Unit 2
Design

Software Analysis and Design Project

Universidad Autónoma de Madrid

Index

- **Introduction**.
  - Concepts of Object Orientation.
- **Structure modelling.**
  - Class diagrams.
- **Behaviour modelling.**
  - State transition diagrams.
  - Sequence diagrams.
- **Requirements Traceability**

Object Orientation

- Operations are the fundamental blocks in the structured programming paradigm (C, Pascal).
  - Functions and data are separate from each other.
  - This is useful for small scale systems (≈5000 LOC)

- The object oriented paradigm focuses equally on both data and operations.
  - Objects: Single units that agglutinate state information and operations.
  - “structs (C-style)+functions”.

Object Orientation

Classes and Objects

name: George III country: United Kingdom reignStart: 1760 reignEnd: 1820

name: Louis XIV country: France reignStart: 1774 reignEnd: 1792

- All kings have common aspects.
- We can represent those aspects in a class.
- Specific kings would be instances (objects) of the class.

King
- name: String - country: String - reignStart: Date - reignEnd: Date
+ reign() + abdicate()

class

george:King
name="George III" country="United Kingdom" reignStart=1760 reignEnd=1820

louis:King
name="Louis XIV" country="France" reignStart=1774 reignEnd=1792

objects

Object Orientation

Classes and Objects

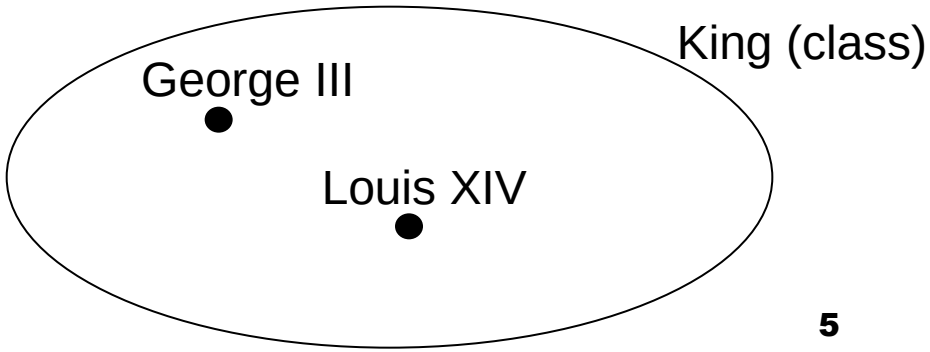
Class

- Declares ***properties*** (attributes) of all its instances.
- Declares ***operations*** (methods) that can be applied to all its instances.

Object

- Includes values for the attributes declared in the class.
- Reacts to invocations of the methods declared in the class, using the values of its attributes as state

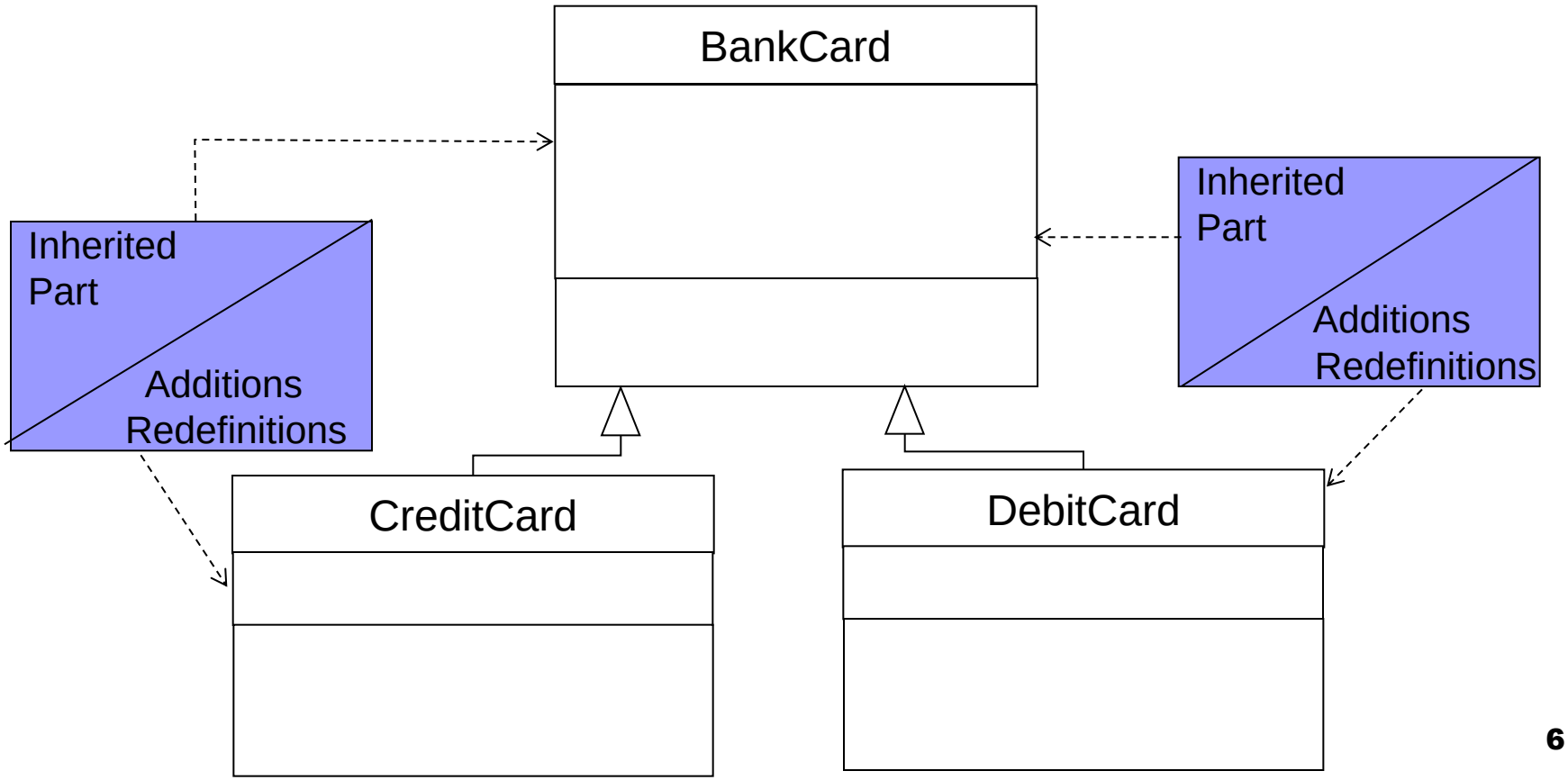
In terms of sets, we can understand a class as the definition of the set of all its instances



Object Orientation

Inheritance

- Hierarchies of class specialization.
- Inheritance of properties and operation.



