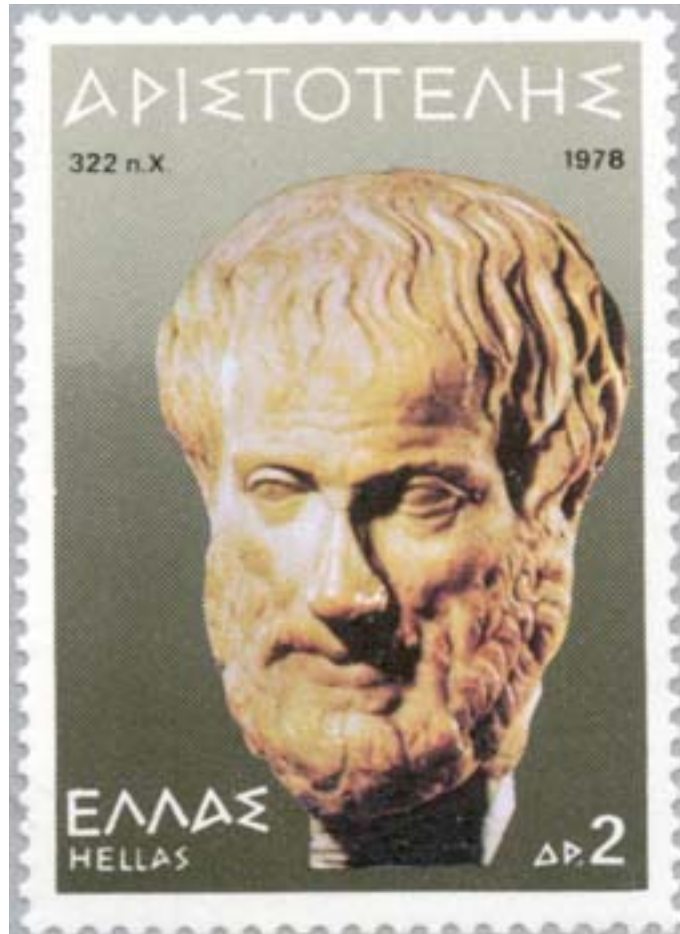
UML basics

Paolo Ciancarini



The soul
never thinks
without an image

Aristotle, *De Anima*

Agenda

- Evolution of UML: UML 1.* and UML 2.*
- Structures, behaviors, interactions
- The basic diagrams of UML 1.*

UML is a modeling language

- A modeling language allows the specification, the visualization, and the documentation of the development of a software system
- The models are *artifacts* which clients and developers use to communicate
- UML 1.* is a modeling language
- UML 2.* is also a programming language

Meaning of models for software

- A model is a *description* of the structure and meaning of a system
- A model is always an *abstraction* at some level: it captures the essential aspects of a system and ignores some details

- **Important**: a model can be also *generator* of potential *configurations* of systems

Roots of UML

At the beginning of the ’90 there was a convergence:

- **Booch method** (Grady Booch)
- **OMT** (Jim Rumbaugh)
- **Fusion/OOSE** (Ivar Jacobson)

(Grady Booch), (Jim Rumbaugh) – ’94 – join *Rational Software Corporation*

(Ivar Jacobson) – ’95 – joins Rational

Evolution of UML

- OO languages appear, since mid 70's to late 80's
- Between '89 and '94, OO methods increased from 10 to 50
- Unification of ideas began in mid 90's
    - 1994 Rumbaugh joins Booch at Rational
  - 1995 v0.8 draft Unified Method
    - 1995 Jacobson joins Rational (*Three Amigos*)
  - 1996 June: UML v0.9 published

pre-UML

  - 1997 Jan: UML 1.0 offered to OMG
  - 1997 Jul: UML 1.1 OMG standard
  - 1998: UML 1.2
  - 1999: UML 1.3
  - 2001: UML 1.4
    - 2003 Feb: IBM buys Rational
  - 2003: UML 1.5
  - 2004: UML 1.4.2 becomes the standard ISO/IEC 19501

UML 1.x

  - 2005: UML 2.0
  - 2007: UML 2.1.2
  - 2009: UML 2.2
  - 2010: UML 2.3
  - 2011: UML 2.4
  - 2013: UML 2.5

UML 2.0

OMG

- Object Management Group, founded in 1989
- Consortium of 800 industries (eg. IBM, HP, Apple, etc.) and interested universities (Bologna is member)
- Produces specifications of reference architectures, eg. CORBA
- Other specifications: UML, various MDA technologies
- UML as managed by OMG is a standard *de facto* in continuous evolution
- UML1.4 is a ISO standard *de jure*

Main UML specification documents

- **Superstructure**:
  defines the UML elements (diagrams, etc.)
- **Infrastructure**: defines the UML core metamodel
- **OCL** (Object Constraint Language):
  formal language for writing predicates,
  constraints, and formulas inside diagrams
- **XMI** (XML Metadata Interchange):
  DTD for UML models
- UML Diagram Interchange: XMI + graphic info

Canonical diagrams (vers 1.5)

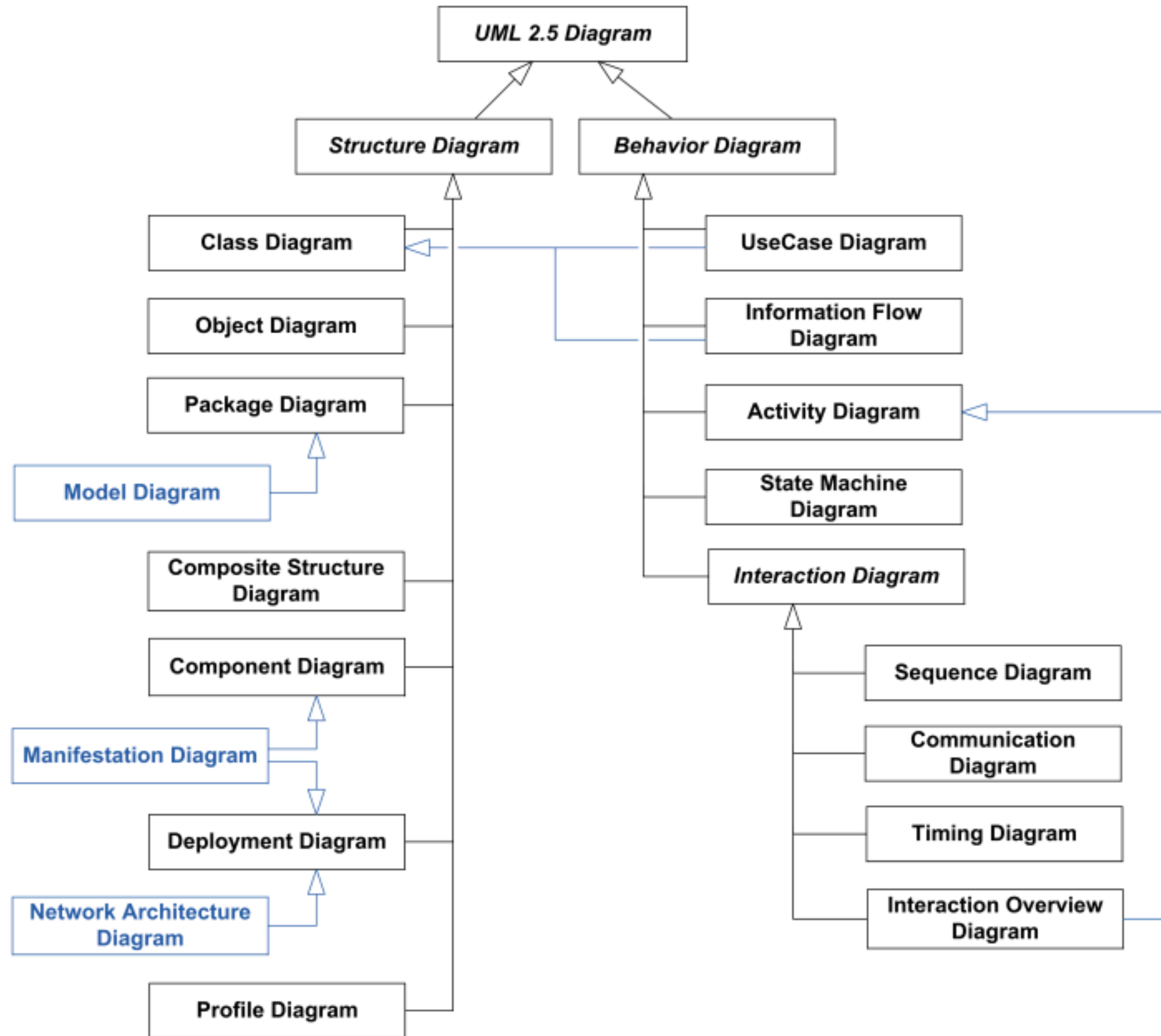
- Use case
- Class (Object diagrams are class diagrams without classes 🙂)
- Behavior
  - Statecharts
  - Activity
  - Interaction
    - Sequence
    - Collaboration
- Implementation
  - Components
  - Deployment

Canonical diagrams (Superstructure, vers. 2.4)

Version 2.4 includes 14 canonical diagrams

- **Structure**
  1. Class
  2. Composite structure
  3. Component
  4. Deployment
  5. Object
  6. Package
  7. Profiles (added in version 2.4)
- **Behavior**
  1. Activity
  2. Statecharts
  3. Usecase
- **Interaction**
  1. Communication
  2. Interaction Overview
  3. Sequence
  4. Timing

UML 2.5 (2013)



Structure and behavior

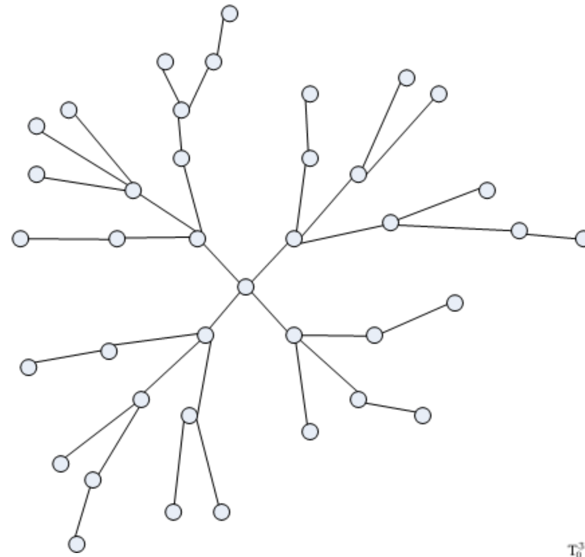
- UML focusses on two aspects of object oriented models: *structure* and *behavior*
- It aims at visualizing both

Tour Eiffel (1889)

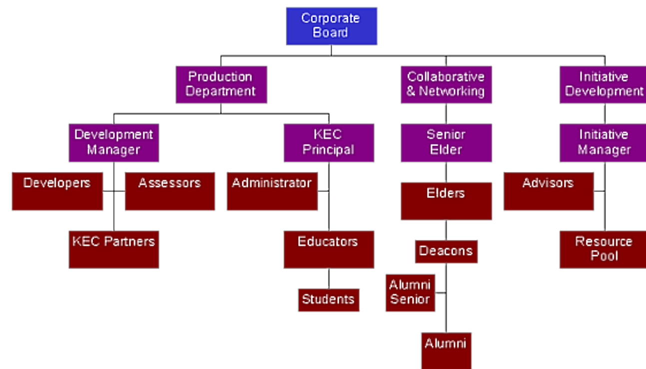
G. Balla: Dinamismo di cane al guinzaglio (1912)

Describing the structure of software

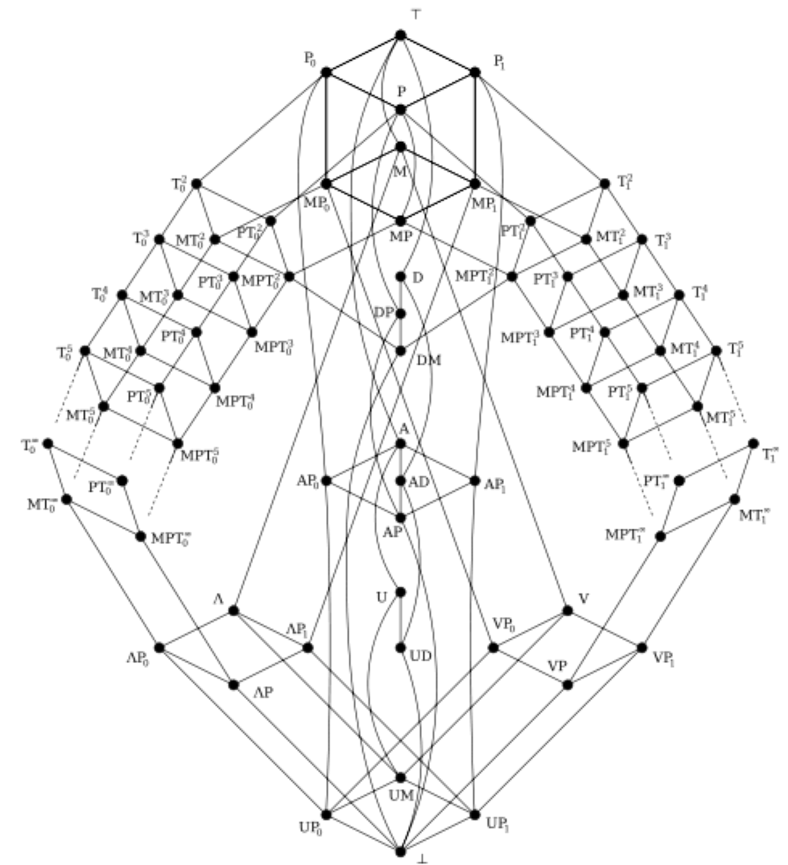
- The description of structure offers an account of what a system is made of, in terms of both its parts and the relationships among them
- A structure may be a hierarchy featuring one-to-many relationships, a network featuring many-to-many links, or a lattice featuring connections between components that are neighbors in space



Network

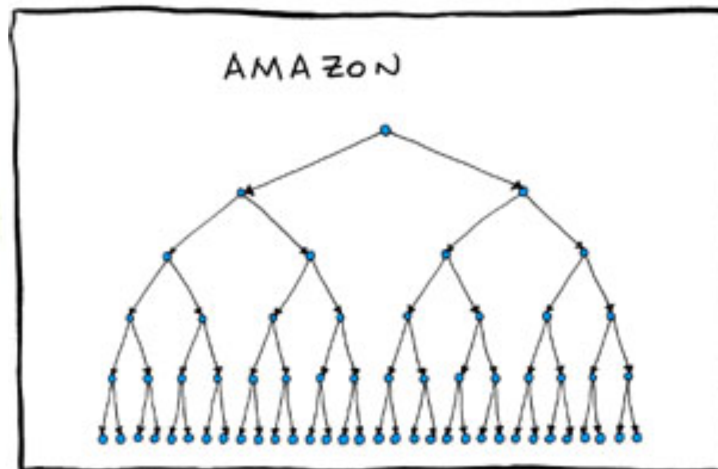


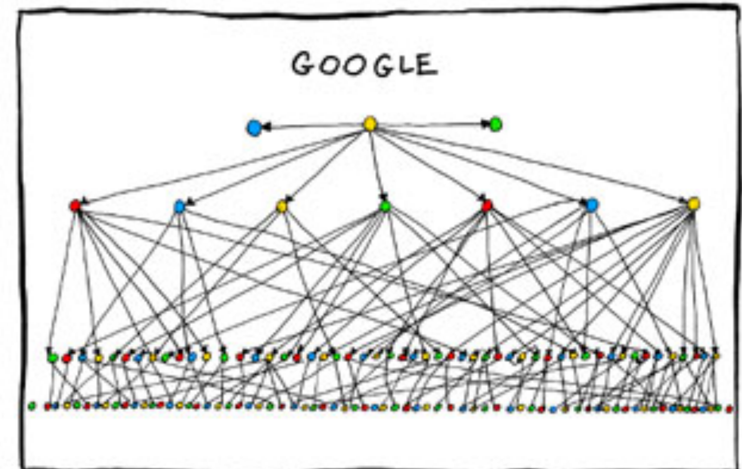
Hierarchy

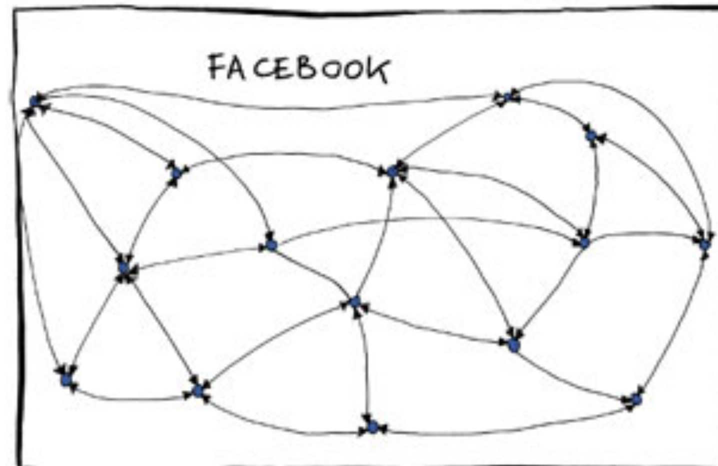


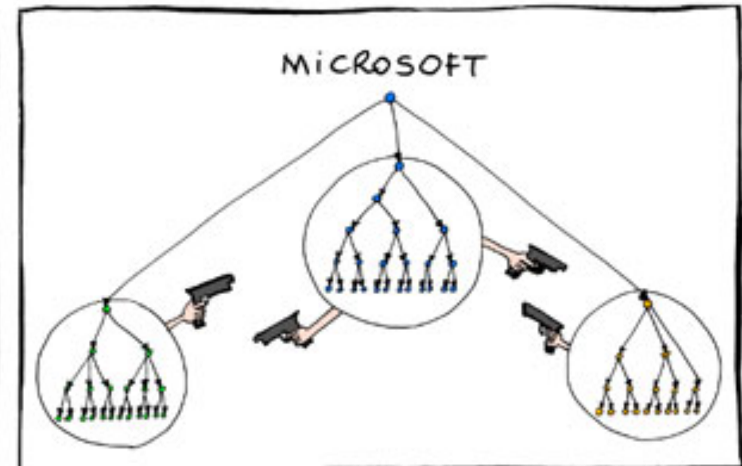
Lattice

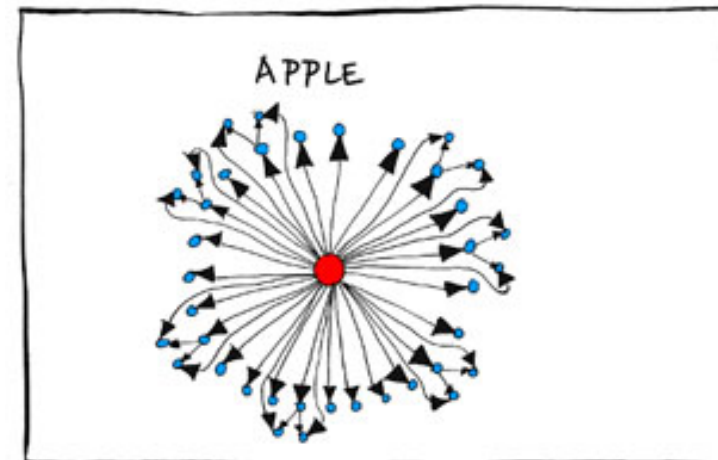
Organizational structures

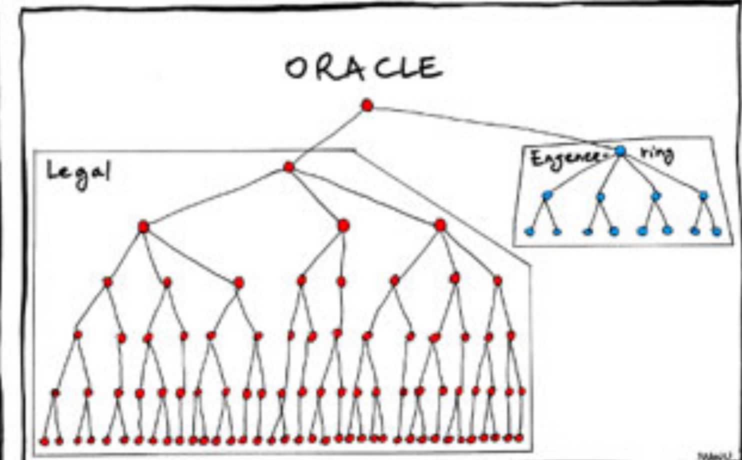




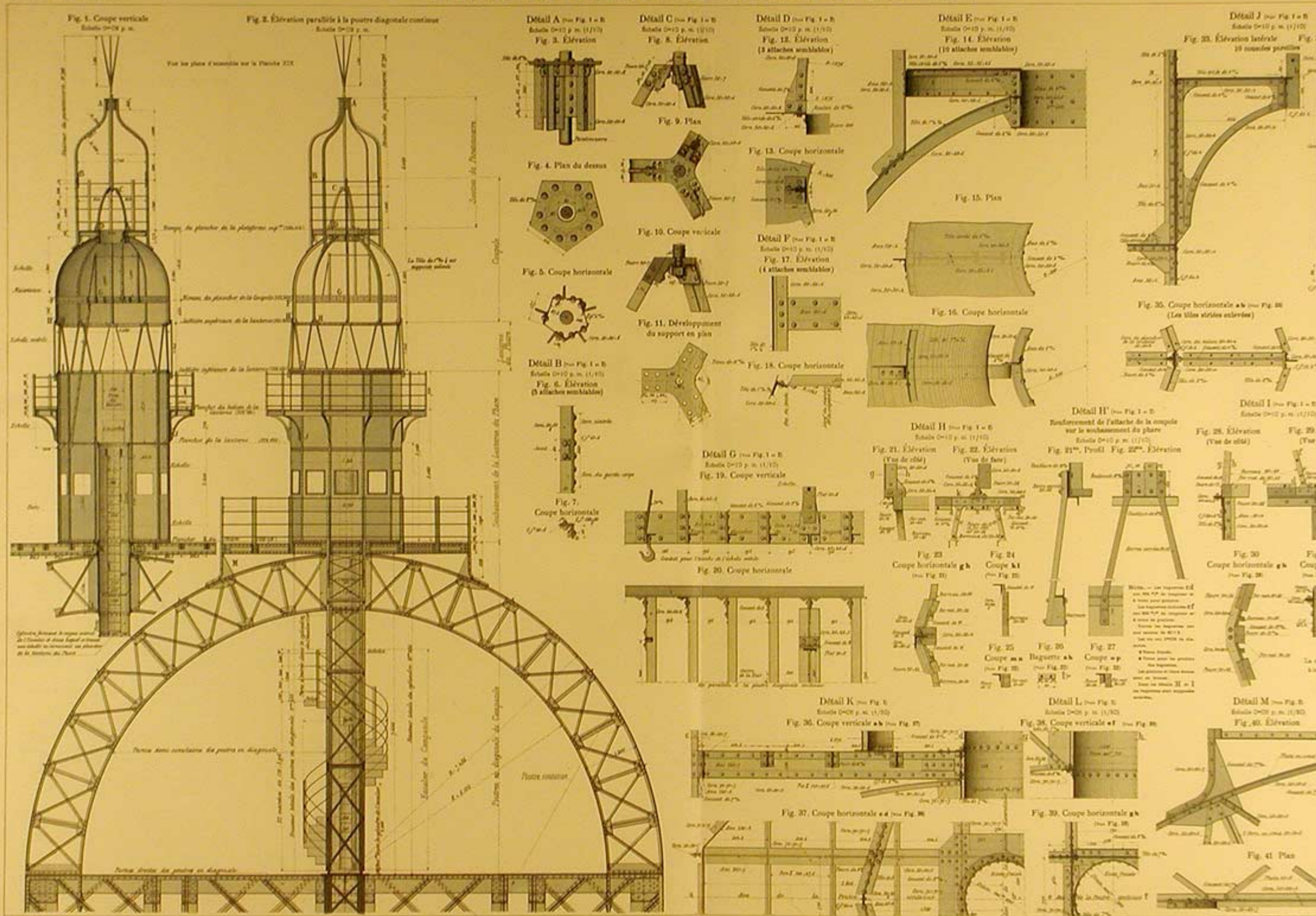




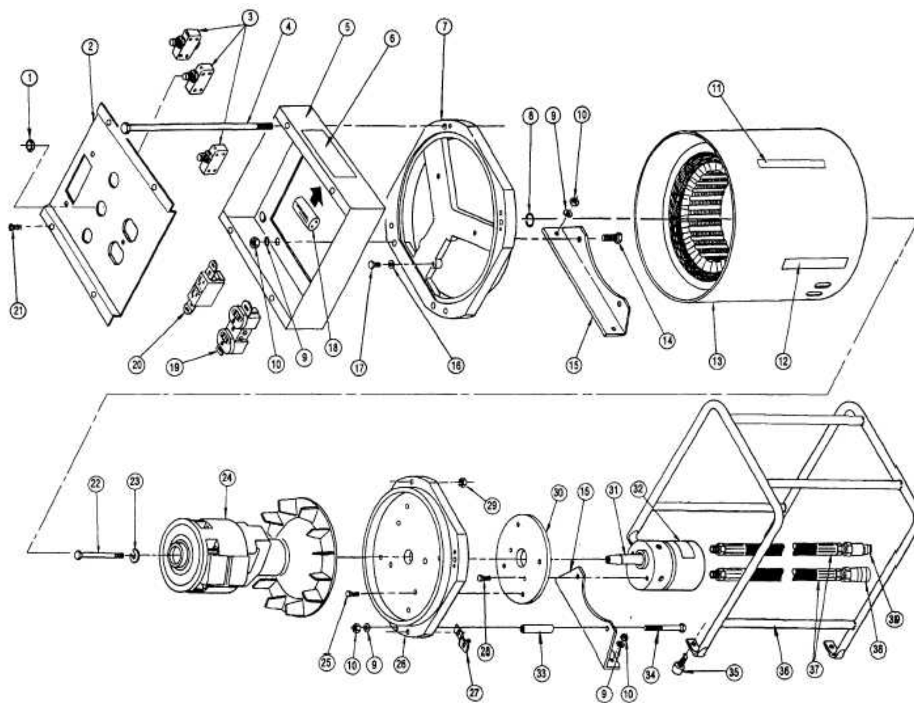


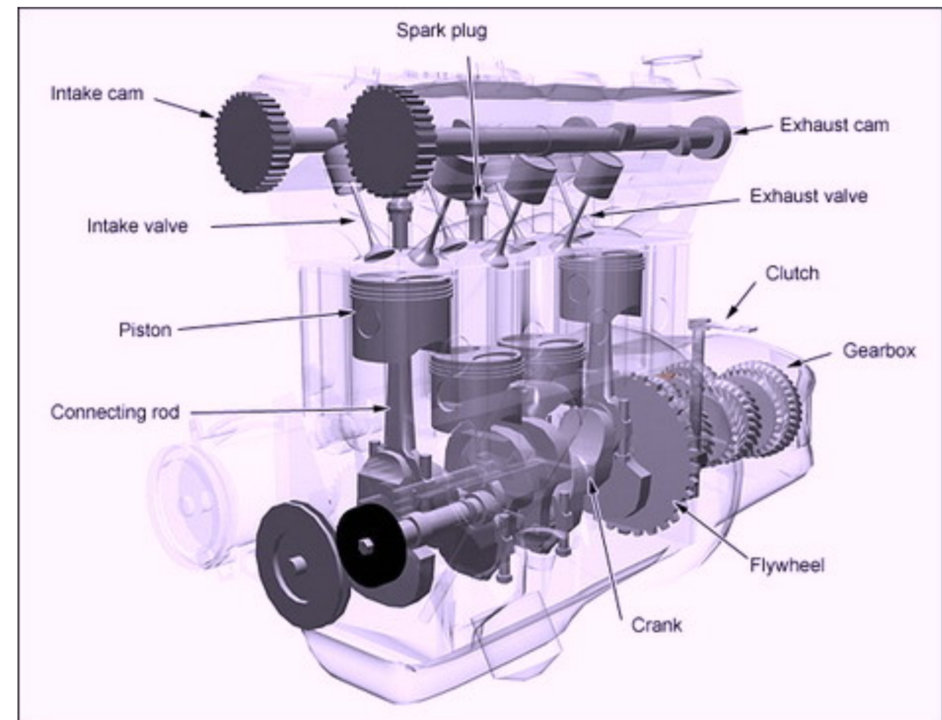


PARTIE SUPÉRIEURE. ENSEMBLE ET DÉTAILS.



Modules vs components

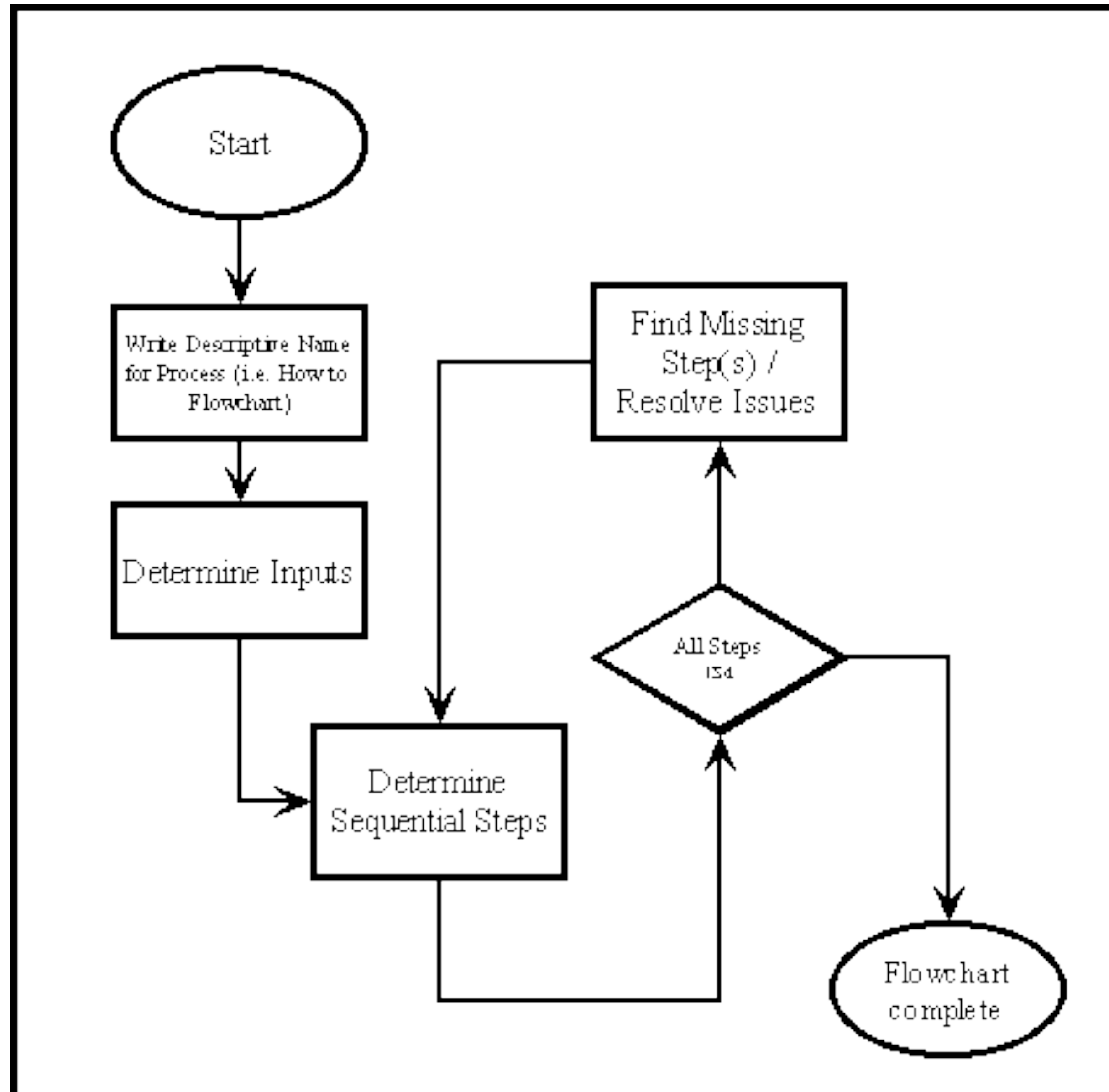




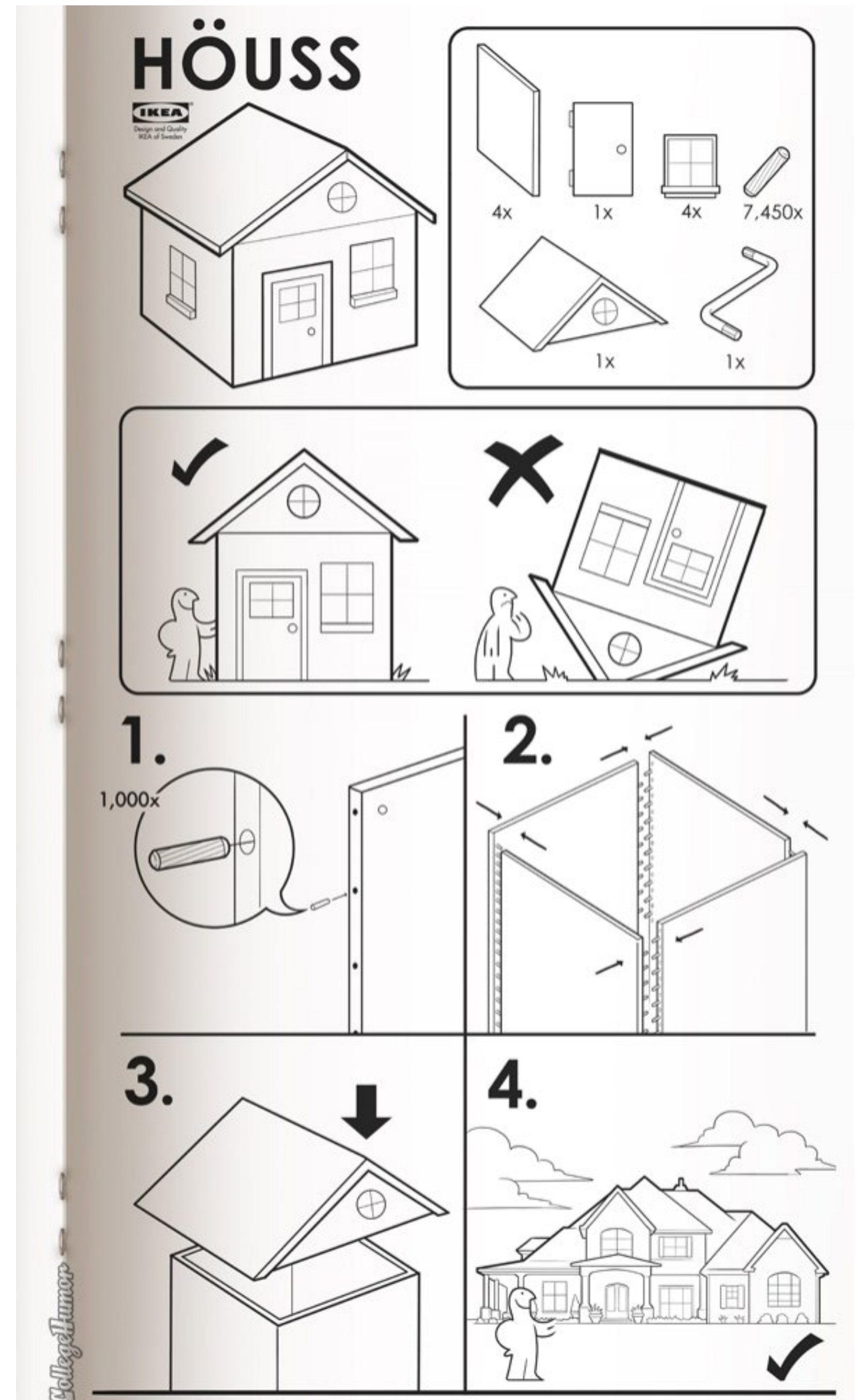
Discuss

- Which ways do you know to pictorially describe “behaviors” - or actions?

Flowchart



Assembly instructions



Lullaby

Johannes BRAHMS
1833-1897
arr. M.A. Caux

Andante cantabile

Violin

Piano

Source : *Wiegenlied*, Op. 49, No. 4 (1868).

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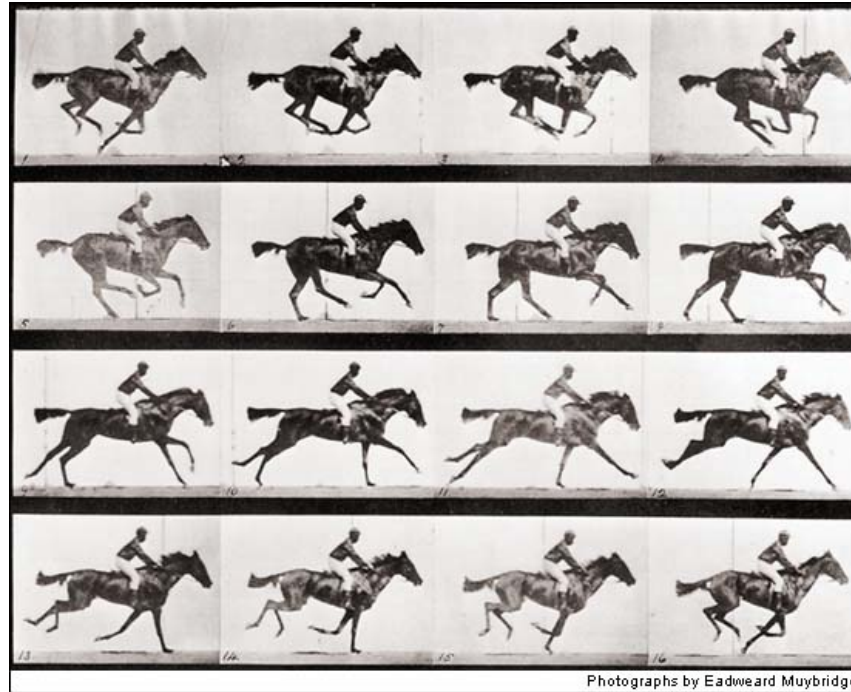


Photographs by Eadweard Muybridge

PARTIES

TOURNOI INTERCLUBS DE PARIS

183. — Défense des deux cavaliers.

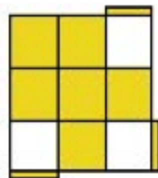
Le 24-2-1929.

O. S. BERNSTEIN-J. Cukierman

1. ♙4♔ ♙4♔
2. ♘3♗♔ ♘3♗♕
3. ♗4♗♕ ♘3♗♔
4. ♙4♕ ♙×♙♕
5. 0—0 ♙3♕

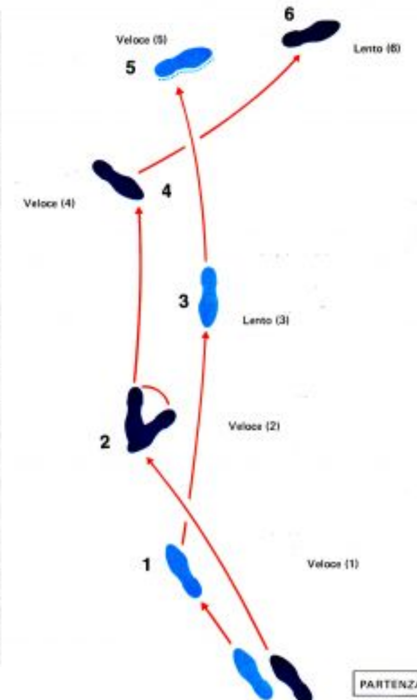
La suite 5. ,,♘×♙♔; 6. ♖1♔, ♙4♕; 7. ♗×♙♕, ♕×♗; 8. ♘3♗♕, ♕4♖♕! etc., conduit en fin de compte à l'égalité. Le coup du texte assure par contre aux Blancs une supériorité en espace dans la première phase de la partie.

6. ♘×♙♕ ♗2♔
7. ♘3♗♕ 0—0
8. ♘♔2♔

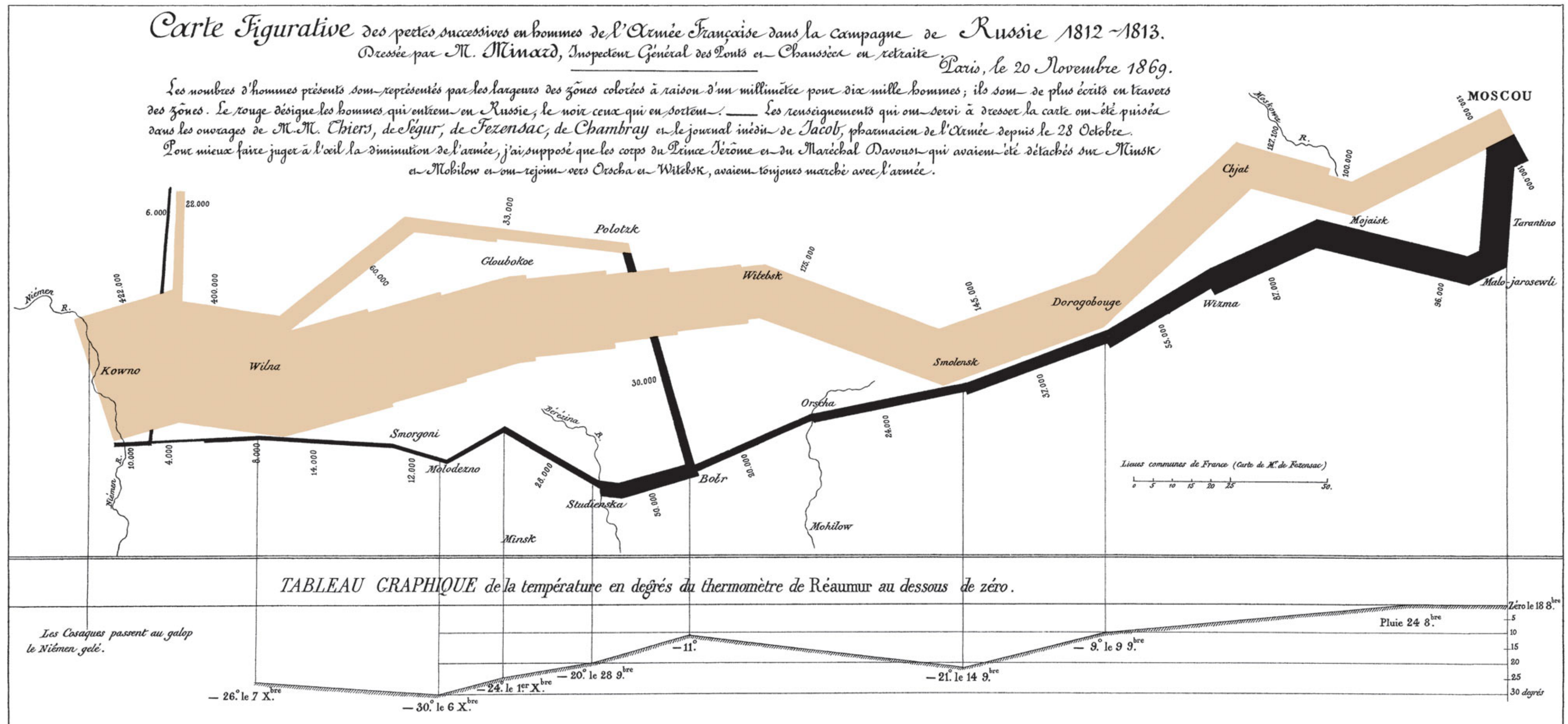


State 1. Twisting three corners anti-clockwise

R' U' R U' R' U2 R U2

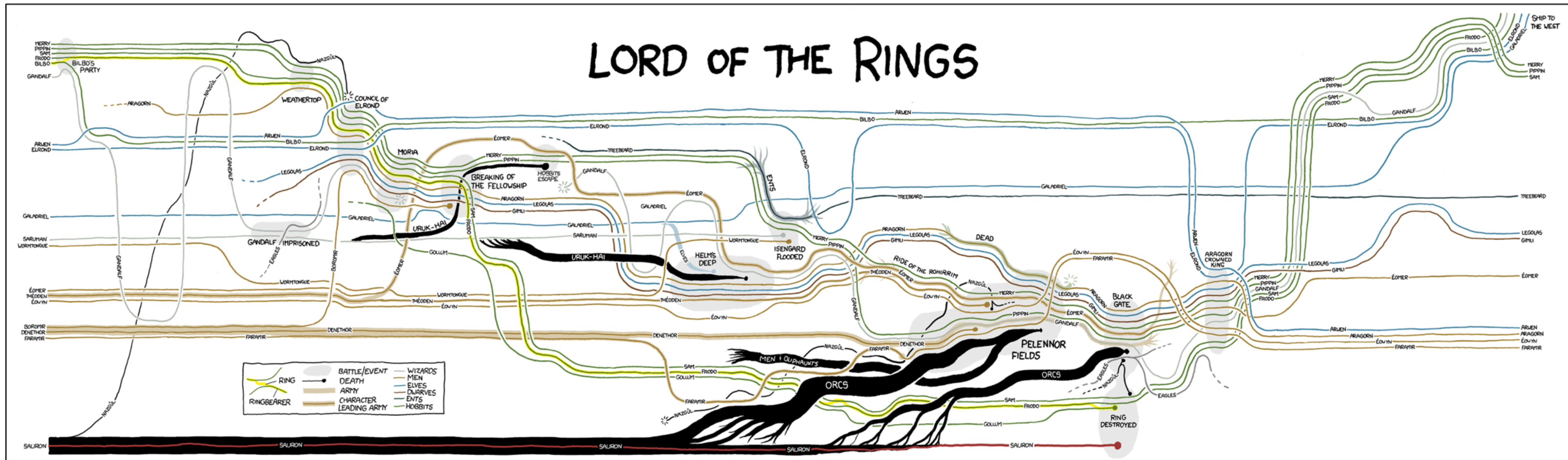


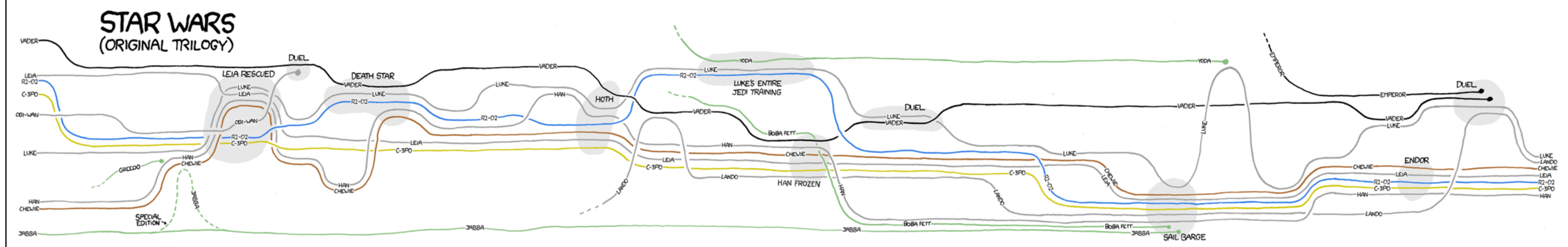
Napoleon in Russia

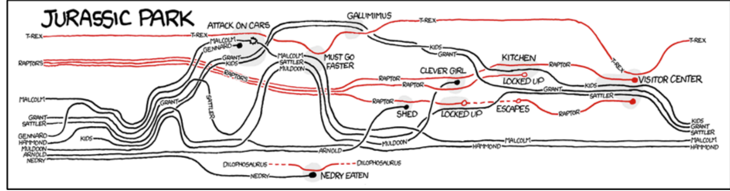


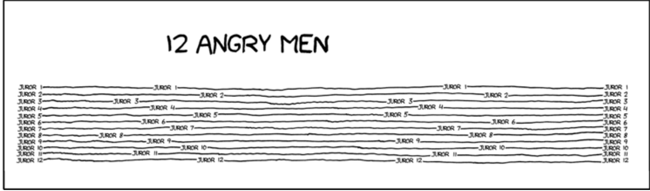
(Minard 1869)

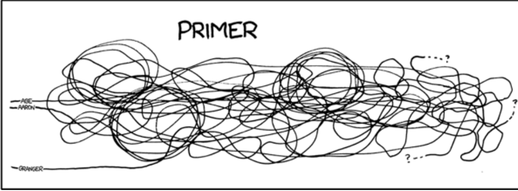
THESE CHARTS SHOW MOVIE CHARACTER INTERACTIONS.
THE HORIZONTAL AXIS IS TIME. THE VERTICAL GROUPING OF THE LINES INDICATES WHICH CHARACTERS ARE TOGETHER AT A GIVEN TIME.



