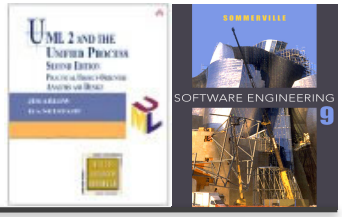
Call event



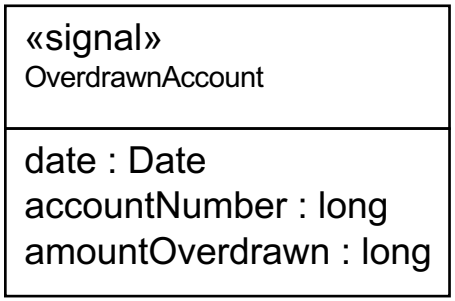
- A call for an operation execution
- The event should have the same signature as an operation of the context class
- A sequence of actions may be specified for a call event - they may use attributes and operations of the context class
- The return value must match the return type of the operation

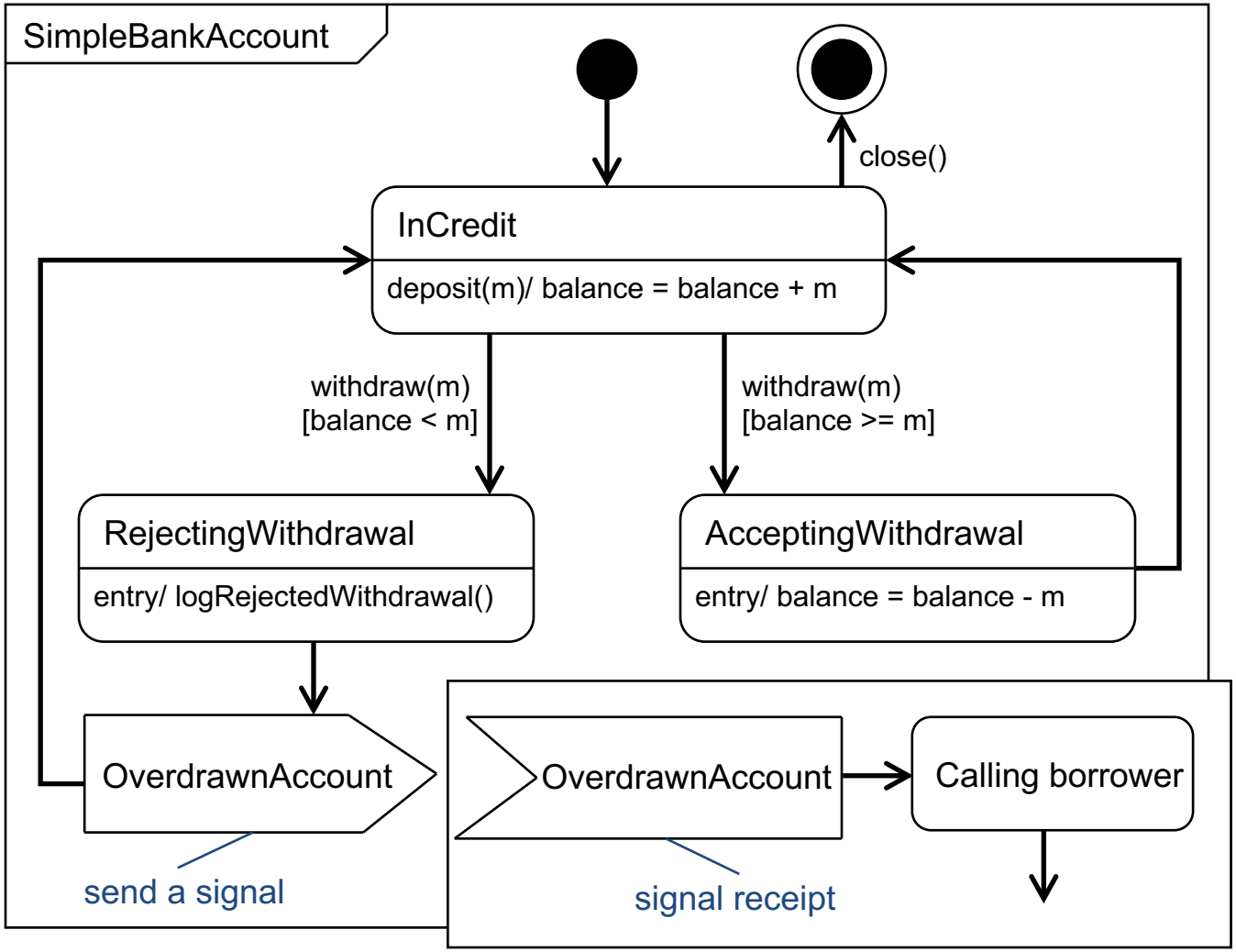


Signal events

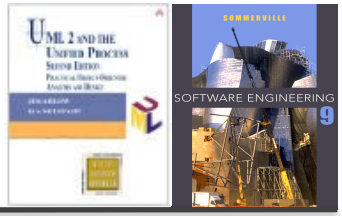


- A signal is a package of information that is sent asynchronously between objects