Object Orientation

Inheritance

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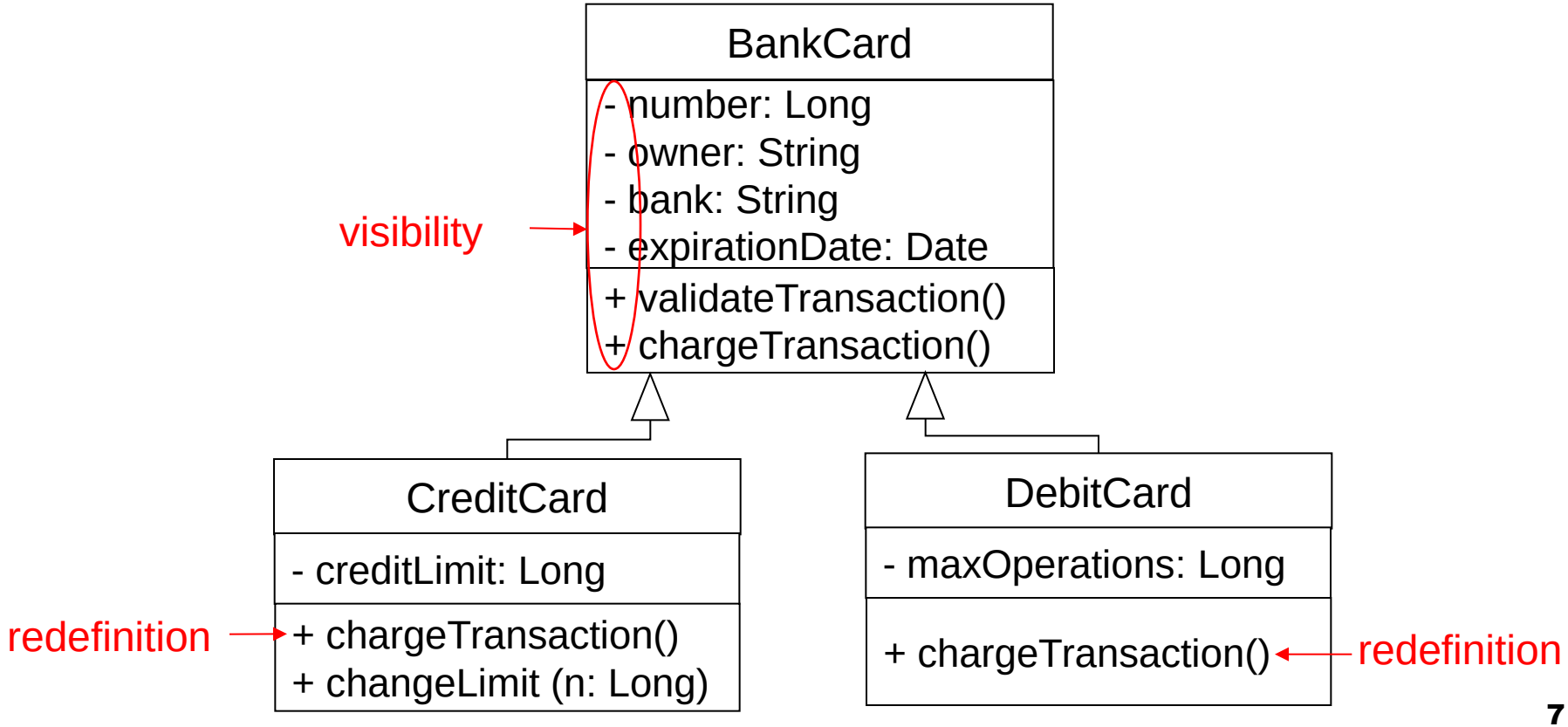
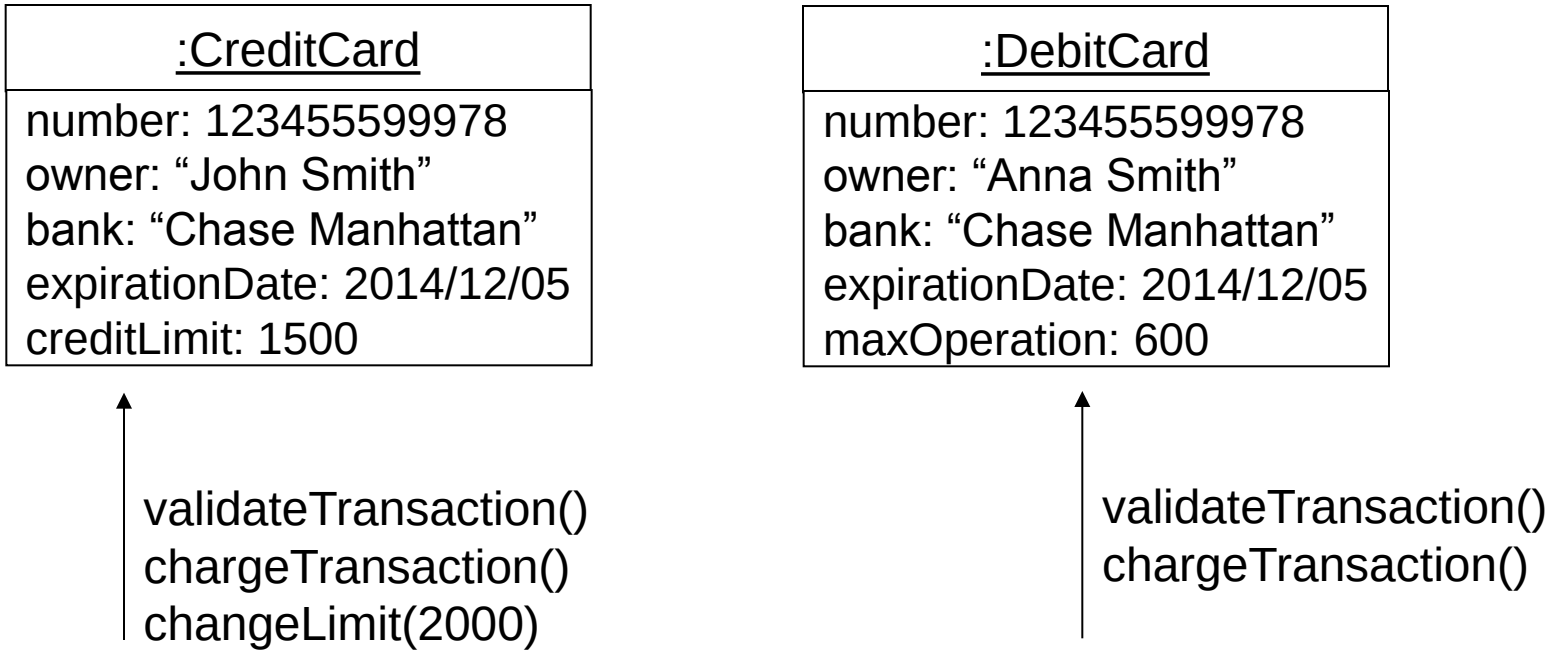


Object Orientation

Inheritance

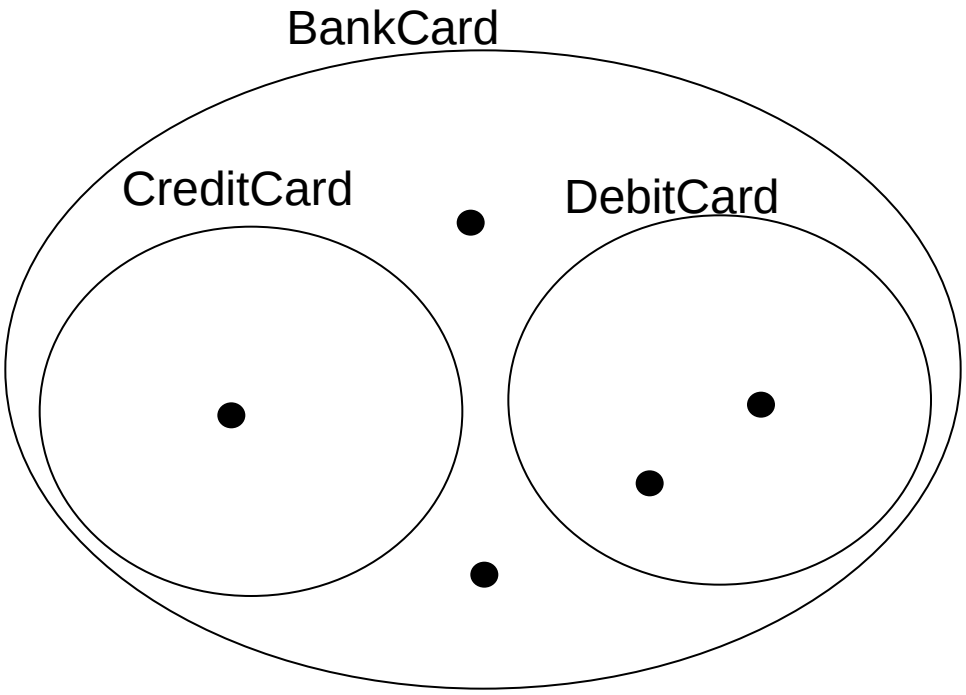
- An object of a subclass inherits the properties of the superclass.
- We can invoke operations defined in the superclass.