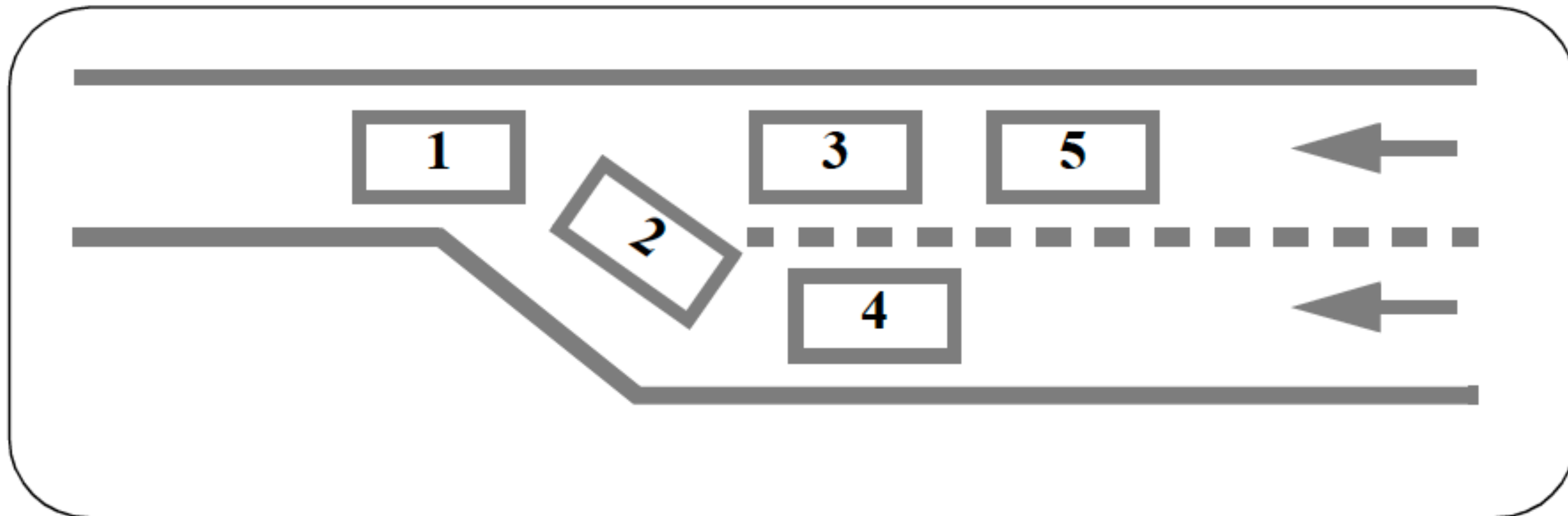








Exercise:
structural or behavioral?

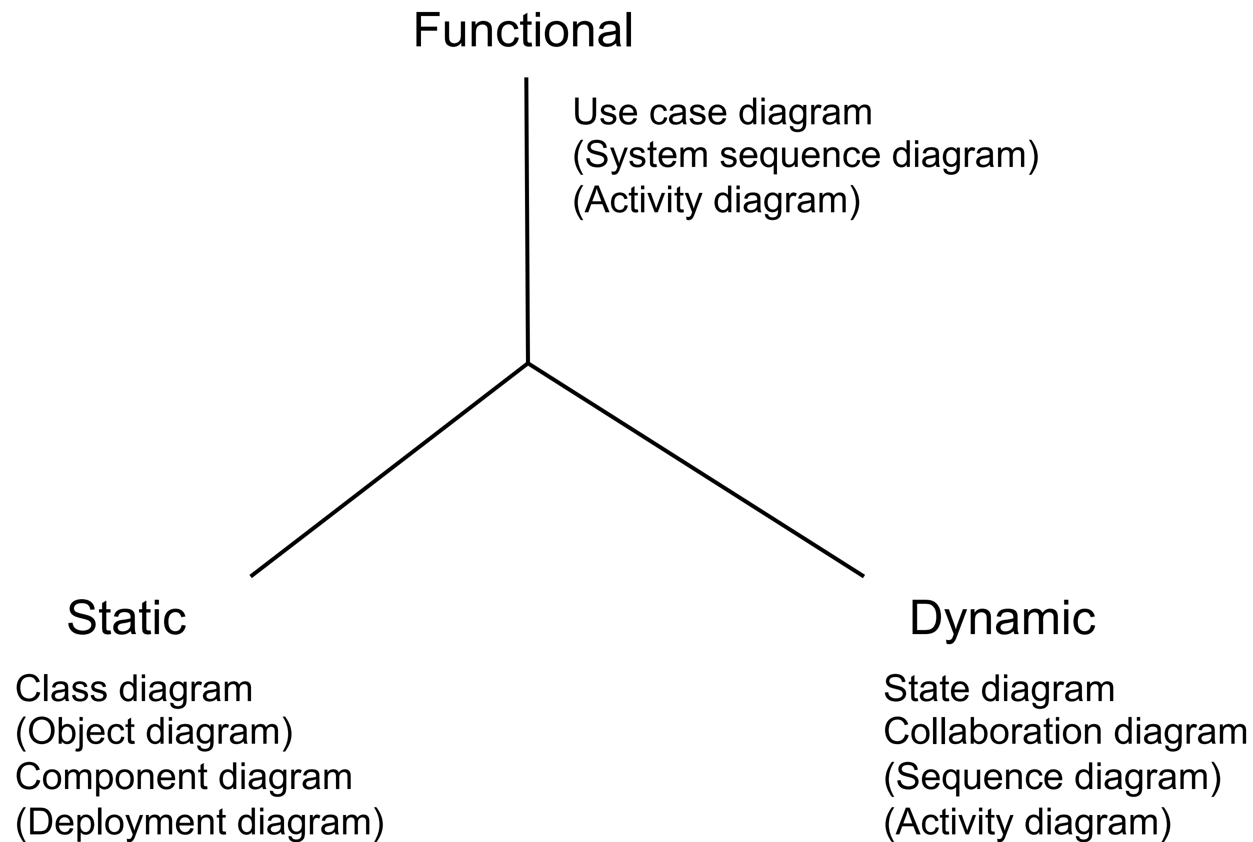


Hint: this picture describes modules (static) or components (dynamic)?

Discuss

- Are structures and behaviors all we need for software design?

Three modeling axes



Example

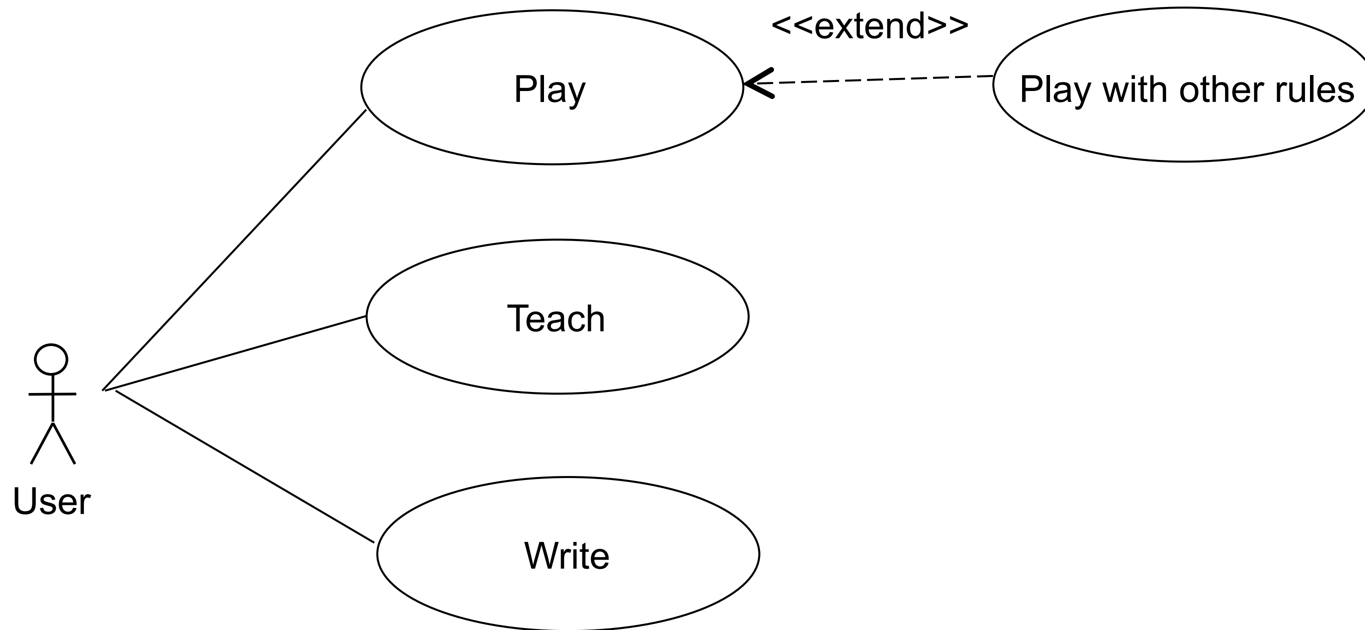
- A chess program could be “stand-alone”, “client-server”, “agent based”, etc.
- Its behavior should always be coherent with the rules of chess
- What is its **goal**? To play and win a chess game against an opponent

Goals and responsibilities

- The very same chess program, with identical structure and behavior, could be used with a different goal?
- For instance, could it be used to learn to play chess? Responsibility of the program: teach chess
- Or to write a chess book, like a chess game editor? Responsibility of the program: write chess texts
- Or to play a game of loser's chess (where who is checkmated wins)? Responsibility: play games with rules slightly different from chess

Each responsibility corresponds to (at least) a use case

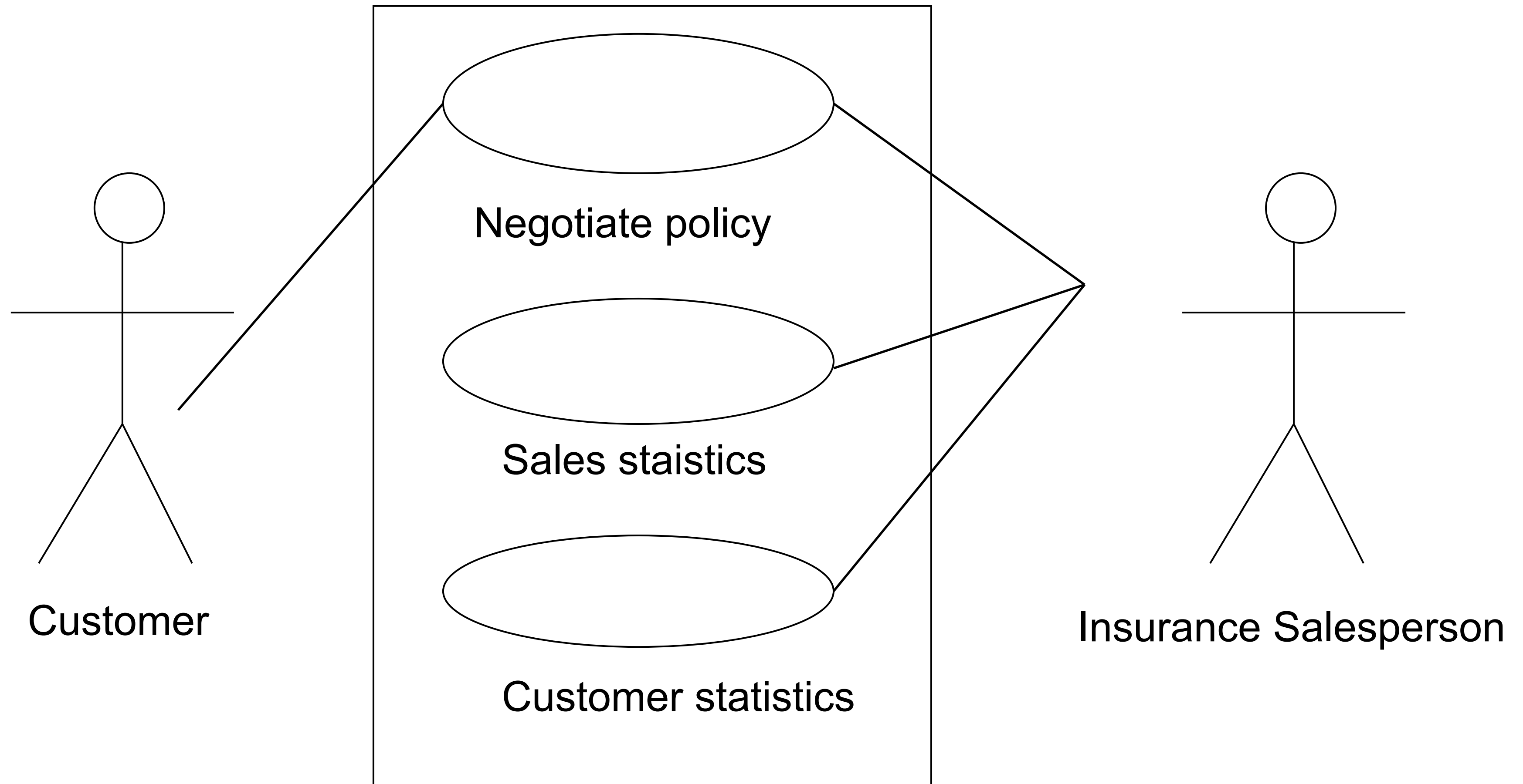
From responsibilities to use cases



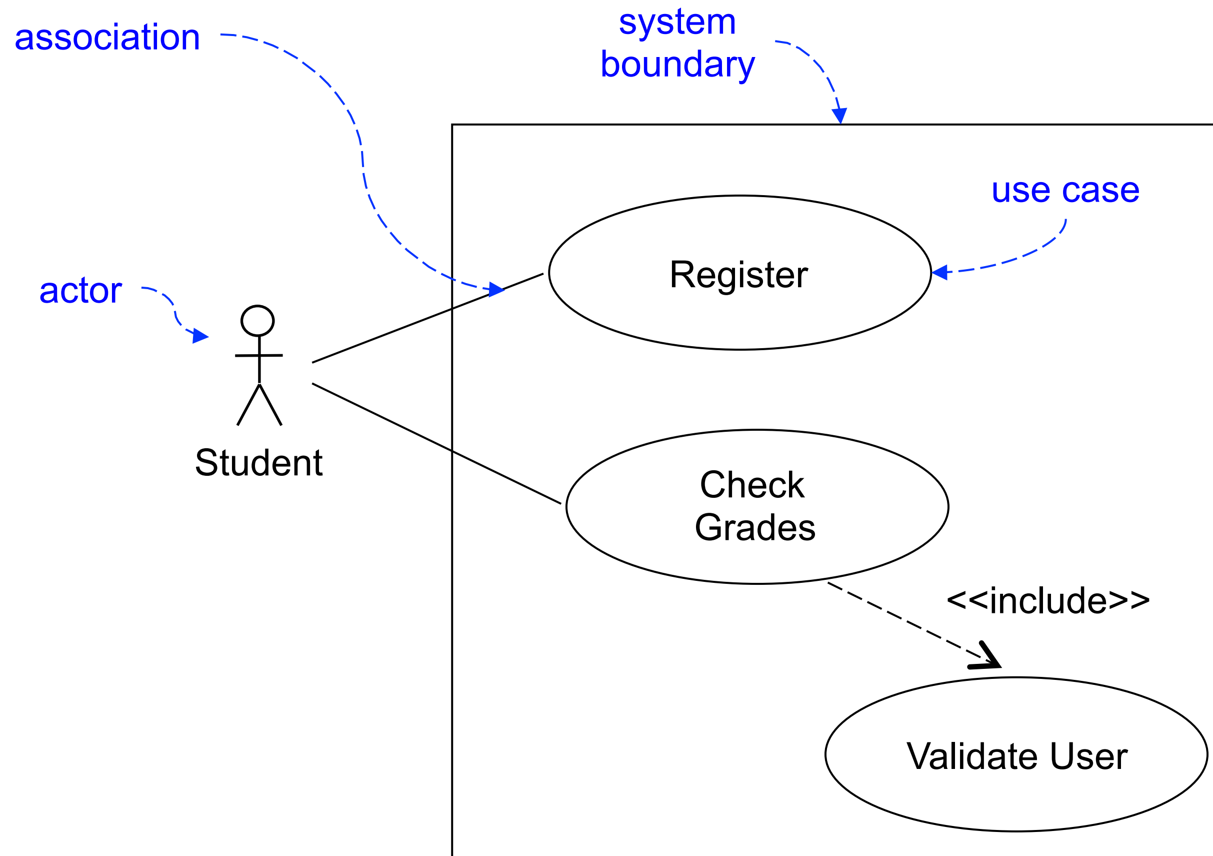
Use Case diagram

- It describes the externally observable behavior of a system, as related to **requirements**
- It describes the main interactions between the system and external entities, including users and other systems
- It is a summary of the main scenarios where the system will be used
- It describes the main user roles

Example



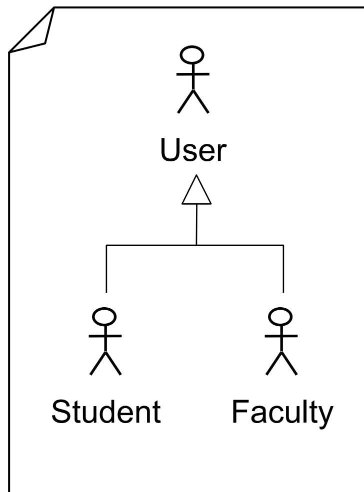
Use Case: elements

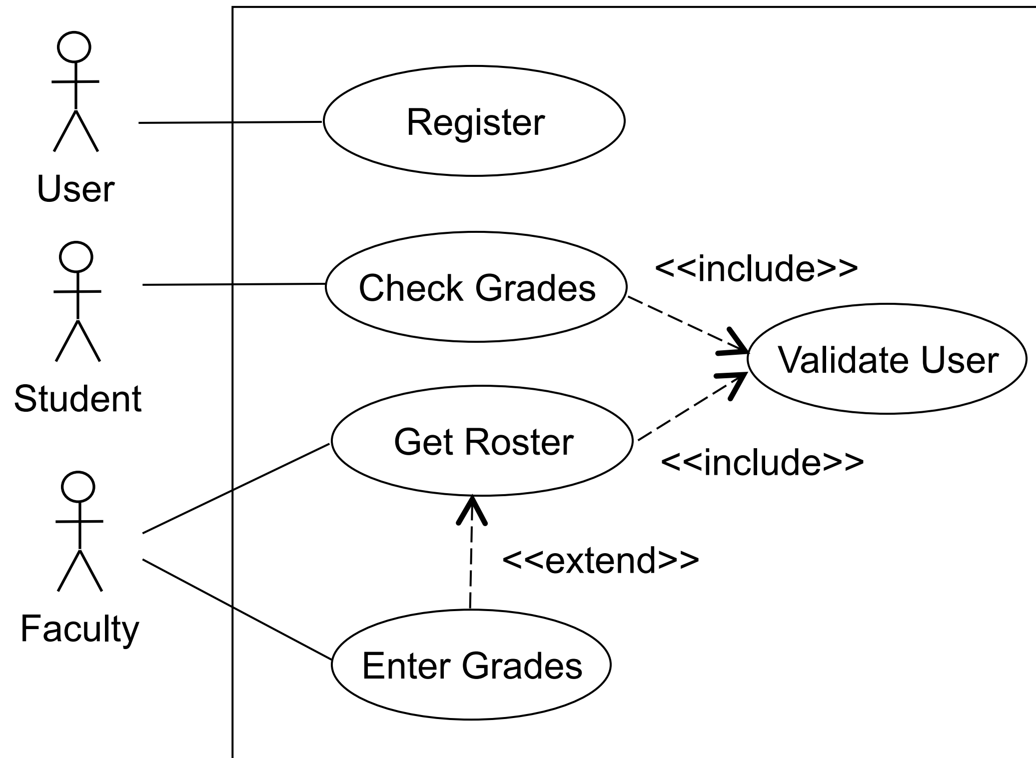


Elements of a Use Case Diagram

- **Actor**:
  - Represents a role played by external entities (humans, systems) that interact with the system
- **Use case**:
  - Describes what the system does (i.e., functionality)
  - Scenario: sequence of interactions between the actors and the system
- **Relationships**:
  - Association between actors and use cases
  - Extension (or generalization) among actors
  - Dependency among use cases: *include* and *extend*

Example

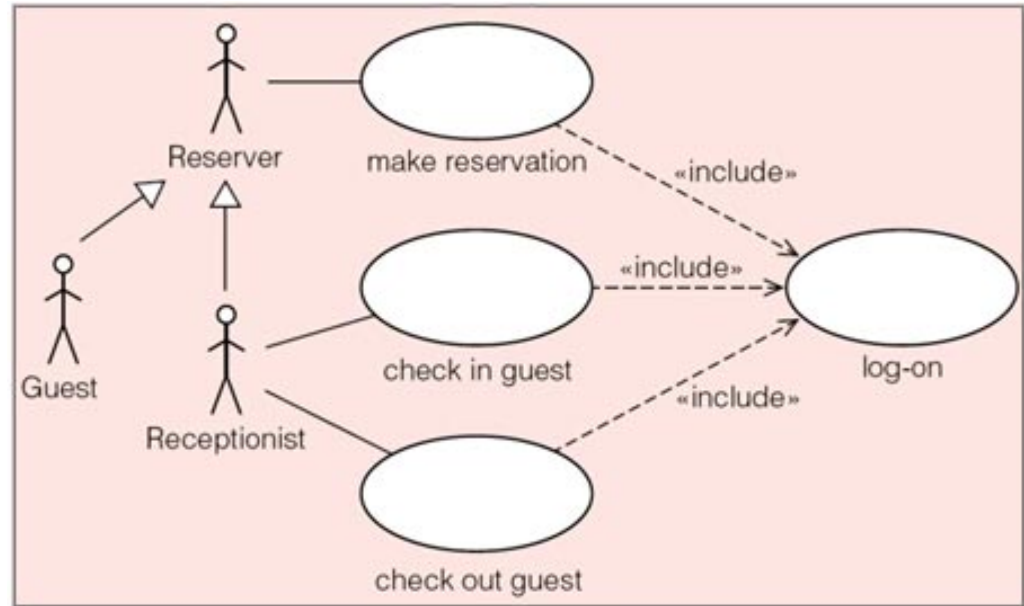




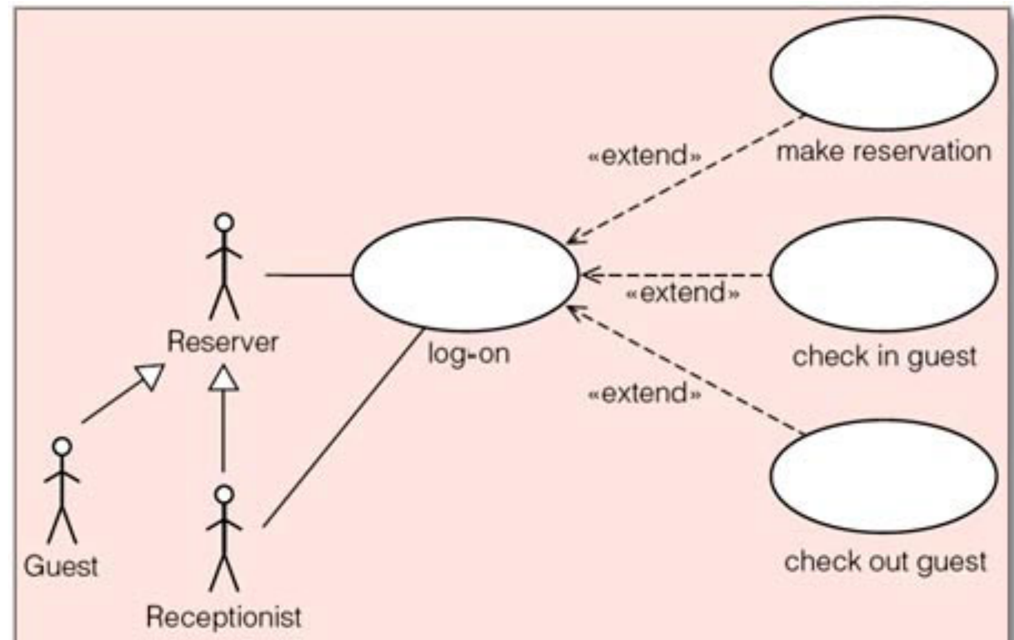
Use Case Scenario

Use Case: Check Grades	
Description: View the grades of a specific year and semester **Actors**: Student **Precondition**: The student is already registered **Main scenario:**	
User	**System**
	1. The system carries out “Validate User”, e.g., for user “miner” with password “allAs”. 2. The system prompts for the year and semester.
3. The user enters the year and semester, e.g., Fall 2013.	
	4. The system displays the grades of the courses taken in the given semester, i.e., Fall 2013.
Alternative: The student enters “All” for the year and semester, and the system displays grades of all courses taken so far. **Exceptional:** The “Validate User” use case fails; the system repeats the validation use case.	

<<extend>> vs <<include>>



- A use case B is included in use cases C and D when these have some common steps represented by B
- A use case B extends a use case C when B applies optionally, under some condition (usually specified in the scenario)



- Note: the lower diagram is formally correct but should be avoided, because the main functions should NOT be described as extensions of logon

Exercise

Draw a use case diagram and a related scenario for the following situation:

- A user can borrow a book from a library;
  - extend it with borrowing a journal
- a user can give back a book to the library
  - including the use case when the user is identified

Exercise: include or extend?

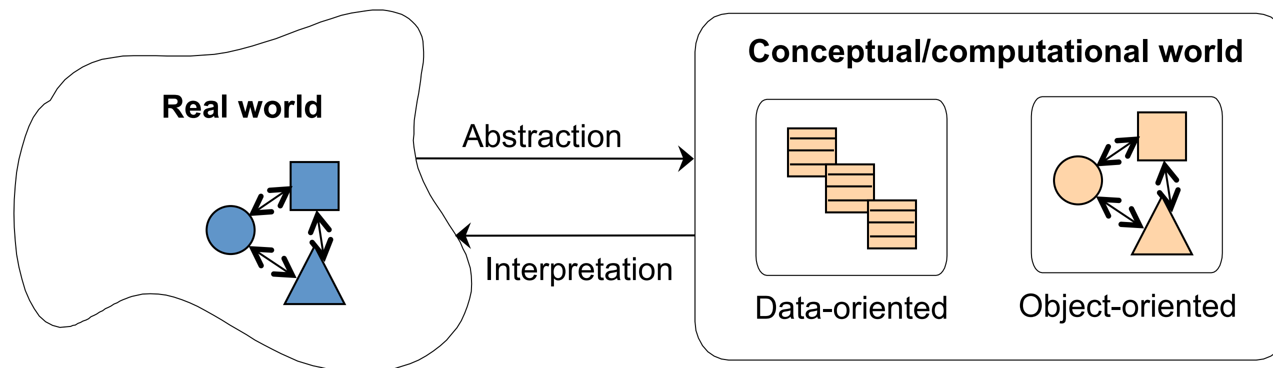
Main use cases: a customer buys something (eg. a book) from a virtual store like Amazon

- The user must be identified
- The book is not currently available, delayed delivery
- When the book is received the service must be graded
- The book is delivered via air mail
- The book is an ebook and can be delivered via Internet

Structure diagrams

Object-Oriented Modeling

- Models describe structures of objects and their behavior
- A system is modeled as **a set of objects** that interact by exchanging messages
- No semantic gap, seamless development process

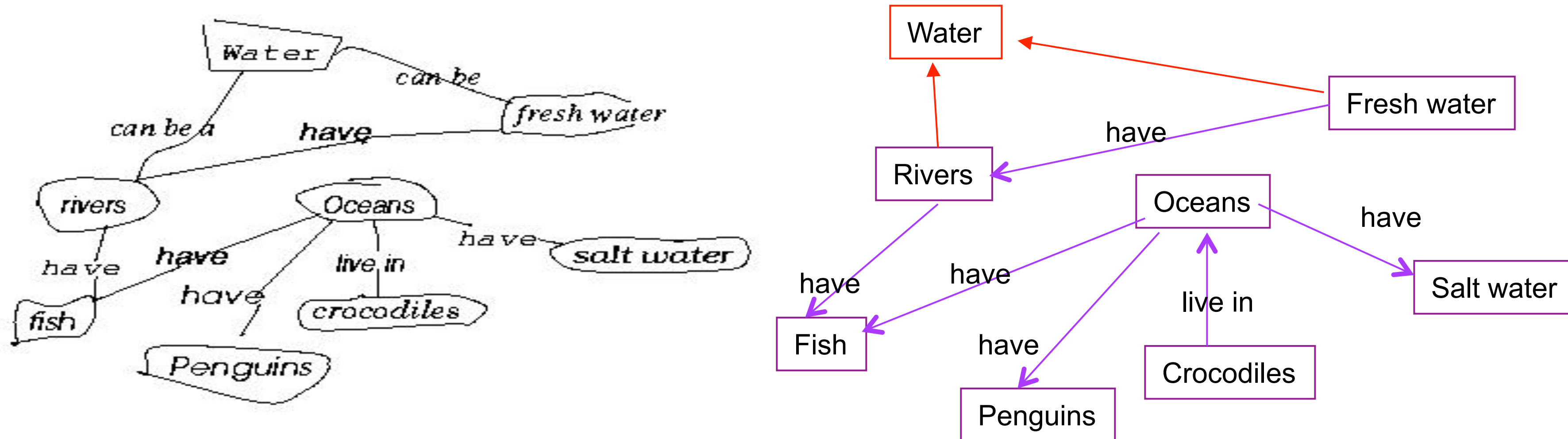


Key Ideas of OO Modeling

- Abstraction
  - hide minor details so to focus on major details
- Encapsulation
  - Modularity: principle of separation of functional concerns
  - Information-hiding: principle of separation of design decisions
- Relationships
  - Association: relationship between objects or classes
  - Inheritance: relationship between classes, useful to represent generalizations or specializations of objects
- Object-oriented language model

  = object (class) + inheritance + message send

The basic *building blocks* of UML



– Elements: domain modeling concepts

– Relationships: connection between model elements that adds semantic information to a model

– Diagrams: collections of elements and relationships representing some "perspective" on a model

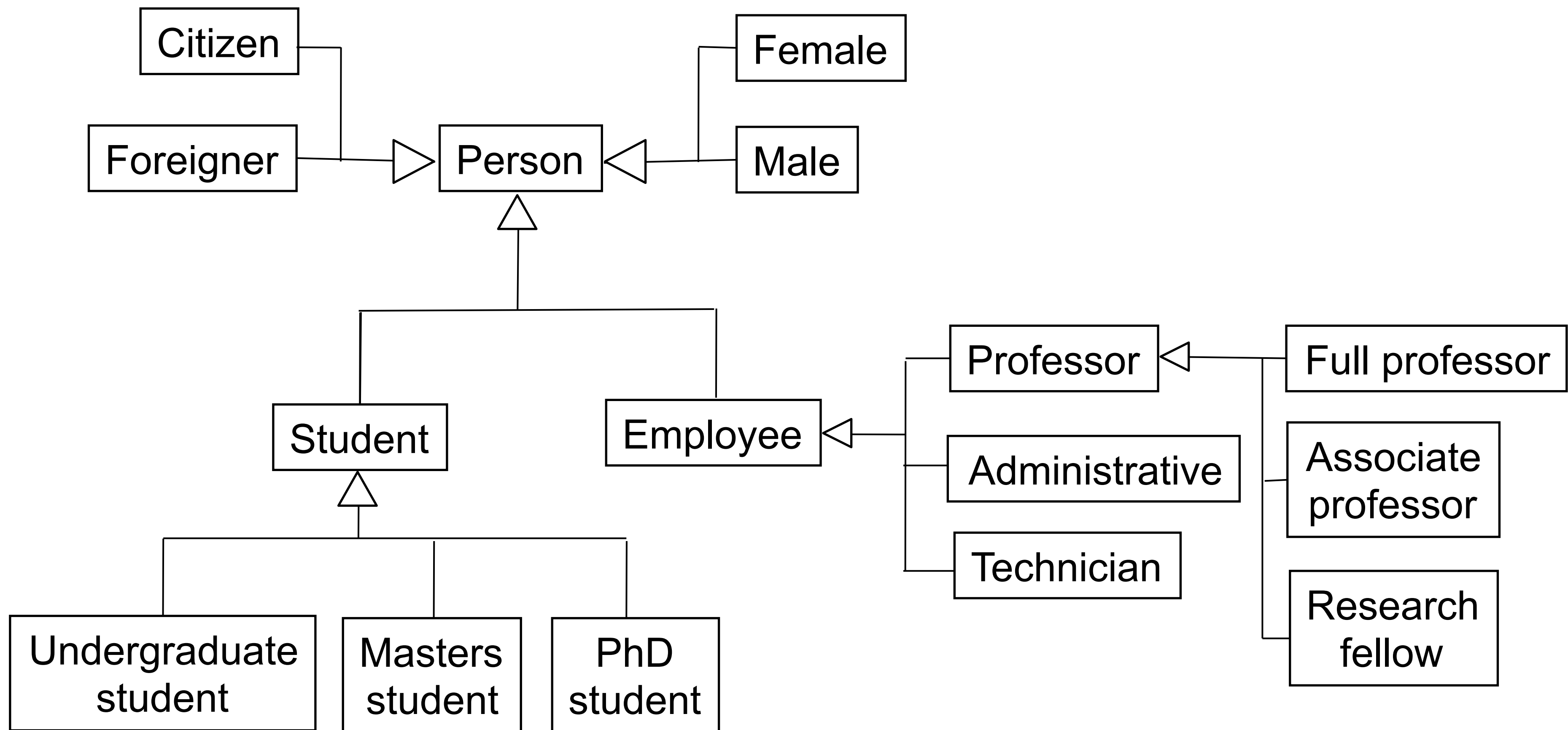
Main idea

- With UML we model systems made of objects which have relationships among them
- Objects are instances of classes
- Classes define the structure of objects and their relationships

Example

- A university is an organization where some persons work, some other study
- There are several types of roles and grouping entities
- We say nothing about behaviors, for the moment

A taxonomy



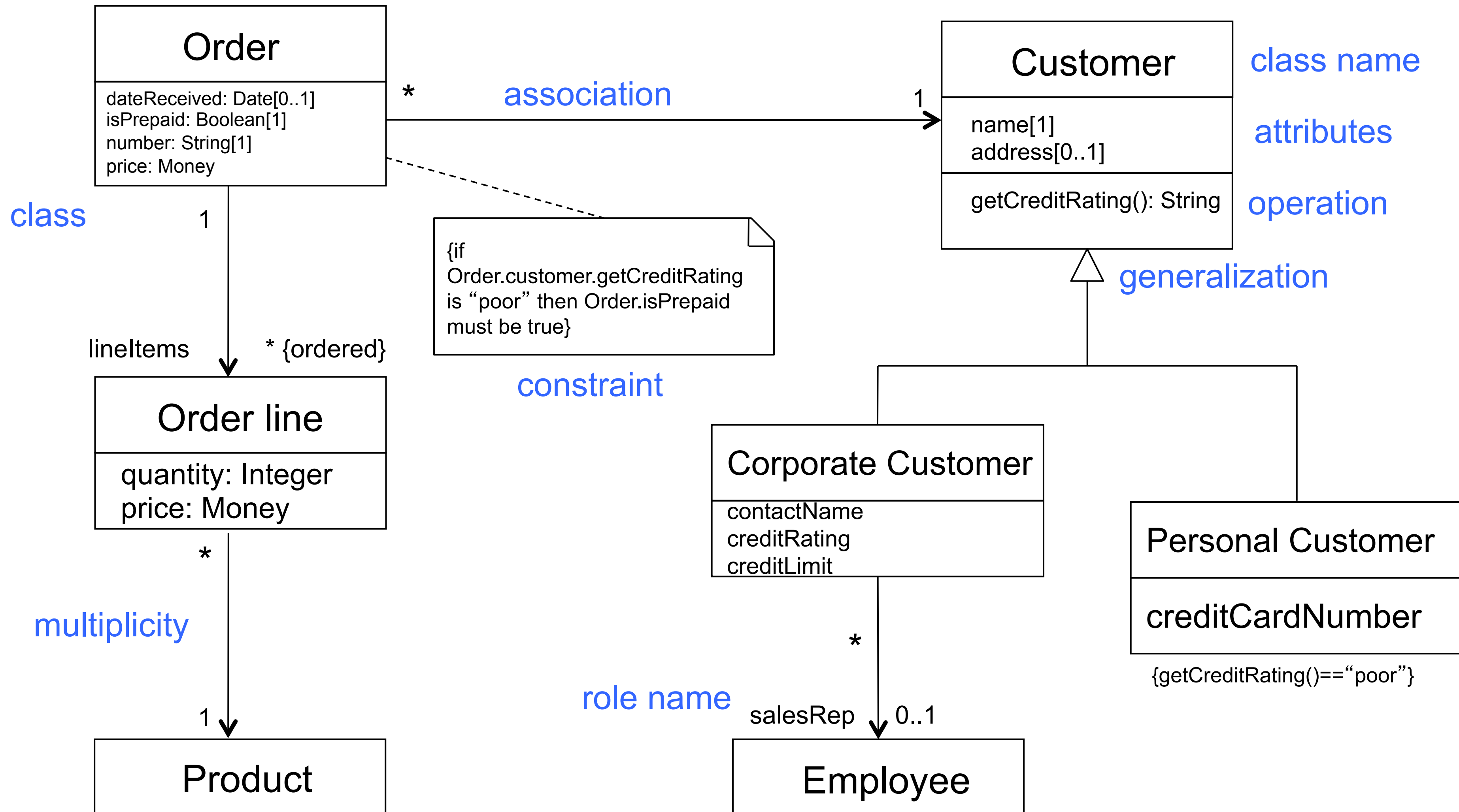
Class

- Is the description of a set of objects
- Defines the structure of the states and the behaviors shared by all the objects of the class (called *instances*)
- Defines a template for creating instances
  - Names and types of all fields
  - Names, signatures, and implementations of all methods

Class diagram

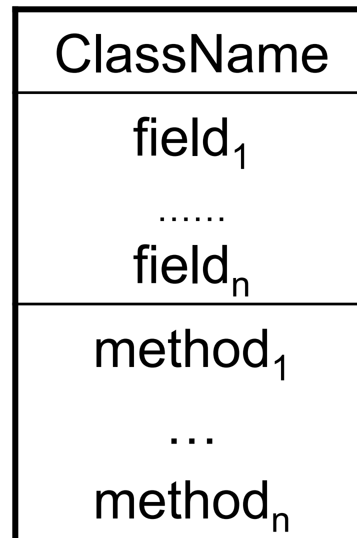
- Most common diagram in OO modeling
- A class diagram is a graph including:
  - Nodes representing classes (types of objects)
    - Nodes can have just a name, or expose some internal structure
  - Links representing relationships among classes
    - Inheritance
    - Association
    - Aggregation or composition
    - Dependency
  - Links can have multiplicities and/or names for roles played by participants

Class diagram: example



Notation for classes

- The notation for classes is a rectangular box with three compartments



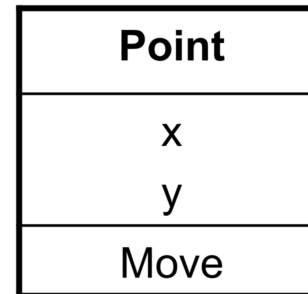
The top compartment shows the class **name**

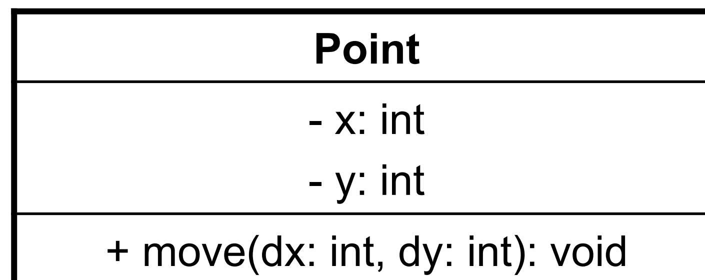
The middle compartment contains the declarations of the fields, or *attributes,* of the class

The bottom compartment contains the declarations of the *methods* of the class

Example

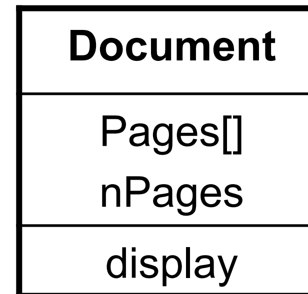
A point defined by classes at three different abstraction levels

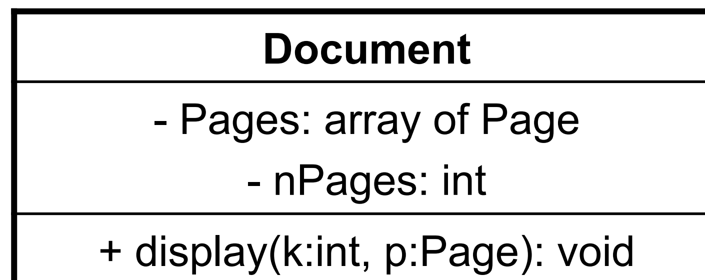




Example

A document defined by classes at three different abstraction levels



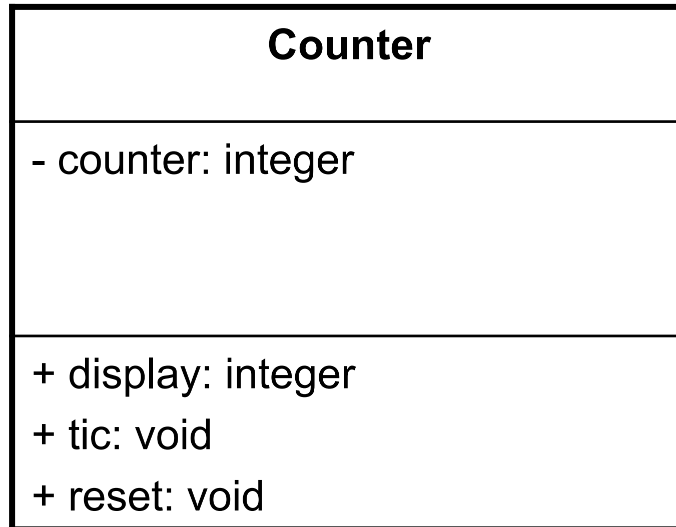


Exercise

Draw a class diagram for the following Java code

```
class Person {
  private String name;
  private Date birthday;
  public String getName() {
    // …
  }
  public Date getBirthday() {
    // …
  }
}
```

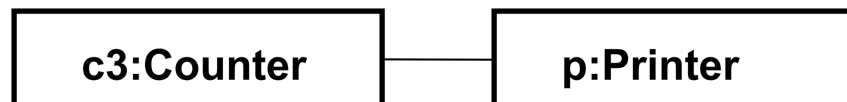
A counter class



A class in UML

```
class Counter{
   private counter: integer;
   public integer display()
    {return counter};
   public void tic()
    {counter = counter + 1};
   public void reset()
    {counter = 0};
}
```

A corresponding class
in a programming language



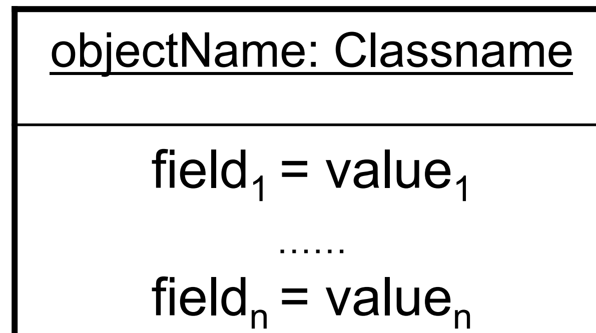
Using an object of type class
in an object oriented system

Object diagram

- An object diagram represents a “snapshot” of a system composed by set of objects
- An object diagram looks like a class diagram
- However, there is a difference: values are allocated to attributes and method parameters
- While a class diagram represents an abstraction on source code, an object diagram is an abstraction of running code

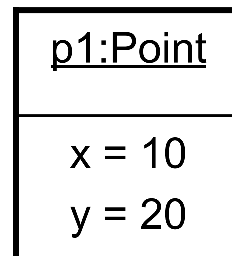
Notation for Objects

- Object: Rectangular box with one or two compartments
- Object name: object name/role name:class name

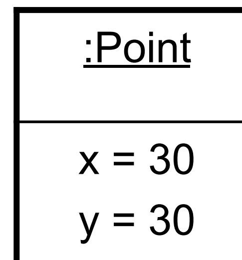


The top compartment shows the name of the object and its class.