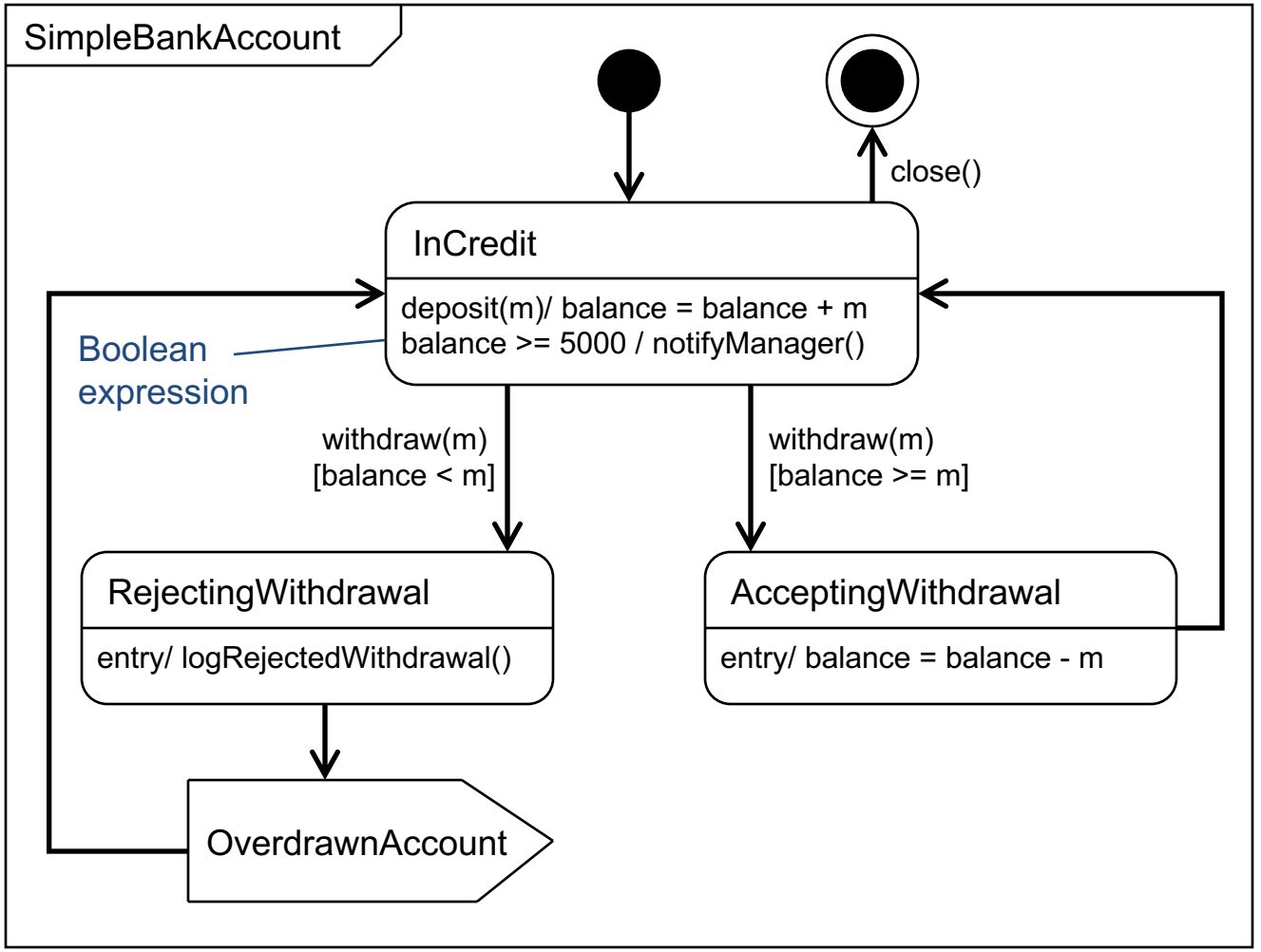




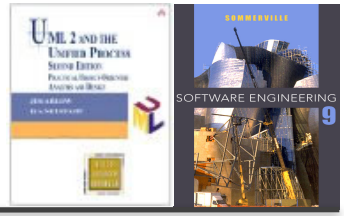
Change events



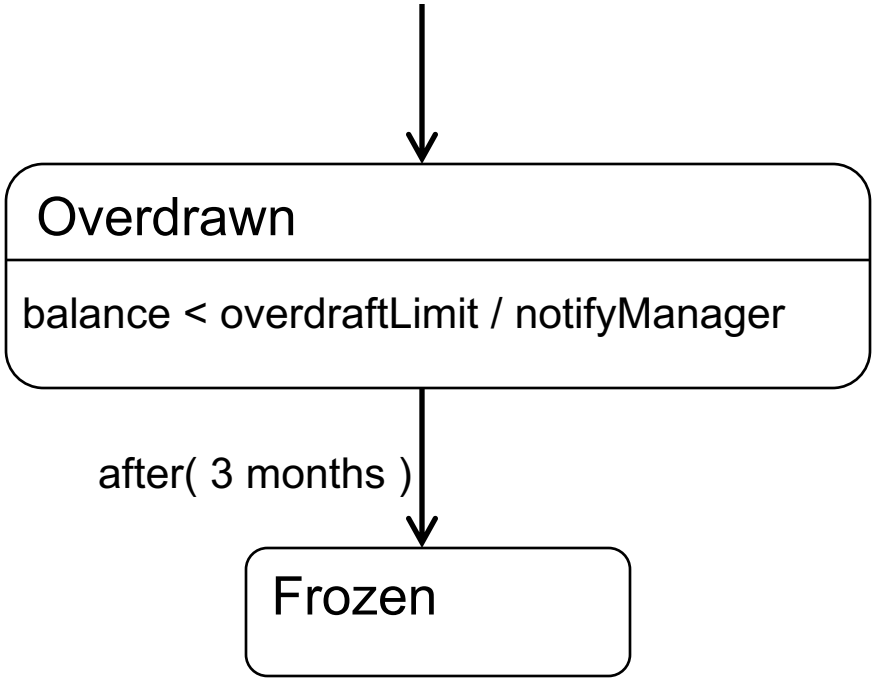
- The action is performed when the Boolean expression transitions from false to true
  - The event is **edge triggered** on a false to true transition
  - The values in the Boolean expression must be constants, globals or attributes of the context class
- A change event implies continually testing the condition whilst in the state