Object Orientation

Inheritance

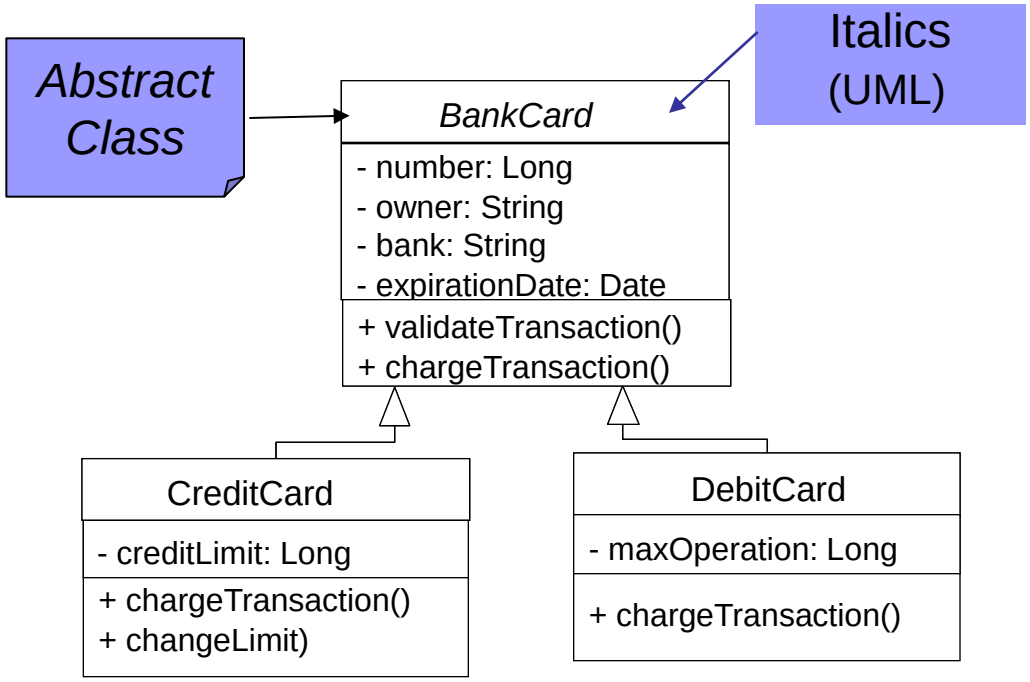
- Safe substitution of supertypes by subtypes.
  - All credit and debit cards are bank cards.
  - There are bank cards that are neither credit nor debit cards (base class is not abstract).
  - No cards are simultaneously credit and debit cards (simple inheritance in this case instead of multiple inheritance).

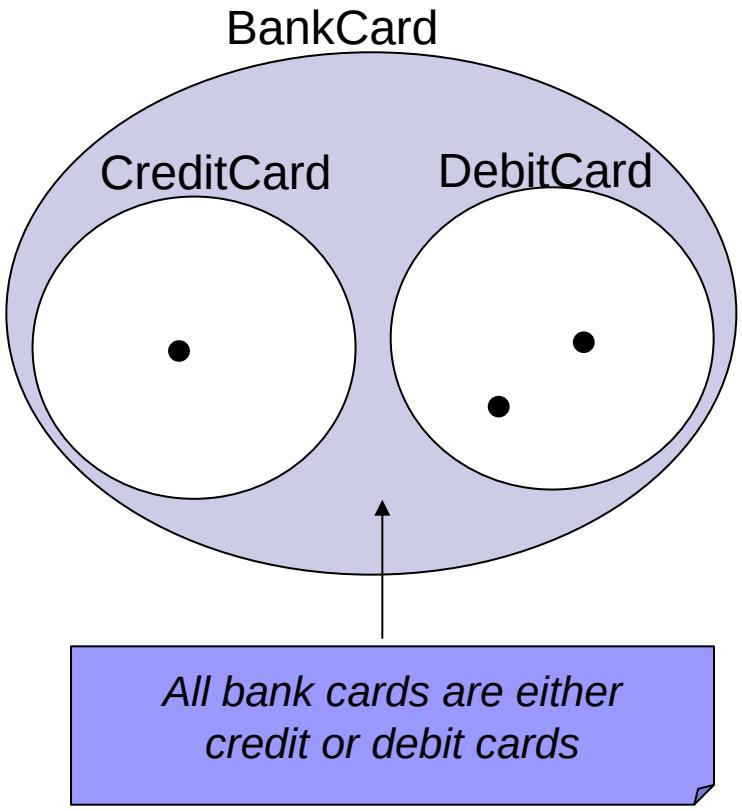


Object Orientation

Abstract Class

- An abstract class cannot be instantiated

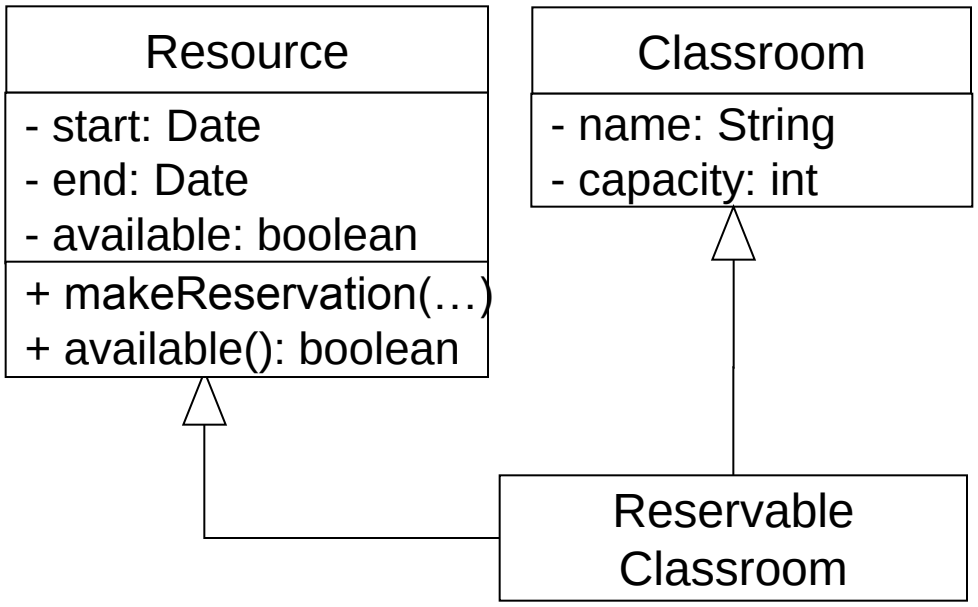


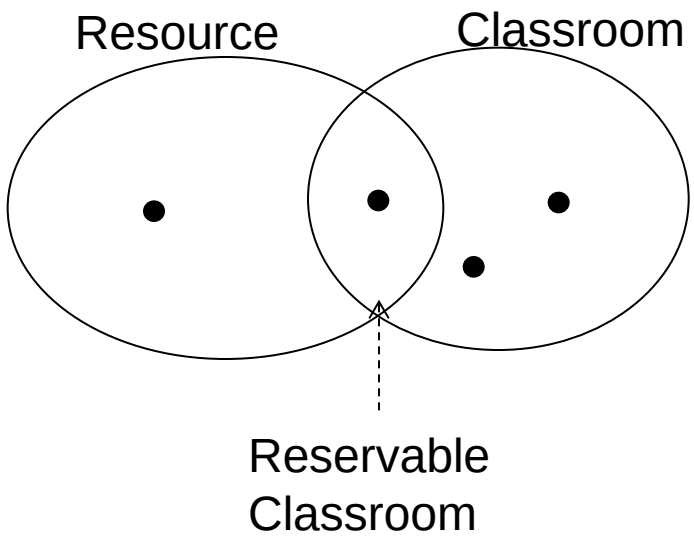


Object Orientation

Multiple Inheritance

- In general, classes can inherit from several superclasses.
- Not allowed in Java. It is allowed in some other programming languages like C++.