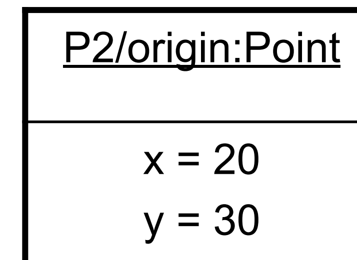
The bottom compartment contains a list of the fields and their values.



named

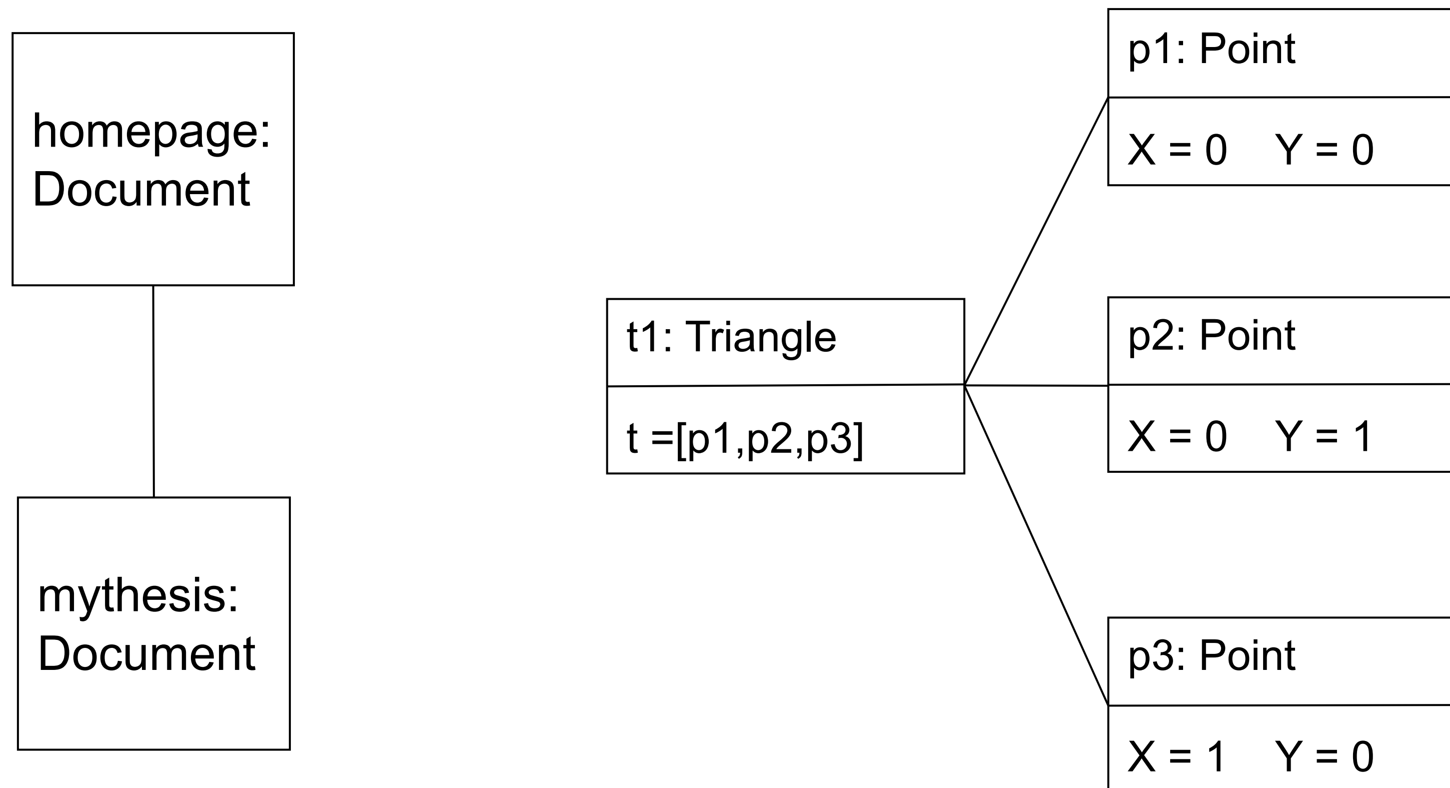


anonymous

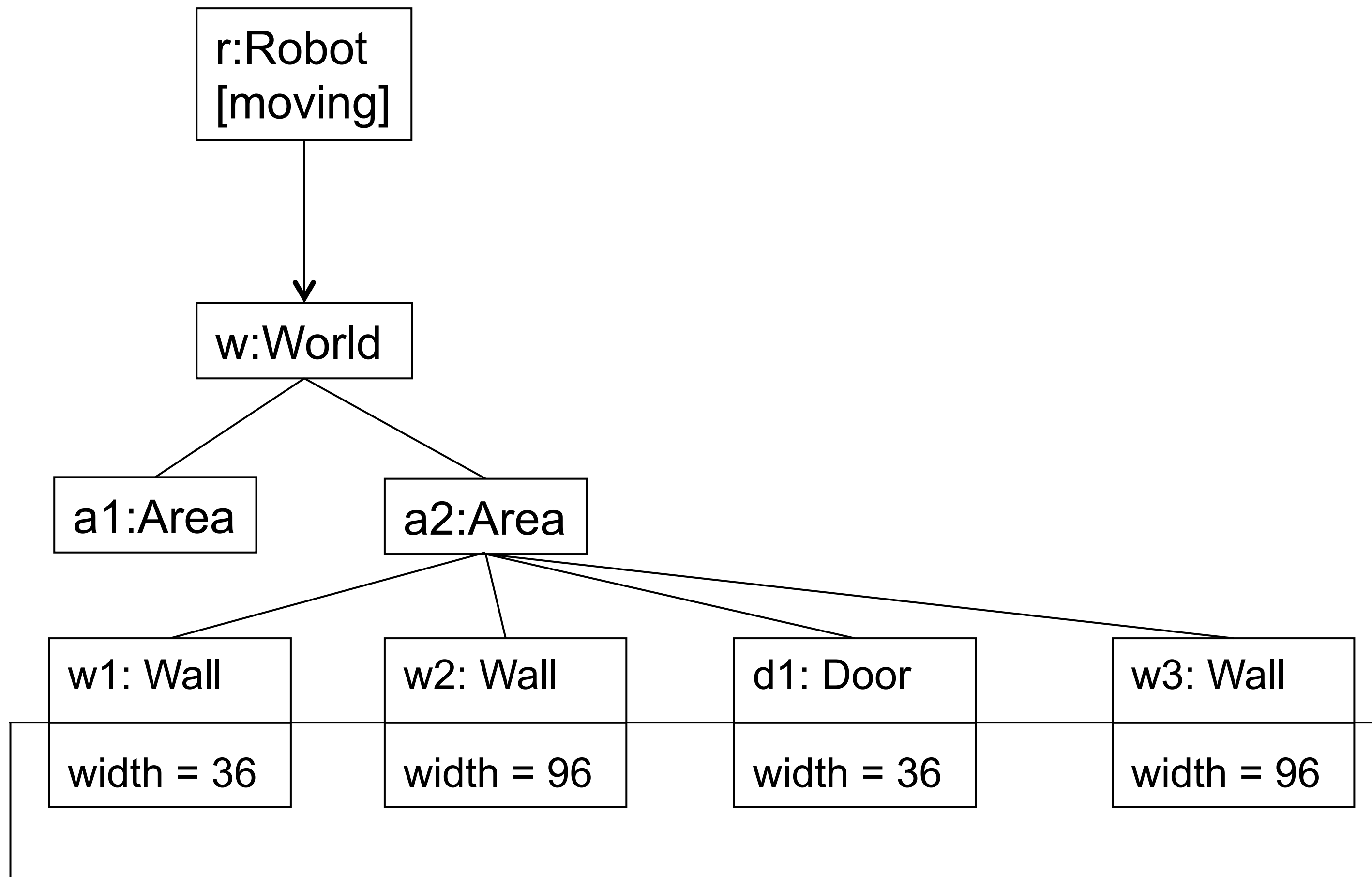


named with role

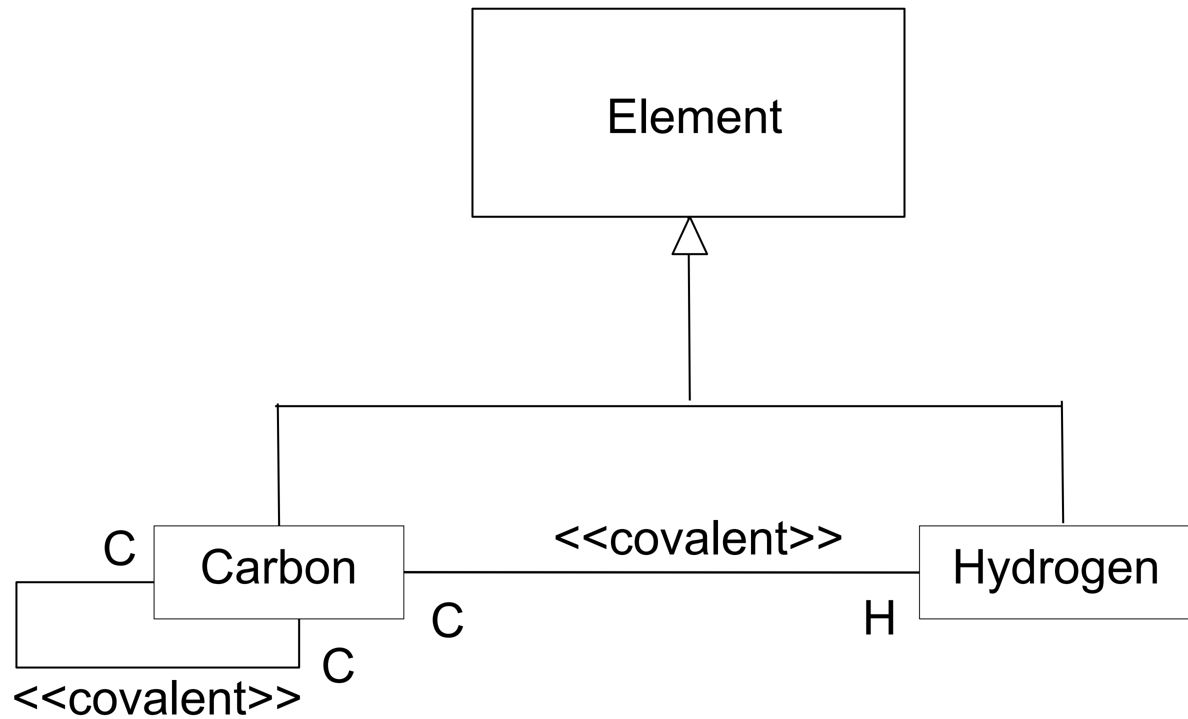
Object diagrams: examples



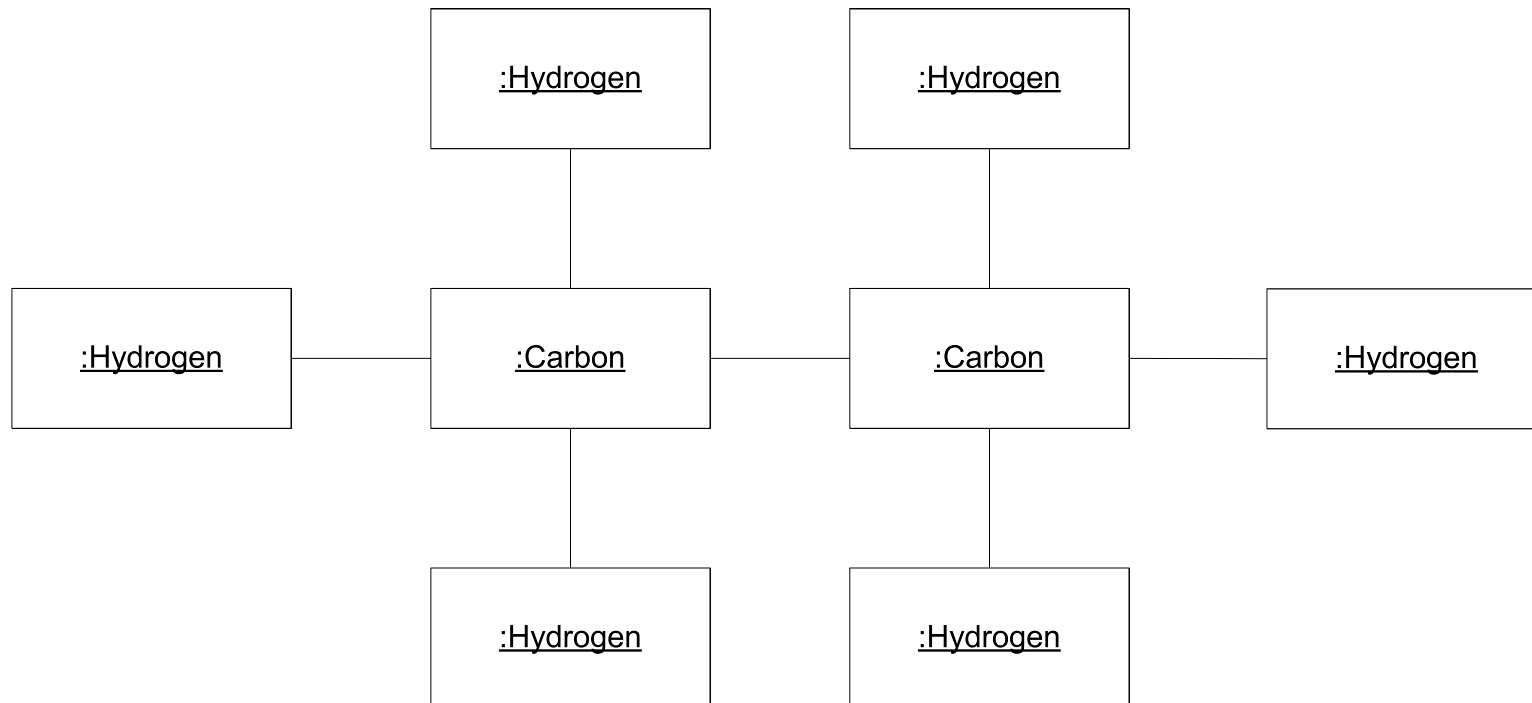
Example (object diagram)



Example: chemical elements (class diagram)



Example: molecule (object diagram)



Objects vs. Classes

	Interpretation in the real world	Representation in the model
Object	An *object* is anything in the real world that can be distinctly identified	An *object* has an identity, a state, and a behavior
Class	A *class* is a set of objects with similar structure and behavior. These objects are called *instances* of the class	A *class* defines the structure of states and behaviors that are shared by all of its instances

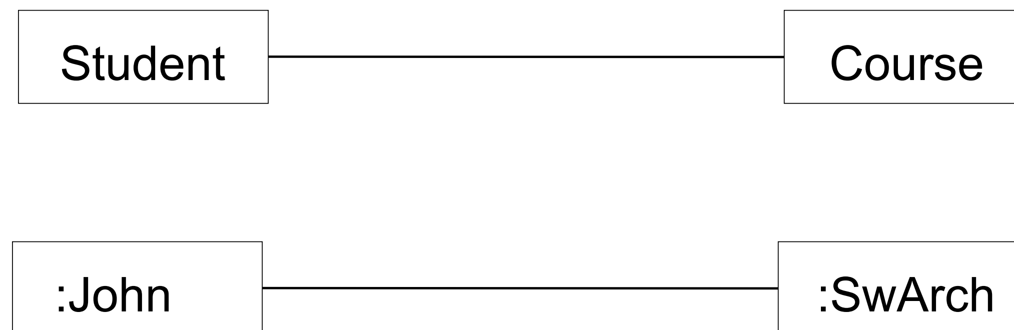
Object = Identity + State + Behavior

- Identity
  - Distinguishes an object from all other objects
- State
  - Consists of a set of *attributes* (or *fields*), which have names, types, and values
- Behavior
  - Defined by the set of *operations* (or *methods*) that may operate on the object
  - Each method has a name, a type, and a value, where
    - The **type** consists of the return type and the list of parameter types of the method, often called *signature*.
    - The **value** is the implementation of the method often expressed as a sequence of statements, in languages like Java and C++

Association

- An association is a binary relationship between classes or objects

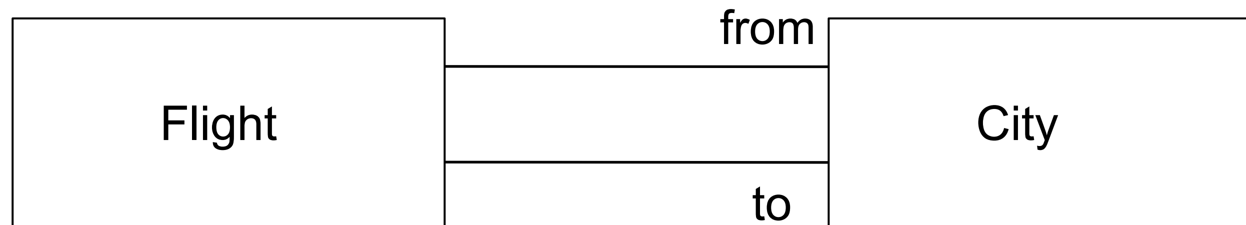
- Represented as a line between boxes

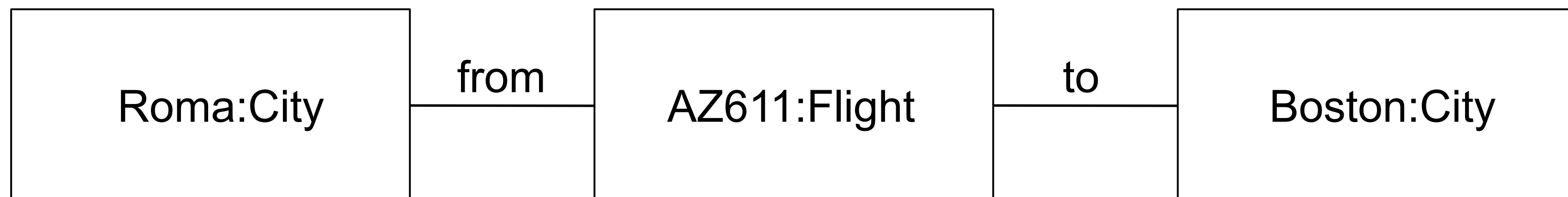


Association and roles

- The simplest relationship among classes is the *association*
- An association represents a structural relationship that connects two classes
- It means that the two classes “know” each other: all objects in a class have some relationship with some object(s) in the other class
- An association can have a name, which usually describes its role

Class diagrams denote systems of objects





Association with direction

- An association may have an optional label consisting of a name and a direction arrow
- The direction arrow indicates the direction of association with respect to the name

An arrow may be attached to the end of path
to indicate that *navigation* is supported in that direction:

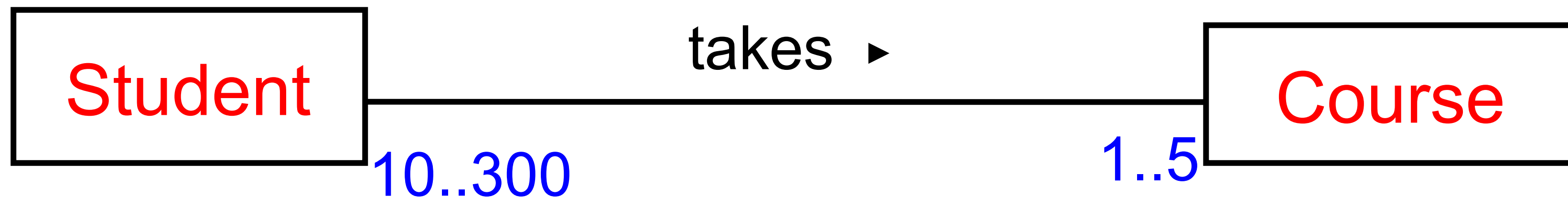
Student knows Course, Course does not know Student

Roles and multiplicity

- An association line may have a *role name* and a *multiplicity specification*
- The multiplicity specifies an integer interval, e.g.,
  - *l..u*   closed (inclusive) range of integers
  - i   singleton range
  - 0..*   nonnegative integer, i.e., 0, 1, 2, …

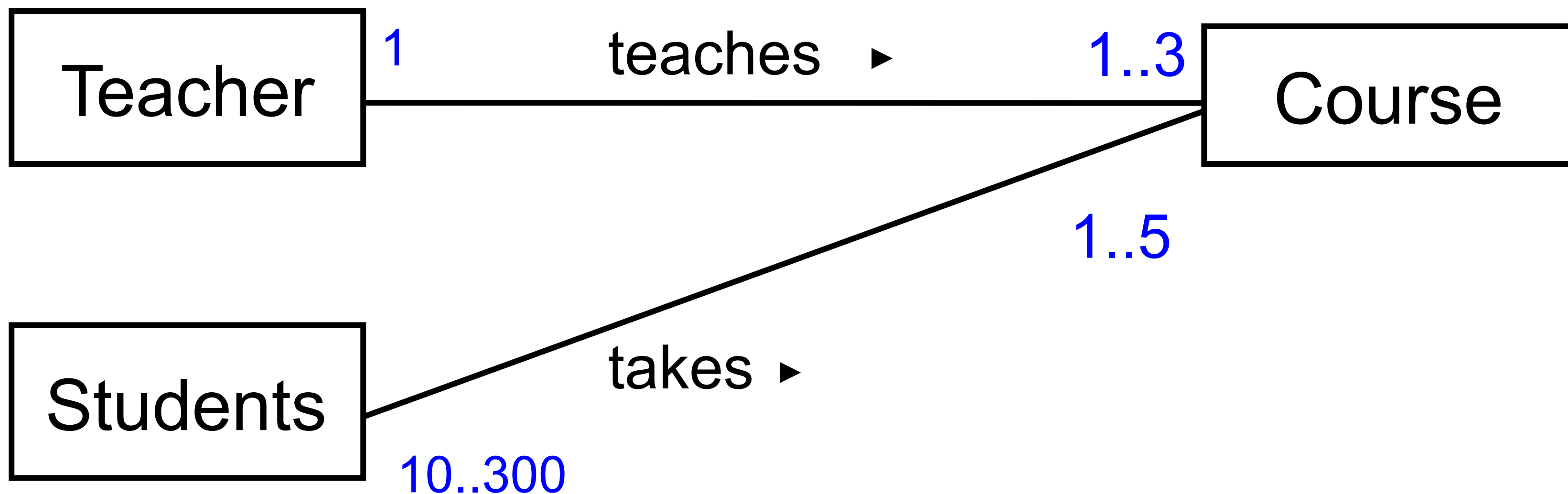
Association example

- A Student can take up to five Courses
- Every Student has to be enrolled in at least one course
- Up to 300 students can enroll in a course
- A class should have at least 10 students



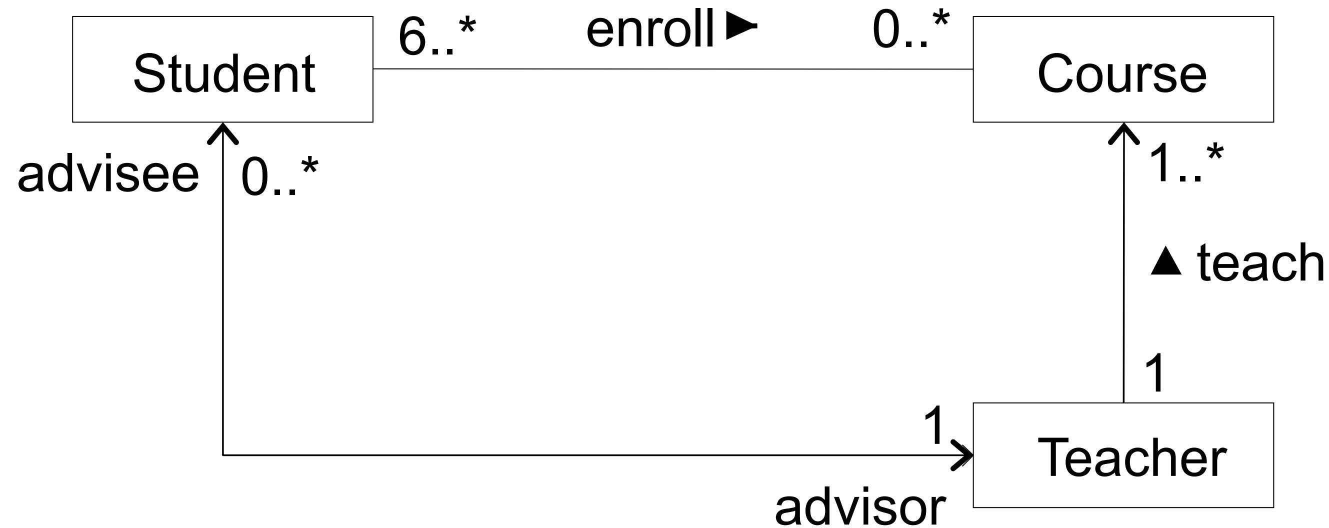
Example

- A teacher teaches 1 to 3 courses
- Each course is taught by only one teacher
- A student can take between 1 to 5 courses
- A course can have 10 to 300 students



Exercise

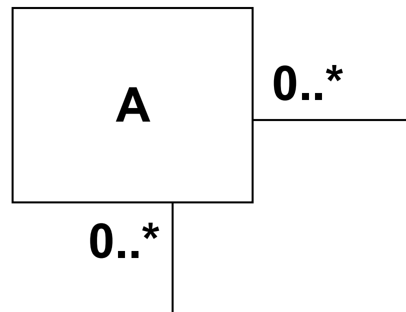
Explain the meaning of this diagram

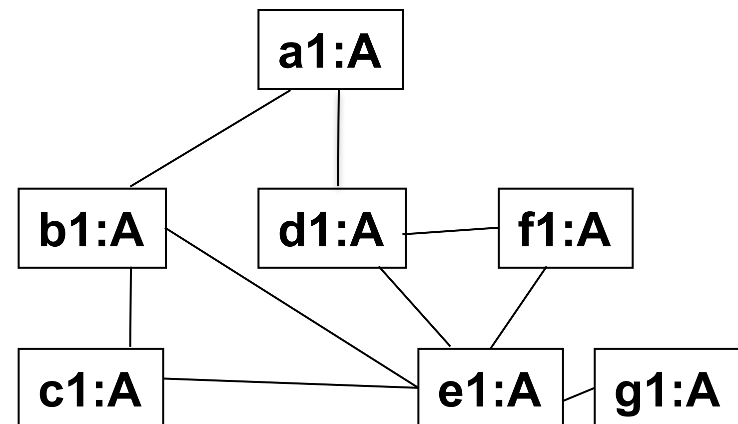


Exercise

Net data structures

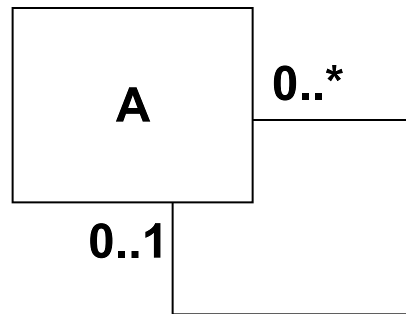
- How we can represent a net of objects from the same class?
- A class with an association to itself with both ends of the association marked with 0..*

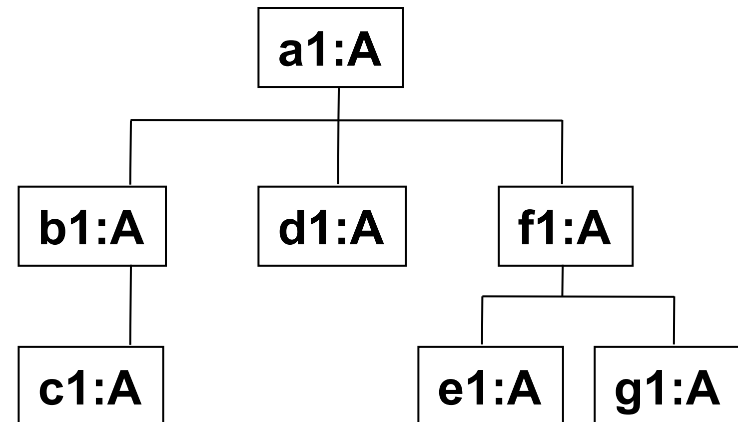




Hierarchic data structures

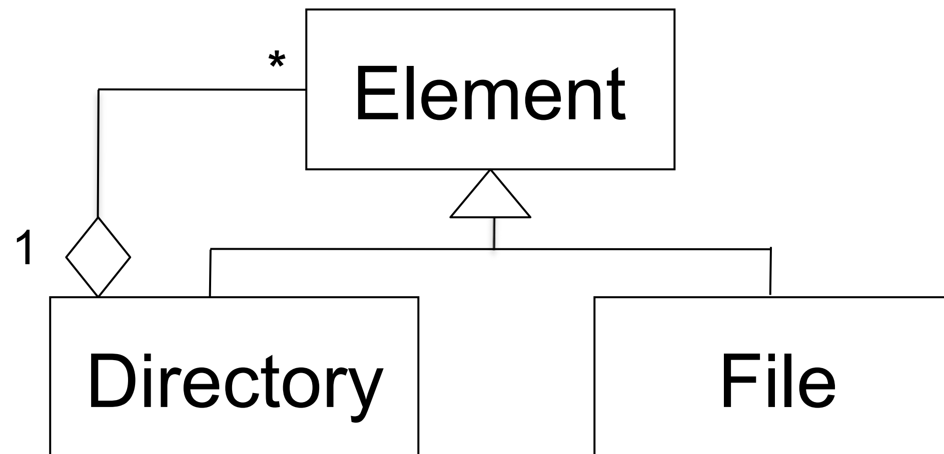
- How we can represent a hierarchy of objects from the same class?
- A class with an association to itself with one end of the association marked with 0..* (*children*) and the other as 0..1 (*parent*)





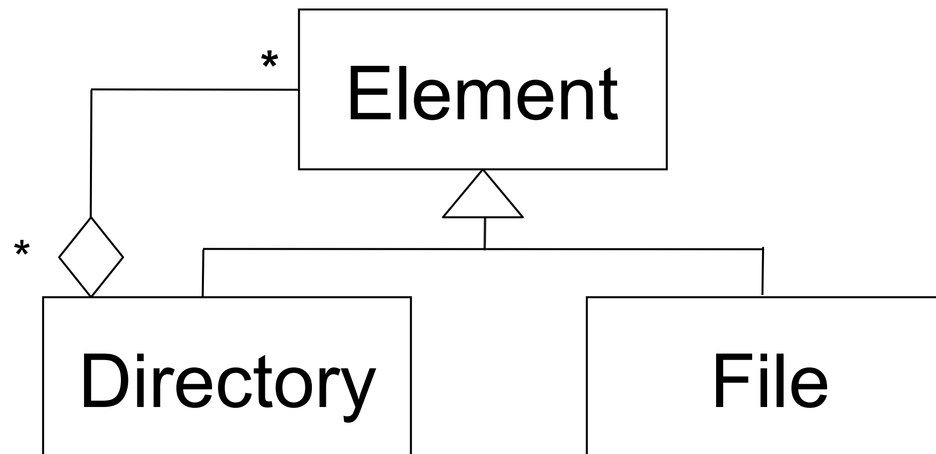
Hierarchic file system

- A directory can contain any number of elements (either a file or a directory)
- Any element is part of exactly one directory



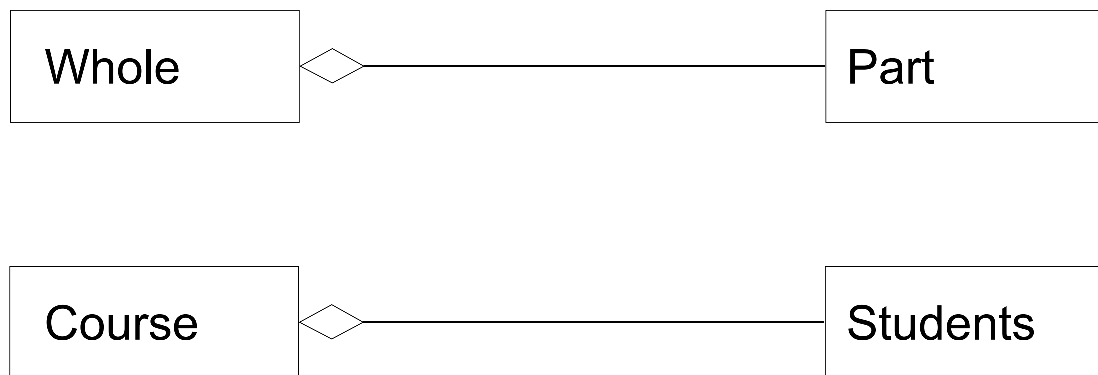
Non-hierarchic file system

- A directory can contain any number of elements (either a file or a directory)
- An element can be part of many directories

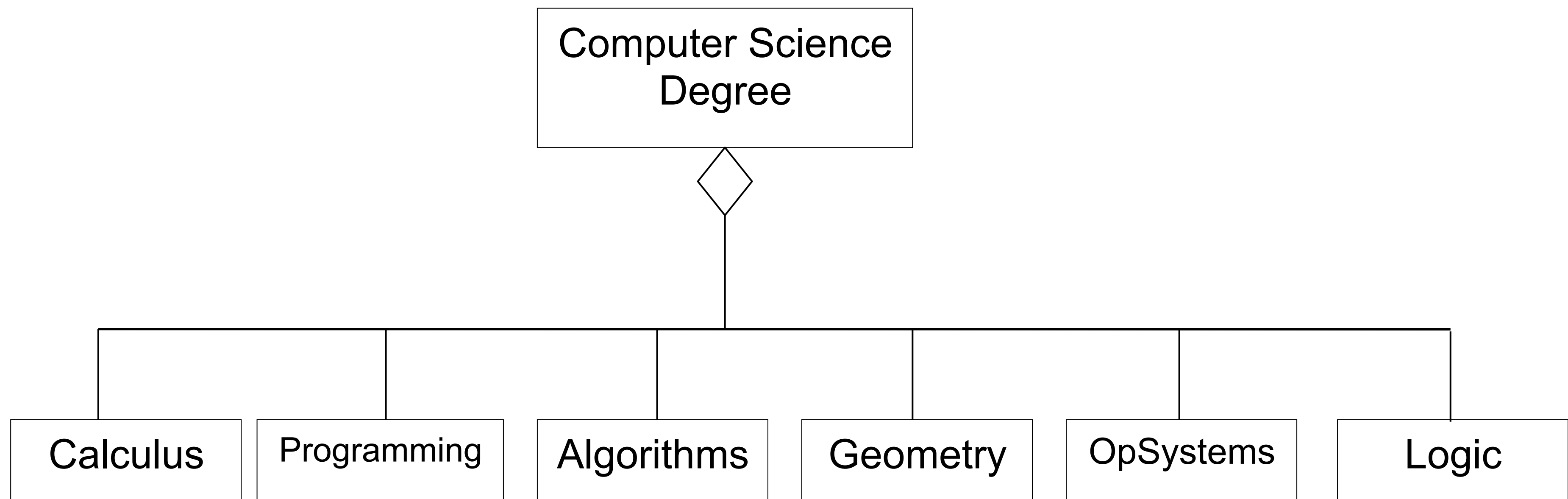


Aggregation

- An *aggregation* is a special form of association representing *has-a* or *part-whole* relationship
- It distinguishes the whole (aggregate class) from its parts (component class)
- WARNING: an aggregation does not bind the parts' lifetime to the whole (they can exist separately)

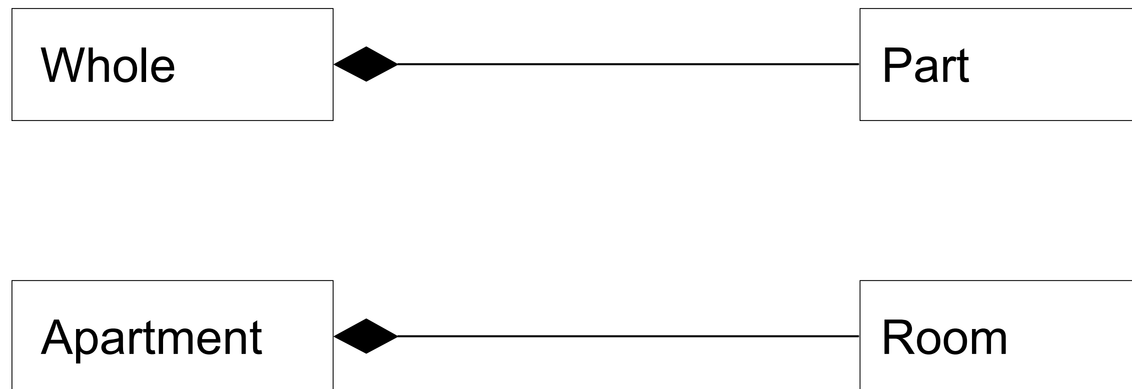


Example of an aggregation hierarchy

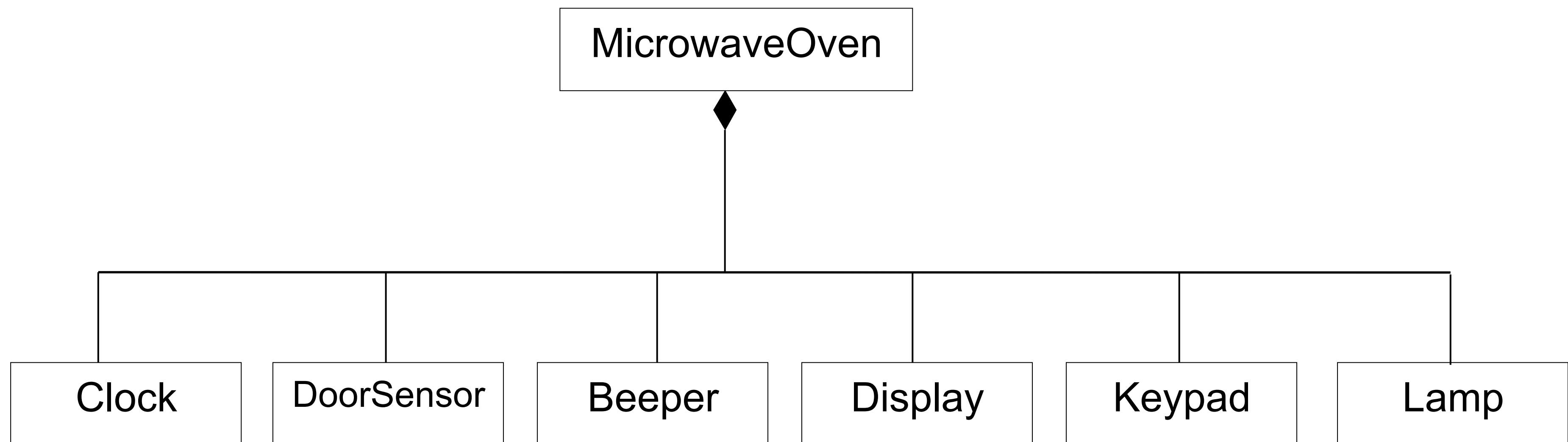


Composition

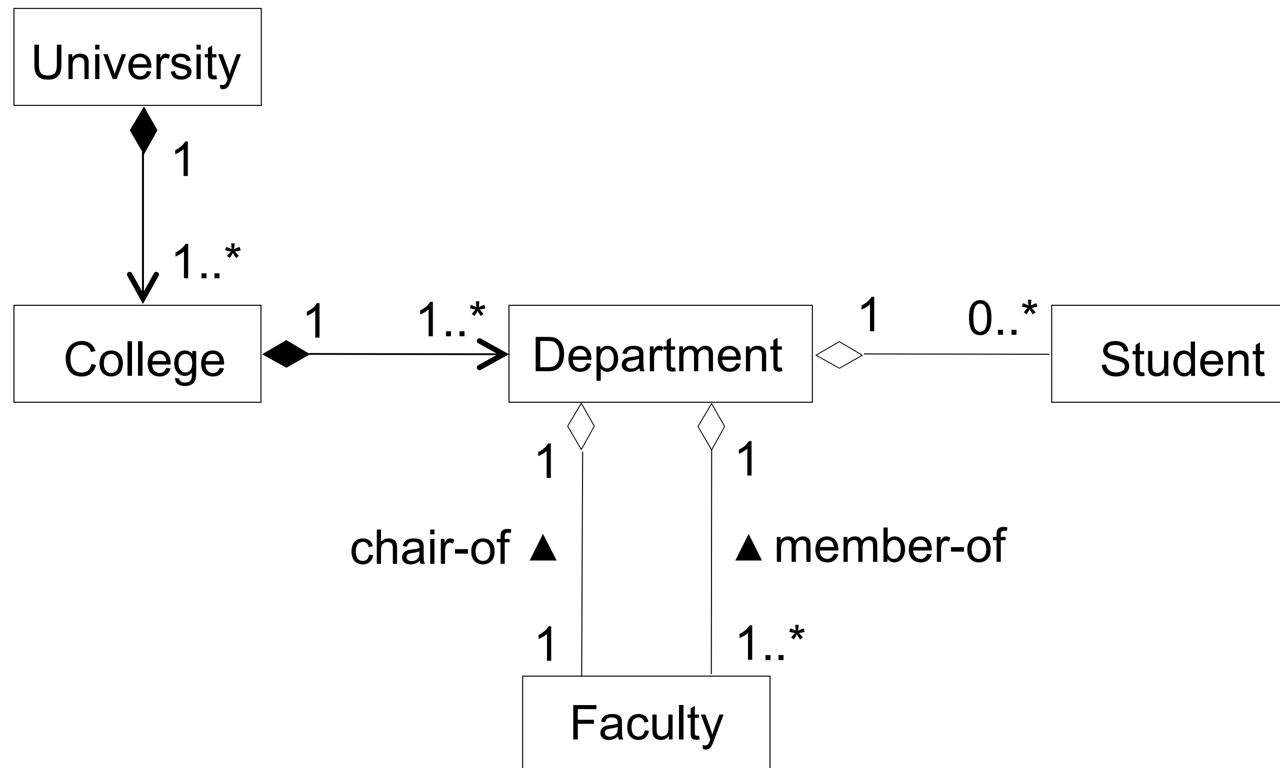
- A *composition* is a stronger form of aggregation
- It implies exclusive ownership of the component class by the aggregate class
- The lifetime of the parts is entirely included in the lifetime of the whole (a part can not exist without its whole)



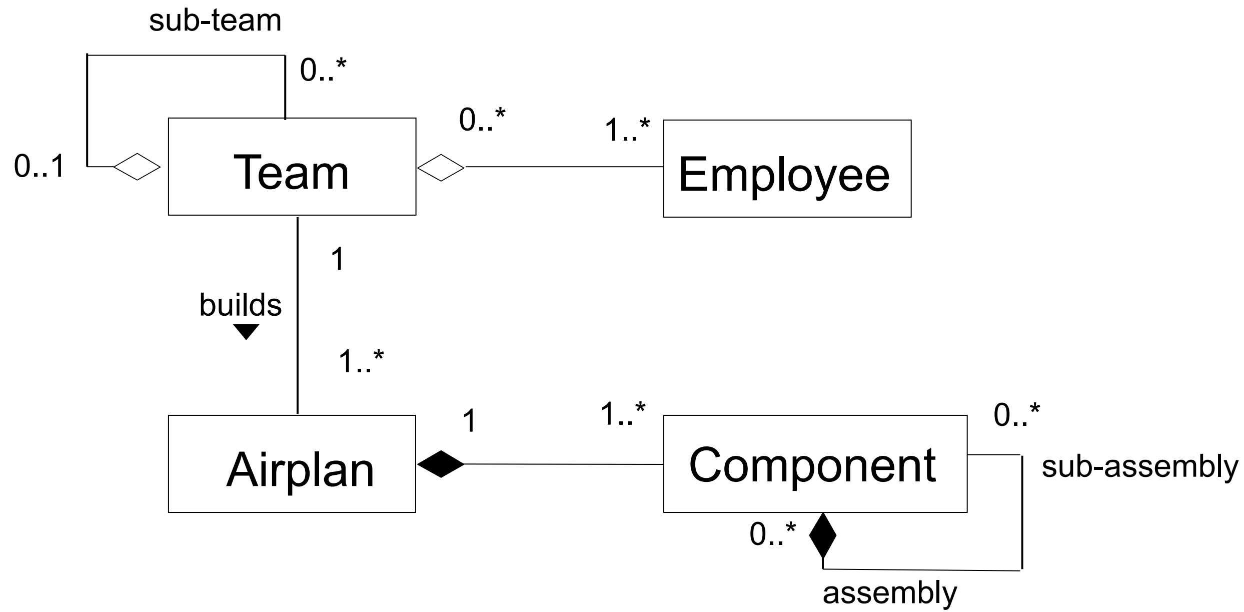
Example of a composition hierarchy



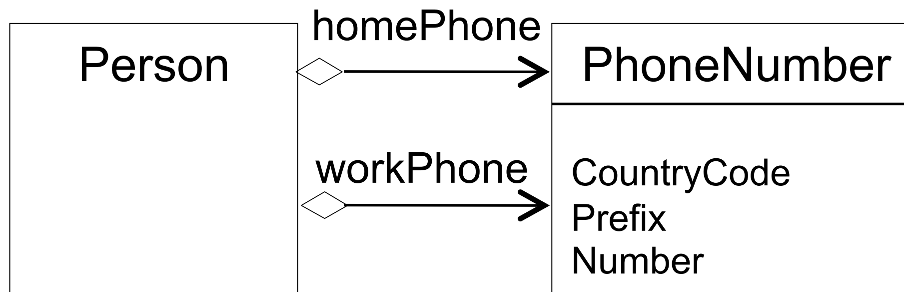
Example



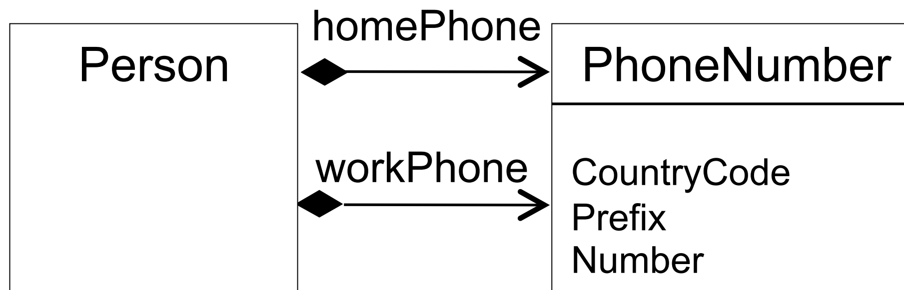
Example



Aggregation vs composition

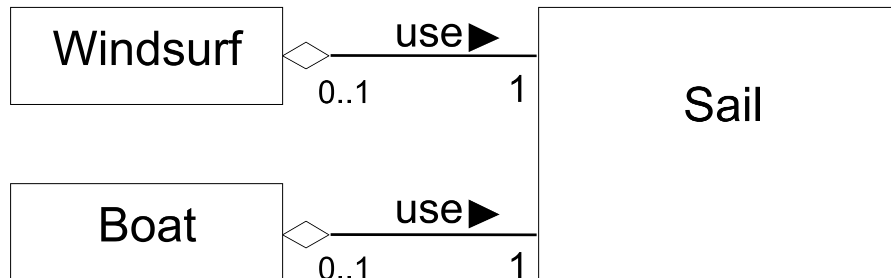


Aggregation:
A Person uses two phone numbers;
Numbers are independent from
Persons

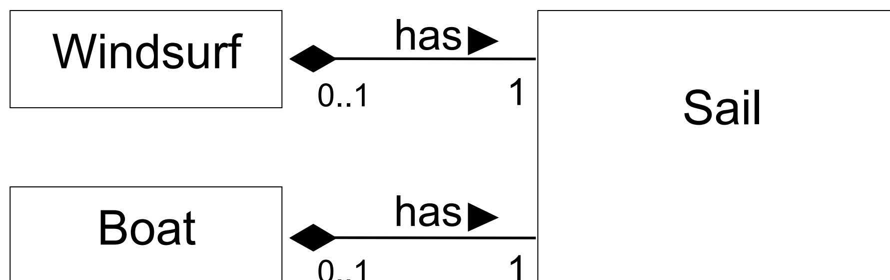


Composition:
A Person has two phone numbers;
Numbers are dependent from
Persons

Aggregation vs composition



Aggregation:
Windsurfs and boats use sails.
The same sail can be used
in a Windsurf or in a Boat



Composition:
Here windsurfs and
boats have each their
own sails which are
destroyed when the
"container" is
destroyed

Exercise

aggregation or composition ?