Time events

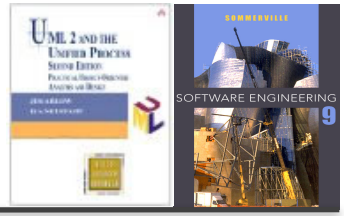


- Time events occur when a time expression becomes true
- There are two keywords, **after** and **when**
- Elapsed time:
  - after(3 months)
- Absolute time:
  - when(date =20/3/2000)

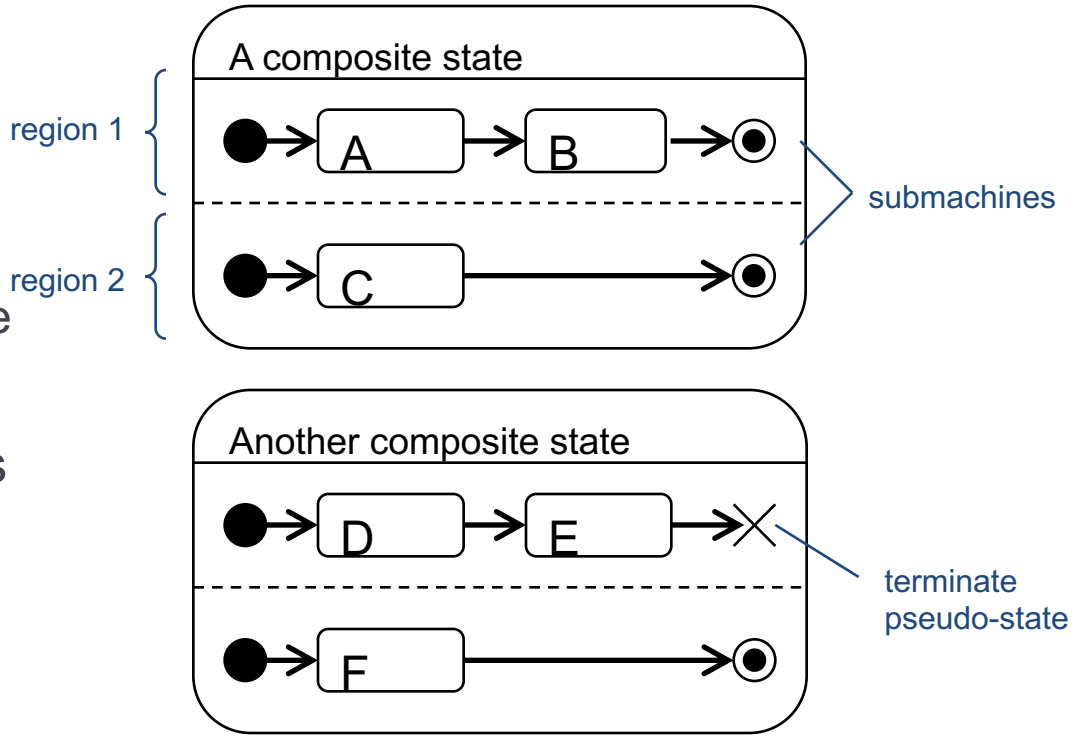


Context: CreditAccount class

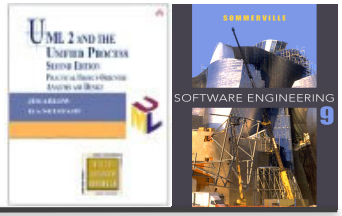
Composite states