Object Orientation

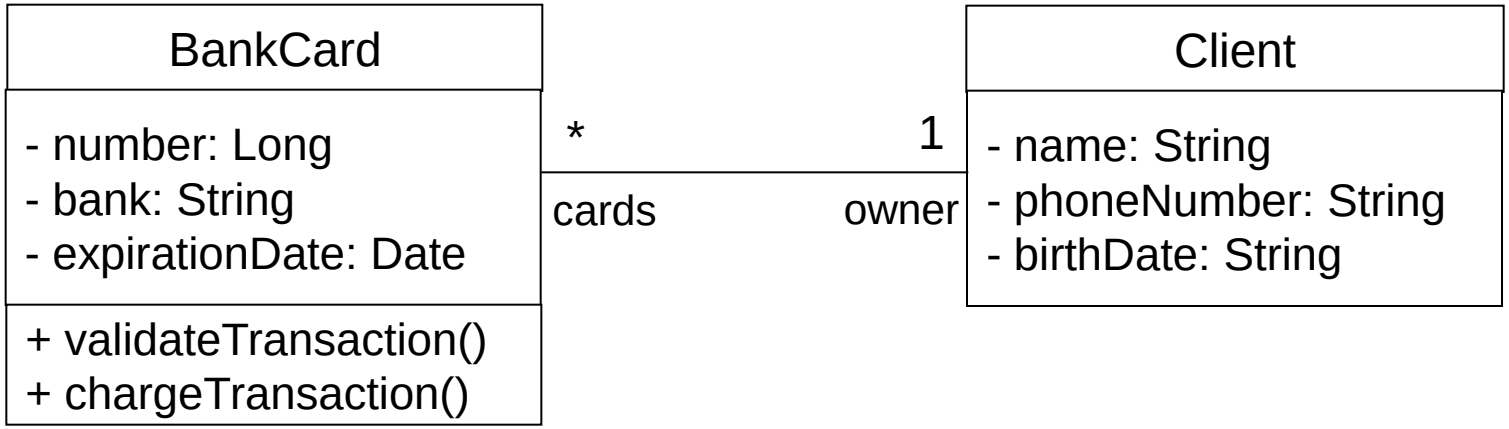
Associations

- Objects are not isolated. They must “know each other” in order to be able to invoke methods from other objects.
  - The application functionality is implemented by means of collaborations between different objects.
- Associations are represented by means of a (decorated) line between two classes.
  - In code, this amounts to an object having a reference to another object (an attribute of the first one).

Object Orientation

Associations

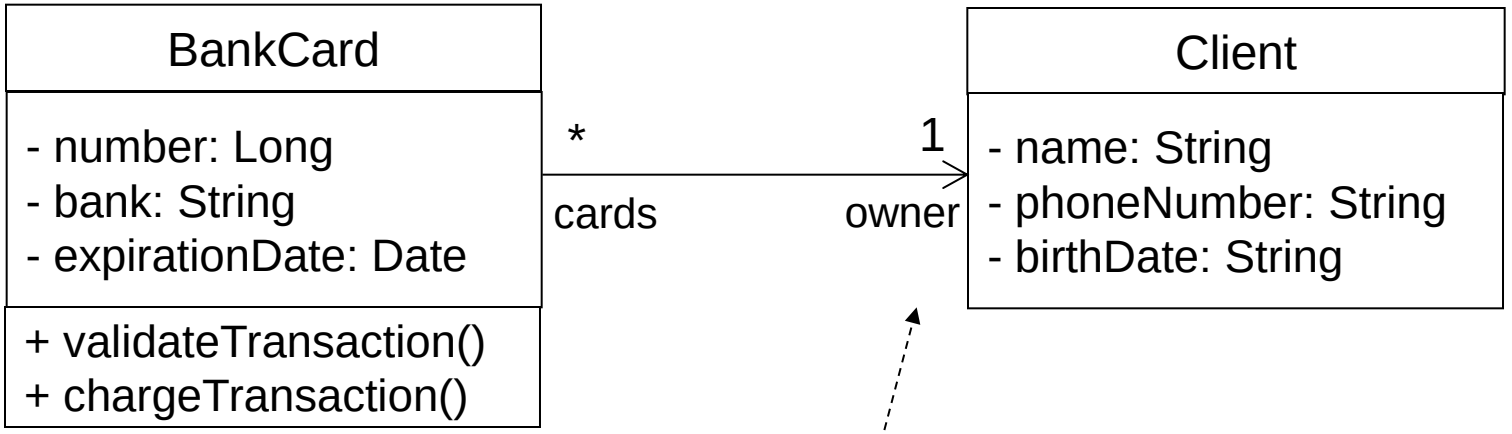
- Multiplicity (a.k.a Cardinality):
  - Allowed interval of objects that can be related to a source object (and vice-versa).
- Roles:
  - Names of the association ends.



Object Orientation

Associations

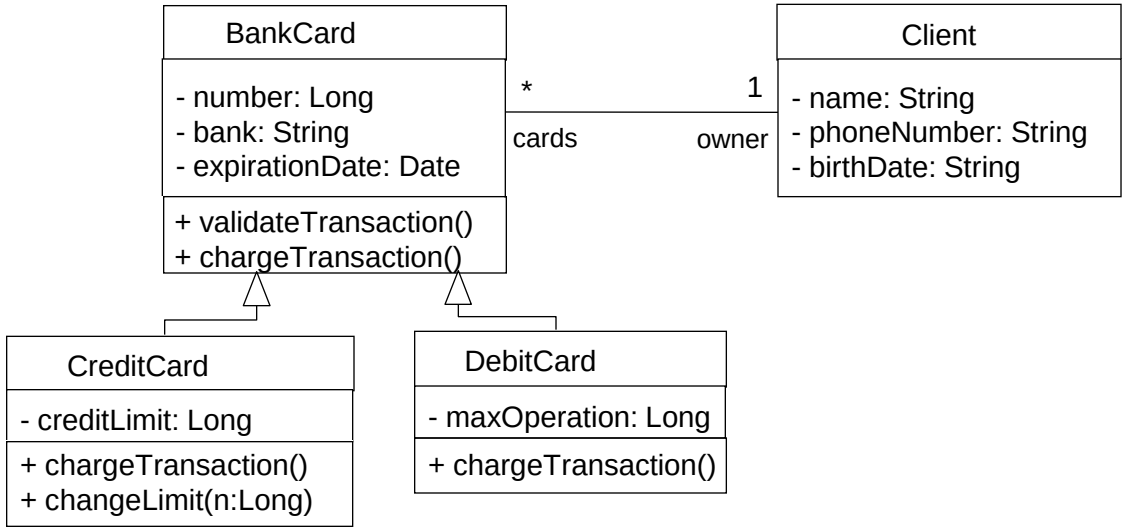
- Navigation: Indicates whether an object can access the objects at the other end.



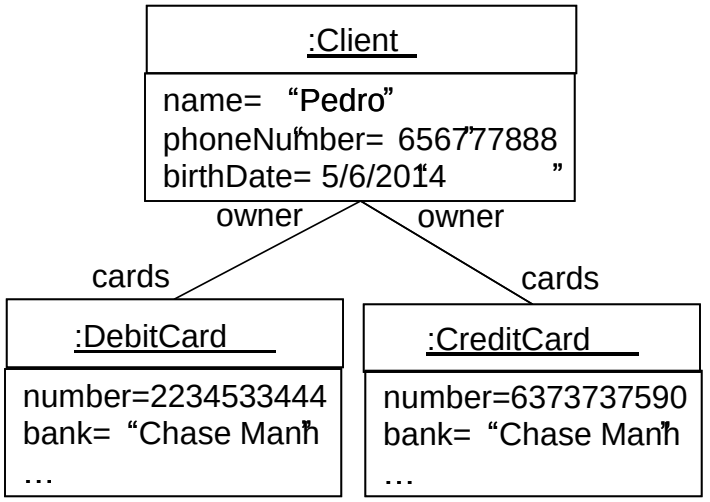
Object Orientation

Inheritance of Associations

- An association that is declared in a base class is inherited by each subclass.