- Building and rooms
- Course and lessons
- TV channel and programs
- Parliament and members
- Sky and stars
- Country and cities
- City and buildings
- Wood and trees

Example

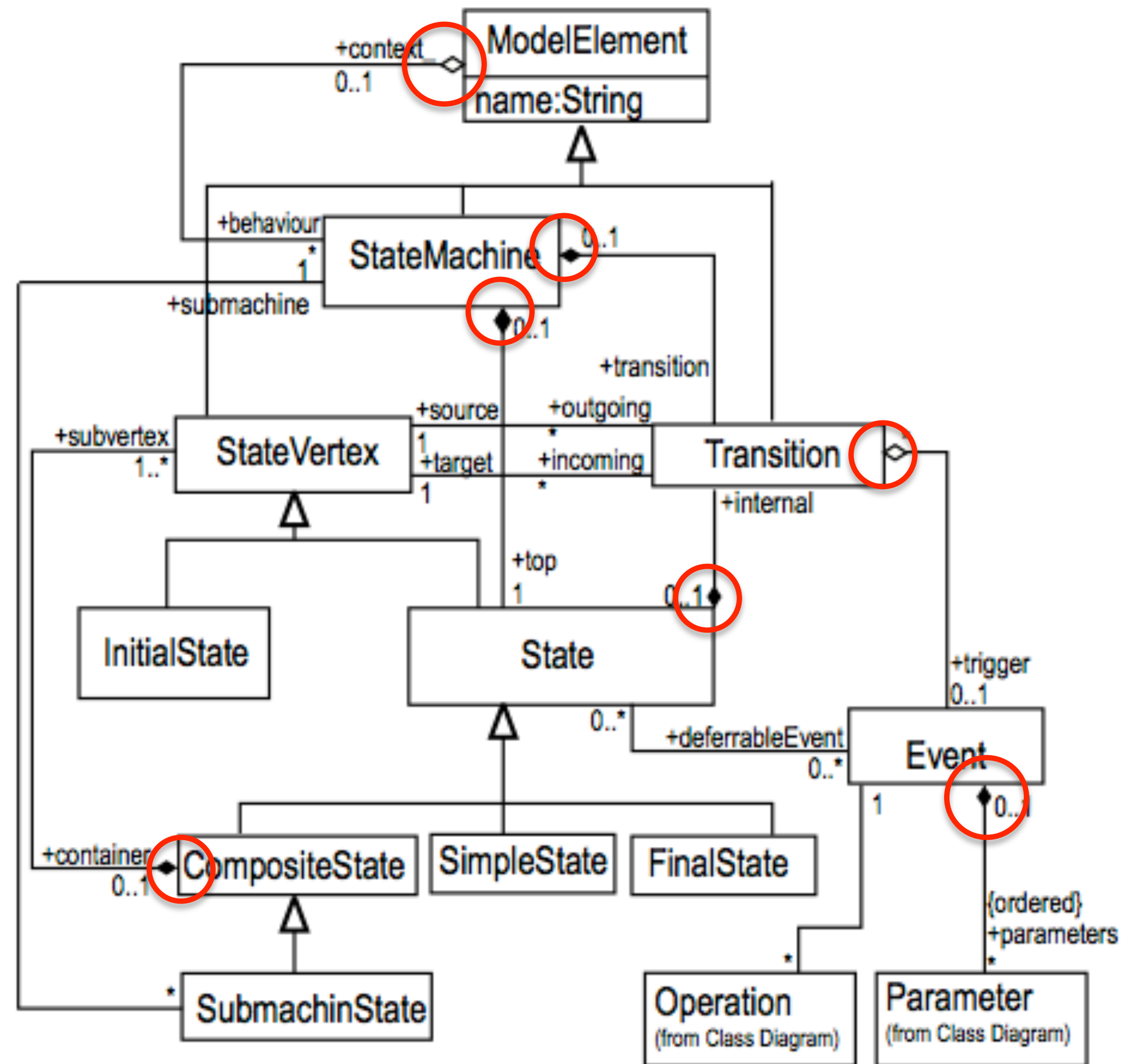


Figure 4. A fragment of the Statechart diagram metamodel (excerpt from the UML standard v1.4)

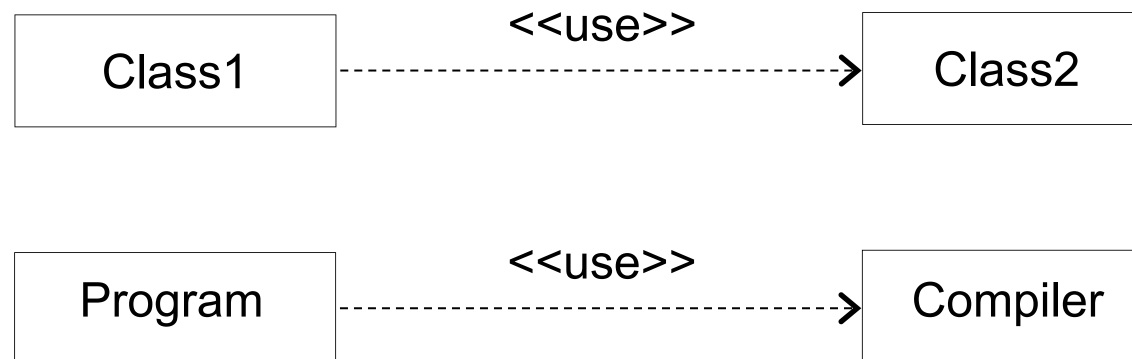
Exercise

Imagine some aggregation or composition relationships among the following classes and draw a corresponding class diagram

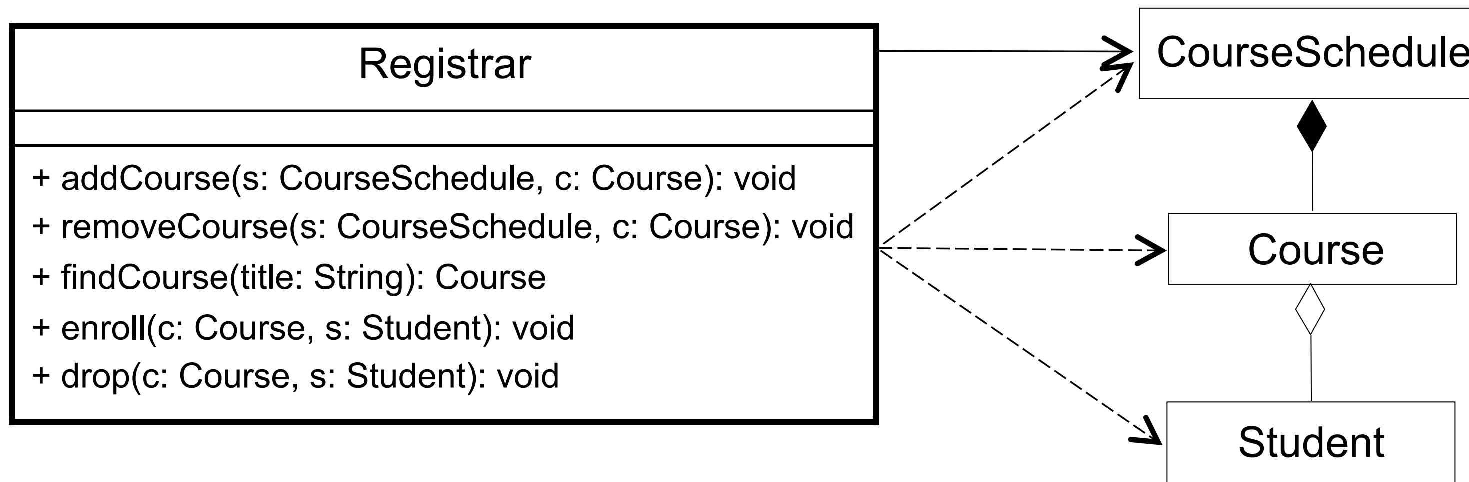
- Employee
- Manager
- Office
- Department

Dependency

- A dependency of A from B is a relationship between two entities A and B such that the proper operation of A depends on the presence of B, and changes in latter would affect the former
- Example: a common form of dependency is the *use* relation among classes

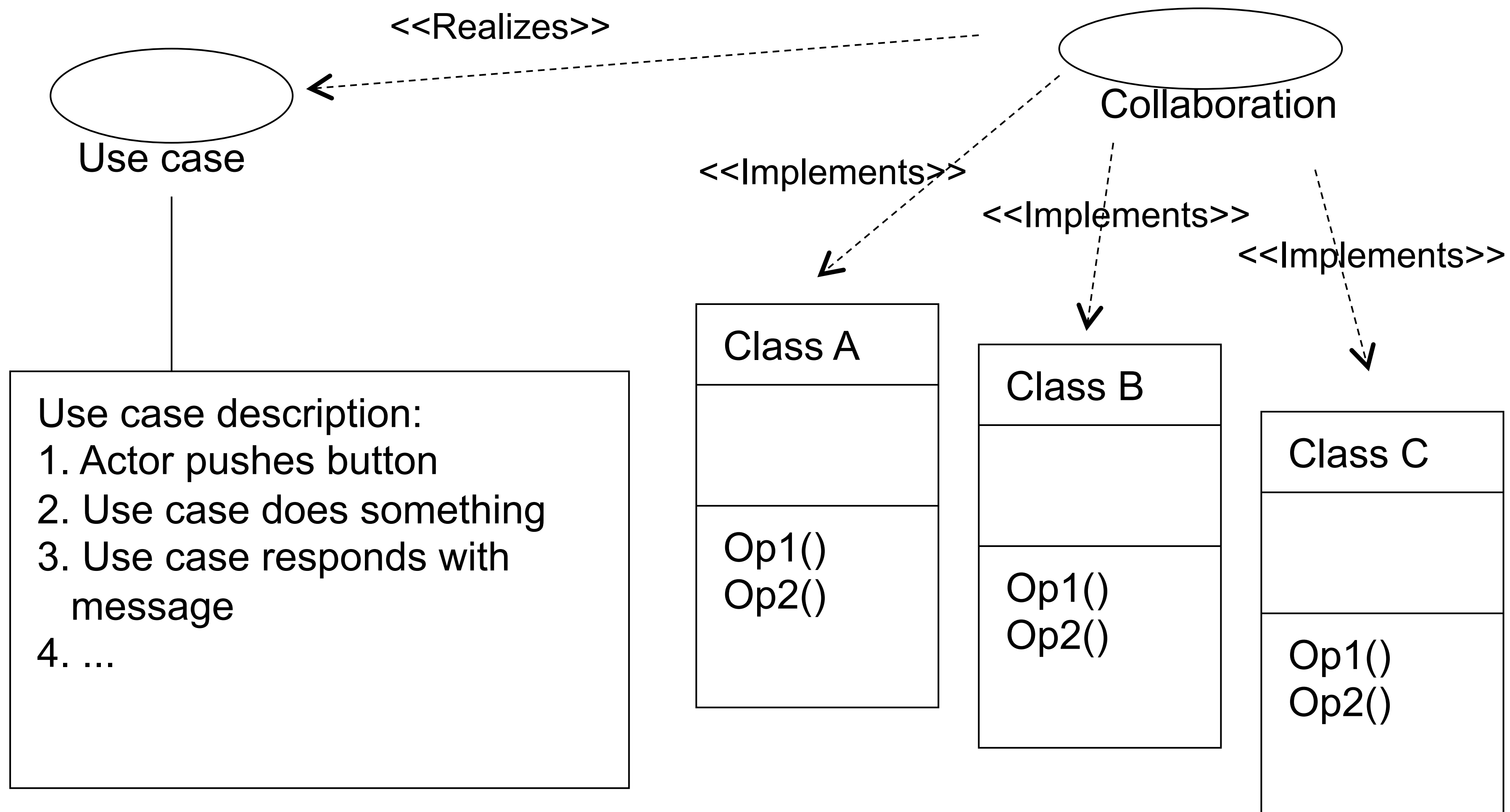


Example: dependencies in a class diagram

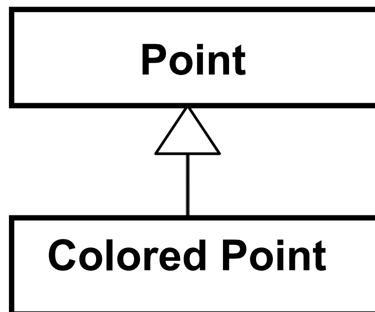


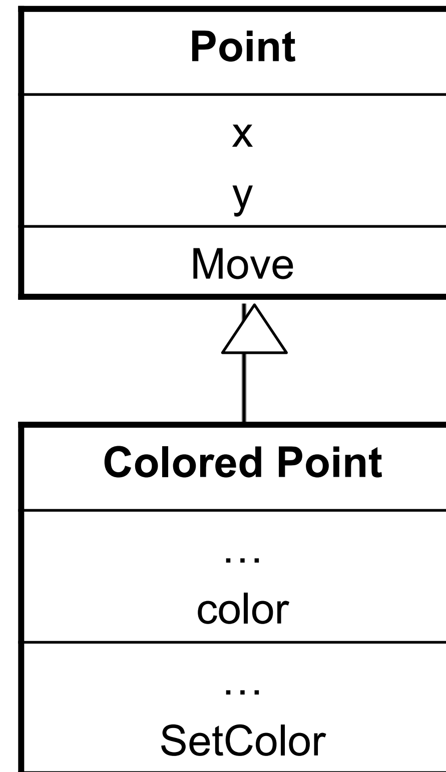
Dependencies are often omitted from a class diagram unless they convey some significant information

Example: realizing a use case

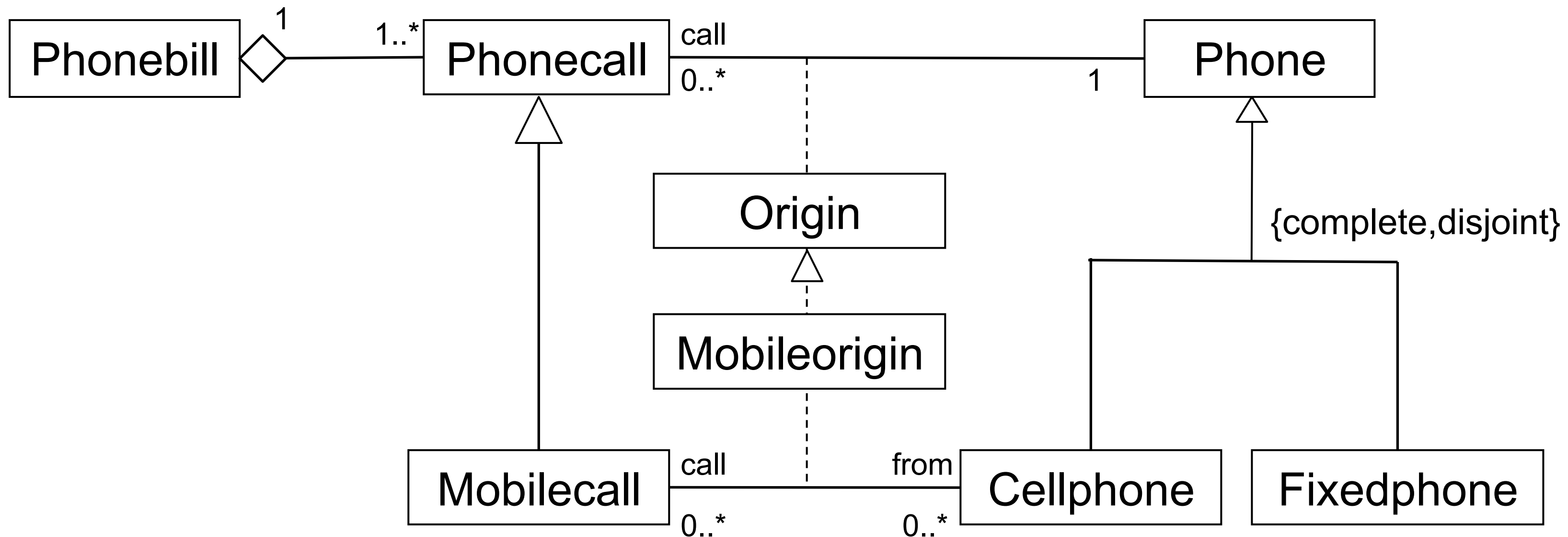


Class and superclass





Example

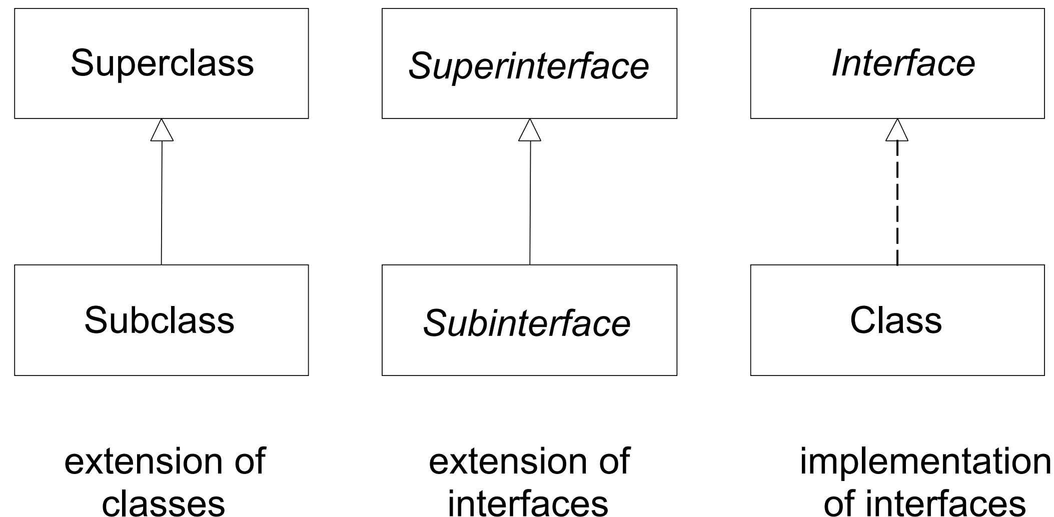


Inheritance

- Key relationship in object modeling
- Inheritance defines a relationship "IS_A" among classes or interfaces
- In UML there are three kinds of inheritance
  - *extension* relation between two classes (*subclass* and *superclass*)
  - *extension* relation between two interfaces (*subinterface* and *superinterface*)
  - *implementation* relation between a class and an interface

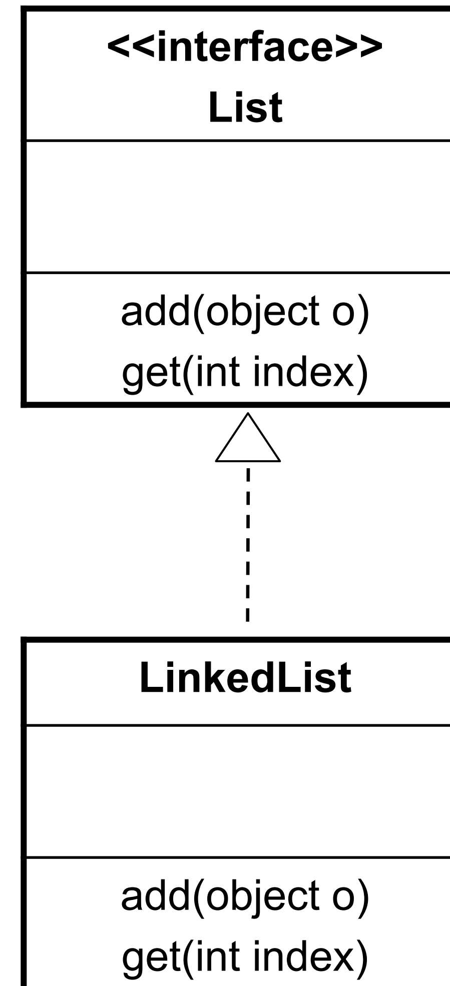
Three kinds of inheritance

- An extension relation is called *specialization* and *generalization*
- An implementation relation is called *realization*

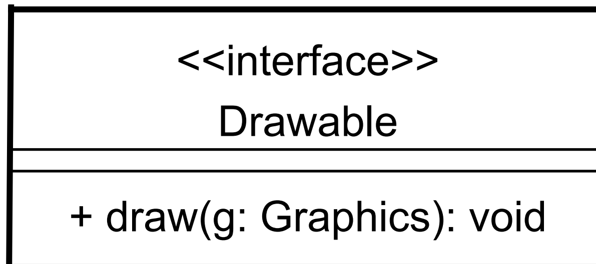


Interface

- Interfaces are like classes, but have no “implementation”
- A class implementing an interface has a special inheritance arrow toward the interface
- LinkedList implements List



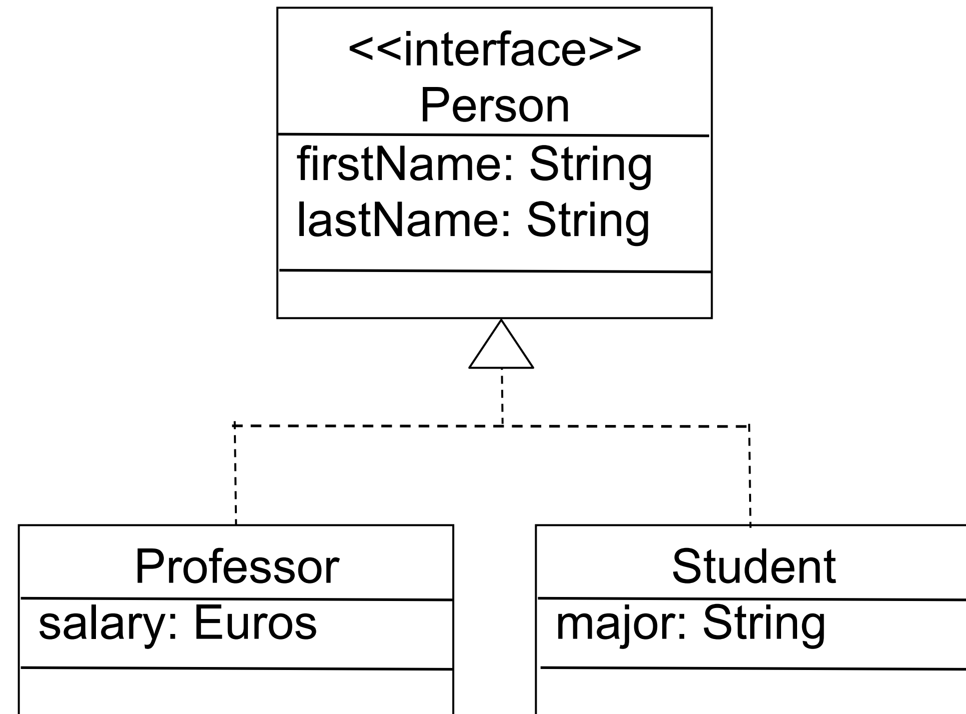
Interfaces in Java



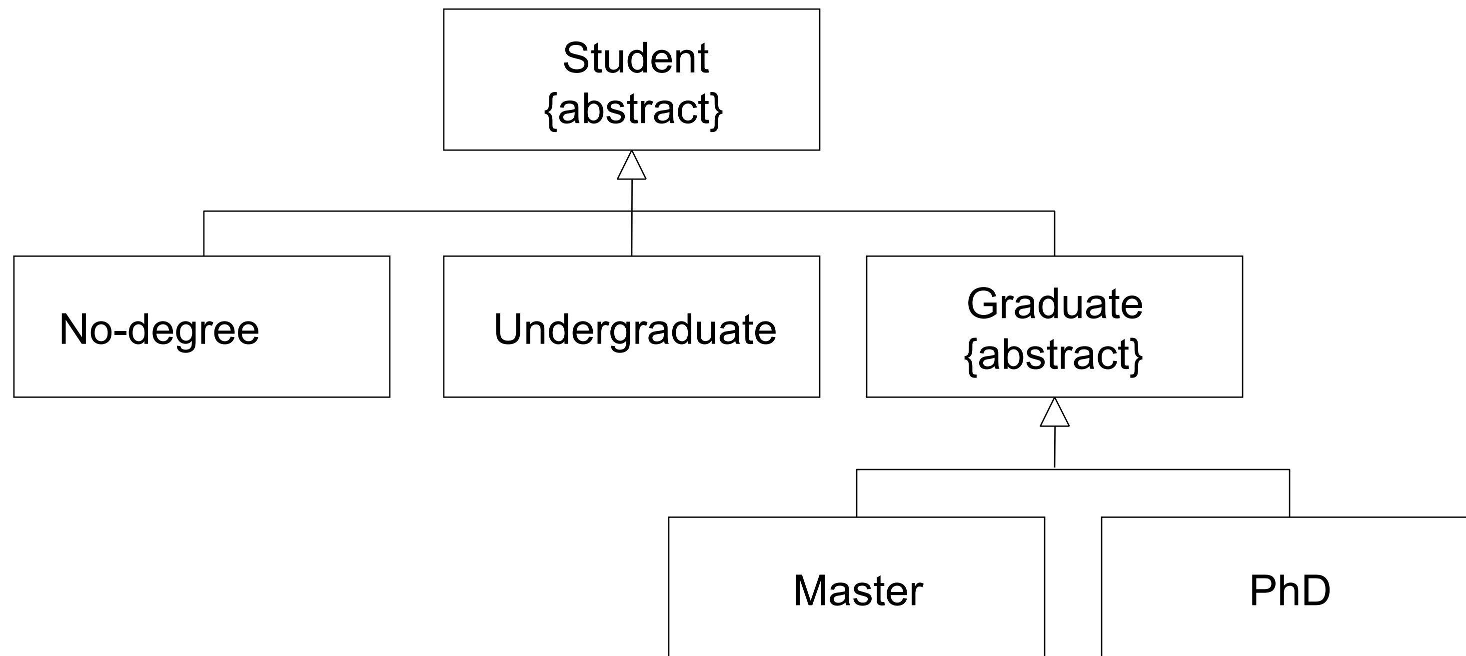

```
interface Drawable {
   void draw(Graphics g);
}
```

Interfaces

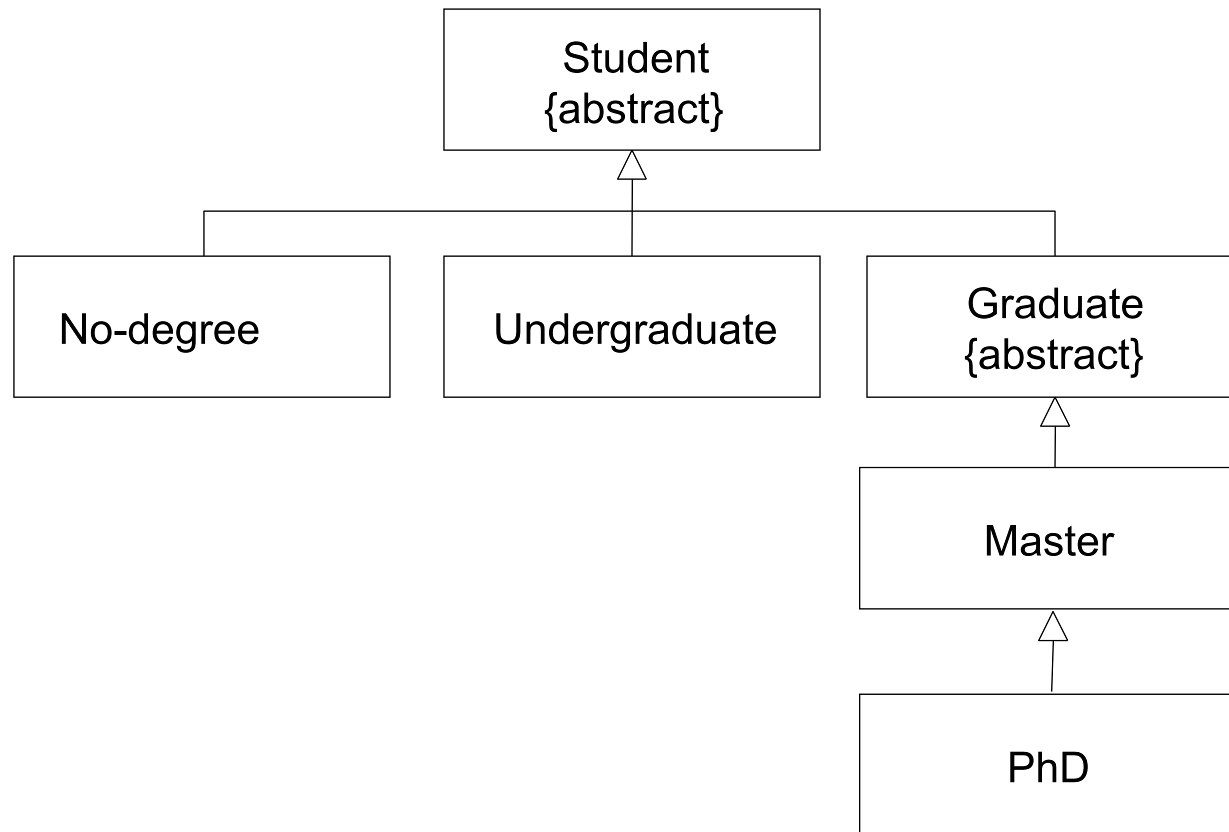
- A class and an interface differ: a class can have an actual instance of its type (but it can also have zero instances), whereas an interface must have at least one class to implement it
- **Example**: both the Professor and Student classes implement the Person interface



Example



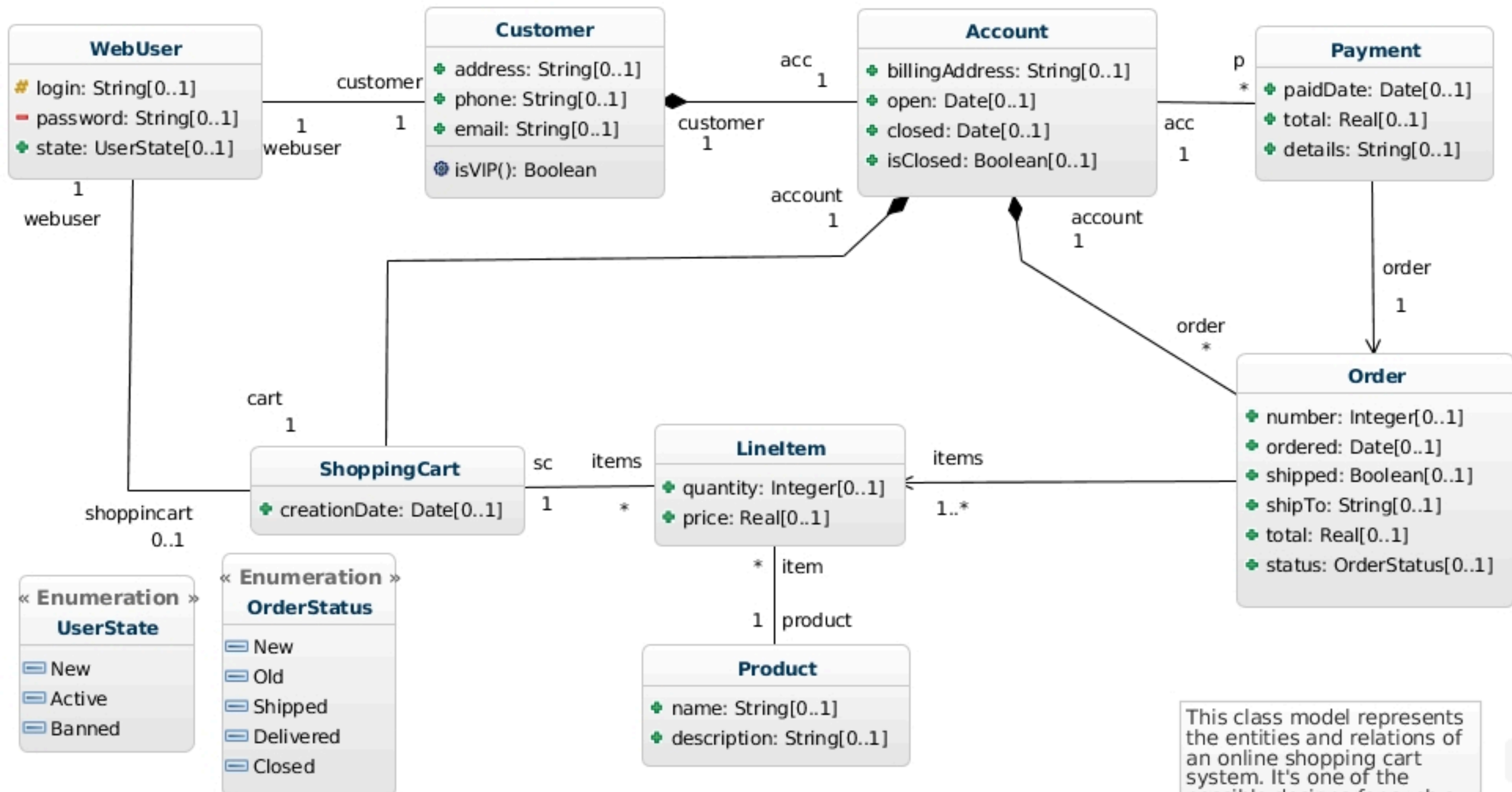
Example



Exercise

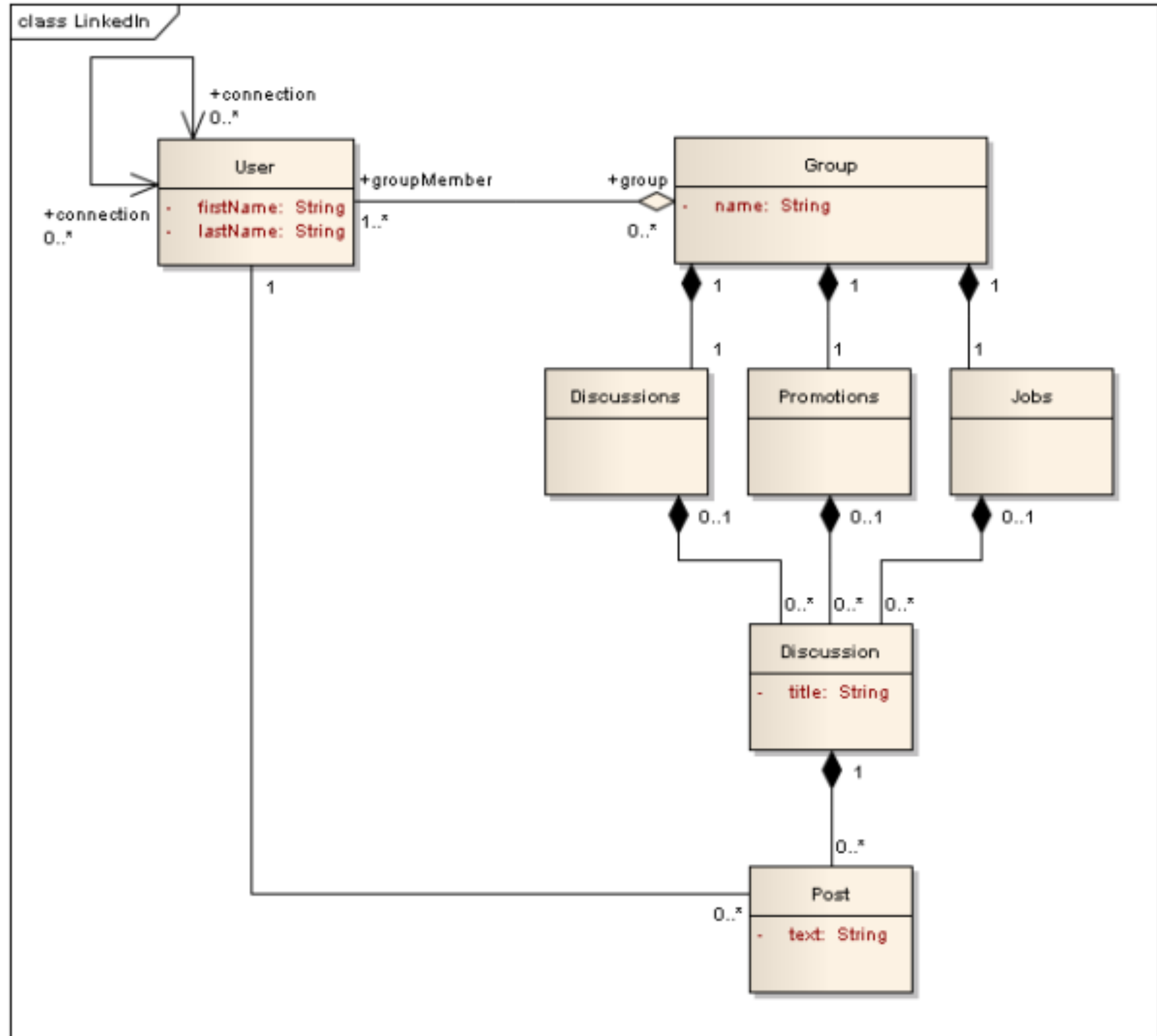
- Draw a class diagram showing inheritance relationships among classes Person, Employee, and Manager
- Draw a class diagram showing inheritance relationships among classes Person, Student, Professor, and Assistant

Real example: online shopping cart



http://blog.genmymodel.com/class-diagram-public-top5.html

Real example: LinkedIn



Real example: Facebook

Photo

0..1

+eventPicture

Network
+name: string
+/numberOfMembers: integer

???

WorkNetwork

SchoolNetwork

RegionalNetwork

+members

Account
+name: string
+email: Email
+password: string
+securityQuestion: string
+securityAnswer: string

+friends

+guest???

+administrator

+/friendsEvents

+markedEvents

+ownedEvents

Event
+name: string
+tagline: string[0..1]
+host: string
+description: string[0..1]
+start: DateAndTime
+end: DateAndTime
+location: string
+street: string[0..1]
+cityOrTown: string
+phone: string[0..1]
+efmail: string[0..1]
+showTheGuestList: boolean
+wallEnabled: boolean
+photosEnabled: boolean
+onlyAdminPhotoUpload: boolean
+videosEnabled: boolean
+onlyAdminVideoUpload: boolean
+postItemEnabled: boolean
+onlyAdminVideoUpload: boolean
+access: EventAccessKind
+isShown: boolean

+/type

EventType
+name: string

EventSubtype
+name: string

<<enumeration>>
EventAccessKind
+open
+closed
+secret

EventInvitation

0..*

<<enumeration>>
AttendanceStatus
+attending
+notAttending
+maybeAttending
+notYetReplied
+blocked

Message

Notification

Profile
+status: string

??? +???

CreditCard
+cardHolderSName: string
+creditCardType: CreditCardType
+creditCardNumber: integer
+expirationDateMonth: integer
+expirationDateYear: integer
+country: string
+address: string
+cityOrTown: string
+stateOrProvinceOrRegion: string
+zipOrPostalCode: string

<<enumeration>>
CreditCardType
+visa
+mastercard
+discover
+americanExpress

BasicInformation
+sex: Sex
+interestedInMen: boolean
+interestedInWomen: boolean
+lookingForFriendship: boolean
+lookingForARelationship: boolean
+lookingForWhateverICanGet: boolean
+lookingForDating: boolean
+birthdayDay: Date
+hometown: string
+politicalViews: PoliticalView
+religiousViews: string

PersonalInformation
+activites: text
+interests: text
+favoriteMusic: text
+favoriteTVShows: text
+favoriteMovies: text
+favoriteBooks: text
+favoriteQuotes: text
+aboutMe: text

ContactInformation
+emailsOnlyForFriends: boolean
+screenNamesOnlyForFriends: boolean
+mobilePhoneOnlyForFriends: boolean
+landPhoneOnlyForFriends: boolean
+addressOnlyForFriends: boolean
+websiteOnlyForFriends: boolean

Job
+employer: string
+position: string
+description: text
+city: string
+state: string
+country: string
+startMonth: integer
+startYear: integer
+stillInThisJob: boolean
+endMonth: integer
+endYear: integer

HighSchool
+name: string
+year: integer

School
+name: string
+year: integer
+attendedFor
+concentration: string[1..3]

<<enumeration>>
PoliticalView
+veryLiberal
+liberal
+...

+contactEmail

+additionalEmail

Email
+email: Email

Address
+address: string
+city: string
+state: string
+country: string

ScreenName
+name: string
+im: InstantMessengerSyste

Website
+website: text

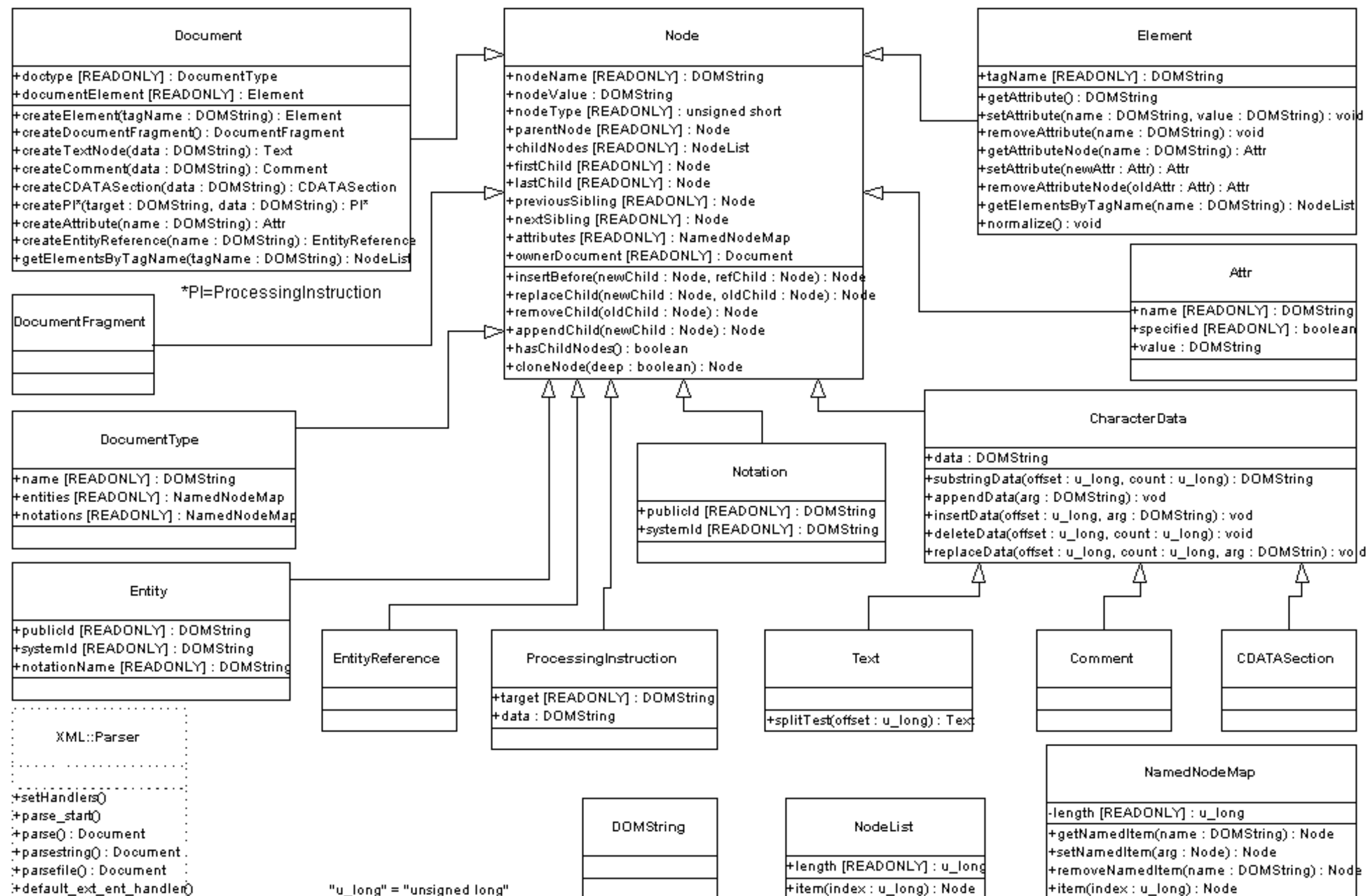
<<enumeration>>
InstantMessengerSystem
+aim
+googleTalk
+skype
+windowsLive
+yahoo
+gaduGadu

Real example: DOM

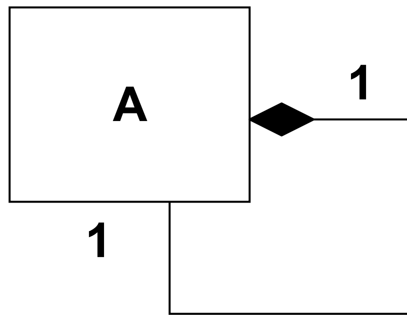
Logical View

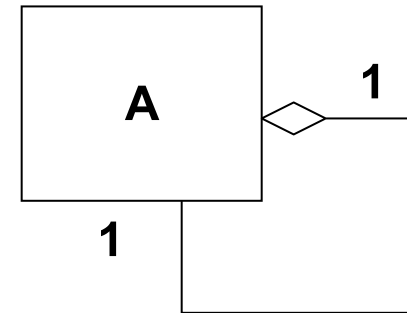
DOM (Core) Level One

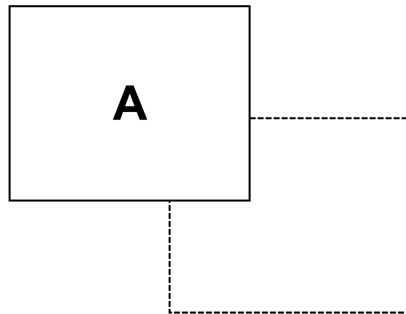
Invoke "get *Name*" to read instance variable *name* when using XML::DOM or XML4J

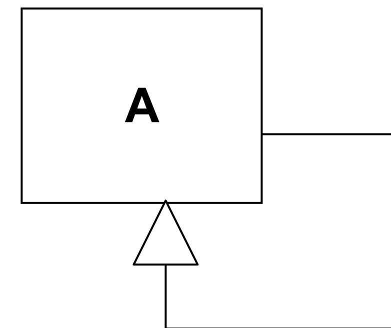


Strange examples









Behavior diagrams

G. Balla: Dinamismo di cane al guinzaglio (1912)

M.Duchamp: Nude descending a staircase (1912)

Modeling Behavior

- Statechart diagram
  - Depicts the flow of control inside an object using **states** and **transitions** (finite state machines)
- Activity diagram
  - Describes the **control flow** among objects by actions organized in workflows (Petri Nets)

OBJETC' S DYNAMICS

- Sequence diagram
  - Depicts objects' interaction by highlighting the **time ordering** of method invocations
- Communication (collaboration) diagram
  - Depicts the **message flows** among objects

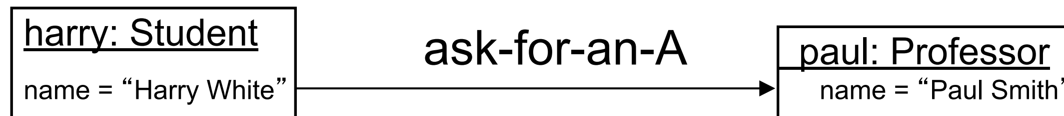
OBJETCS' INTERACTION

Behavioral elements

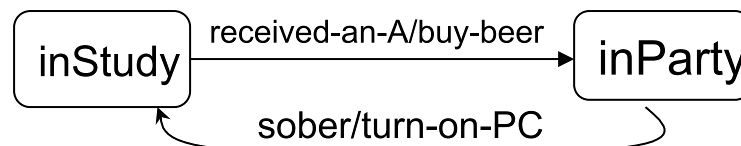
- ❑ Verbs in the requirements
- ❑ Dynamic parts of UML models: "behavior over time"
- ❑ Usually connected to structural elements

Two primary kinds of behavioral elements:

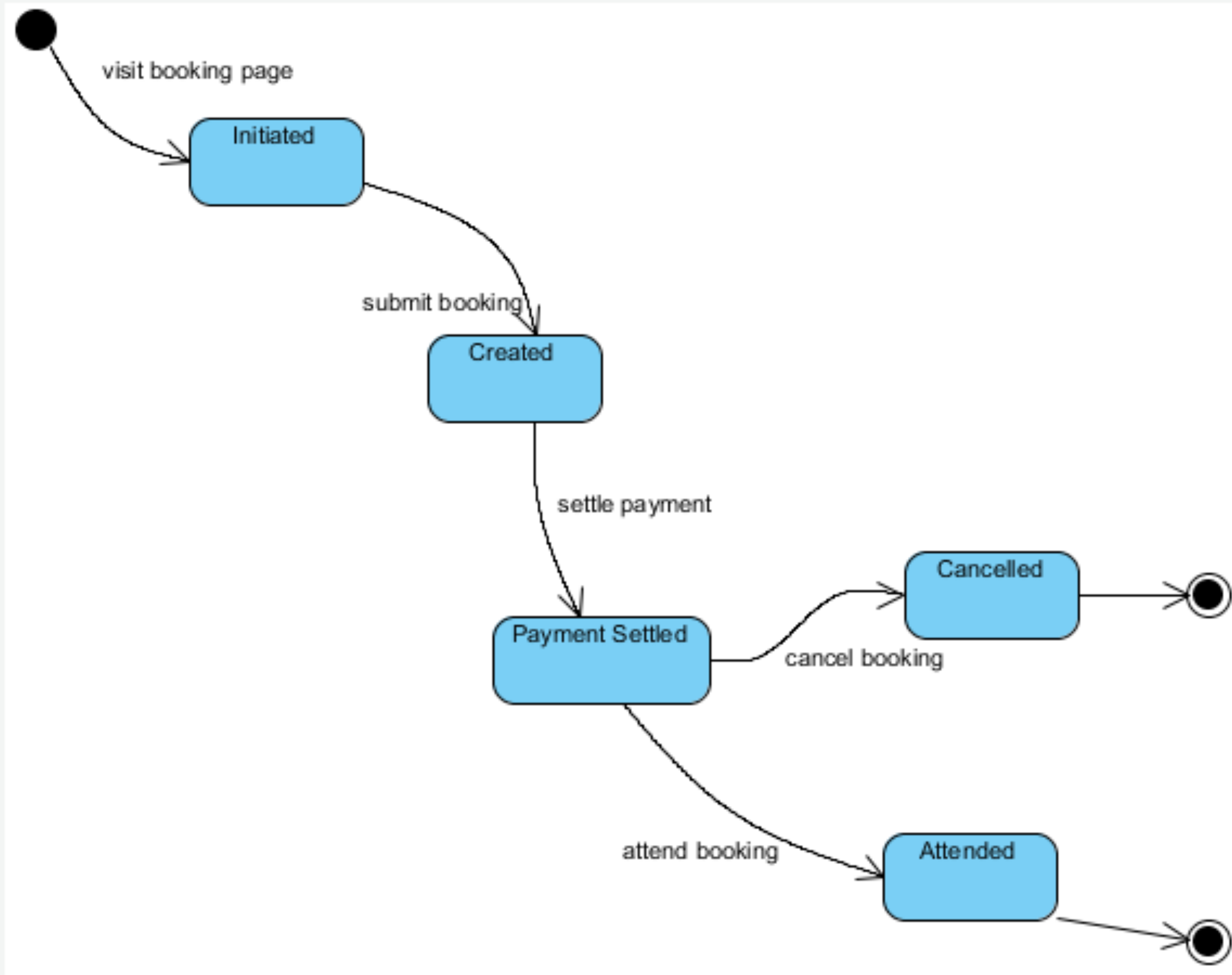
❑ ***Interaction***
a set of objects exchanging messages, to accomplish a specific purpose.