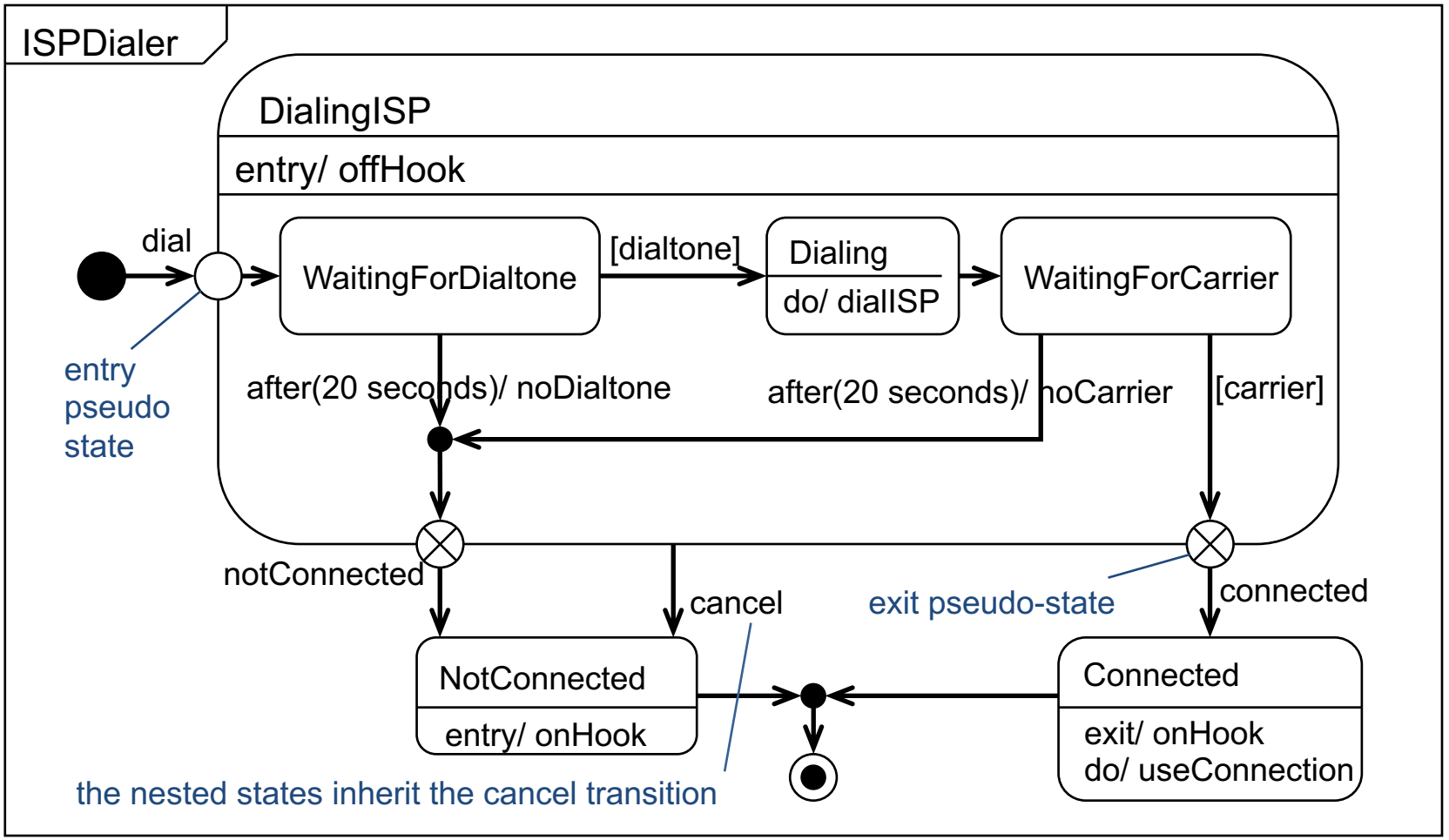


- Have one or more regions that each contain a nested submachine
  - Simple composite state
    - exactly one region
  - Orthogonal composite state
    - two or more regions
- The final state terminates its enclosing region – all other regions continue to execute
- The terminate pseudo-state terminates the whole state machine