Class diagram

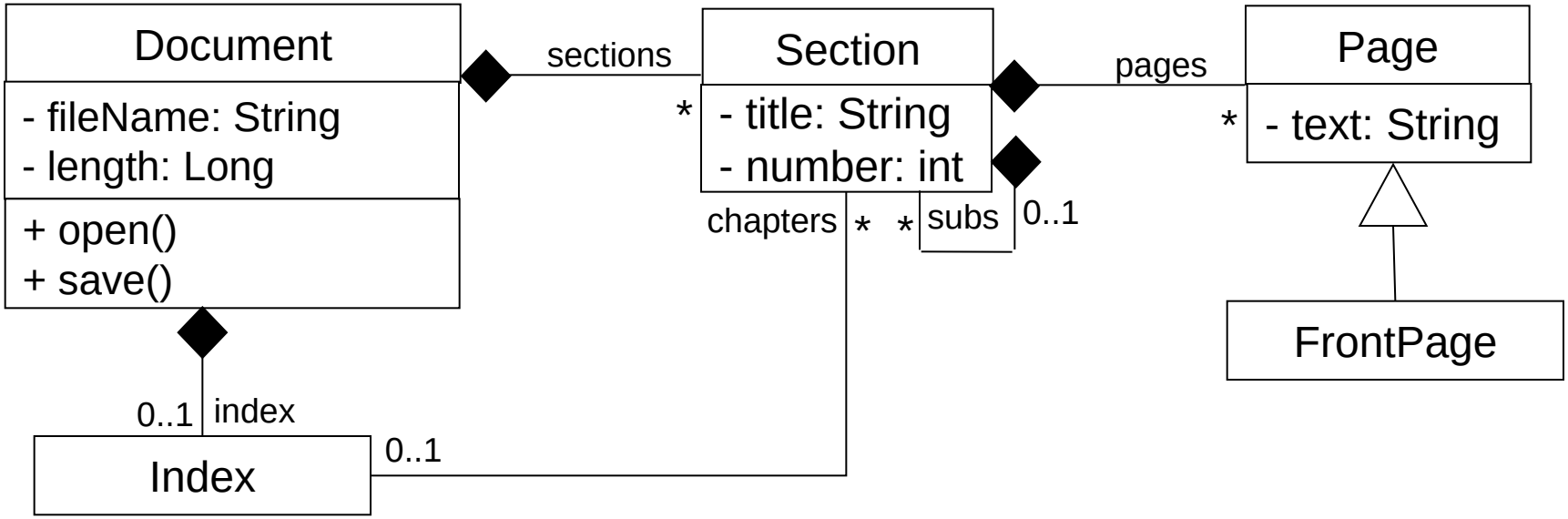


Object diagram

Object Orientation

Composition and Aggregation

- Some relations have special semantics:
  - ◆ Composition (a class made up of different parts)
  - ◇ Aggregation (weaker composition)



Object Orientation

Composition and Aggregation

- Some relations have special semantics:
  - ◆ Composition (a class made up of different parts)
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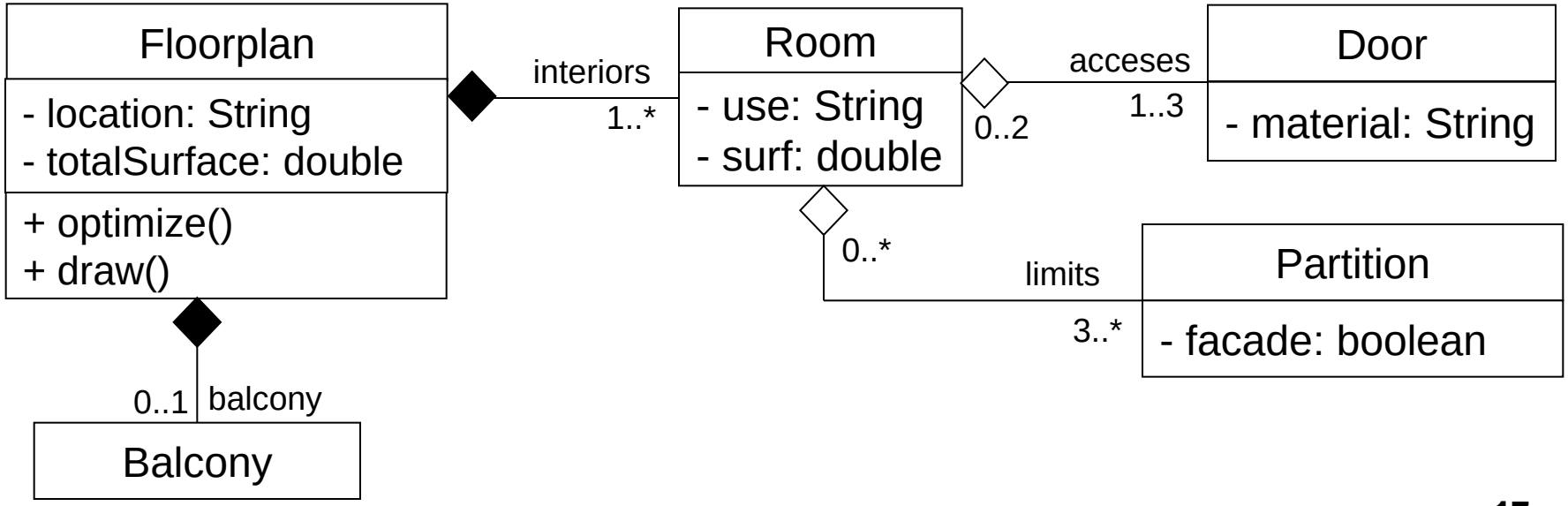

Project

- Build the class diagram for the project.

Index

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- **Behaviour modelling.**
  - State transition diagrams.
  - Sequence diagrams.
- **Requirements Traceability**

Behaviour modelling

- A class diagram describes the structure of the application, but it does not describe its behaviour:
  - Which actions are performed by each method?
  - How is the state of an object changed when methods are invoked?
  - What are the allowed order for invoking methods?
  - How do several objects collaborate among themselves in order to perform a task?

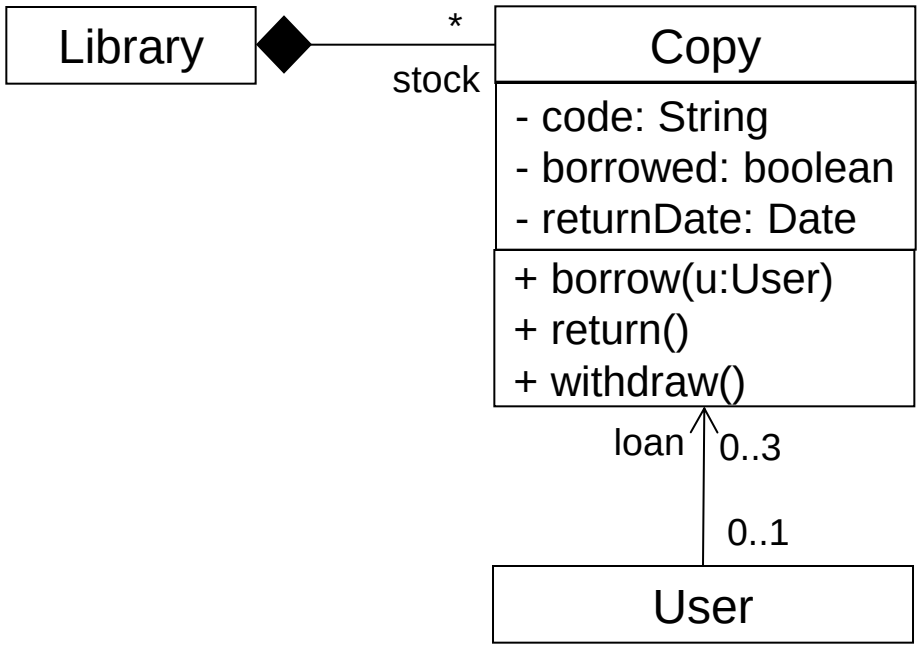
Behaviour modelling

Behaviour diagrams

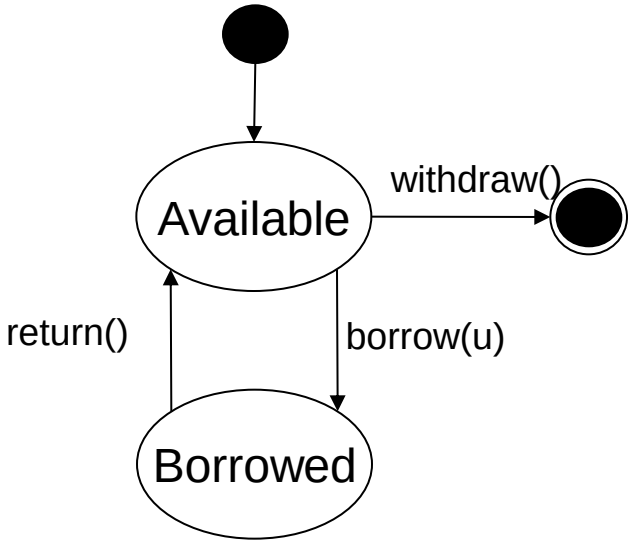
- A class diagram describes the structure of the application, but it does not describe its behaviour:
  - Which actions are performed by each method?
    - Pseudocode (“action semantics” language).
    - Activity diagram
  - How is the **state of an object** changed when methods are invoked?
    - **State transition diagram** (“statecharts”).
  - How do **several objects** collaborate among themselves in order to perform a task?
    - **Sequence diagram**.
    - Collaboration/communication diagram.