❑ ***State Machine***
specifies the sequence of states an object goes through during its lifetime in response to events

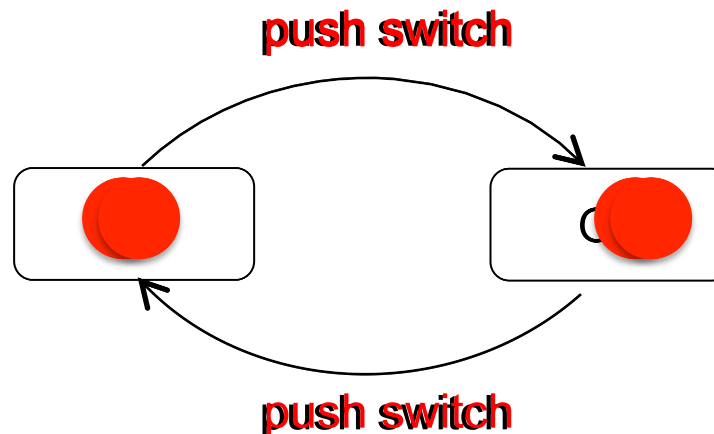


State diagram: booking object

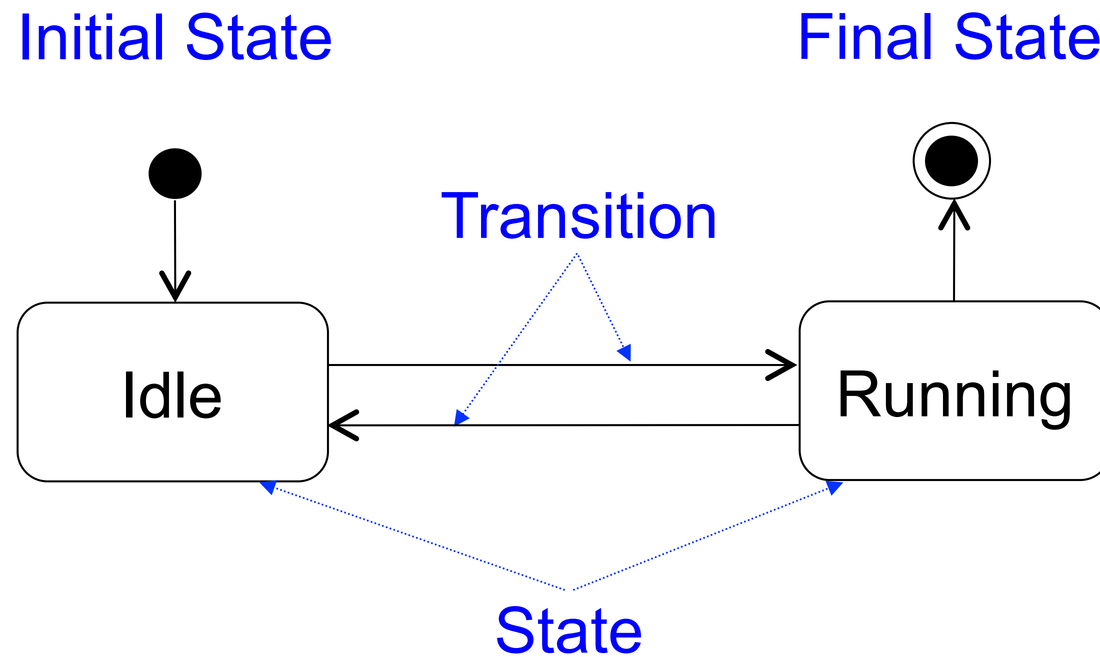


State diagram

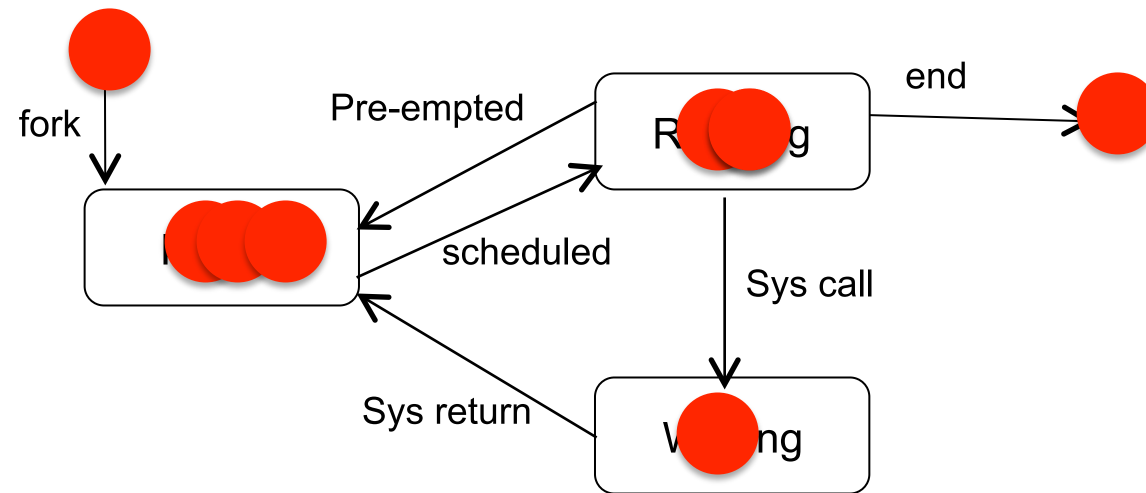
- A state diagram represents the behavior of an object
- Graph: net of states (nodes) and transitions (arrows)
- Graph representing a **finite state machine**
- Useful for modeling a reactive (event-driven) system
- Animation by "*token game*"



State diagram: elements



Example: Unix process

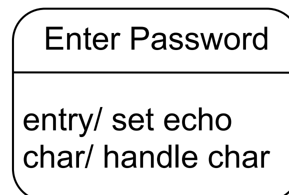


State

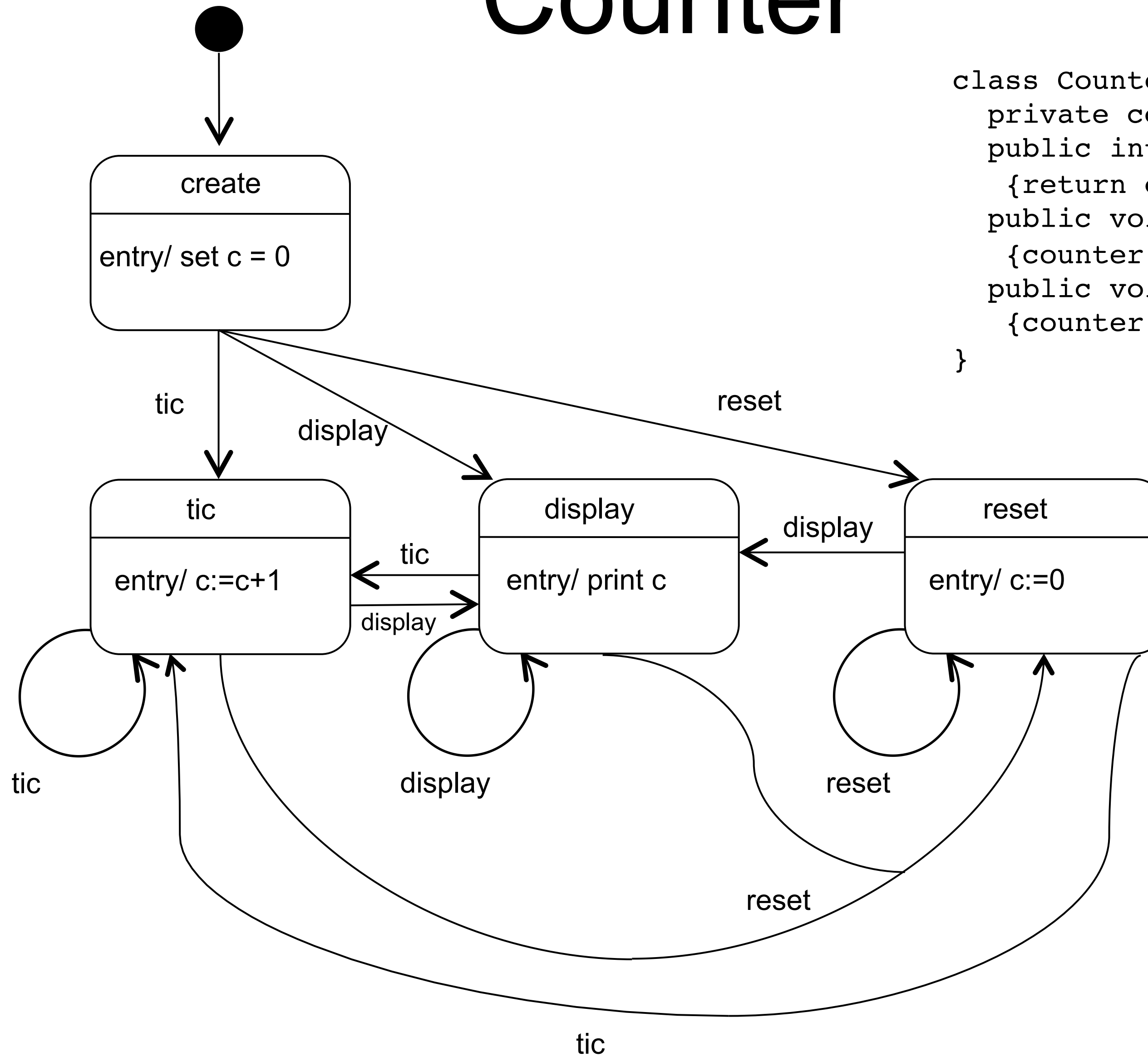
- Situation in the life of an object (or system) during which it:
  - Satisfies some condition,
  - Performs some activity, or
  - Waits for some events
- Set of values of properties that affect the behavior of the object (or system)
  - Determines the response to an event,
  - Thus, different states may produce different responses to the same event

State in a state diagram

- States are rounded rectangles with at least one section
  - Mandatory field: name
- optional: list of internal actions (with optional guards)
  - format: event-name argument-list | [guard condition] / action-expression
  - special actions: '`entry/`' and '`exit/`' (these cannot have arguments or guards)
- optional: invoking a nested state machine
  - format: do/machine-name
  - 'machine-name' must have initial and final states



Counter




```
class Counter{
  private counter: integer;
  public integer display()
   {return counter};
  public void tic()
   {counter = counter + 1};
  public void reset()
   {counter = 0};
}
```

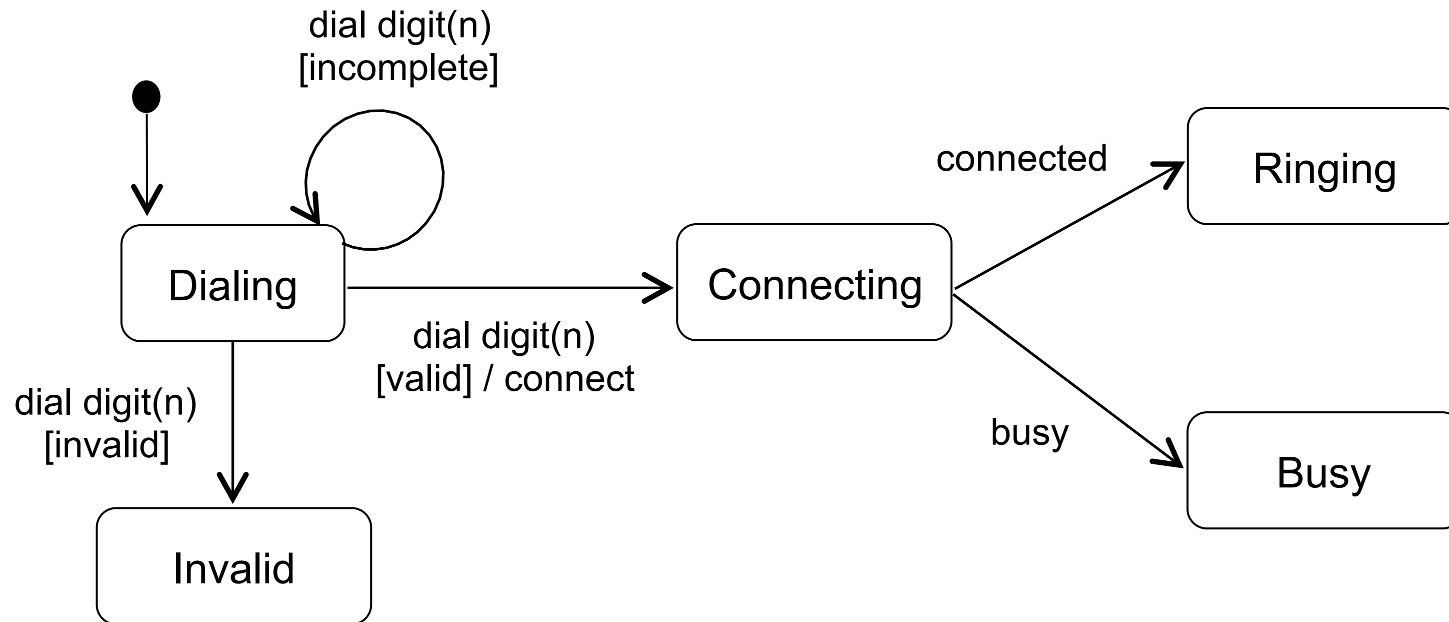
Transition

- Relationship between two states indicating that a system (or object) in the first state will:
  - Perform certain actions and
  - Enter the second state when a specified event occurs or a specified condition is satisfied
- A transition consists of:
  - Source and target states
  - Optional *event*, *guard condition*, and *action*

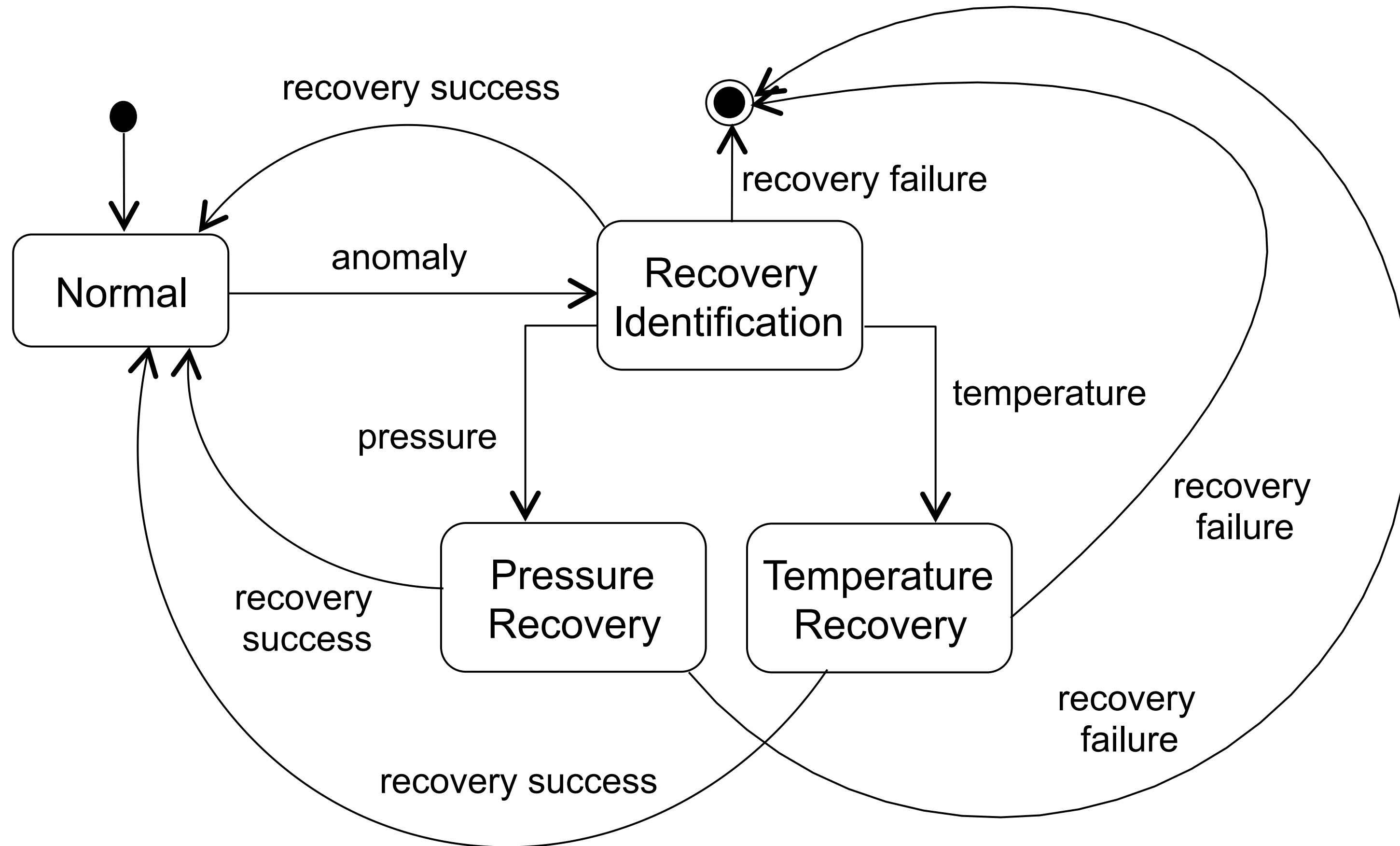
Definition: *event* and *action*

- *Event*
  - An occurrence of a stimulus that can trigger a state transition
  - Instantaneous and no duration
- *Action*
  - An executable atomic computation that results in a change in state of the model or the return of a value

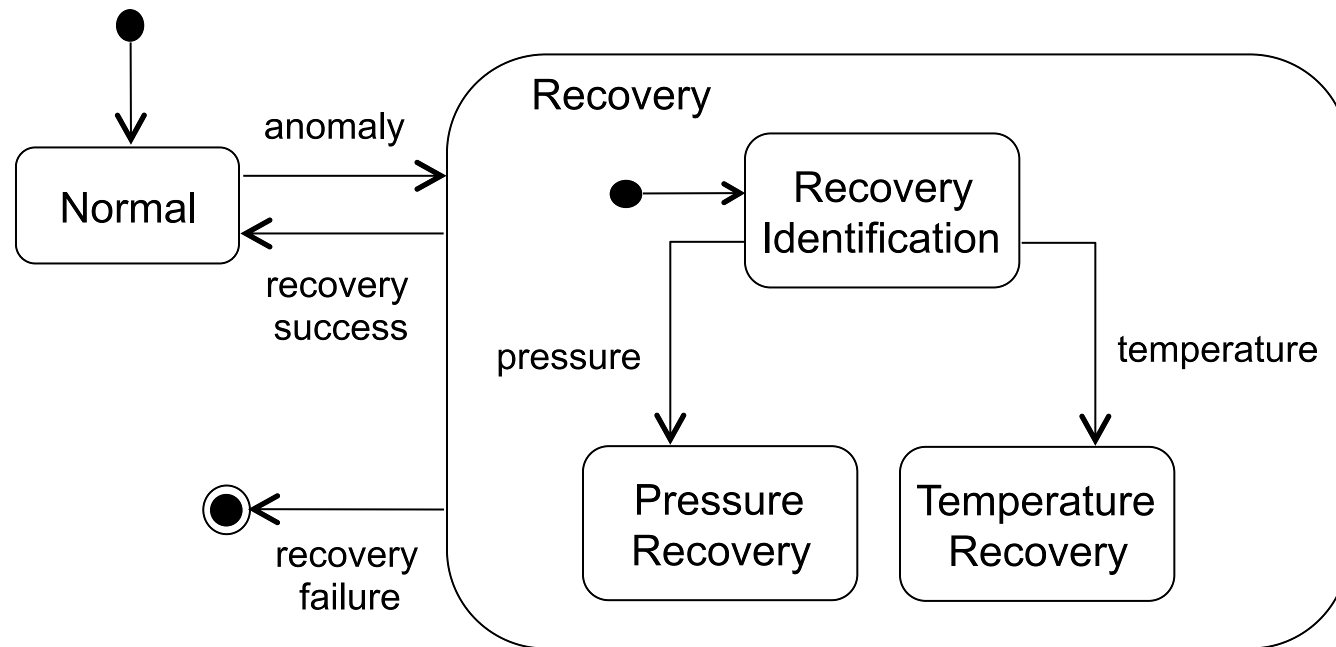
Example



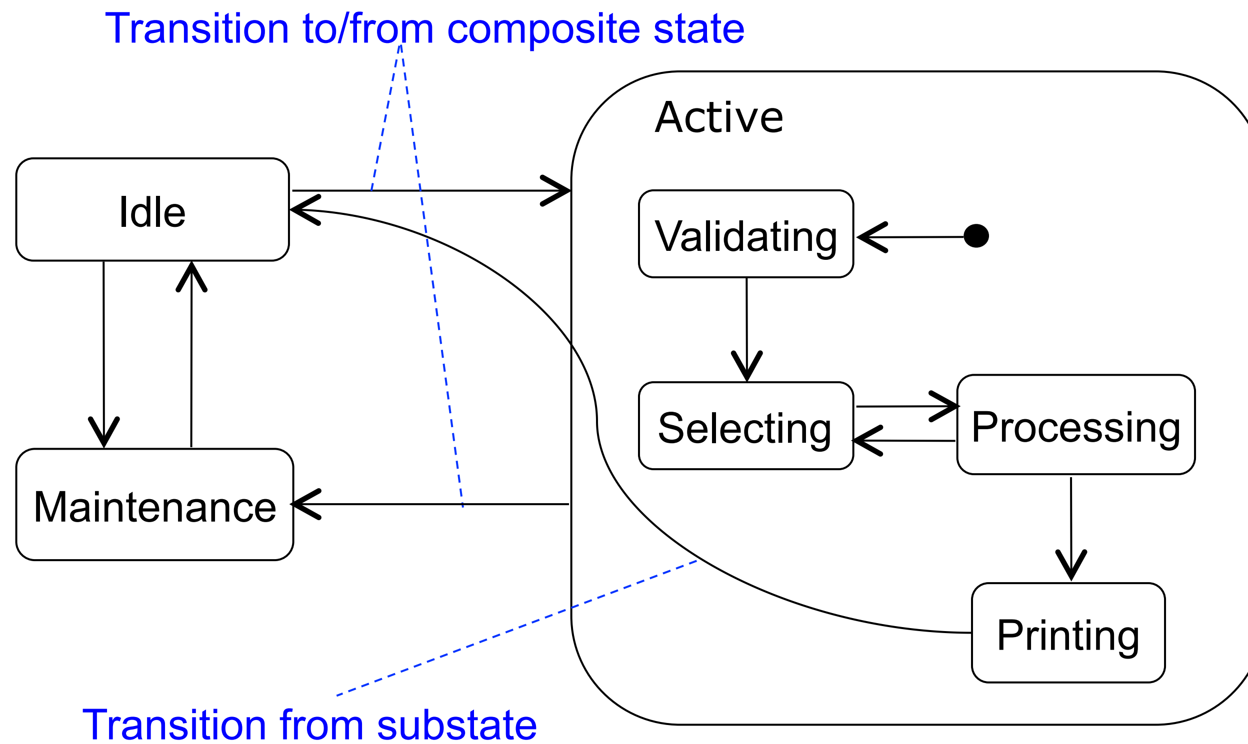
Example



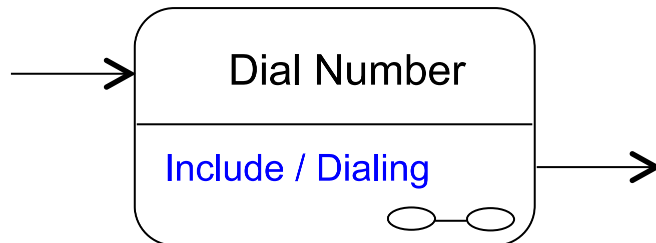
Composite states

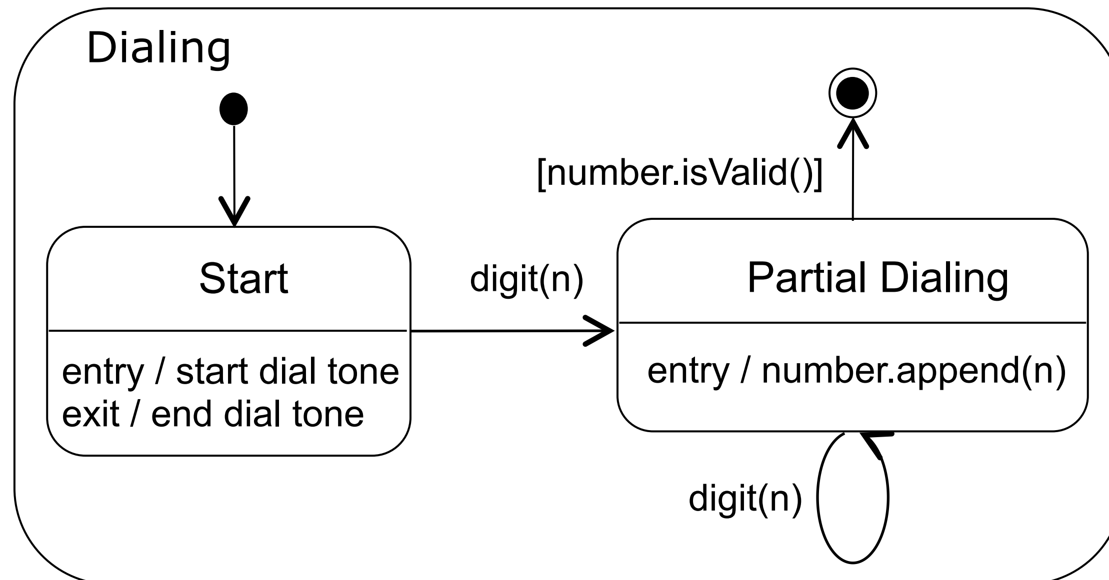


Composites and transitions



Including composite states

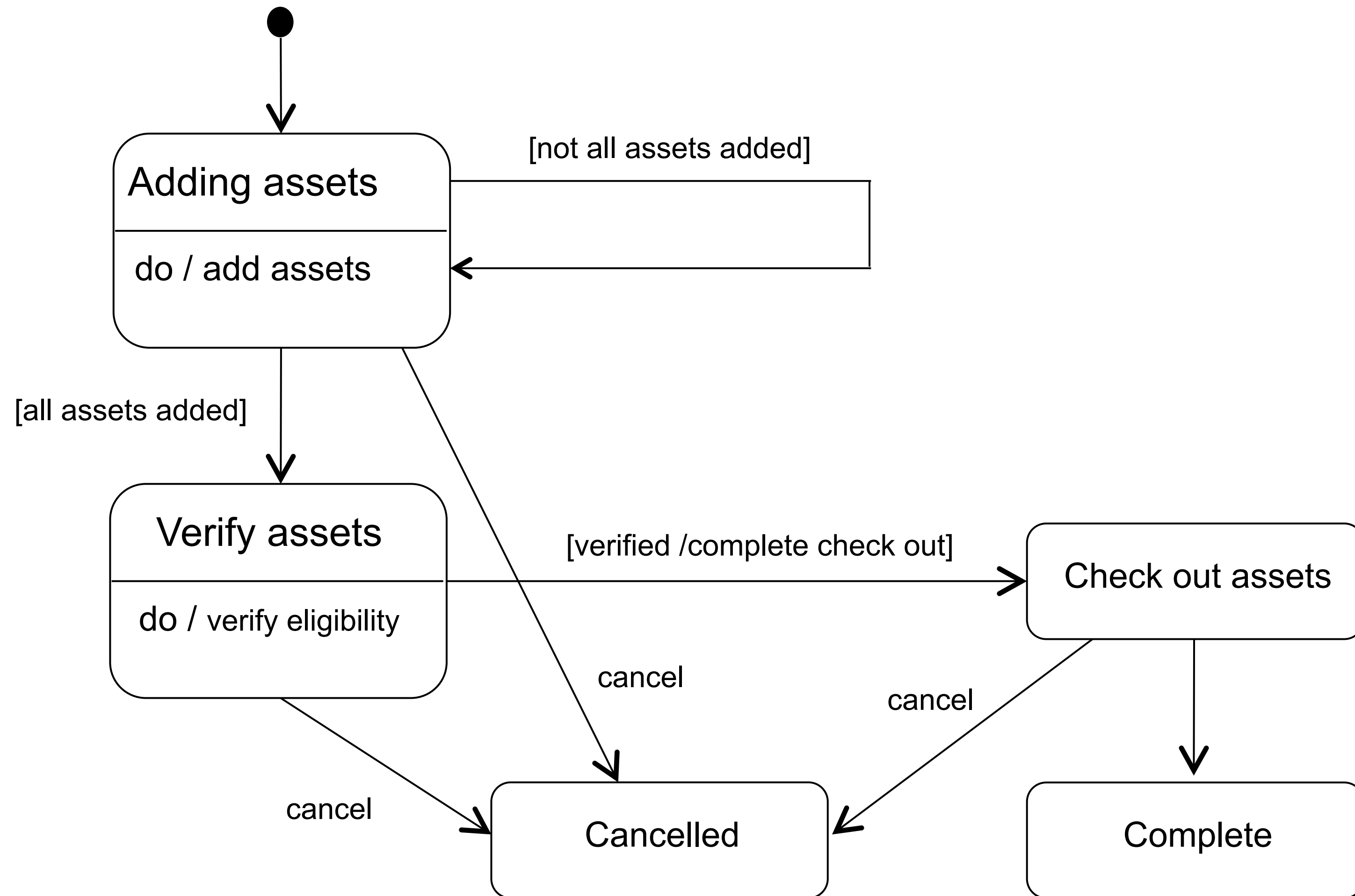




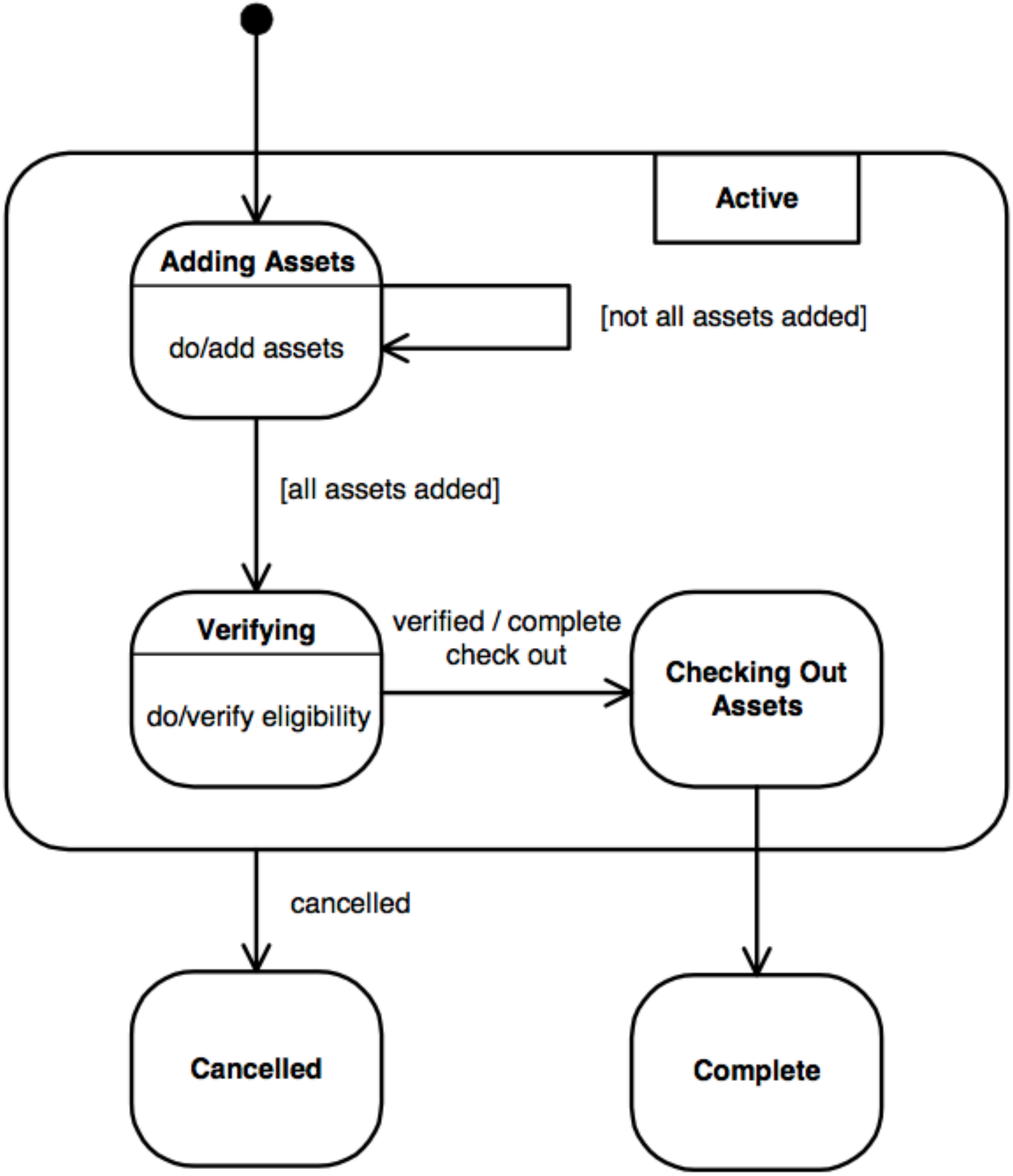
Composite state

- Used to simplify diagrams
- Inside, it looks like a statechart
- It may have composite transitions
- It may have transitions from substates
- It can be sequential or parallel

Example

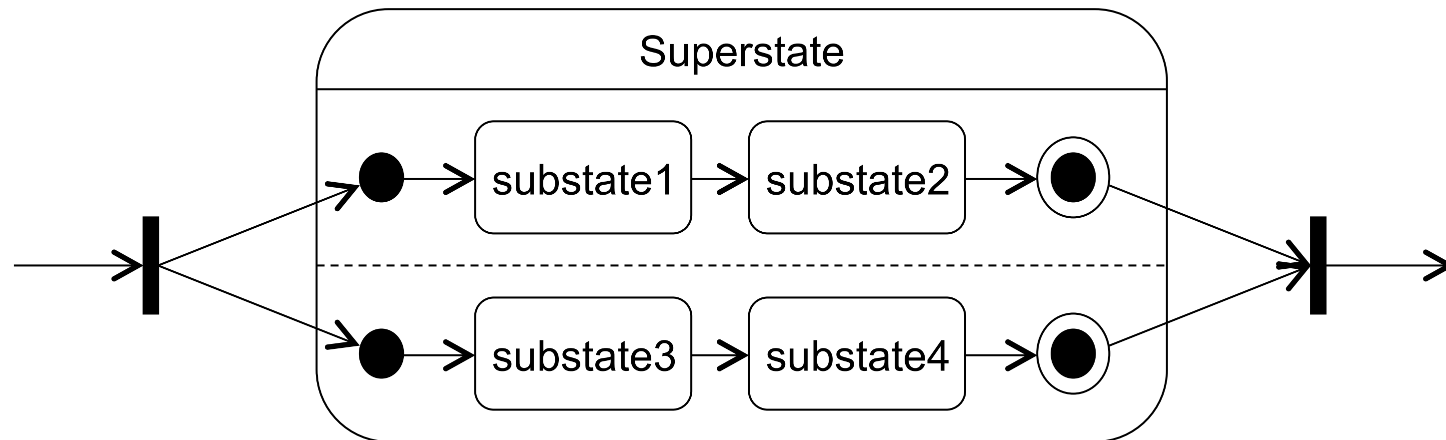


Exploiting a composite state

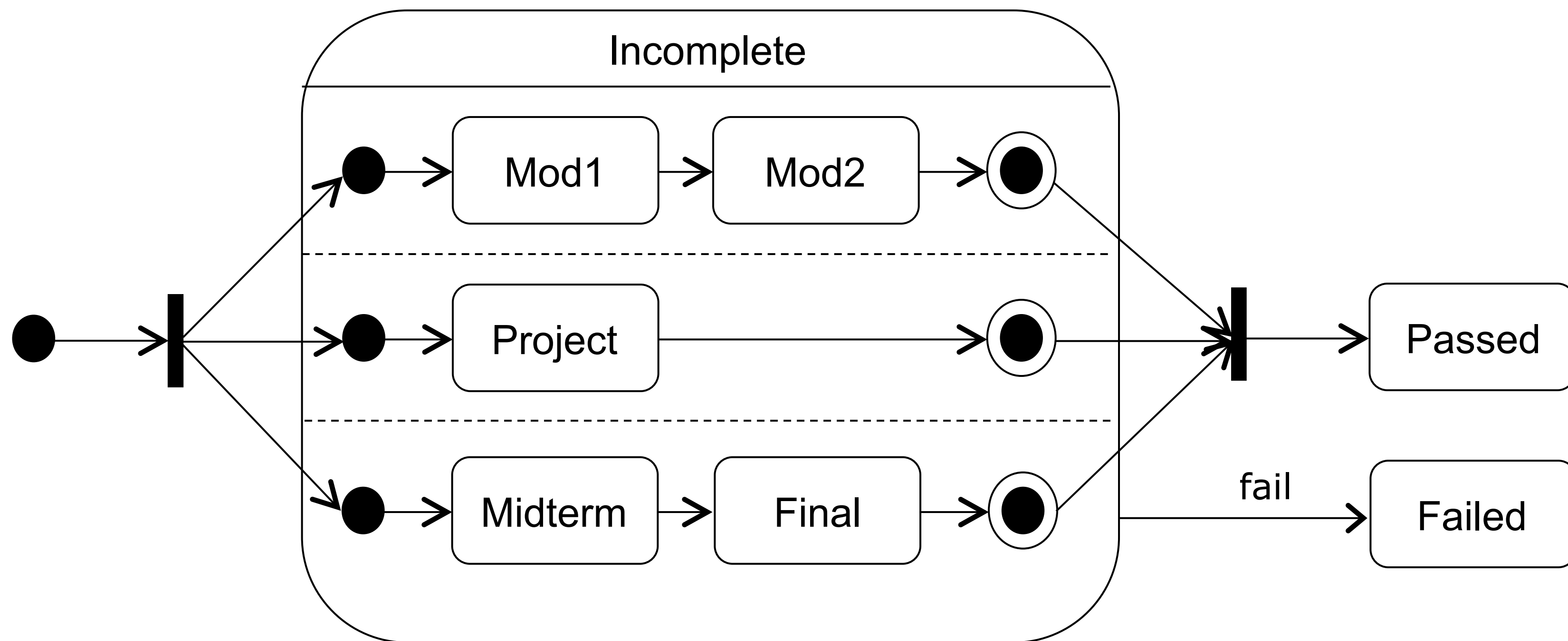


Parallel composition

- Concurrency (multiple threads of control)
- Synchronization



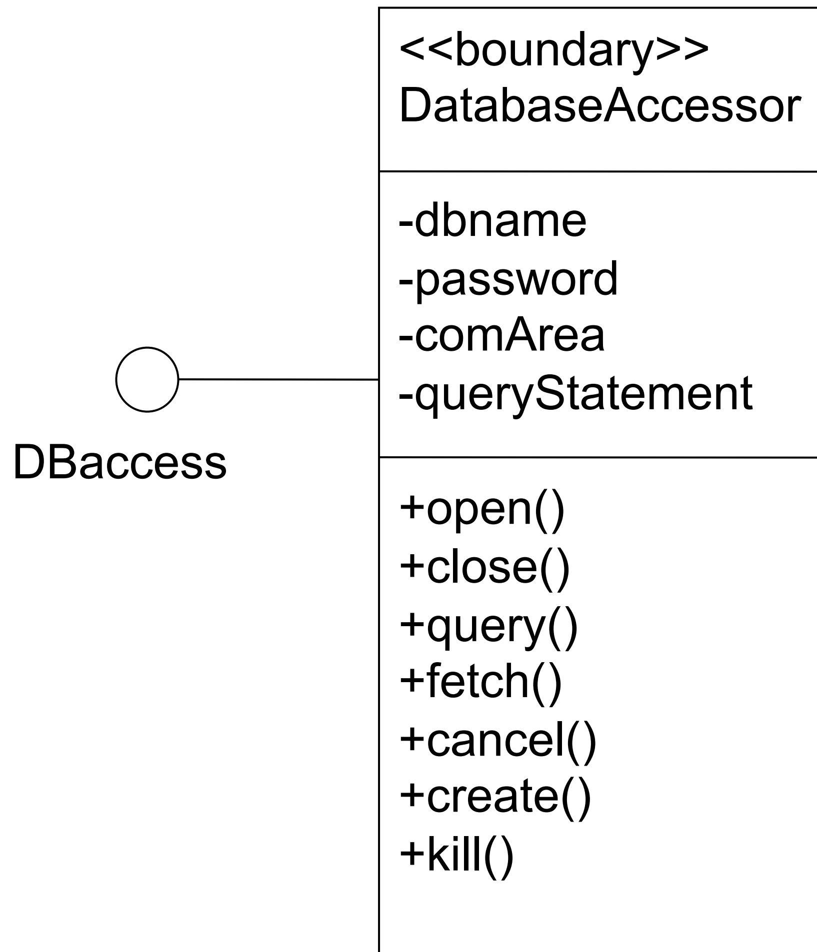
Example



Protocol state machine

- Normally we use a state diagram to show the internal behavior of all objects of a class
- Sometimes, however, we want to show a complex protocol (set of rules governing communication) when using an interface for a class
- For example, when we access a database we need to use operations like open, close and query. But these operations must be called in the right order: we cannot query the database before we open it

Protocol state machine



DBaccessor {protocol}
create /
Created
open / [successful login]
close /
Opened
[queryStatement <> null] query / [comArea set]
cancel / [comArea cleared]
Queried
fetch / [comArea.recordAvailable]
close /
cancel / [comArea cleared]
Fetching
close /
Closed
kill /

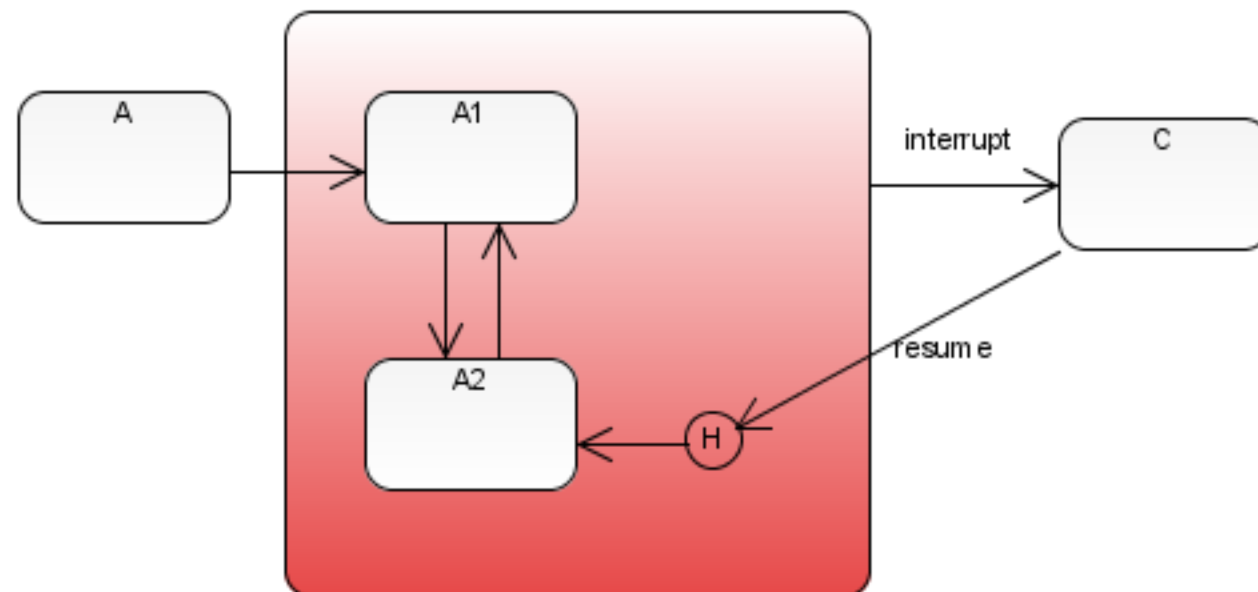
Behavioral vs protocol state machine

- Two kinds of state machines: *behavioral state machines* and *protocol state machines*
- Behavioral state machines can be used to model the behavior of individual entities (e.g., class instances)
- Protocol state machines are used to express usage protocols and can be used to specify the legal usage scenarios of classifiers, interfaces, and ports

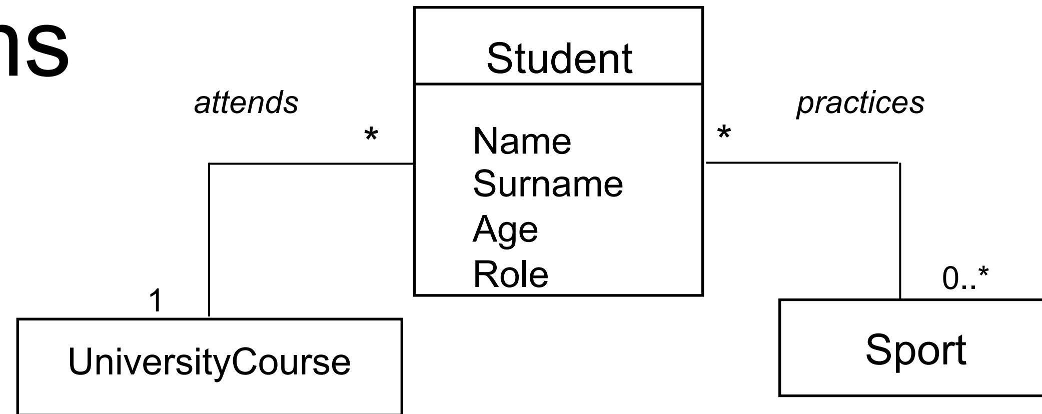
History pseudo state

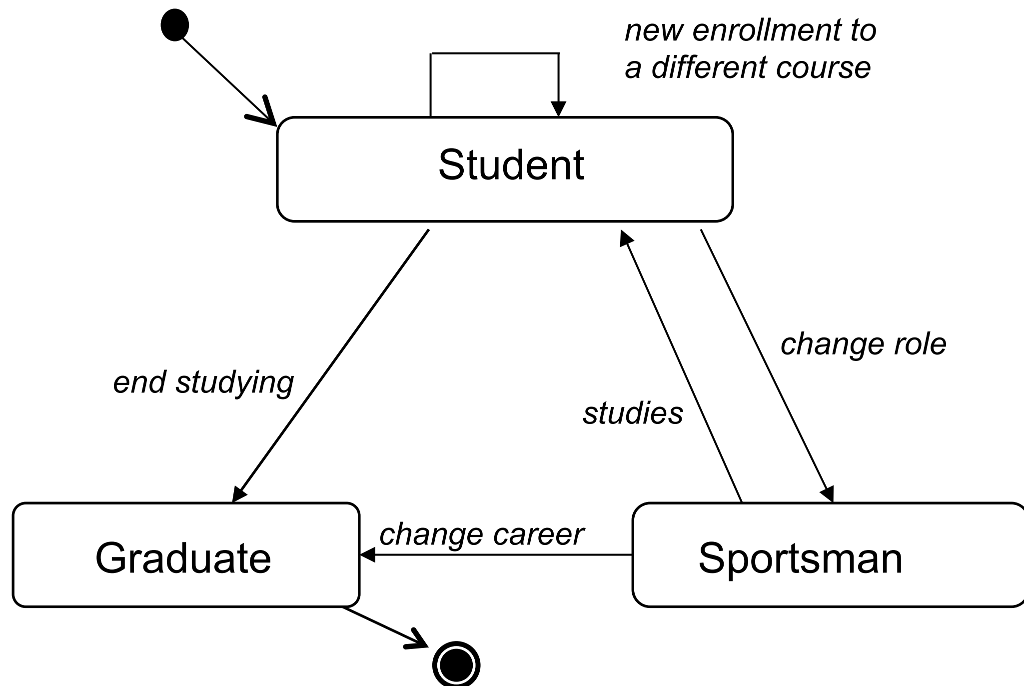
- A **history** pseudostate represents the most recent active substate of its containing state
- There are two kinds of this pseudostate: shallow or deep
  - Shallow (H): only the topmost active level of superstate is recorded
  - Deep (H*): all nested active levels in the superstate are recorded