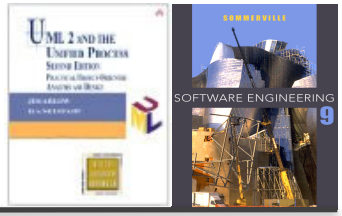


Simple composite states



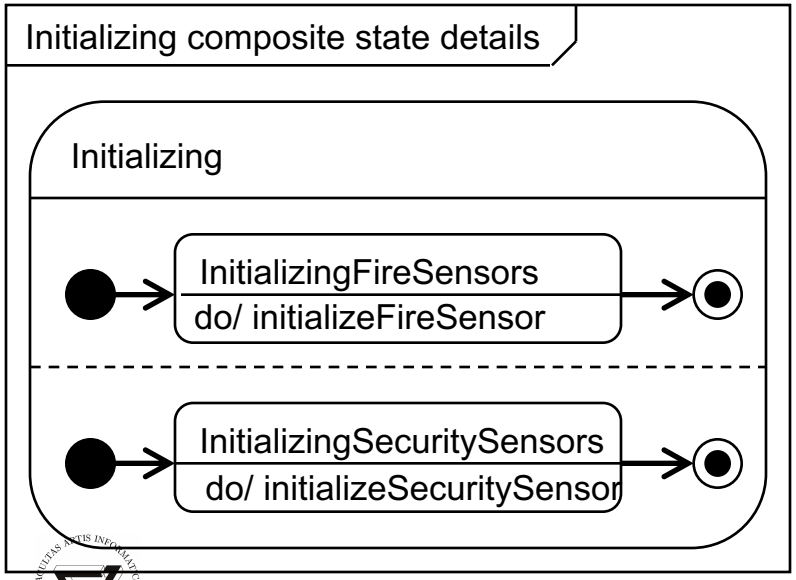


Orthogonal composite states

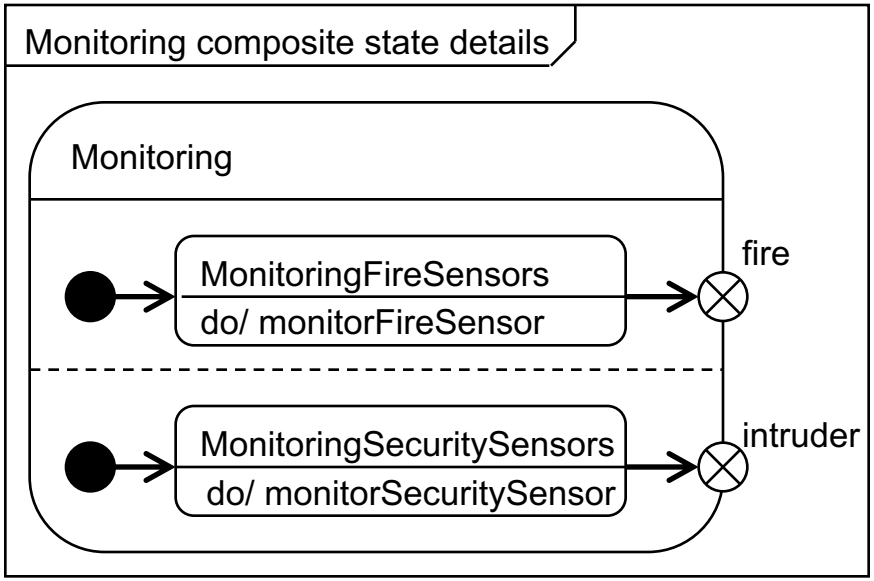


- Has two or more regions
- When we enter the superstate, both submachines start executing concurrently - this is an implicit fork

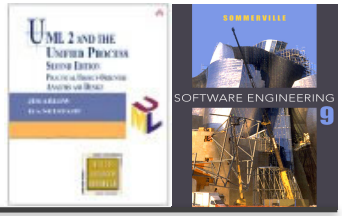
Synchronized exit - exit the superstate when *both* regions have terminated



Unsynchronized exit - exit the superstate when *either* region terminates. The other region continues



Key points



- ✧ Behavioral and protocol state machines
- ✧ States
  - Initial and final
  - Exit and entry actions, activities
- ✧ Transitions
  - Guard conditions, actions
- ✧ Events
  - Call, signal, change and time
- ✧ Composite states
  - Simple and orthogonal composite states