State transition diagram

- Associated to a class.
- Describes its evolution when their methods are invoked.
- Similar to a finite automaton.



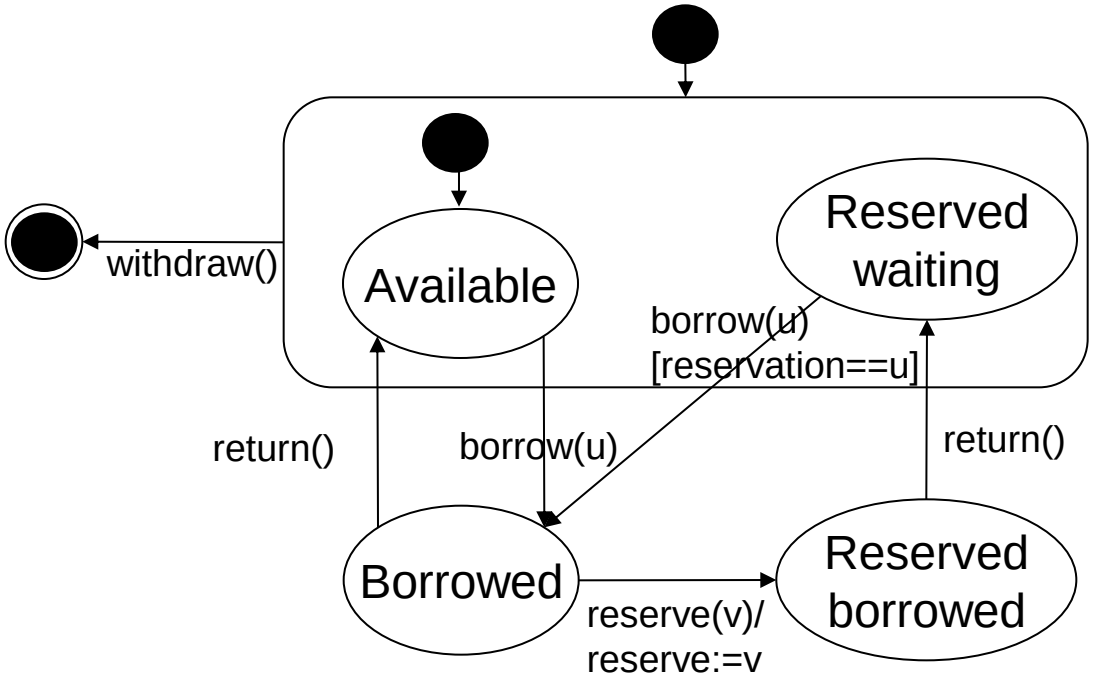
Class diagram



State transition diagram (class: Copy)

State transition diagram

- Hierarchy of states.
- Transitions with guards and actions.



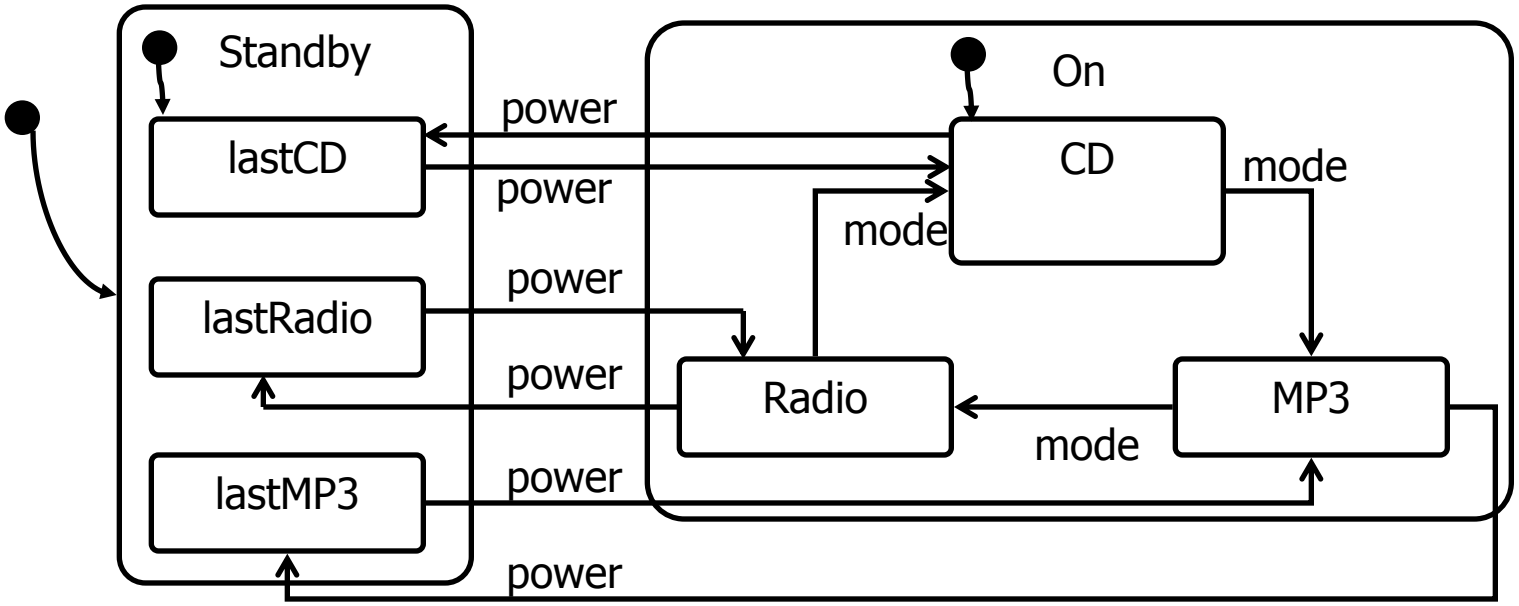
State transition diagram

Exercise

- Model the behaviour of a sound system.
- The system can be ON or in Standby.
- The system has a radio, MP3 and CD player. It is posible to activate them by means of the "*mode*" button.
- When the system is turned on, the last state from its previous use is activated.