(See the Superstructure sect 15.3.8 for pseudostate definitions and icons)



Consistency among diagrams





Exercise: Cellular Phone

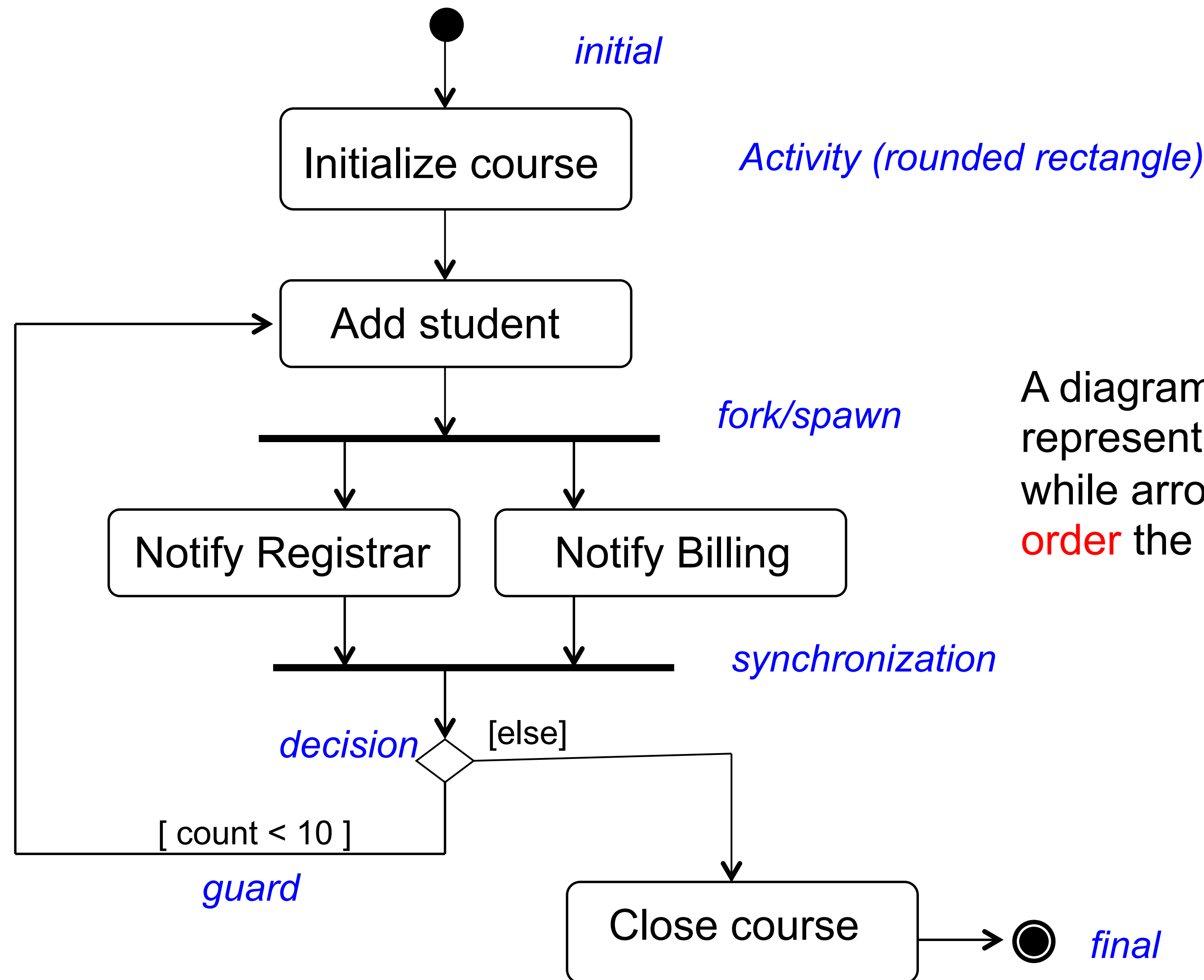
- Draw a statechart describing the operation of a cellular phone. Assume that the phone has keys for:
  - power on and off
  - keypad locking and unlocking
  - 0-9, #, and *
  - talk (or send) and end

  Model the following operations:
  - power on/off
  - keypad locking/unlocking
  - making calls (e.g., dialing, connecting, talking),
  - receiving calls (e.g., ringing, talking)

Activity diagrams

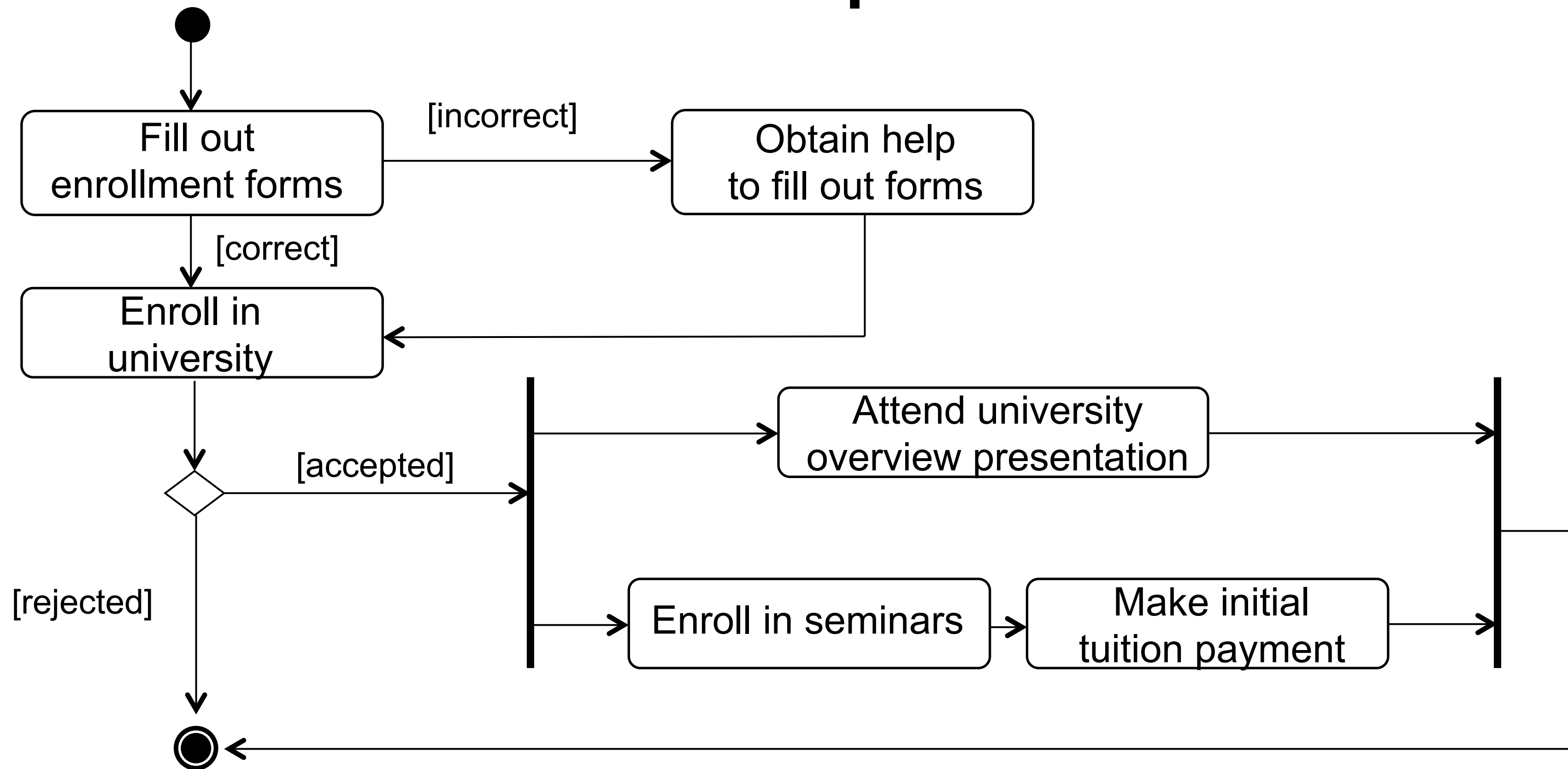
- Activity diagrams represent workflows of actions of several objects (but objects are not shown)
- Actions are composed by sequence, choice, iteration, and concurrency
- AD can be used to describe the activities of the components of a system
- In UML1 AD are based on State Diagrams
  in UML2 they have a different semantics

Activity diagram: elements

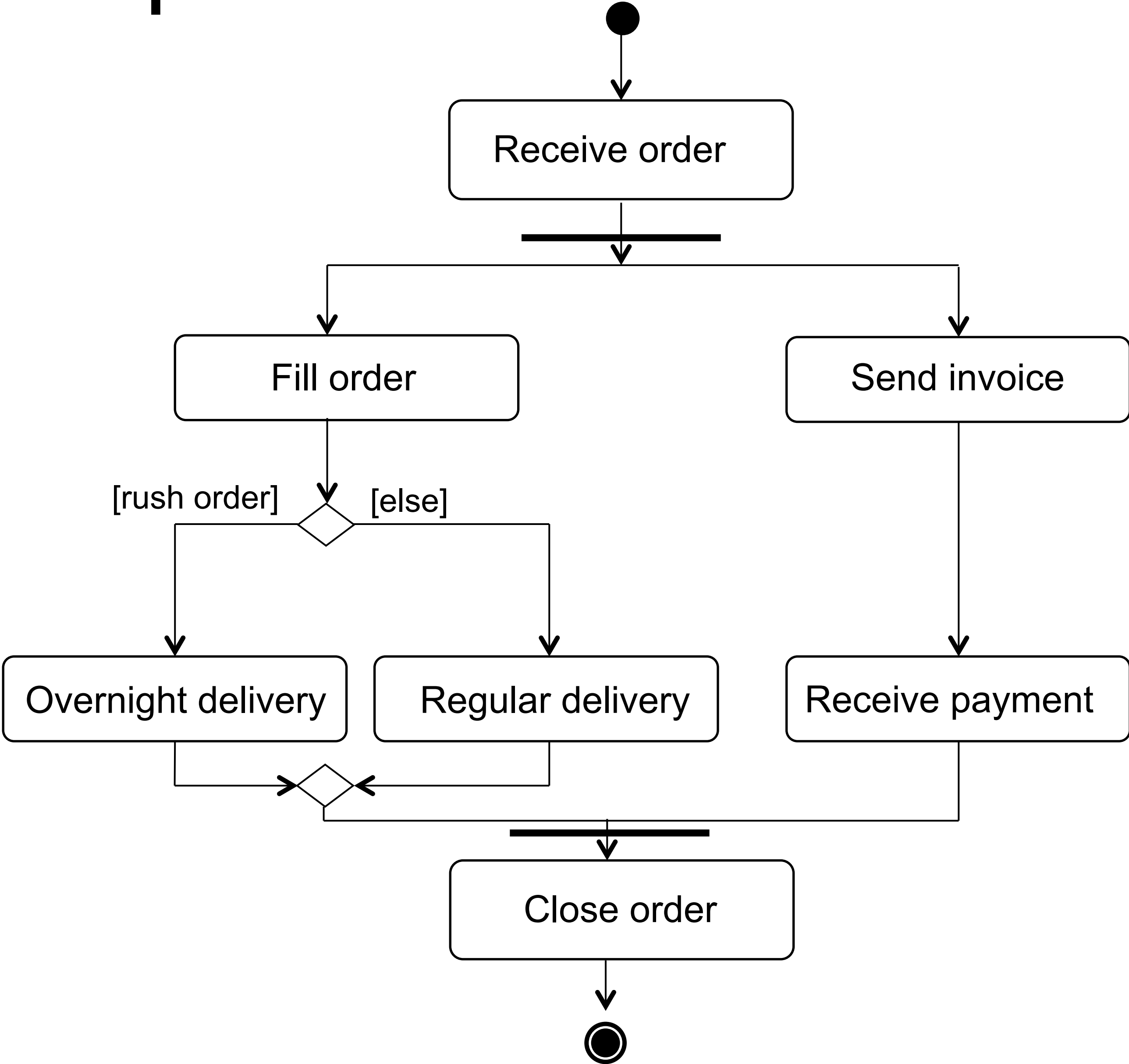


A diagram whose nodes represent activities, while arrows represent the order the activities happen

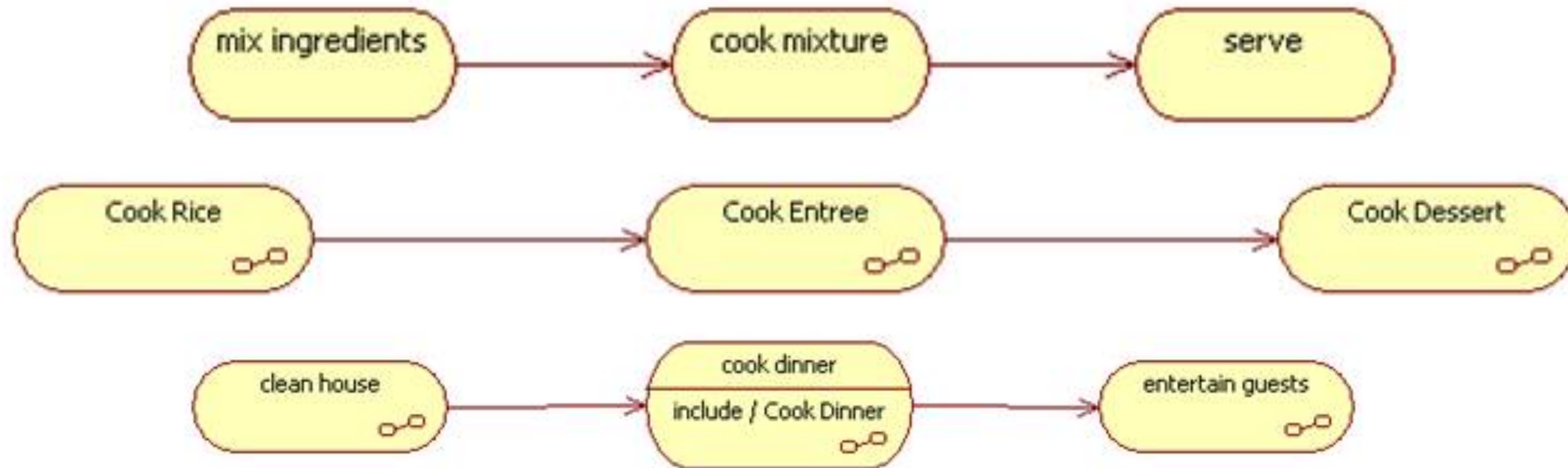
Example

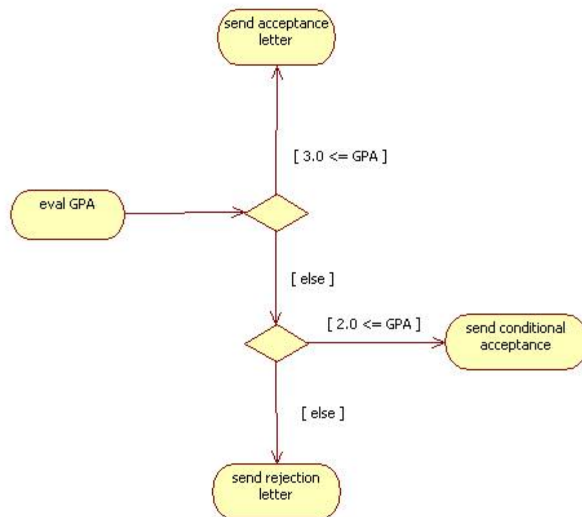


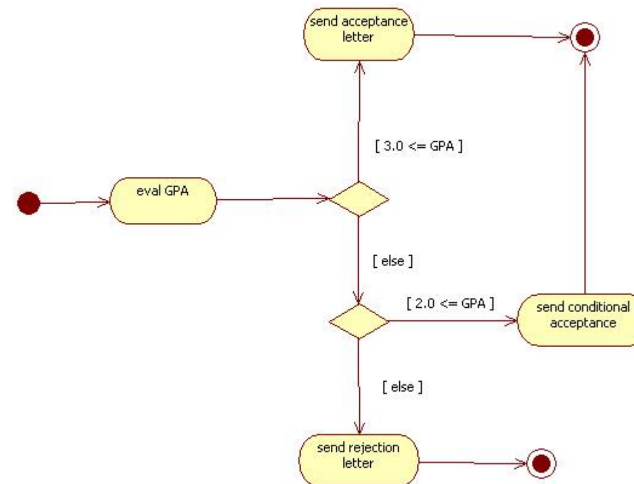
Example



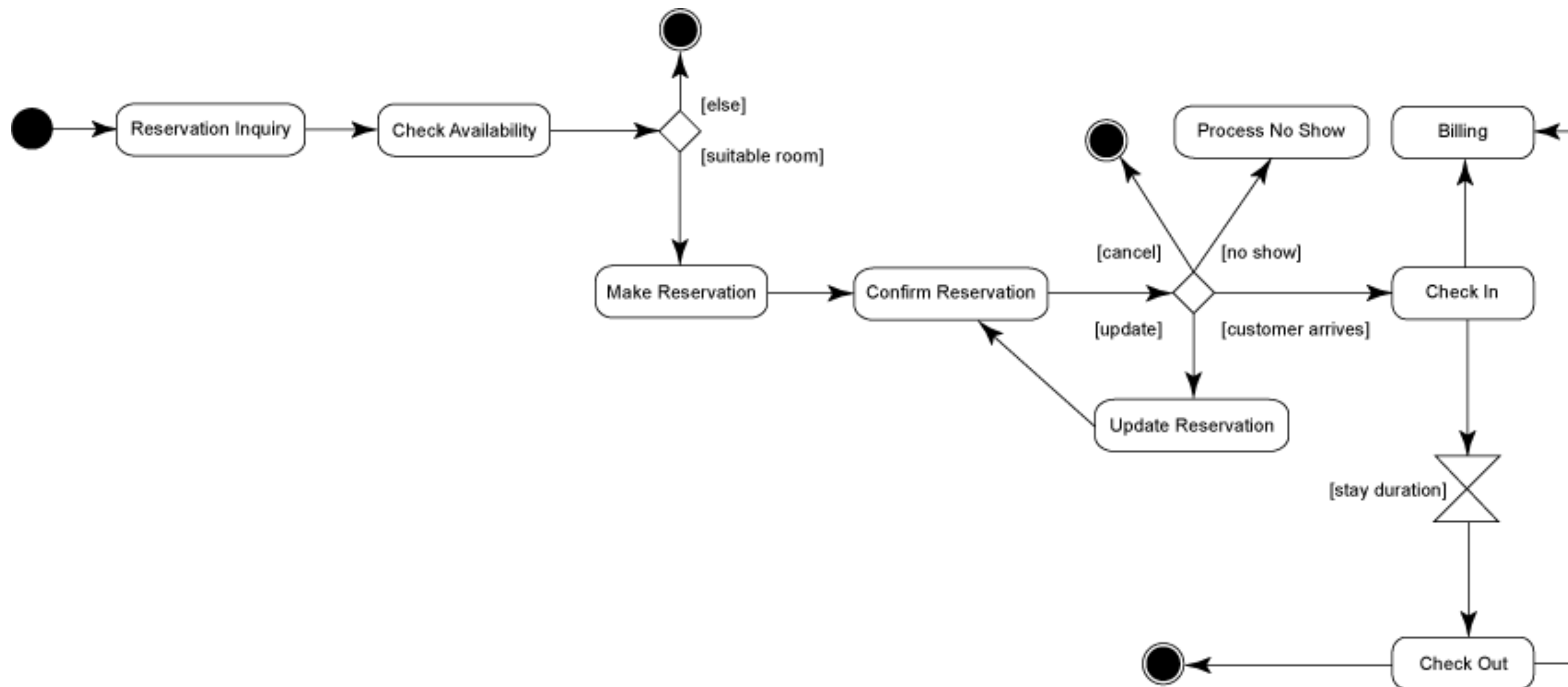
Activity diagram





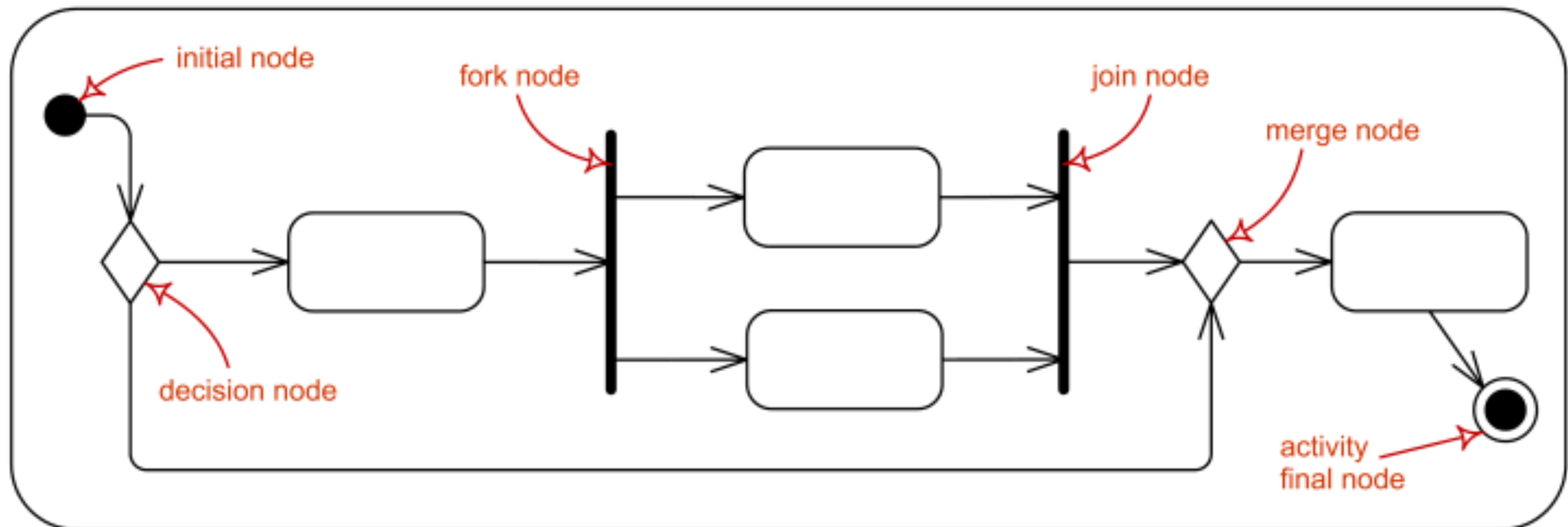


Example: hotel reservation



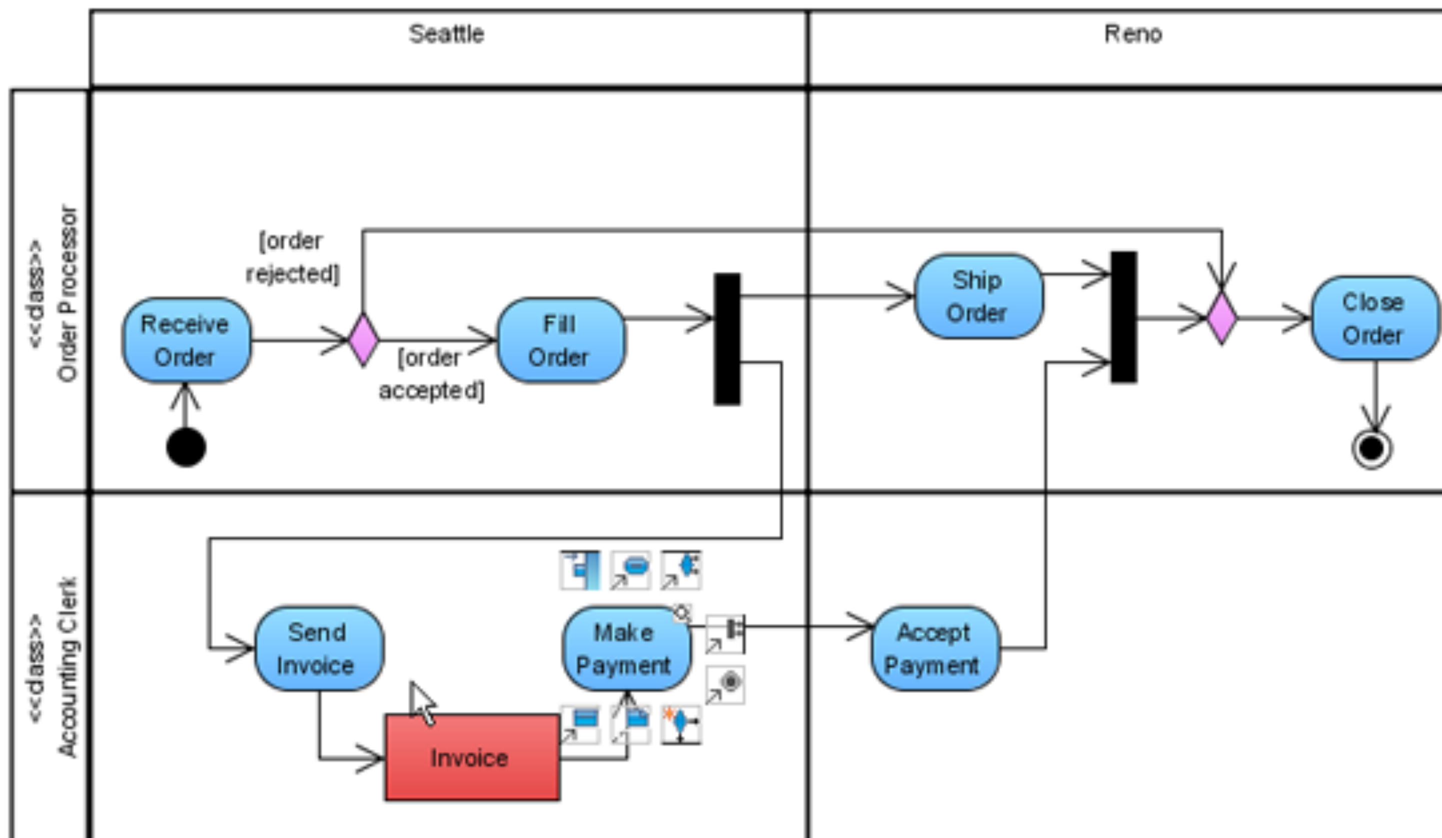
Activity control nodes

- Initial node
- Decision node
- Fork node
- Join node
- Merge node
- Activity final node
- Flow final node

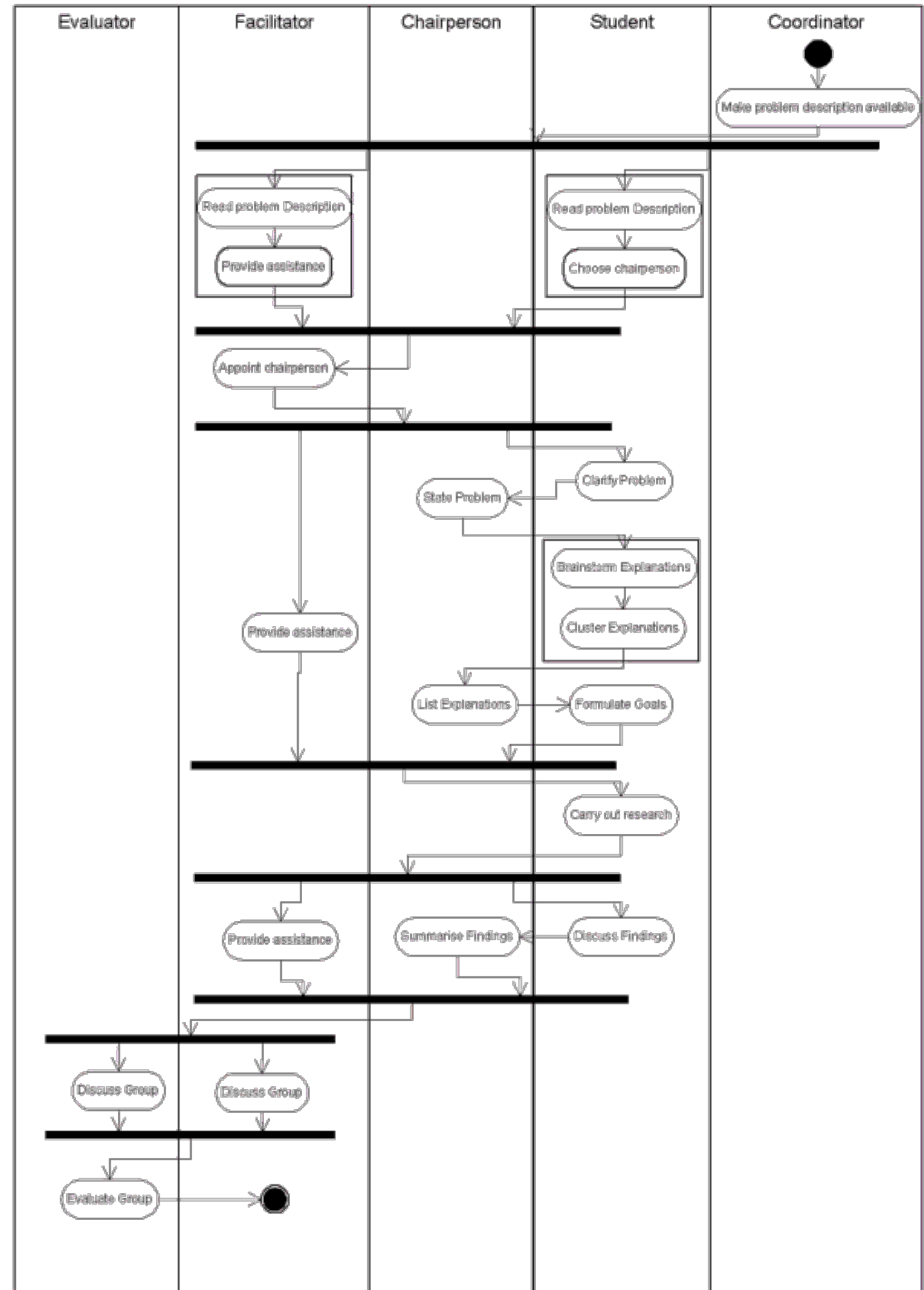


Activity partition

- Partitions divide the diagram to constrain and show some special view
- Partitions often correspond to organizational units in a business model



Swimlanes
in an
activity diagram
showing a
workflow
with several roles



Exercise

Which is the maximum degree of parallelism in this activity diagram?

Portal

Job Execution Service (JES)

CEA service

Get workflow from storage

workflowDefinition:WorkflowString

Submit workflow as job

Create job

job:JobURN

Determine ready job- steps

[for each ready job-step]

Launch job-step

jobStep:_tool

Execute job-step

[more steps & not aborted]

Poll job status

Recover job-step

[job running]

Record job-step status

[job done]

[otherwise]

Record job status

Get job results

What an AD does not show?

- Objects (but they can be inferred)
- States
- Messages
- Data passed between steps
- User interface

How to create an AD

1. Identify the activities (steps) of a process
2. Identify who/what performs activities (process steps)
3. Identify decision points (if-then)
4. Determine if a step is in loop
5. Determine if a step is parallel with some other
6. Identify the order of activities, decision points

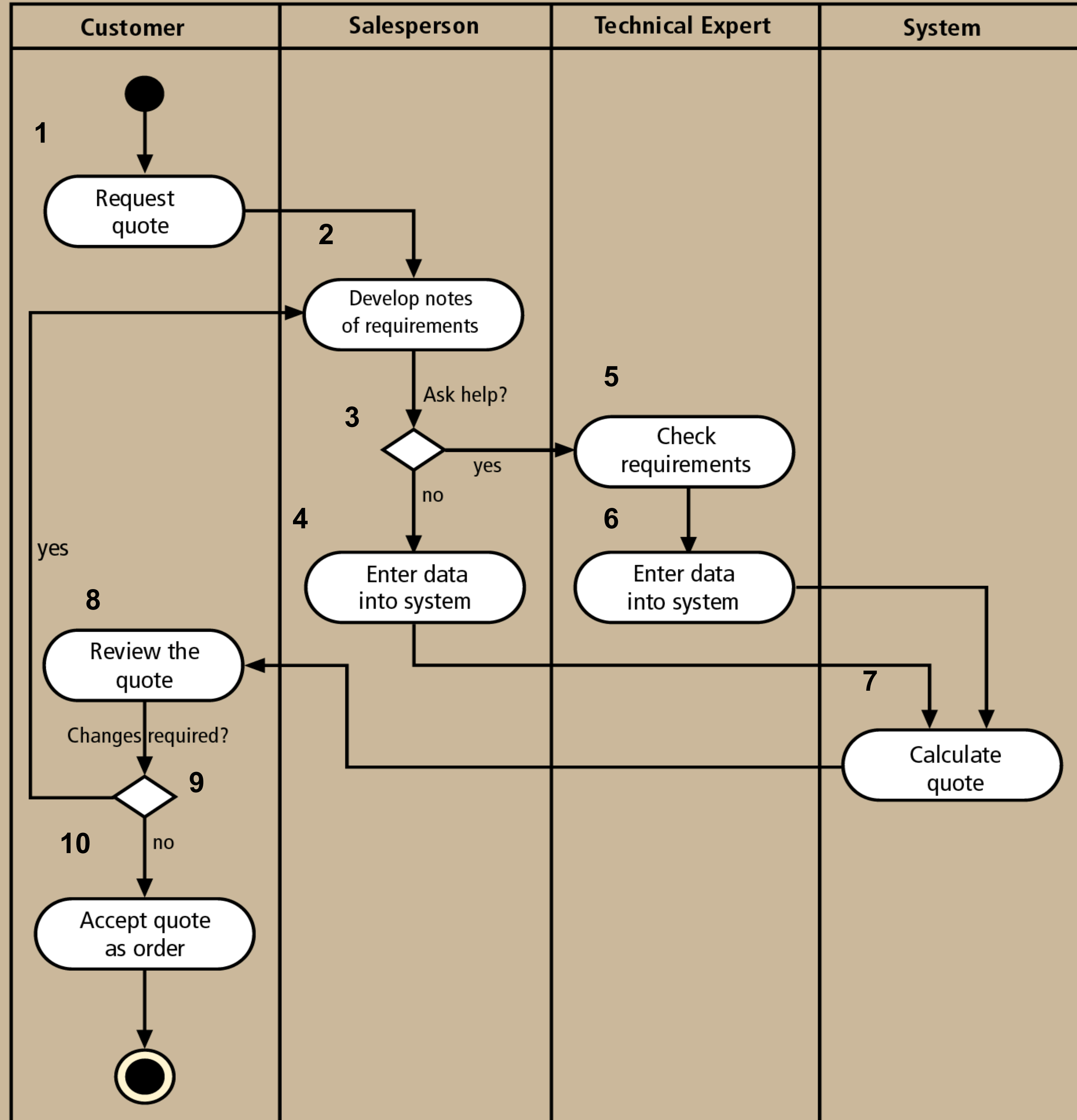
Example

Step ID	Process Step or Decision	Who/What Performs	Parallel Activity	Loop	Preceding Step
1	Request quote	Customer	No	No	-
2	Develop requirement notes	Salesperson	No	Yes	1
3	Decision: Help?	Salesperson	-	Yes	2
4	Salesperson enters data	Salesperson	No	Yes	3
5	Check requirements	Technical Expert	No	Yes	3
6	Tech. expert enters data	Technical Expert	No	Yes	5
7	Calculate quote	System	No	Yes	4, 6
8	Review quote	Customer	No	Yes	7
9	Decision: Changes?	Customer	No	Yes	8
10	Accept quote as order	Customer	No	No	9

How to create an AD (cont.)

7. Draw the swimlanes
8. Draw the start point of the process in the swimline of the first activity (step)
9. Draw the oval of the first activity (step)
10. Draw an arrow to the location of the second step
11. Draw subsequent steps, while inserting decision points and synchronization/loop bars where appropriate
12. Draw the end point after the last step.

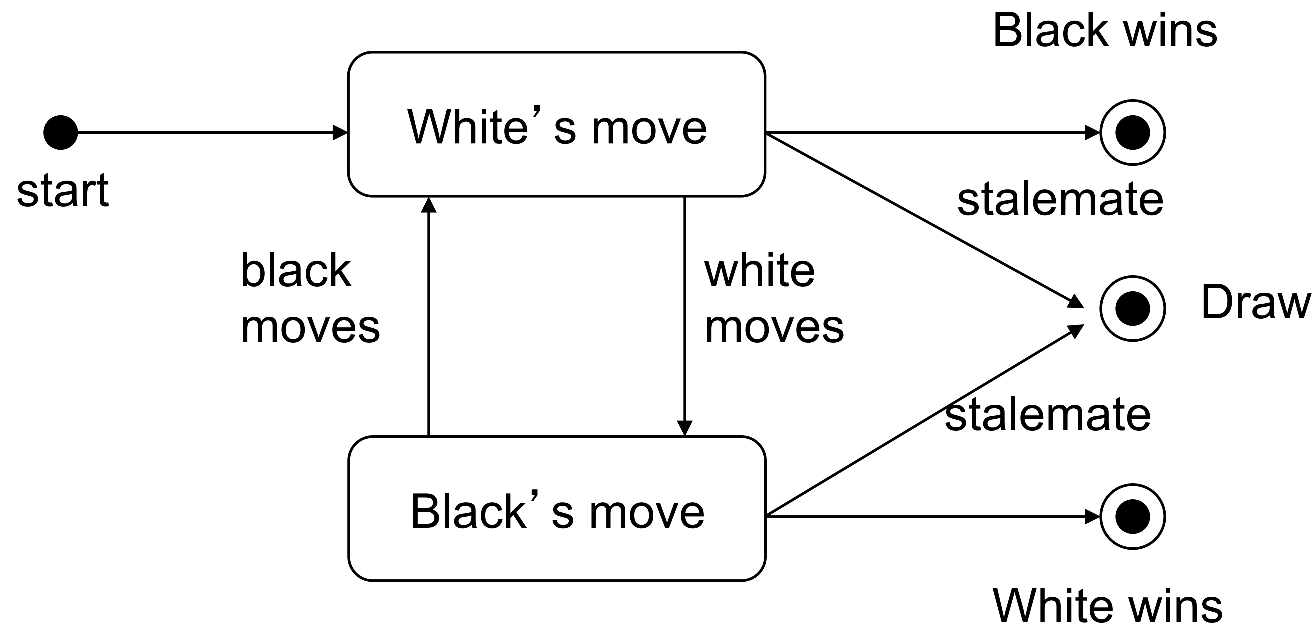
Example



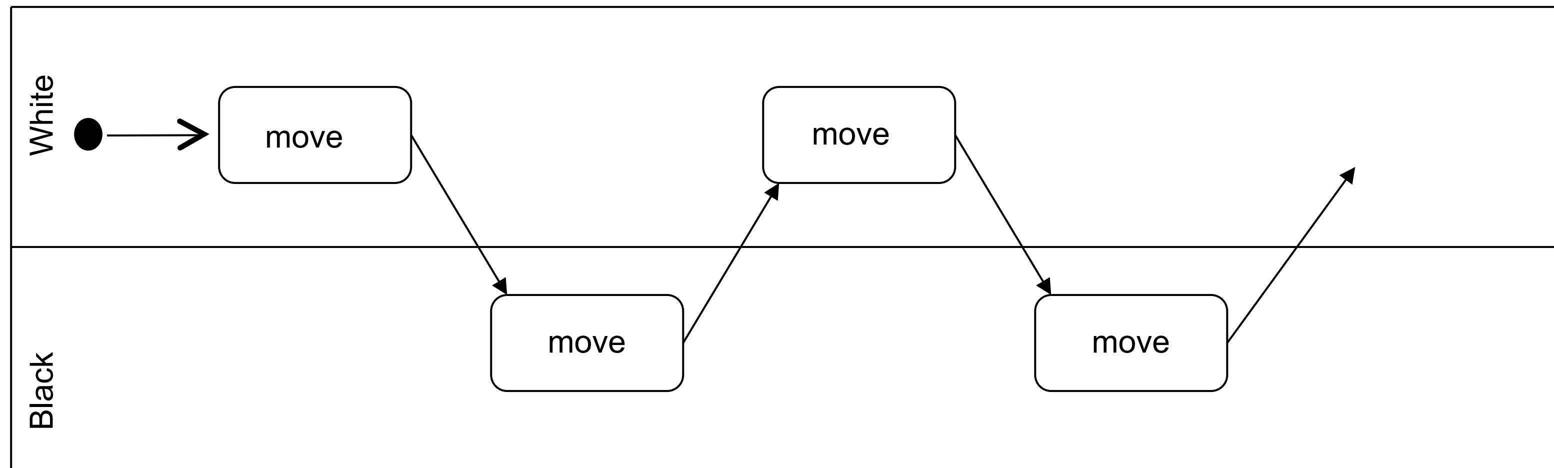
State vs activity diagrams

- Both diagrams describe behaviors, by state changes and actions, respectively
- In UML1 they are equivalent (in AD states are actions)
- In UML2 they differ: ActivityD are based on Petri Nets, StateD on Harel automata
- Their typical usage is also different:
  - State diagrams are single context
  - Activity diagrams are multiple context

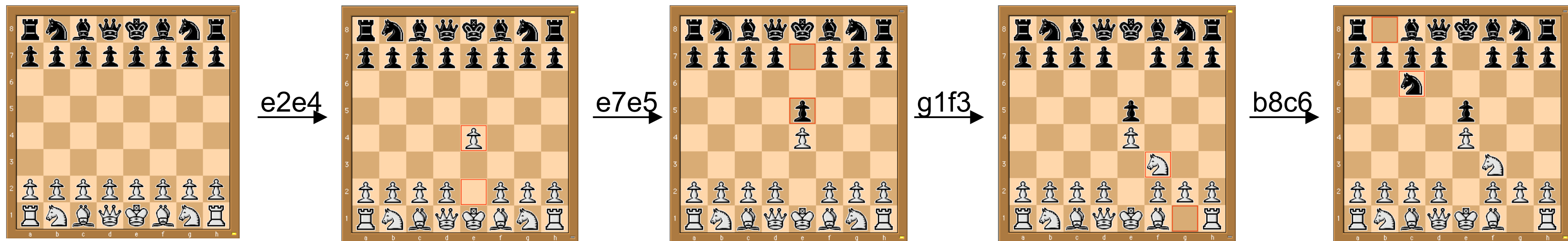
State machine: chess game

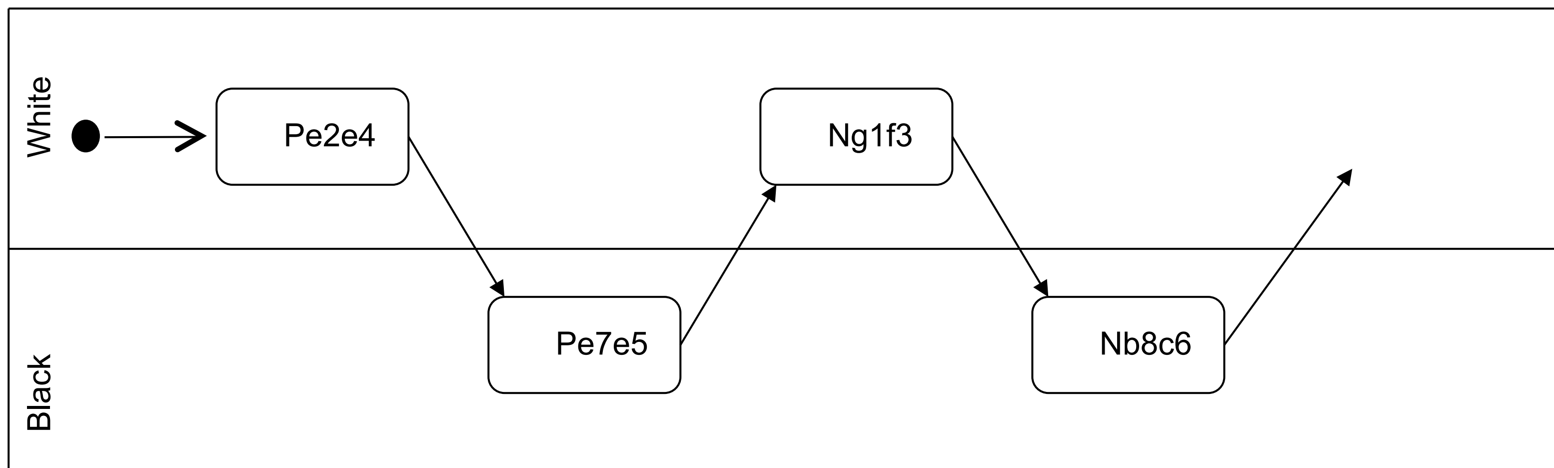


Activity diagram: chess game

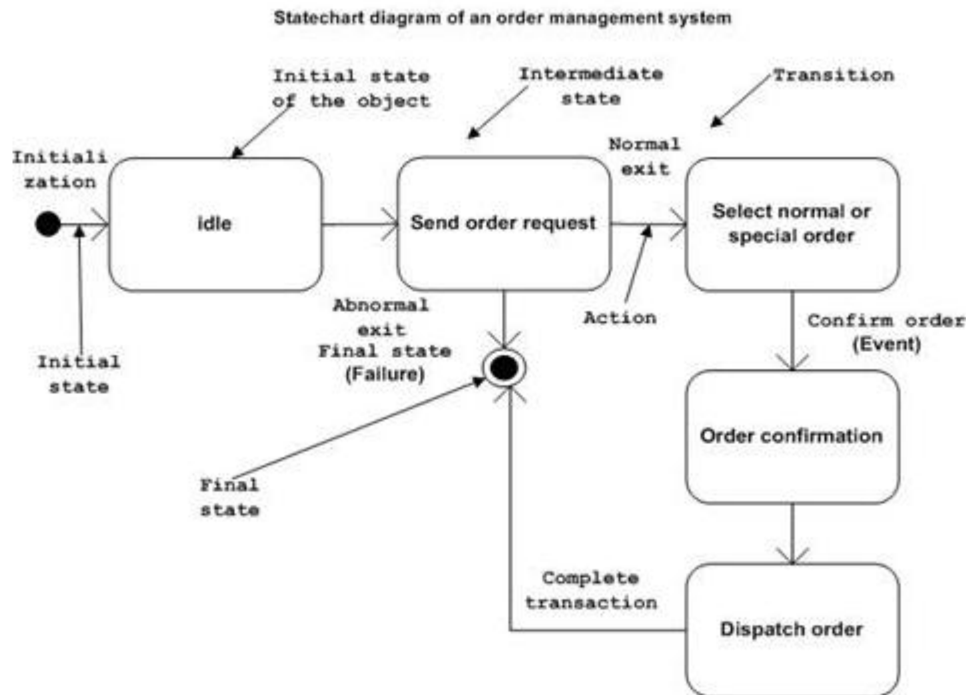


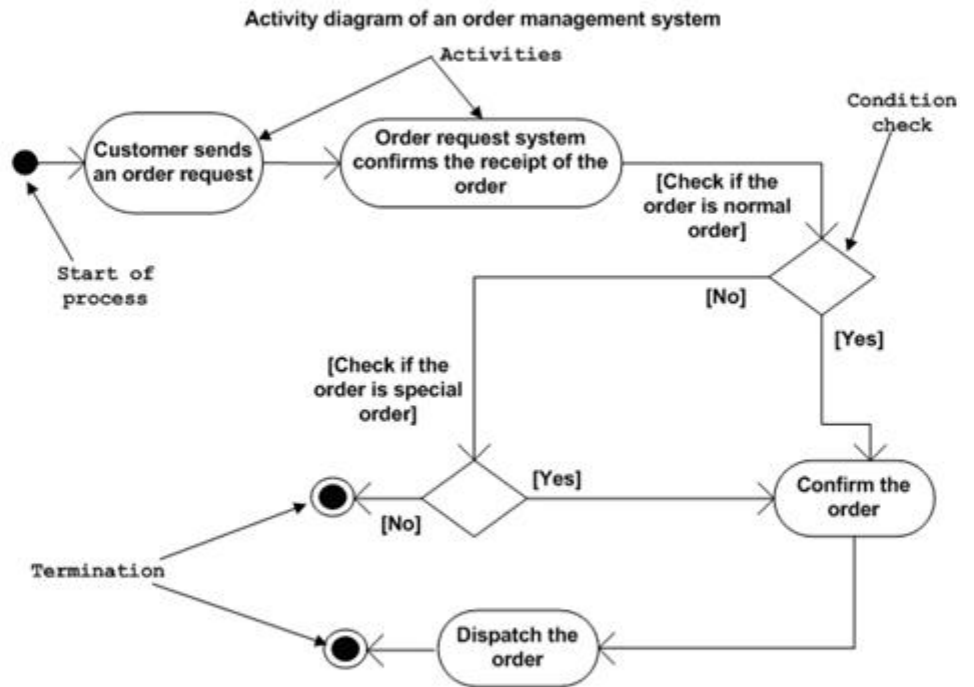
State vs activity diagrams





State vs activity diagrams





Activity diagram vs flowchart

- An activity diagram shows the order in which to do tasks
- The key difference between an activity diagram and a flowchart is that the activity diagram can describe parallel processes, while flowcharts are sequential

Behavior diagrams: interaction

Balla: Dinamismo di cane al guinzaglio, 1912

Modeling Interaction

- Statechart diagram
  - Depicts the flow of control inside an object using **states** and **transitions** (finite state machines)
- Activity diagram
  - Describes the **control flow** among objects by actions organized in workflows (Petri Nets)
- Sequence diagram
  - Depicts objects' interaction by highlighting the **time ordering** of method invocations
- Communication (collaboration) diagram
  - Depicts the **message flows** among objects

INTERACTION

Interaction diagrams

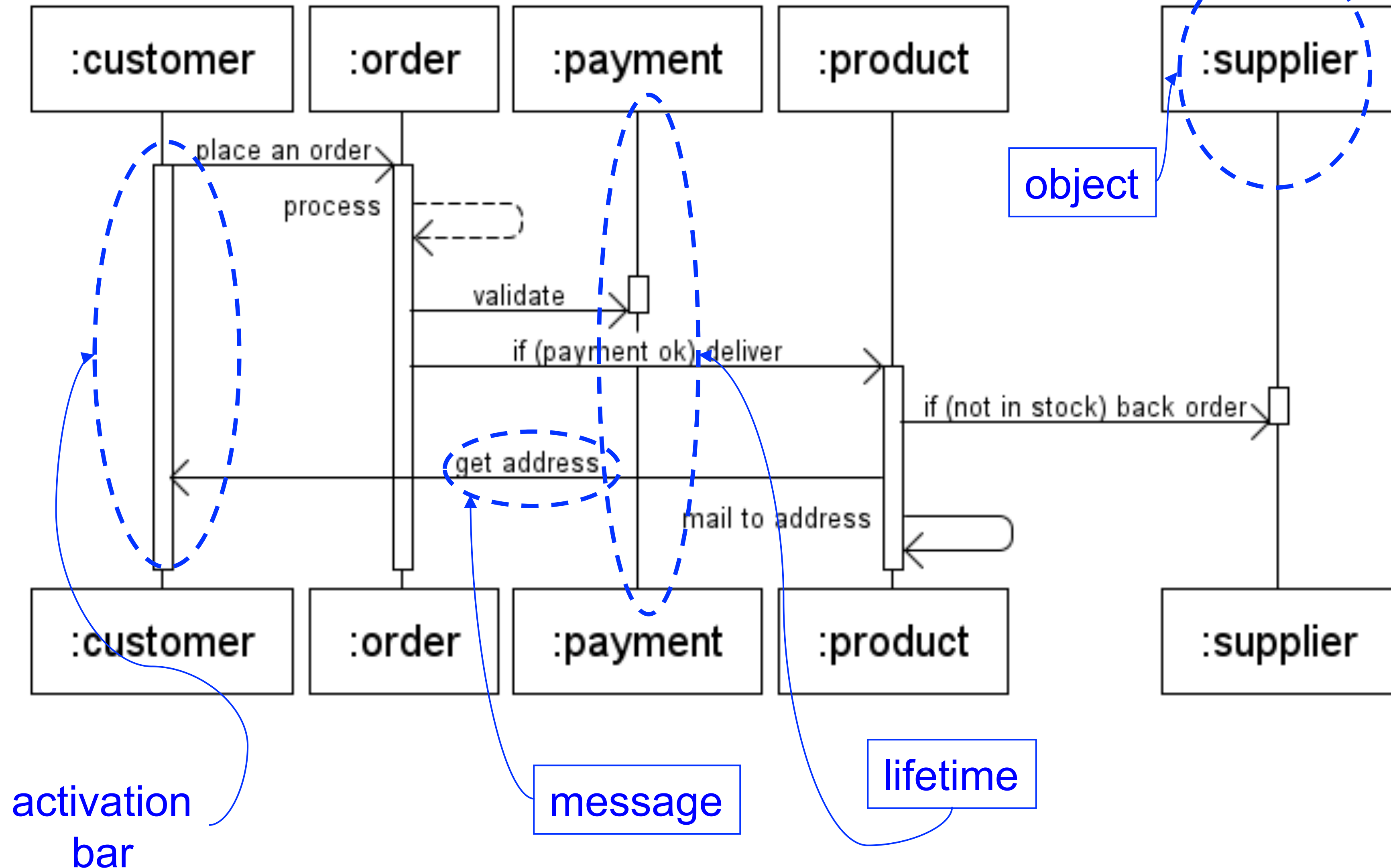
- A use case diagram presents an **outside view** of the system
- The **inside view** of a system is shown by interaction diagrams

- Interaction diagrams describe how a use case is realized in terms of interacting objects
- Two types of interaction diagrams
  - Sequence diagrams
  - Collaboration (Communication) diagrams

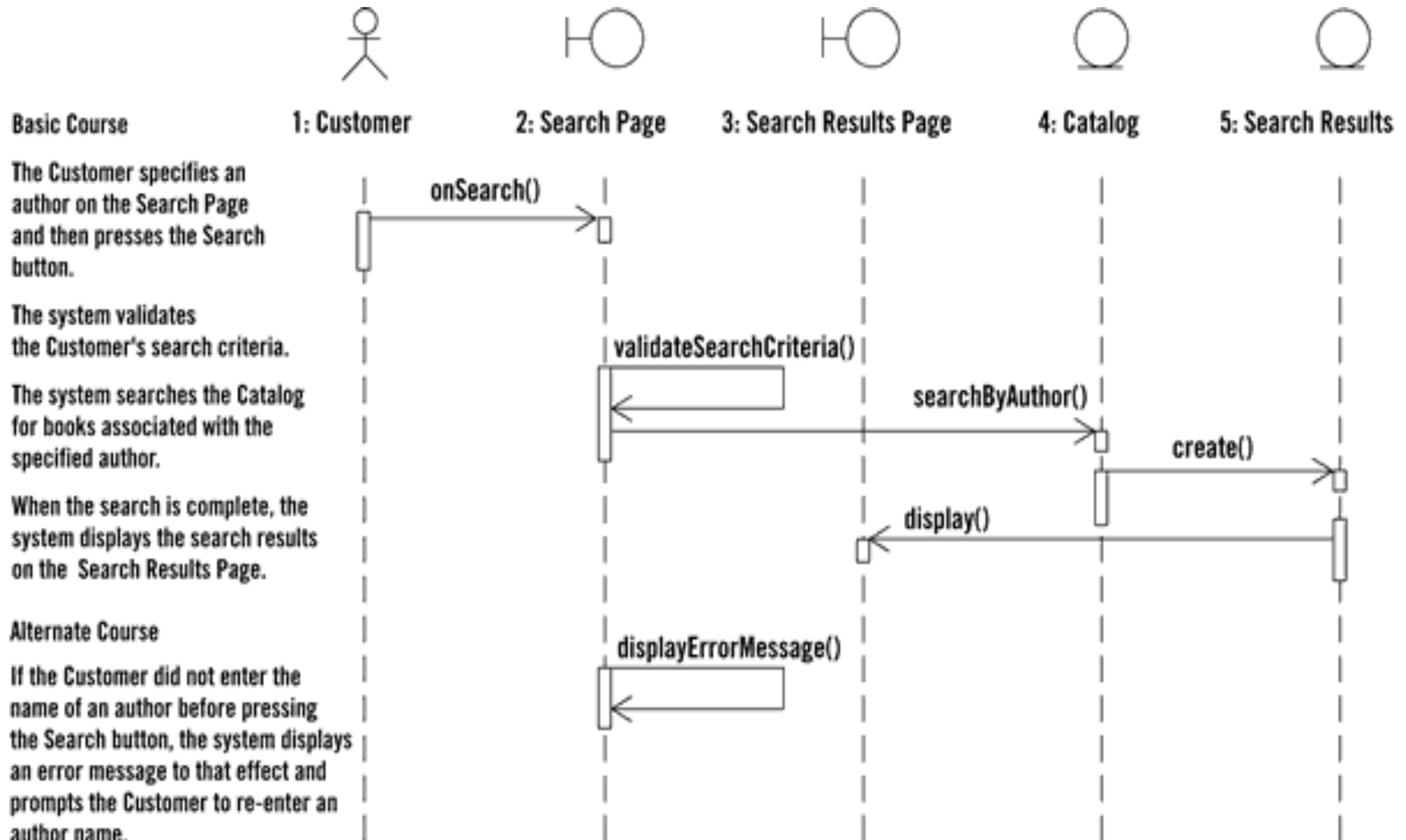
Sequence diagram: main entities

- **participant**: an object that acts in the sequence diagram
- **message**: communication between participant objects
- the **axes** in a sequence diagram:
  - horizontal: which object/participant is acting
  - vertical: time (down -> forward in time)

Sequence diagram: elements

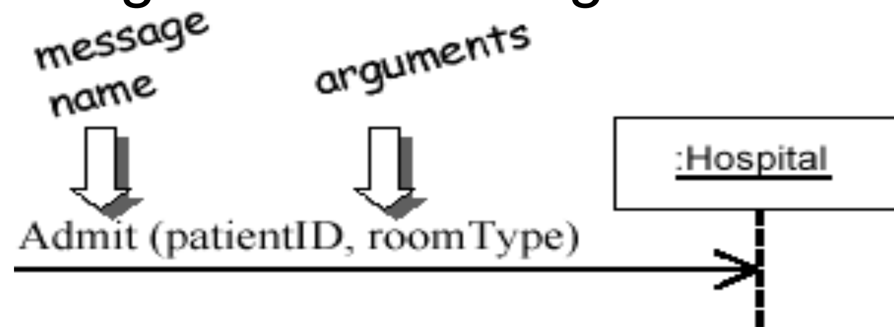


Sequence diagram

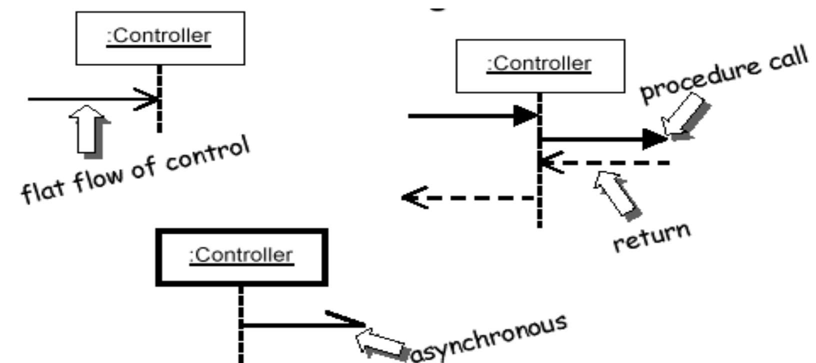


Messages between objects

- message (method call) indicated by an horizontal arrow to another object
  - write the message name and arguments above arrow

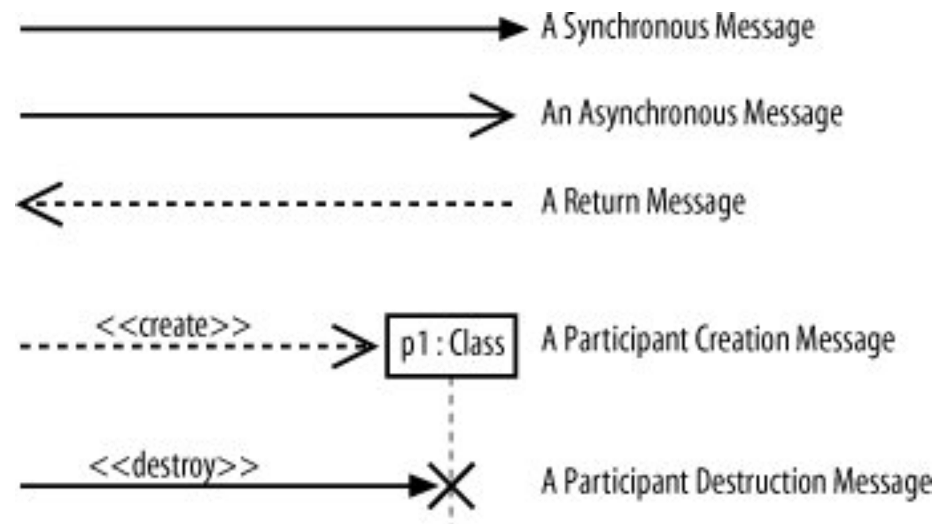


  - dashed arrow back indicates return
  - different arrowheads for synchronous / asynchronous methods

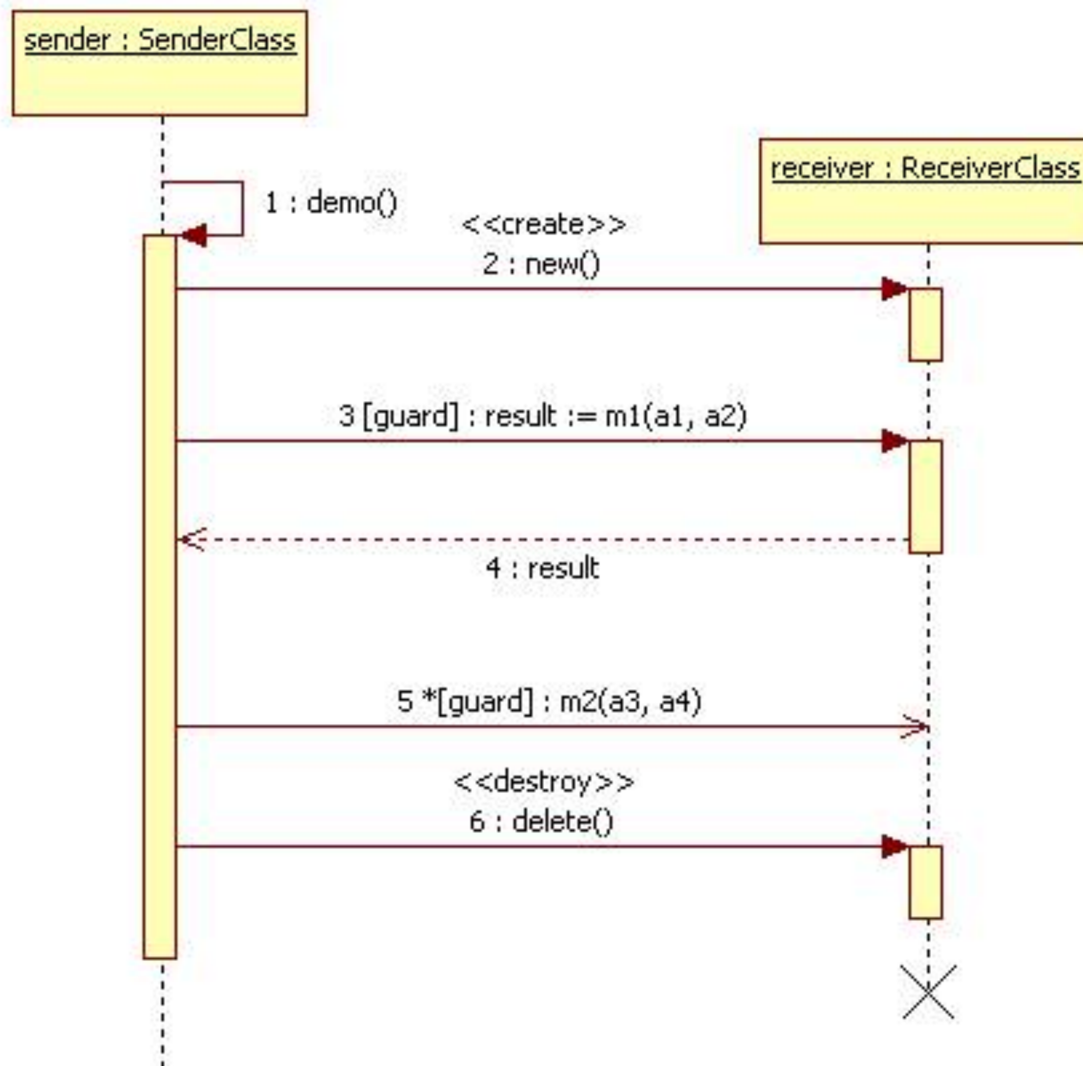


Arrows in a sequence diagram

- A sequence diagram describes sequences of method calls among objects
- There are several types of method calls

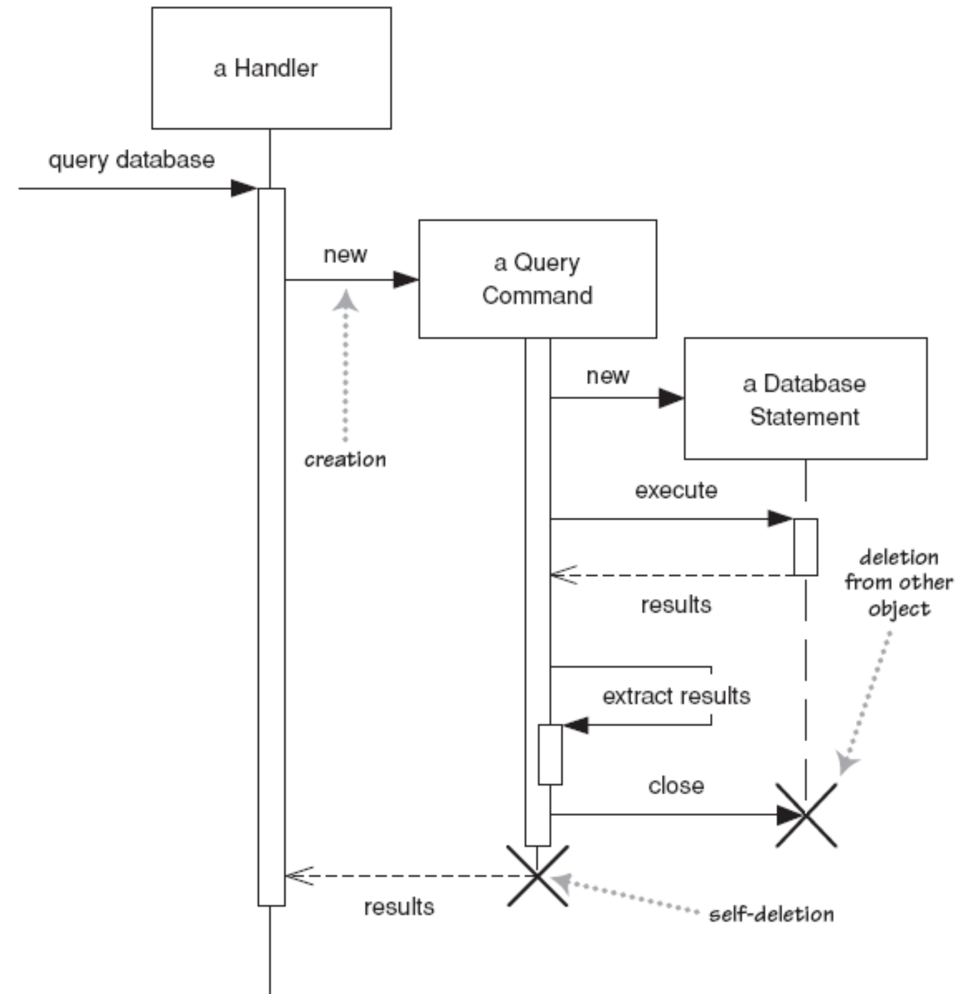


Example with different msgs



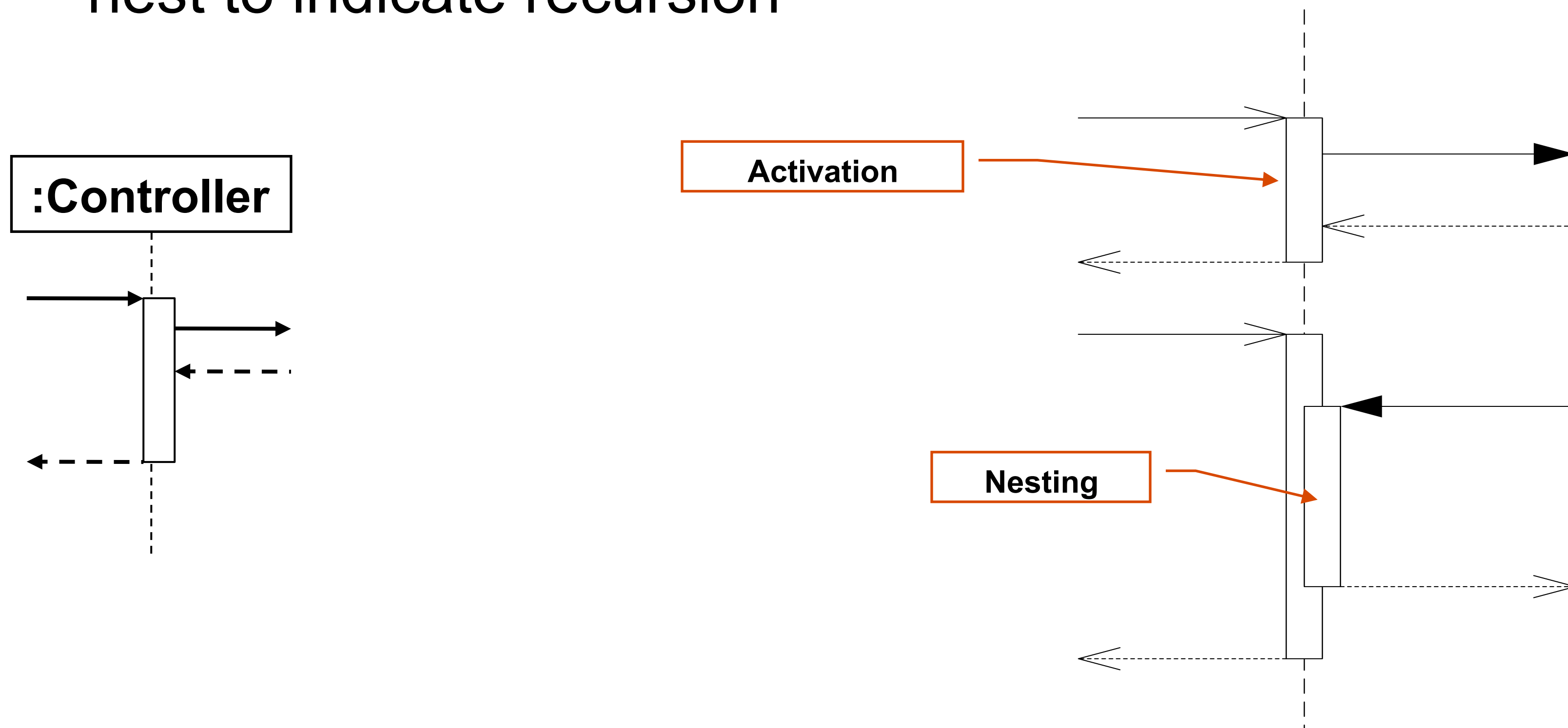
Lifetime of objects

- creation: arrow with 'new' label
  - an object created after the start of the scenario appears lower than the others
- deletion: an X at bottom of object's lifeline
  - Java does not explicitly delete objects; they fall out of scope and are garbage-collected

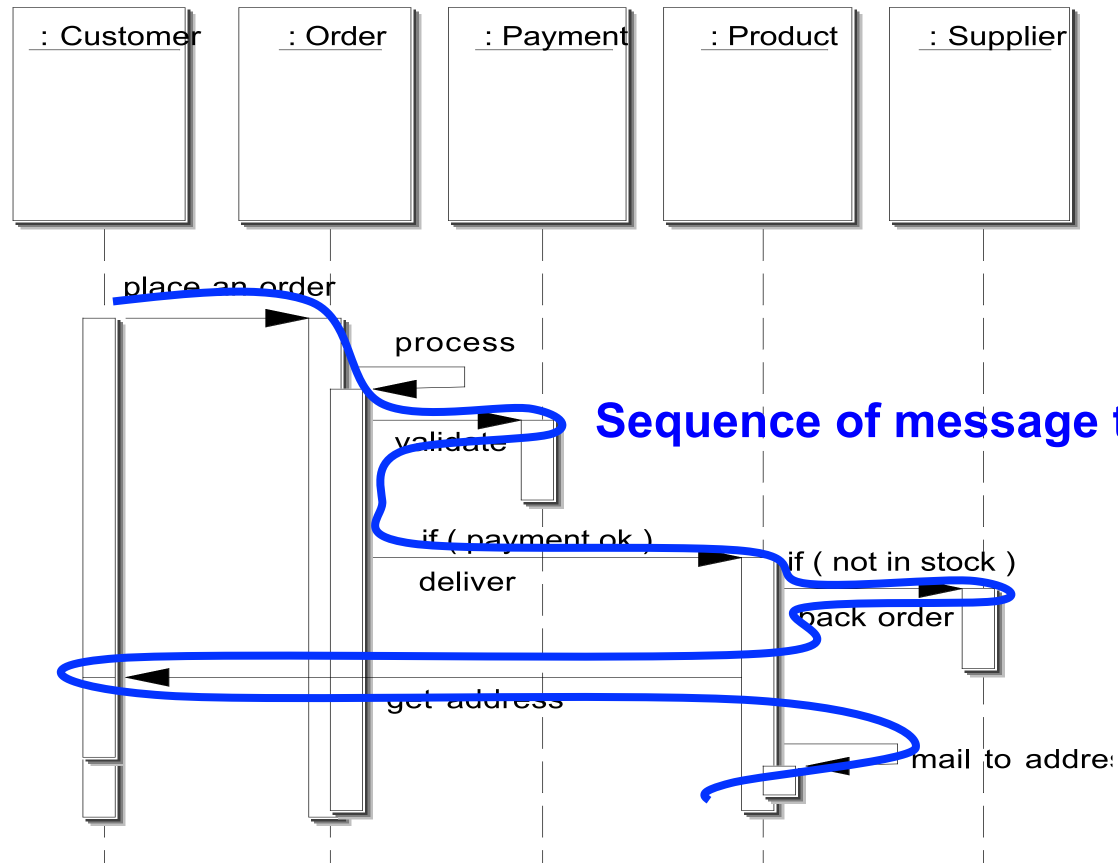


Indicating method calls

- **activation**: thick box over object's life line
  - The object is running its code, or it is waiting for another object's method to finish
  - nest to indicate recursion



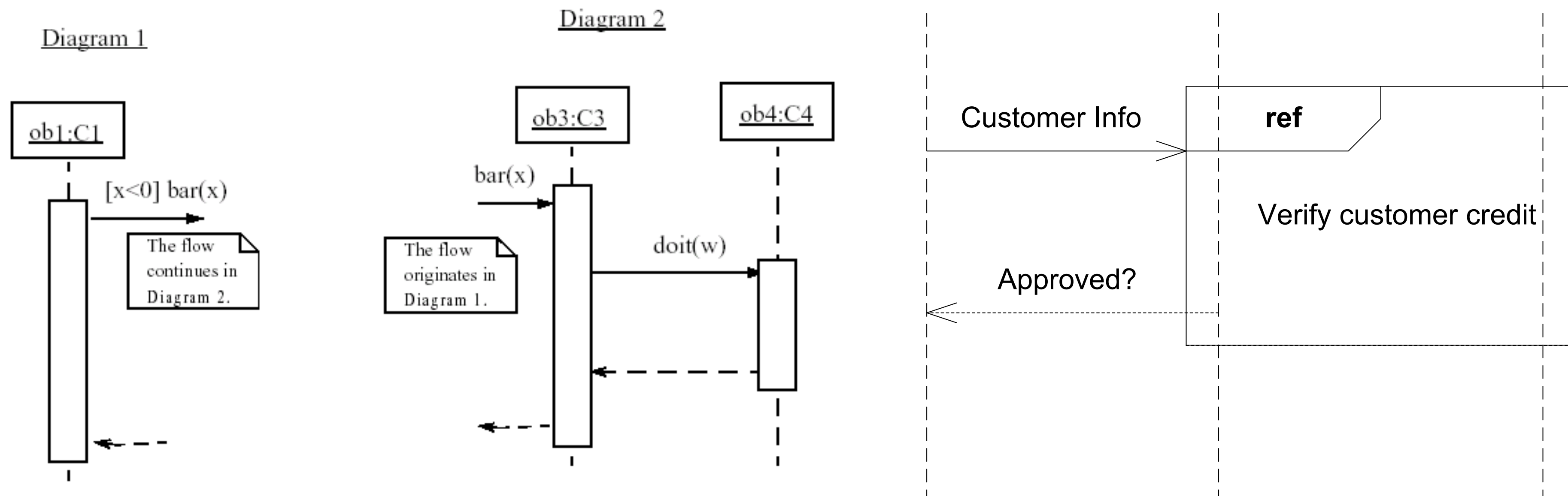
Sequence diagram: flow



Sequence of message transmissions

Linking sequence diagrams

- if a sequence diagram is too large or refers to another diagram, indicate it with either:
  - an unfinished arrow and a comment
  - a "`ref`" frame that names the other diagram

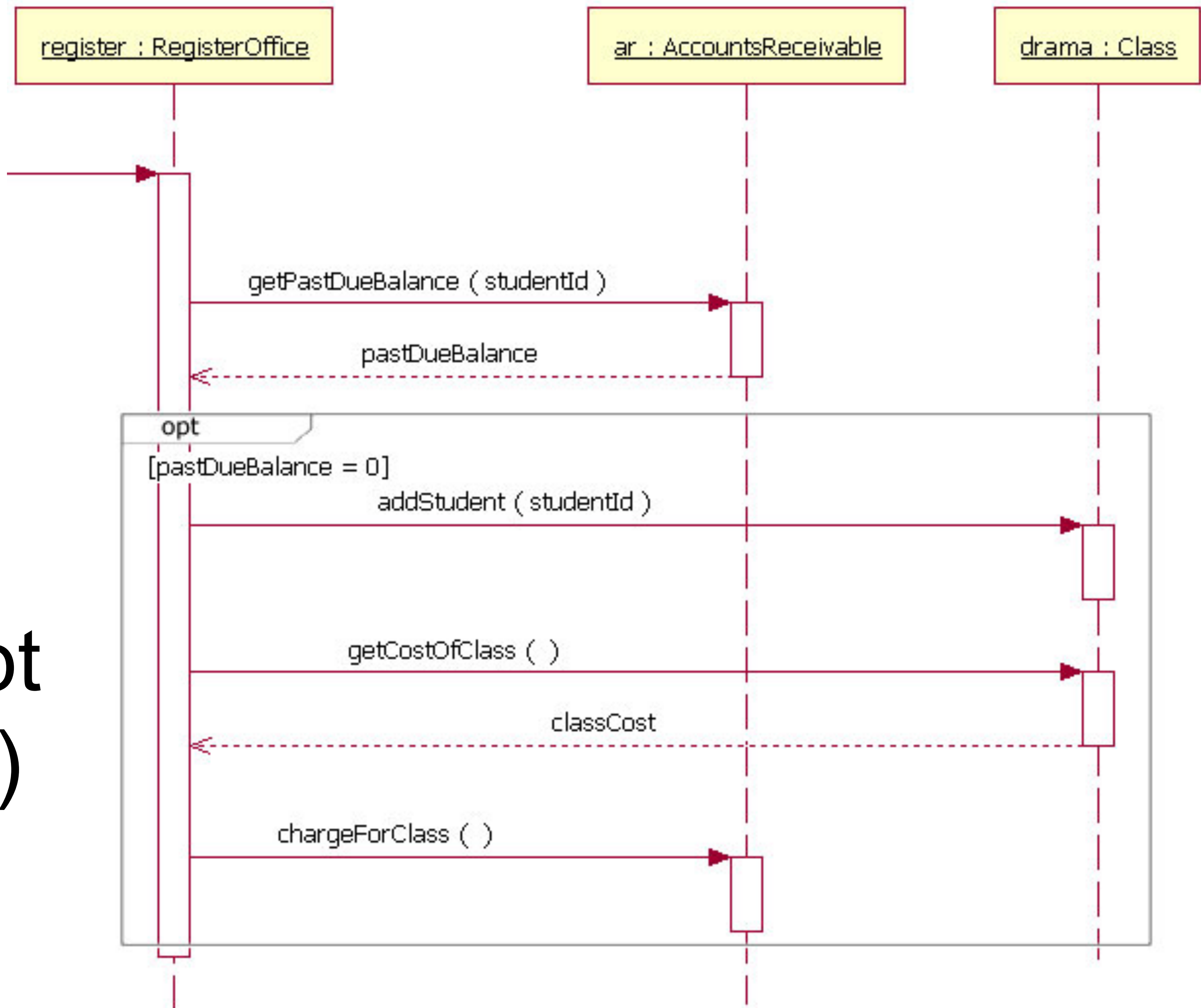


Conditionals and loops

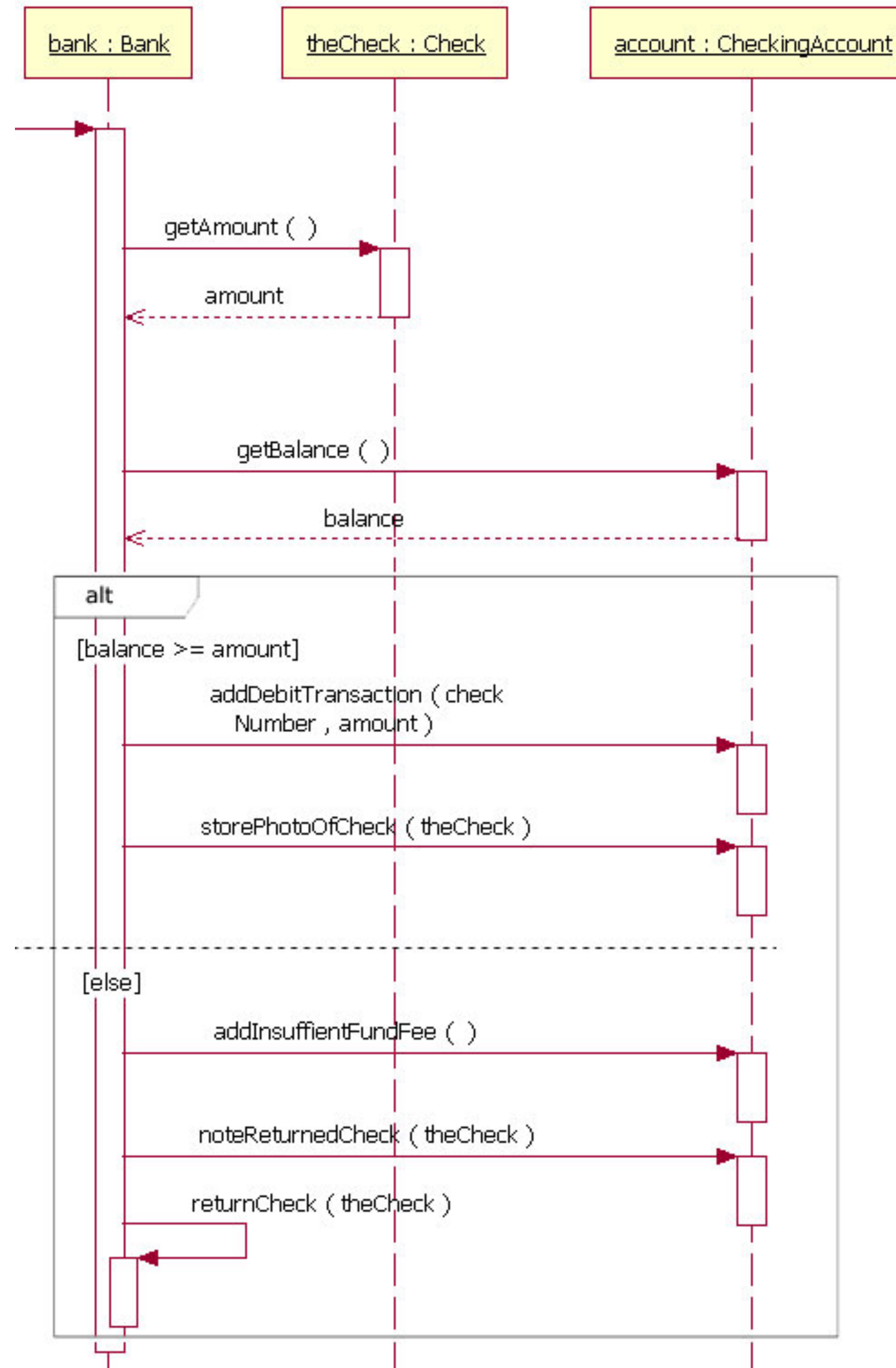
- frame: box around part of a sequence diagram to indicate selection or loop
  - if : `(opt)    [condition]`
  - if-else: `(alt)[condition] else [condition]`
  - loop: `(loop)[condition to loop over]`

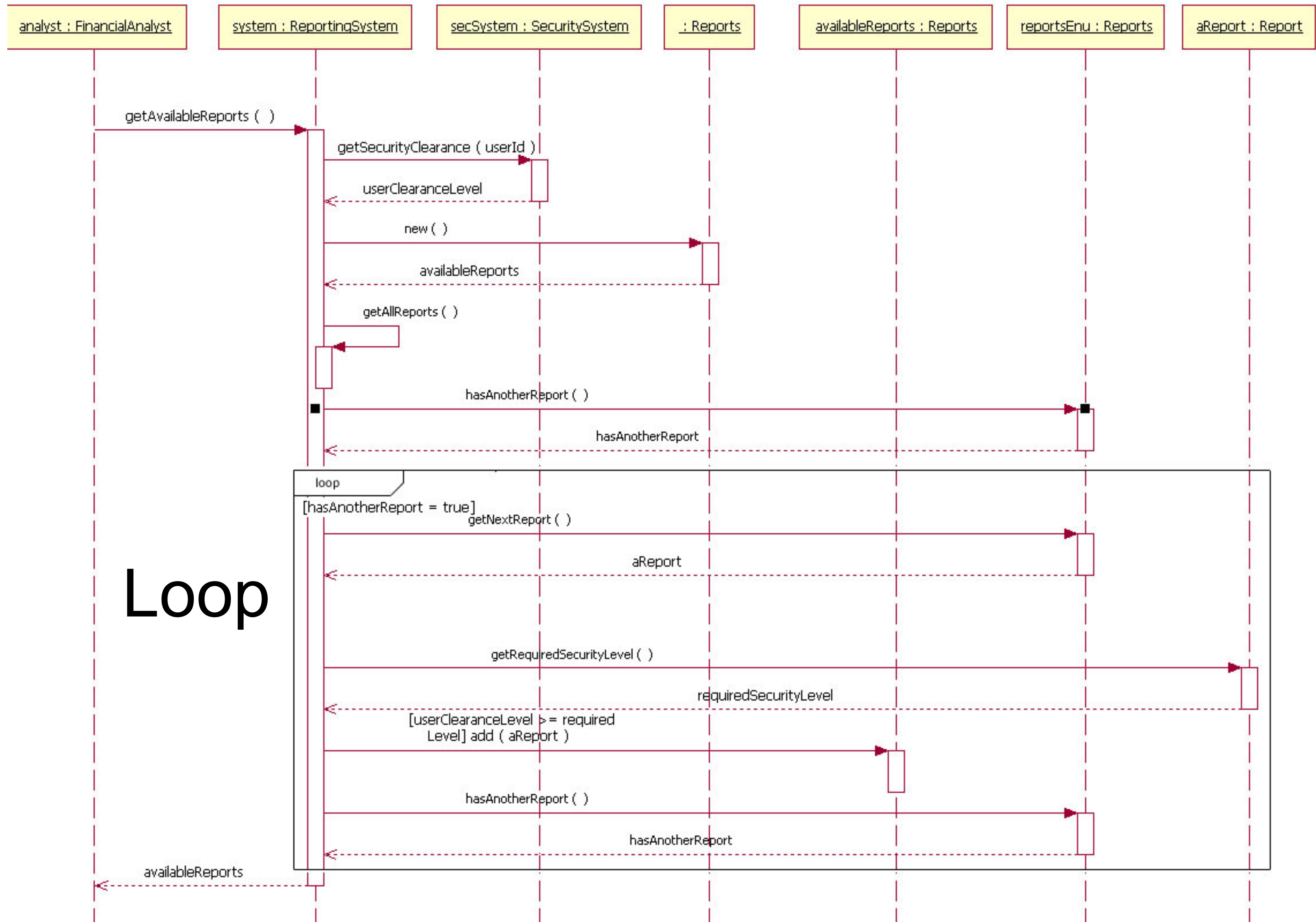
Examples: see the next three slides

Opt
(if)



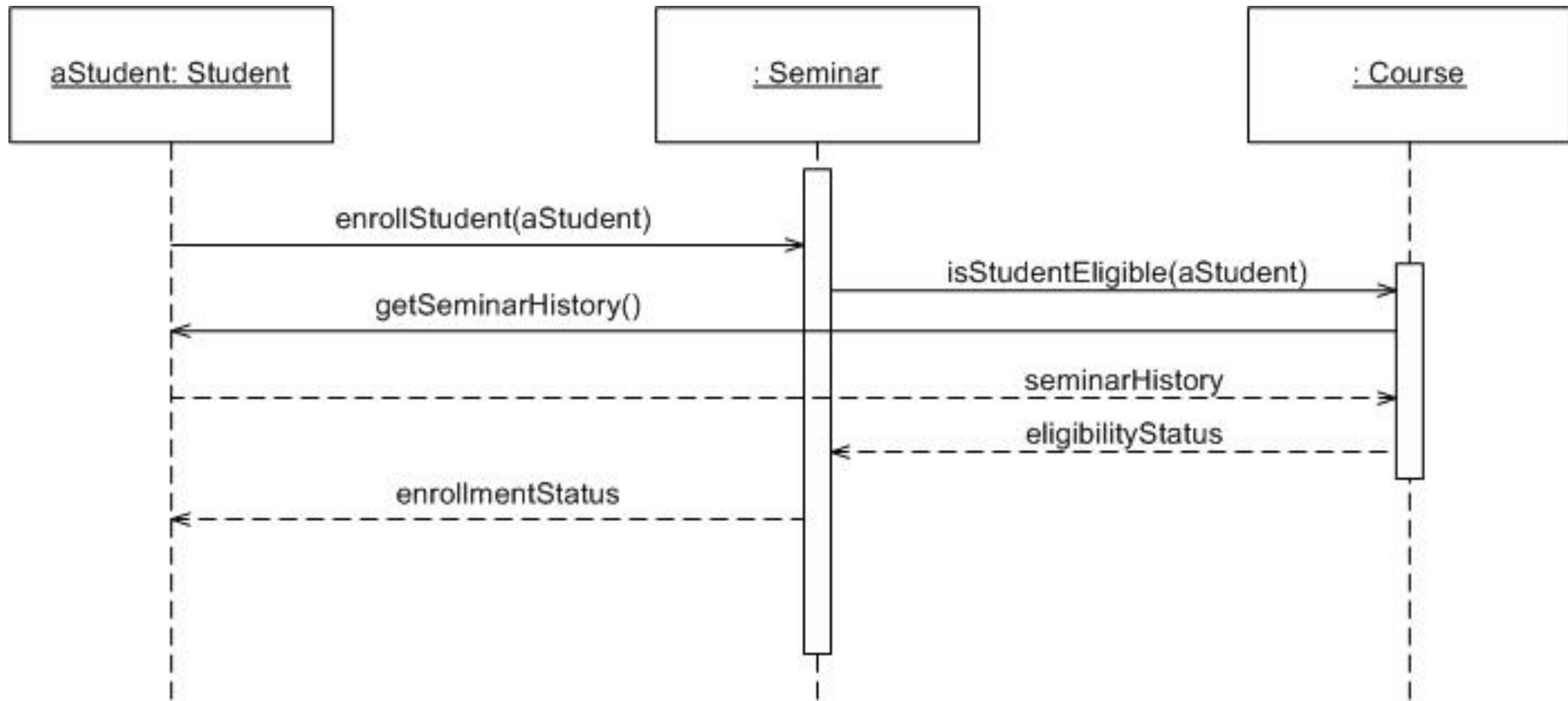
Alt (if-else)




analyst : FinancialAnalyst
system : ReportingSystem
secSystem : SecuritySystem
: Reports
availableReports : Reports
reportsEnu : Reports
aReport : Report
getAvailableReports ( )
getSecurityClearance (userId)
userClearanceLevel
new ( )
availableReports
getAllReports ( )
hasAnotherReport ( )
hasAnotherReport
loop
[hasAnotherReport = true]
getNextReport ( )
aReport
Loop
getRequiredSecurityLevel ( )
requiredSecurityLevel
[userClearanceLevel >= required Level] add (aReport)
hasAnotherReport ( )
hasAnotherReport
availableReports