State transition diagram

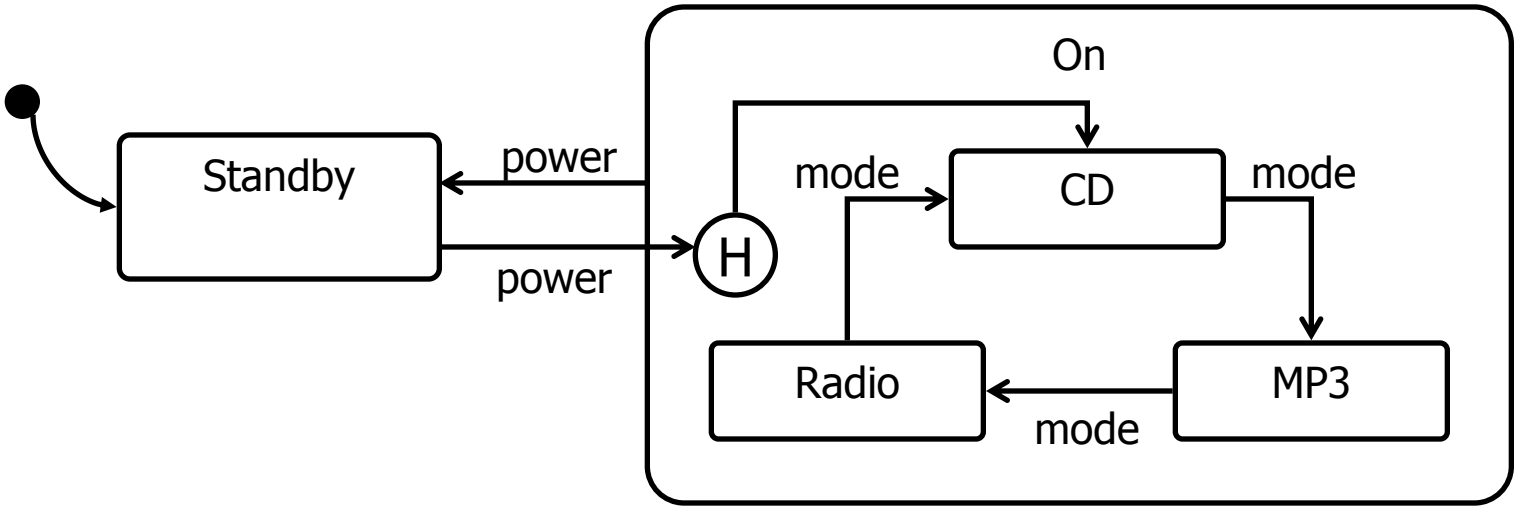
Solution



State transition diagram

History state

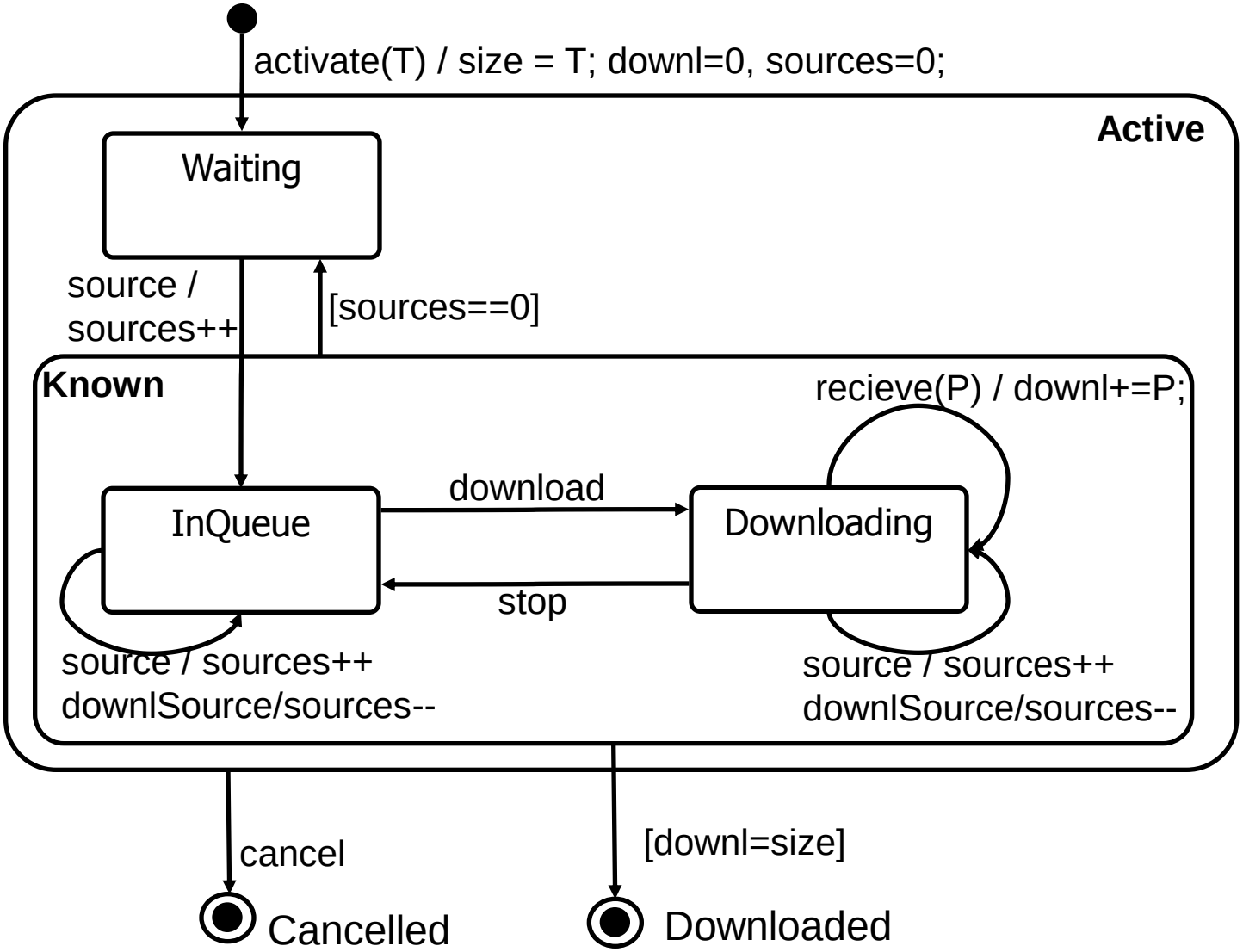
- A ***history*** state remembers the current state the system was in when a hierarchical state was left.
- The first time the hierarchical state is entered, the outgoing transition from the history state is followed.