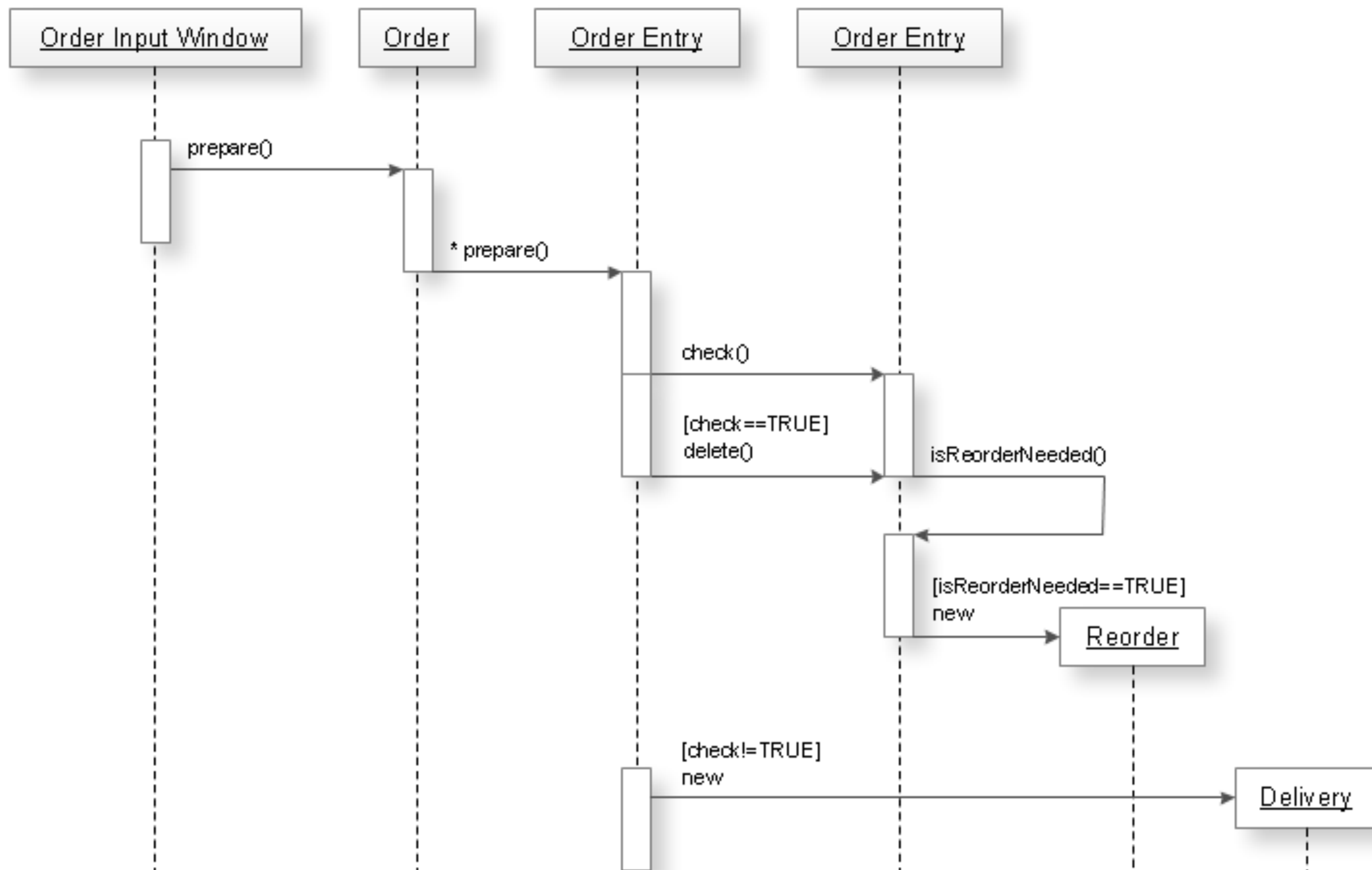
Example

A SD highlights the objects involved in an activity

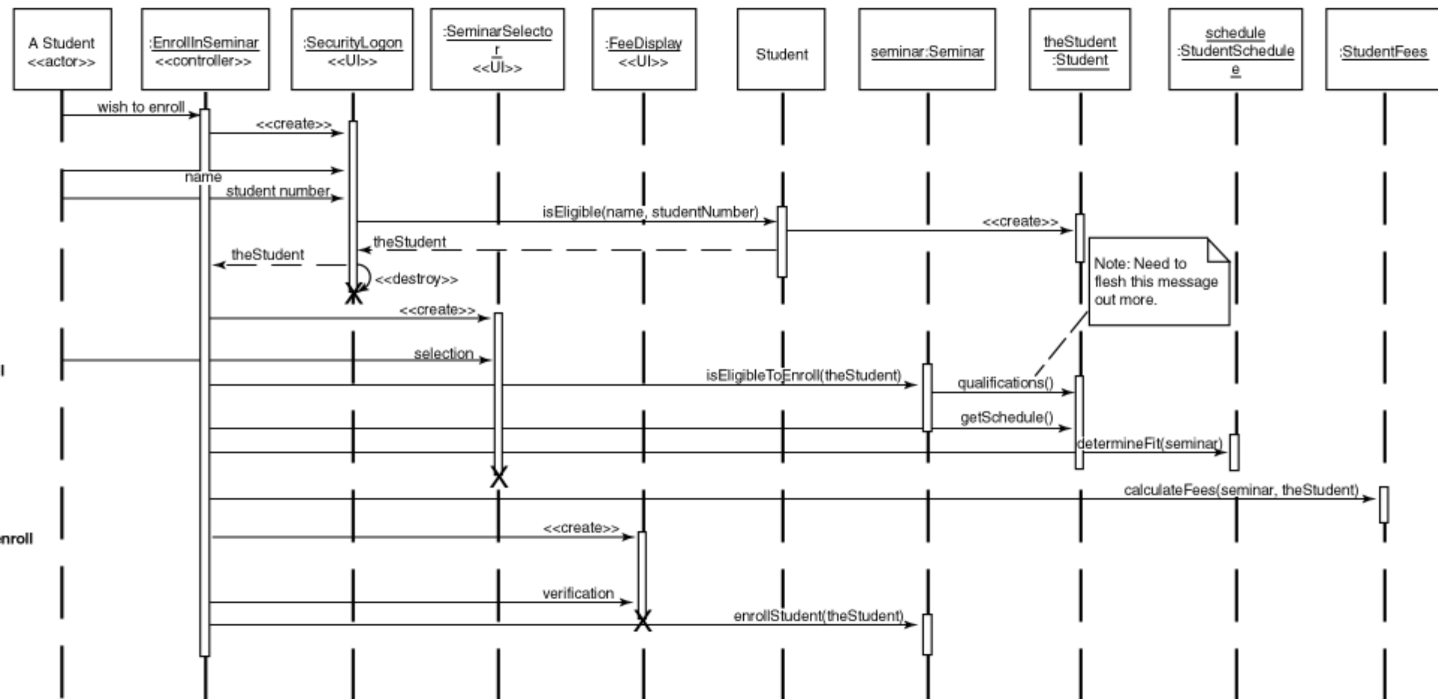


http://www.agilemodeling.com/artifacts/sequenceDiagram.htm

Example



Example



Using a SD for workflow

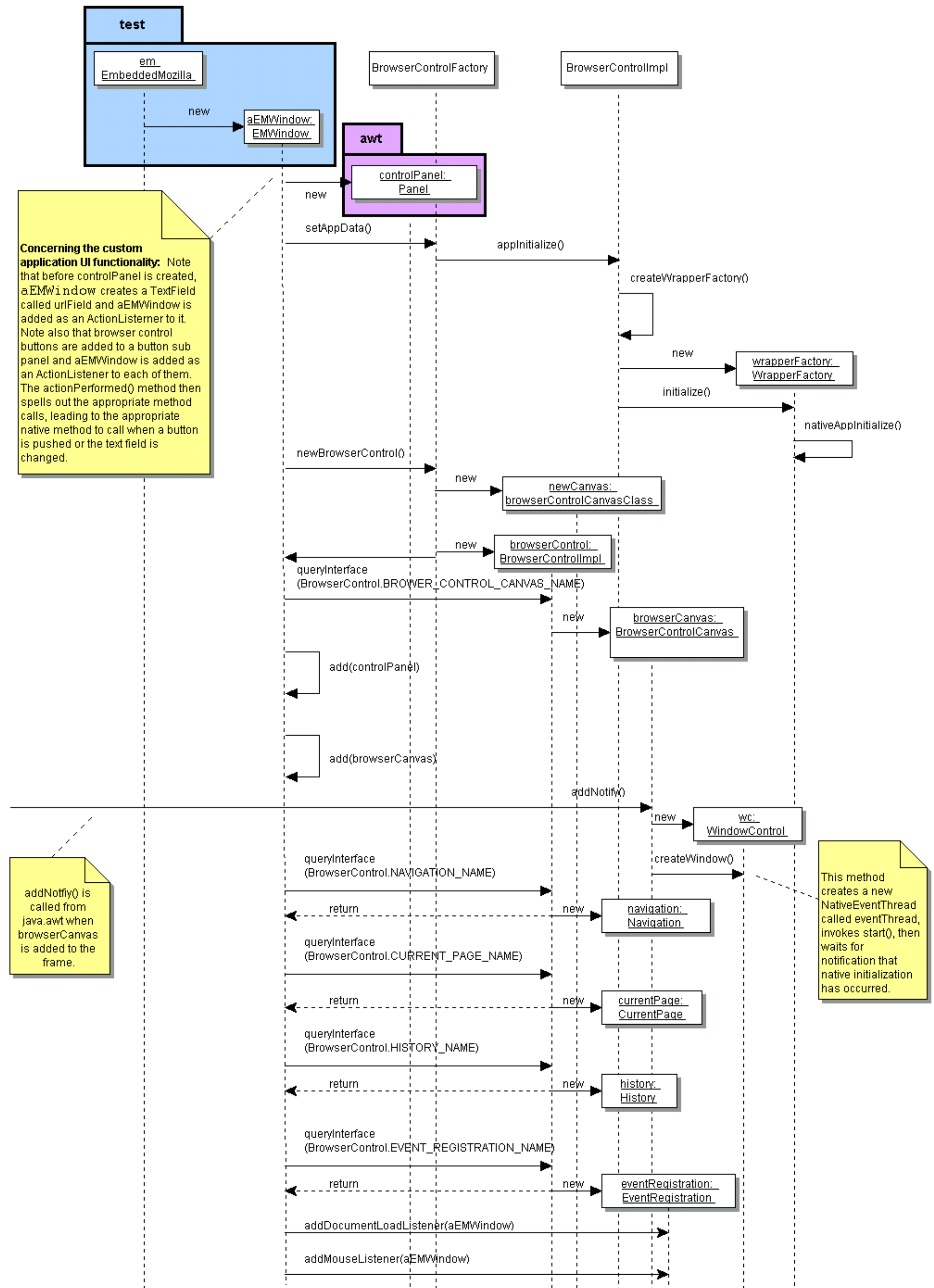
customer
vendor

user
sponsor
business analyst
software architect
project manager
development manager
team leaders
developers
technical specialists
test designer
testers

want
kick off meeting
requirements
analysis
design
communicate and review the proposed solution
development
acceptance

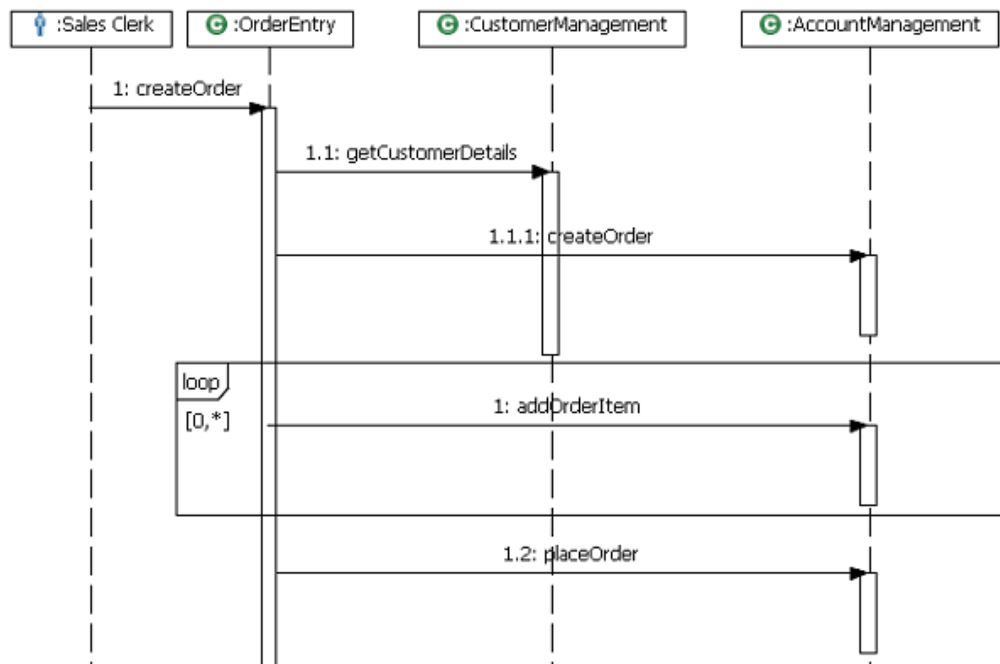
need
need
feasibility study
promise
order
gather requirements
analyse req.
design system
define timeline and milestones
design tests
create team
develop
release
test
manage timeline
review tests
develop
lead and review
test
release
release
release

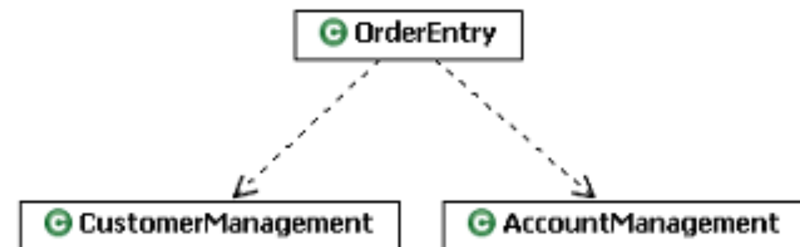
A real example (from Mozilla.org)

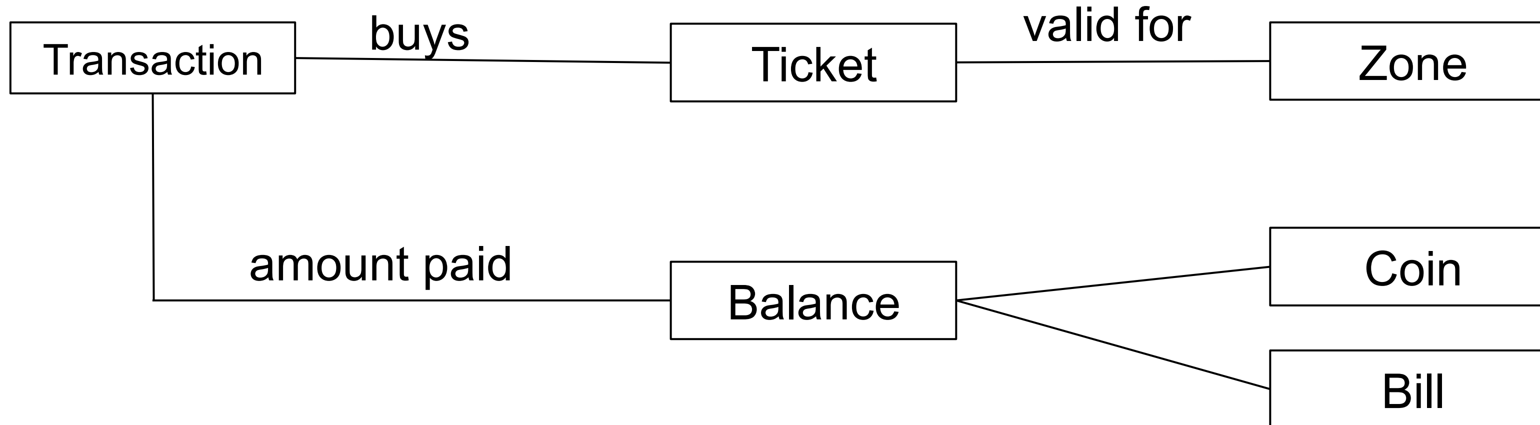


Consistency among diagrams

We can derive the dependencies shown in a class diagram from the interactions defined in a sequence diagram







:Traveler
:TicketDistributor
:Zone
:Balance

selectZone()
getPrice()
amountDue
insertChange()
updateBalance()
amountDue
insertChange()
updateBalance()
ack
<<create>>
:Ticket
printedTicket

Exercise

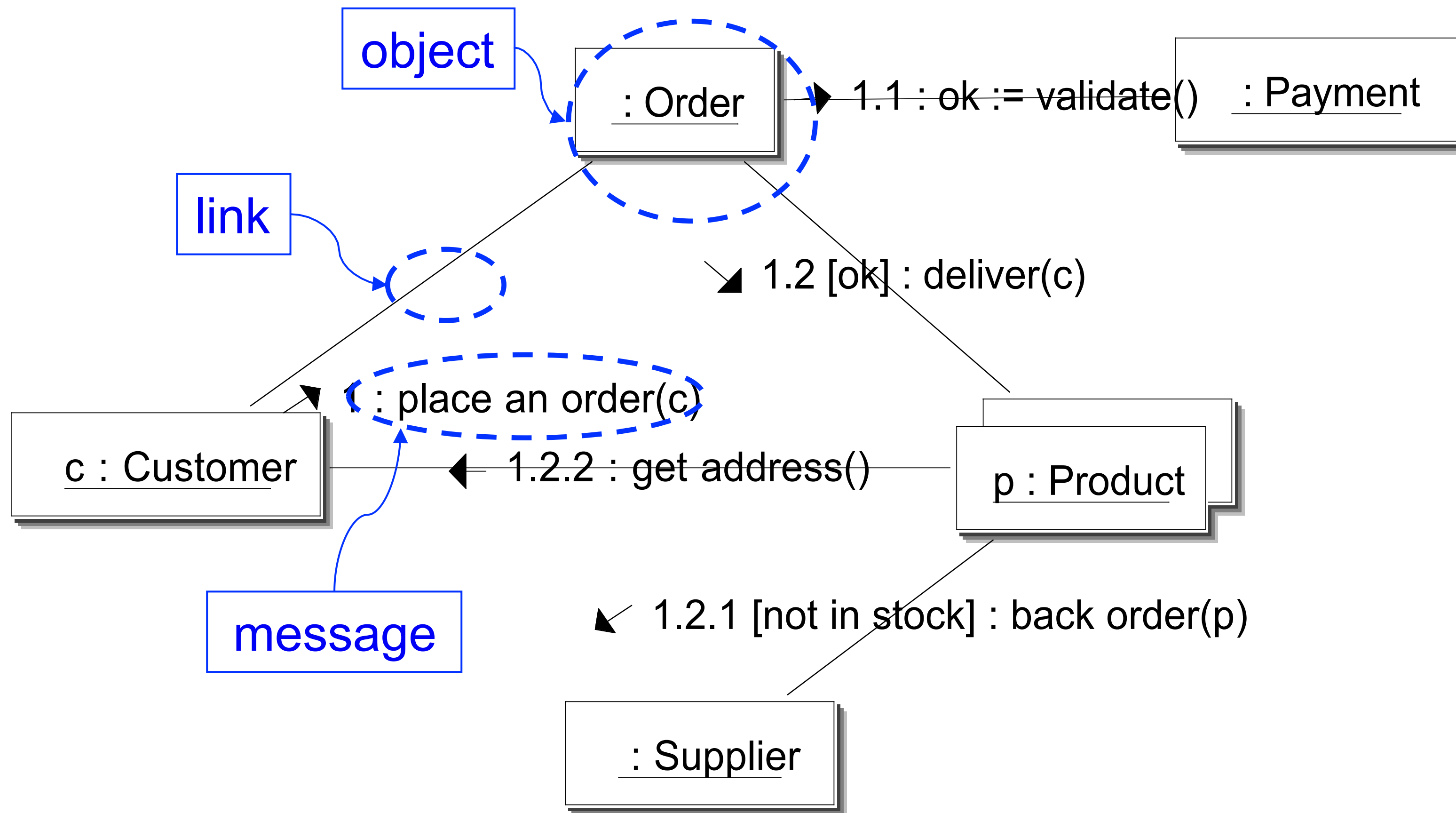
Draw a sequence diagram showing how a customer interacts with a travel agency, a station and a train to reach some destination

Draw a sequence diagram to show how a user prints a document on a printer, and a counter keeps a count of printed pages

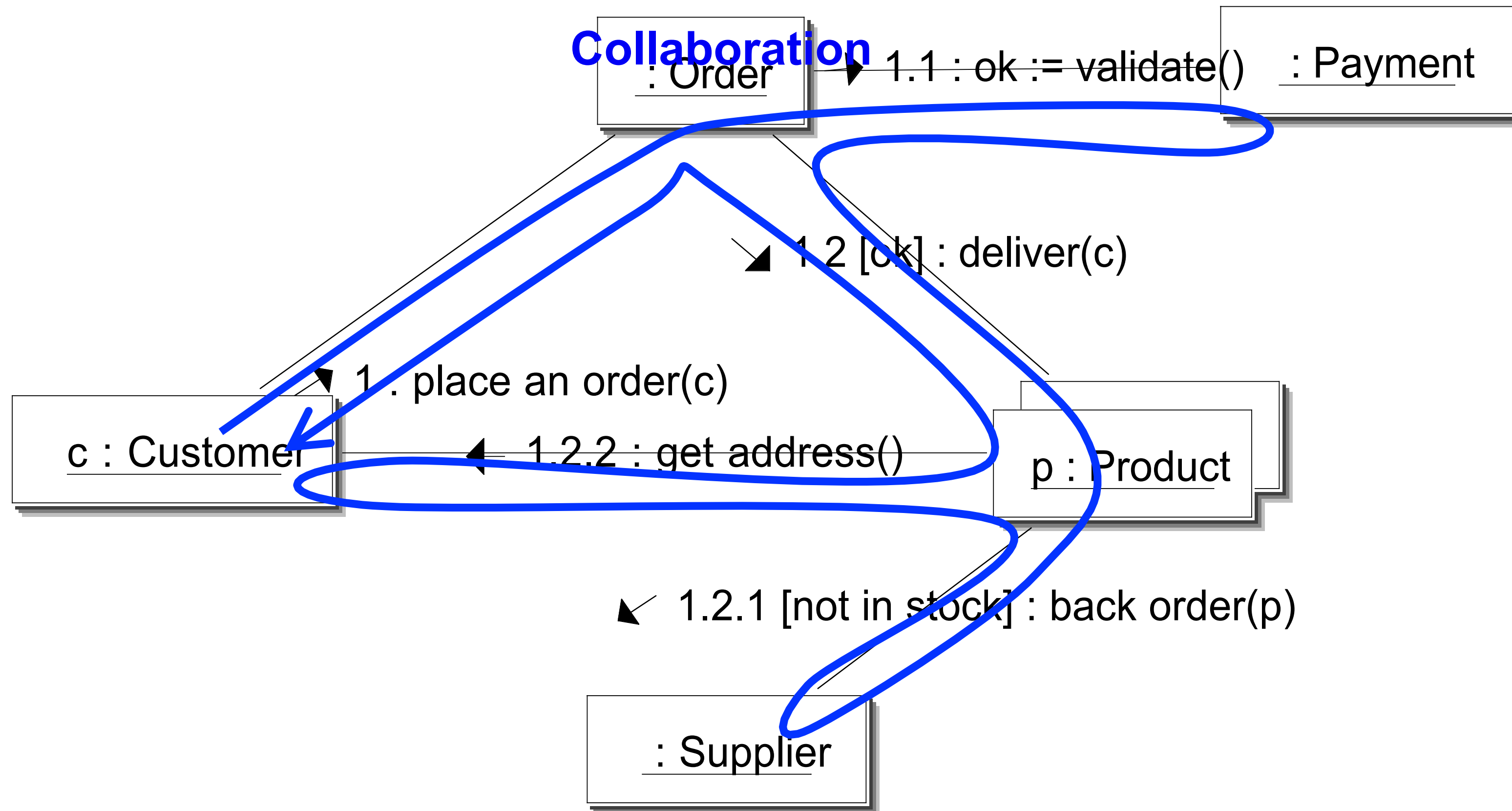
Communication (collaboration) diagram

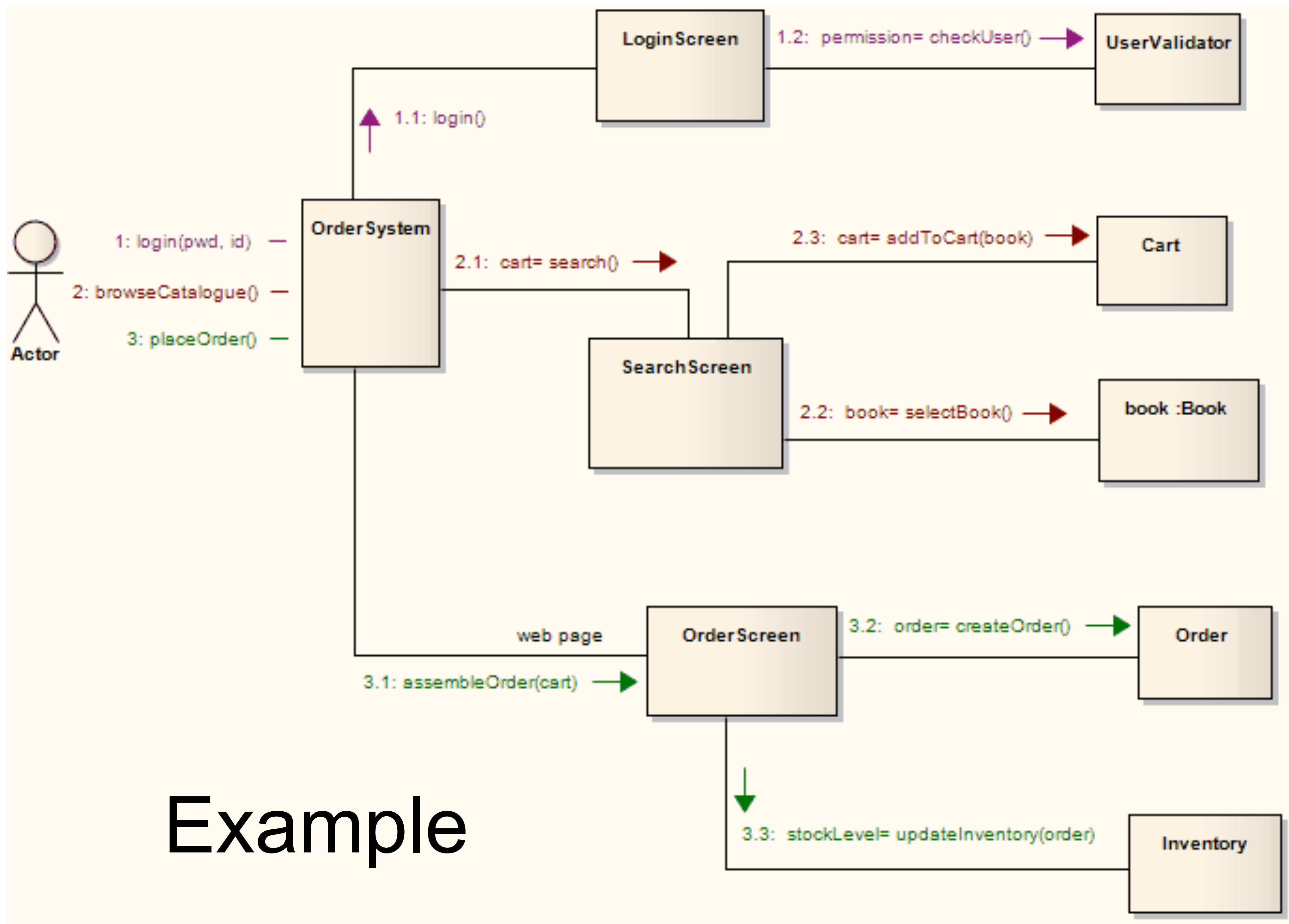
- Communication diagrams show the message flow between objects in an application
- They also show implicitly the basic associations between classes
- Communication diagrams are drawn in the same way as sequence diagrams (and can be semantically equivalent to them)

Communication diagram



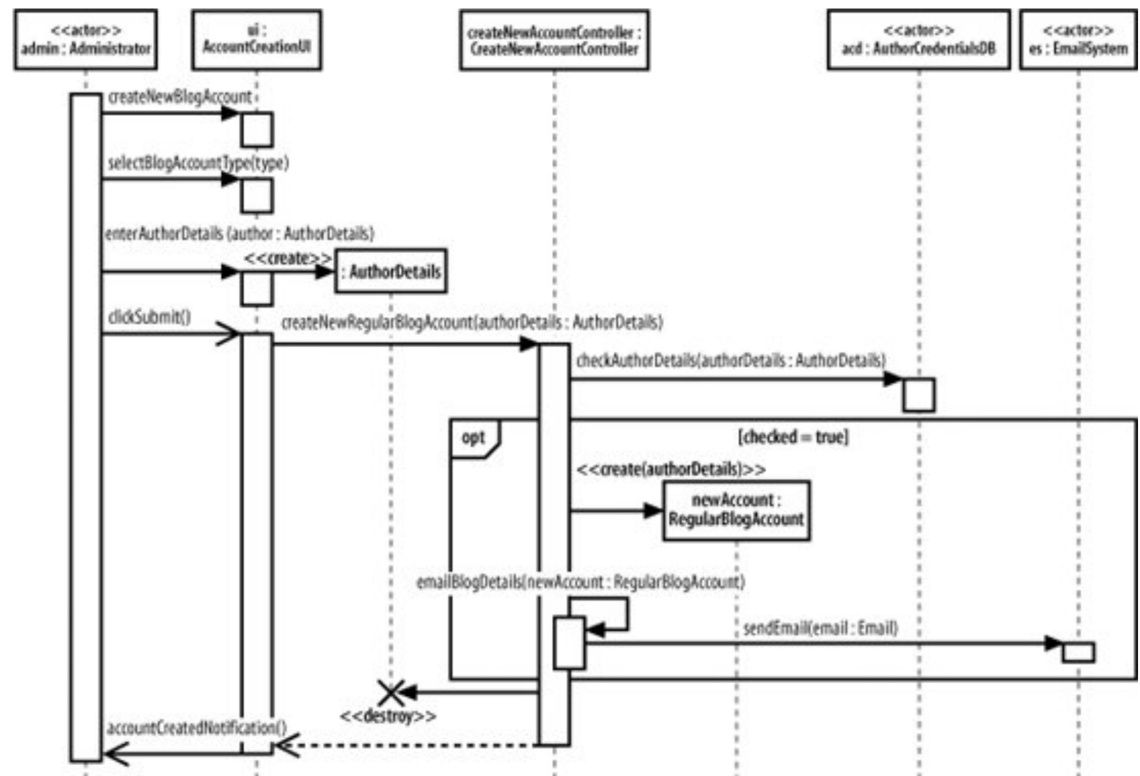
Communication diagram



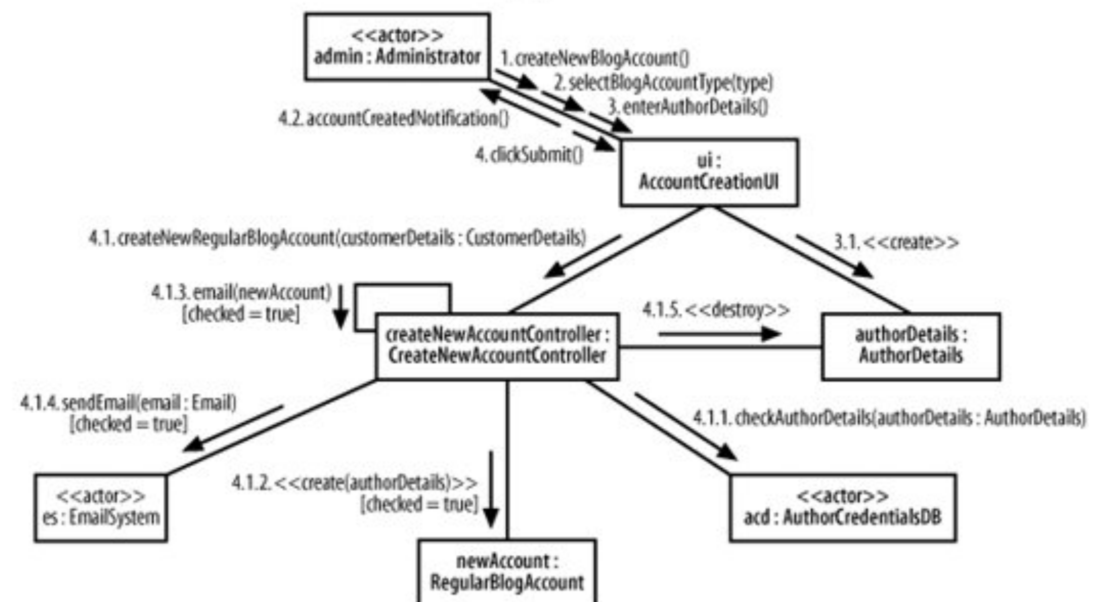

LoginScreen
1.2: permission= checkUser()
UserValidator
1.1: login()
Actor
1: login(pwd, id)
2: browseCatalogue()
3: placeOrder()
OrderSystem
2.1: cart= search()
2.3: cart= addToCart(book)
Cart
SearchScreen
2.2: book= selectBook()
book :Book
web page
OrderScreen
3.1: assembleOrder(cart)
3.2: order= createOrder()
Order
3.3: stockLevel= updateInventory(order)
Inventory
Example

SD vs CD

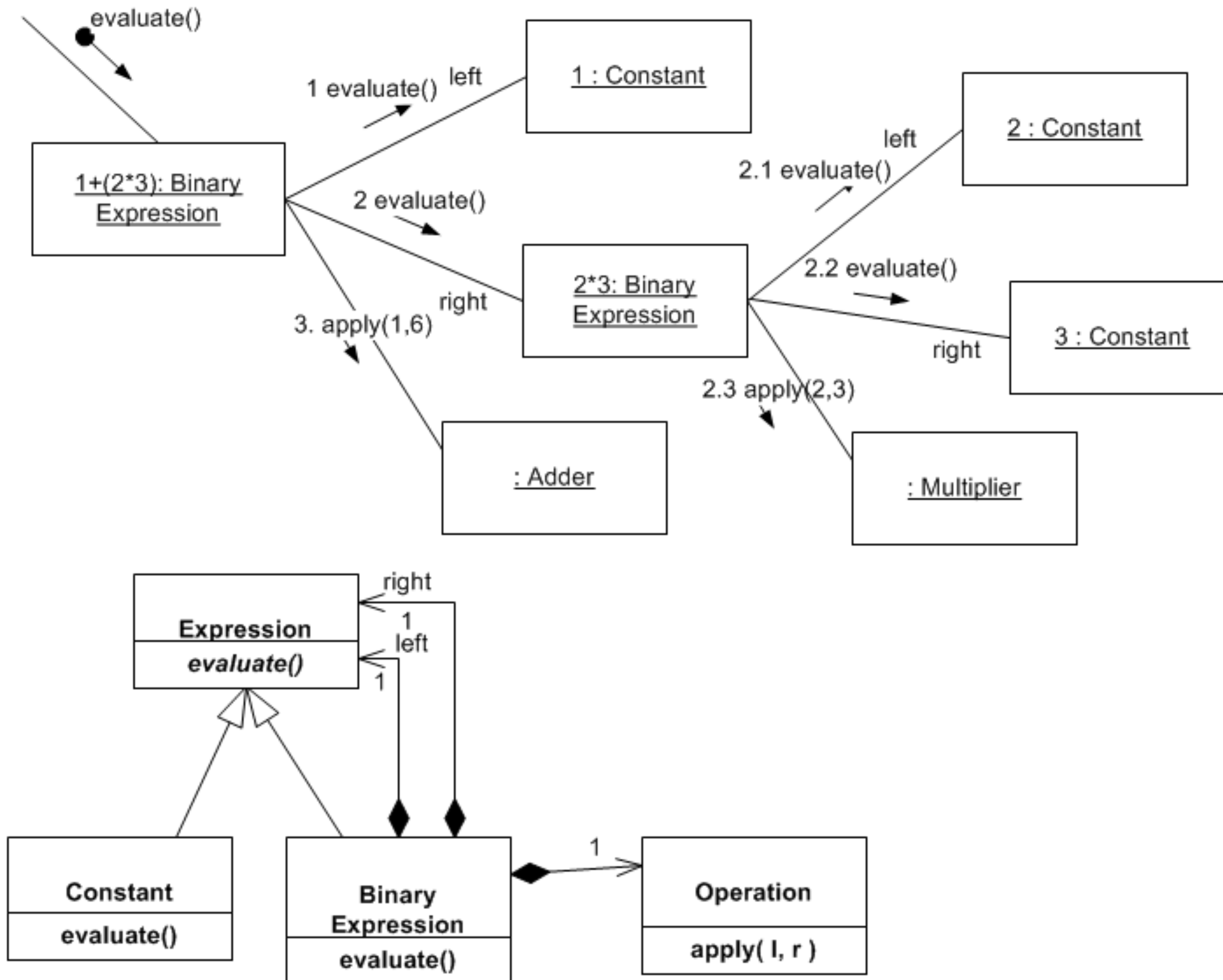
- These two diagrams are equivalent
- Communication diagrams correspond to **simple** Sequence diagrams that use none of the structuring mechanisms such as *interaction uses* or *combined fragments*
- Some complex sequence diagrams can not be represented by equivalent communication diagrams



Vs.



Consistency among diagrams

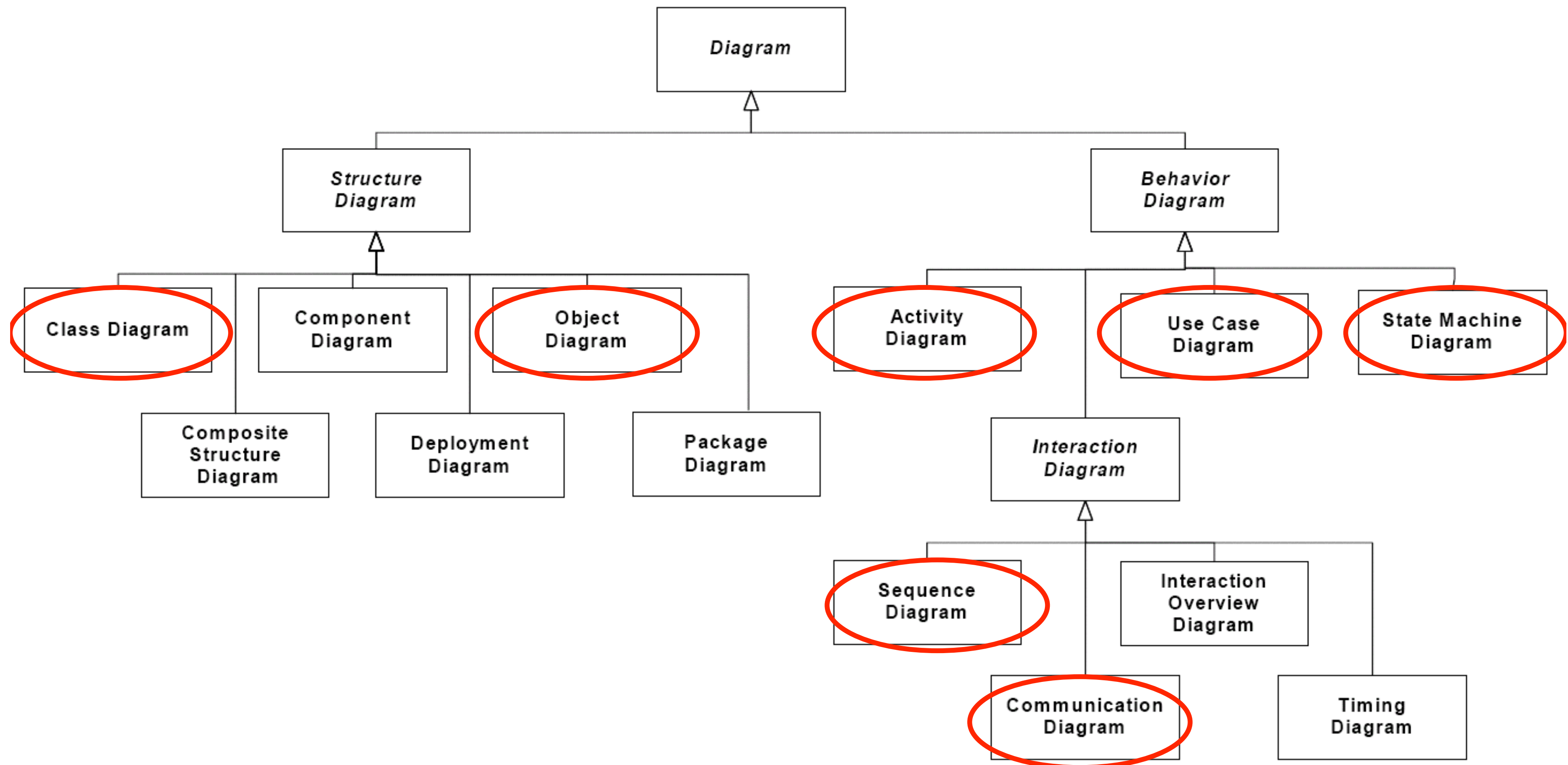


Exercise

Draw a communication diagram showing how a customer interacts with a travel agency, a station and a train to reach some destination

Draw a communication diagram to show how a user prints a document on a printer, and a counter keeps a count of printed pages

Basic diagrams we have seen



Other diagrams

Diagrams we have seen in this lecture:

- Use case, class, object, statechart, activity, interaction (sequence and collaboration)

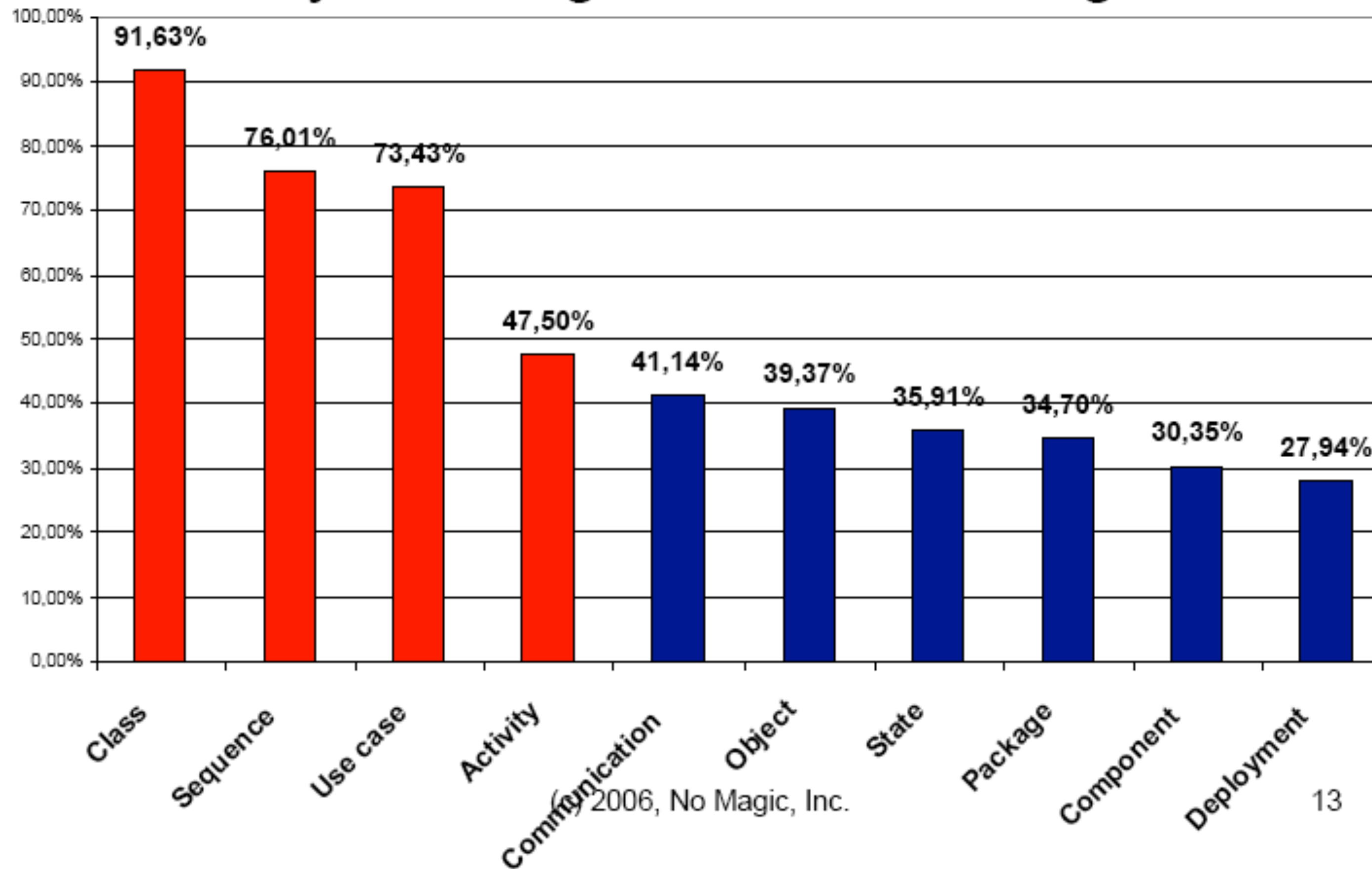
We could add (using UML 1.*):

- Component, Deployment

We could add (using UML 2.*):

- Composite structure, Profiles, Package, Interaction Overview, Timing

Usage survey



See also: www.projectpragmatics.com/Home/resources-for-you-1/the-uml-survey-results-are-in

Main diagrams

The main diagrams that are used in most views are :

- **Use case** diagram
- **Class** diagram
- **Sequence** diagram
- **Activity** diagram

Discuss

- Which diagrams are most useful in each lifecycle phase?

Diagrams in lifecycle

... Requirements ... Design ... Implementation

Use Case

Class diagram

Sequence diagram

Activity diagrams and Statecharts

Diagrams during design

Three main types:

- Class diagrams for domain entities and data structures
- Sequence diagrams for multiple objects interactions via messages
- Statecharts for behaviors and algorithms of a single object

Exercise

Draw, on some game-playing domain (eg. Chess):

- A class diagram
- An object diagram
- A statechart
- A sequence diagram
- A communication diagram
- An activity diagram

Conclusions

- UML is a notation still evolving under control of OMG
- It offers several diagram types, in order to describe different views on a model
- Basic diagrams from UML 1.* are: use cases, classes, behaviors (statechart+activity), interactions (sequence +communication)
- Several tools available
- UML and the diagrams need a *process* to be used consistently and effectively (for instance, RUP)

Summary

- UML includes a number of diagram-based notations to **model** software systems using an object oriented approach
- UML is **not** a process (it needs a process, like for instance the RUP)
- It is **not** proprietary: it is an OMG (Object Management Group) and ISO standard

Caveat emptor

When Jim, Ivar, and I began our journey that became manifest in the UML, we never intended it to become a programming language…UML was to be a language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system—in short, a graphical language to help reason about the design of a system as it unfolds.

Most diagrams should be thrown away, but there are a few that should be preserved, and in all, one should only use a graphical notation for those things that cannot easily be reasoned about in code.

As I've also often said, the code is the truth, but it is not the whole truth, and there are things such as rationale, cross-cutting concerns, and patterns that cannot easily be recovered or seen from code…

These are the things for which a graphical notation adds value, and any such notation should be used only if it has predictive power or reasoning power (meaning, you can ask questions about it).

Grady Booch

Self test questions

- Which are the UML 1.* canonical diagrams?
- What is a use case?
- What is a class diagram? What is an object diagram?
- How do we describe a tree-like data structure in a class diagram?
- What is an interaction diagram?
- What is a protocol state machine?
- What is the difference between statecharts and activity diagrams?

Readings

- On use cases

www.ibm.com/developerworks/rational/library/5383.html

- On class diagrams

www.ibm.com/developerworks/rational/library/content/RationalEdge/sep04/bell/index.html

- On activity diagrams

www.ibm.com/developerworks/rational/library/2802.html

- On sequence diagrams

www.ibm.com/developerworks/rational/library/3101.html

UML Specification Documents

- OMG, *UML Specification* version 1.5, 2003
- OMG, *UML Superstructure* version 2.4.1, 2011
- Rumbaugh, Jacobson, Booch, *The UML Reference Manual*, Addison Wesley, 1999 and 2004 (2nd ed)

References on using UML

- Booch, Rumbaugh, Jacobson, *The UML User Guide*, Addison Wesley, 1998 and 2005 (2ed)
- Fowler, *UML Distilled*, 3ed, Addison Wesley, 2003
- Pilone and Pitman, *UML 2.0 in a Nutshell*, OReilly, 2005
- Ambler, *The Elements of UML 2.0 Style*, Cambridge University Press, 2005

Useful sites

- www.uml.org **Documents defining the standard**
- www.omg.org
- www.uml-diagrams.org/
- www.agilemodeling.com/essays/umlDiagrams.htm
- www.tutorialspoint.com/uml/index.htm
- www-306.ibm.com/software/awdtools/rmc/library
- msdn.microsoft.com/en-us/library/dd409436.aspx
- www.cs.gordon.edu/courses/cs211/ATMExample
- opensource.objectsbydesign.com
- vinci.org/uml/
- www.cragsystems.co.uk/ITMUML/index.htm **Online courseware**
- www.eclipse.org/modeling/mdt/uml2/docs/articles/Getting_Started_with_UML2/article.html

Tools

- Eclipse + several plugins, like Omondo
- argouml.tigris.org Argo or Poseidon
- www.genmymodel.com free online tool, sharable diagrams
- www.lucidchart.com web application, need license
- violet.sourceforge.net Open source editor for UML
- www.borland.com/us/products/together/index.html Borland Together
- www.visual-paradigm.com Visual Paradigm suite
- www.nomagic.com Magicdraw suite
- abstratt.com text UML
- www.umlgraph.org web application for class and seq diagrams
- www-01.ibm.com/software/rational/ Rational Rose
- jazz.net IBM platform
- smartuml.sourceforge.net UML on tablet PC
- metauml.sourceforge.net Beautiful UML diagrams in LaTeX
- softwarestencils.com/uml Images reusable in a graphic editor
- yuml.me Fast draw of UML diagrams for web pages

UML blogs and fan clubs

- www.linkedin.com/groups/UML-Lovers-143183/about
- bulldozer00.com/uml-and-sysml/
- geertbellekens.wordpress.com/about-geert-bellekens/

Questions?