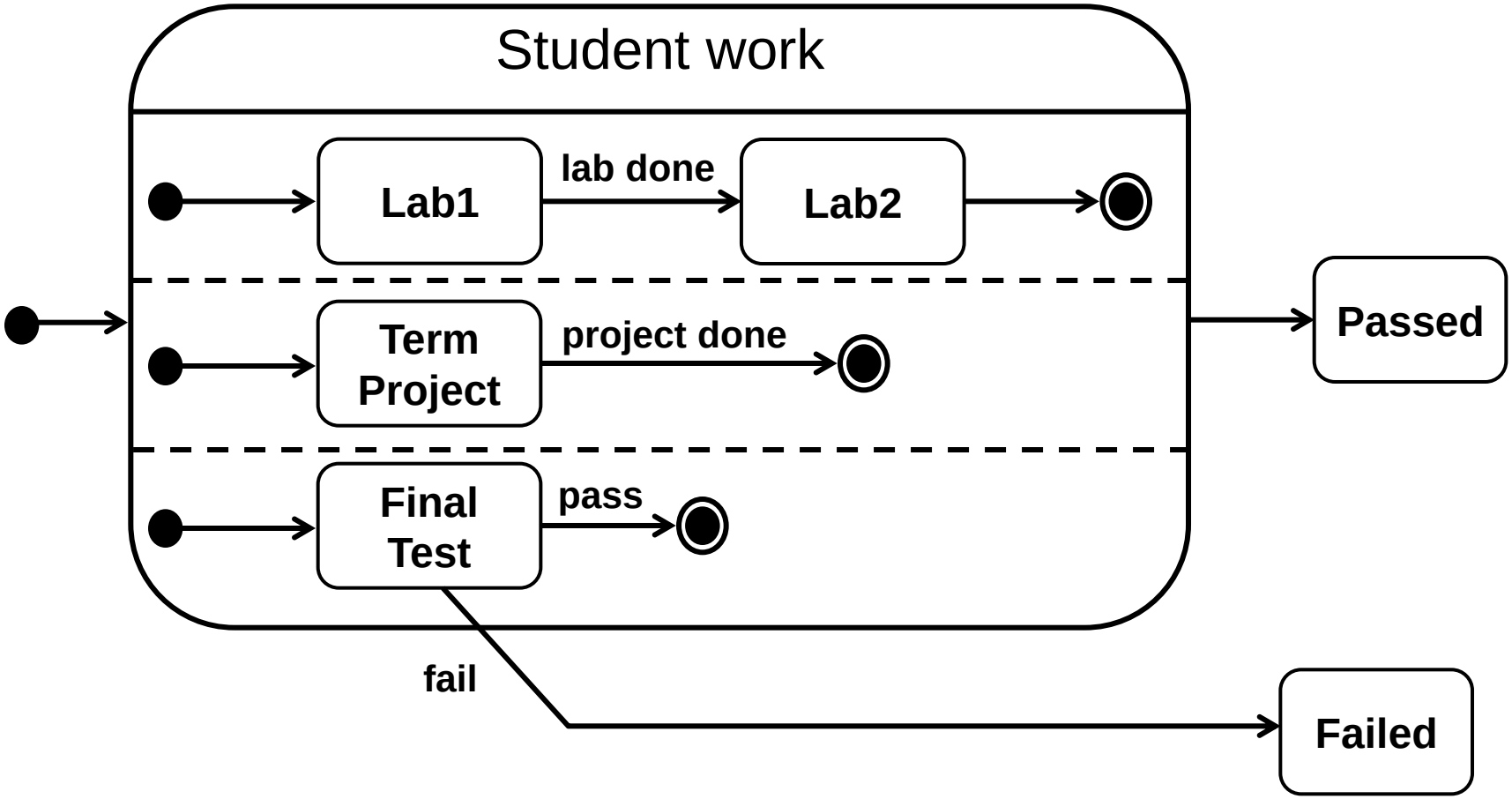
Exercise

- Model the behaviour of a *"shared resource"* in a P2P system. Its life cycle is as follows:
  - A user activates the download of a shared resource with size T.
  - When a source is available for the resource, the resource is enqueued. More sources can be available at any moment.
  - Once the resource is in the queue, at any moment it can start being downloaded.
  - While the resource is being downloaded, data packets of size P arrive to the user device.
  - Downloading can end before all data are transferred or when all data are downloaded.
  - At any moment before the resource is completely downloaded the user can cancel the process.

Exercise solution



Orthogonal Components



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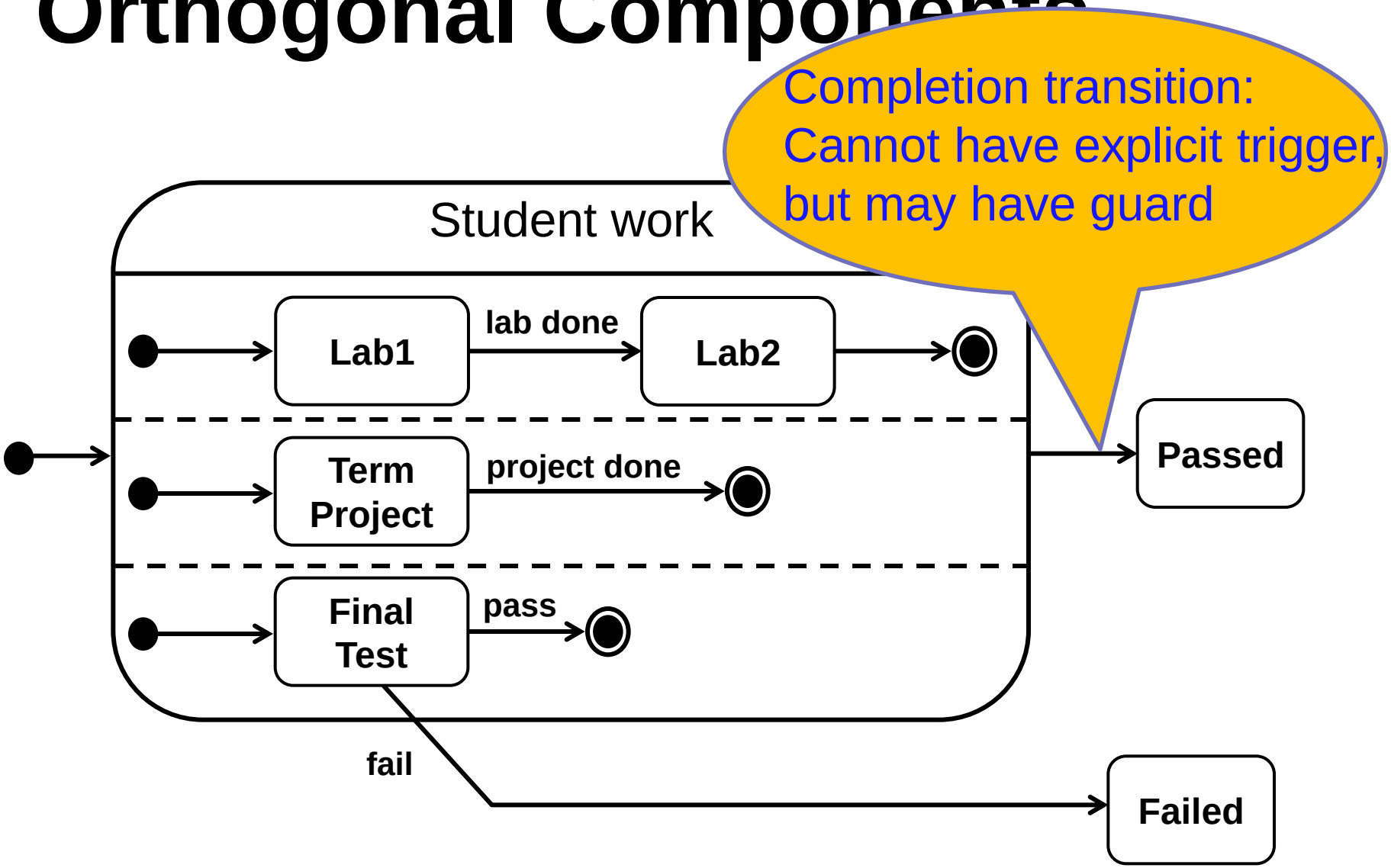
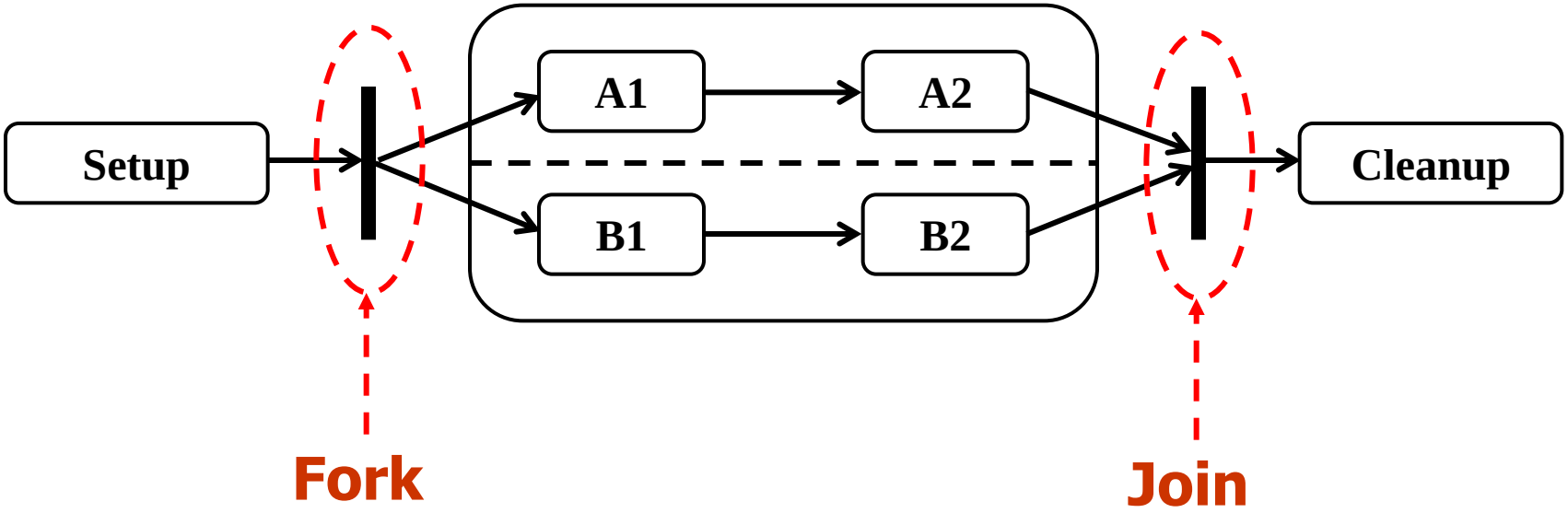


Orthogonal Components

Synchronization pseudostates

- Fork and Join



Orthogonal Components

Synchronization pseudostate

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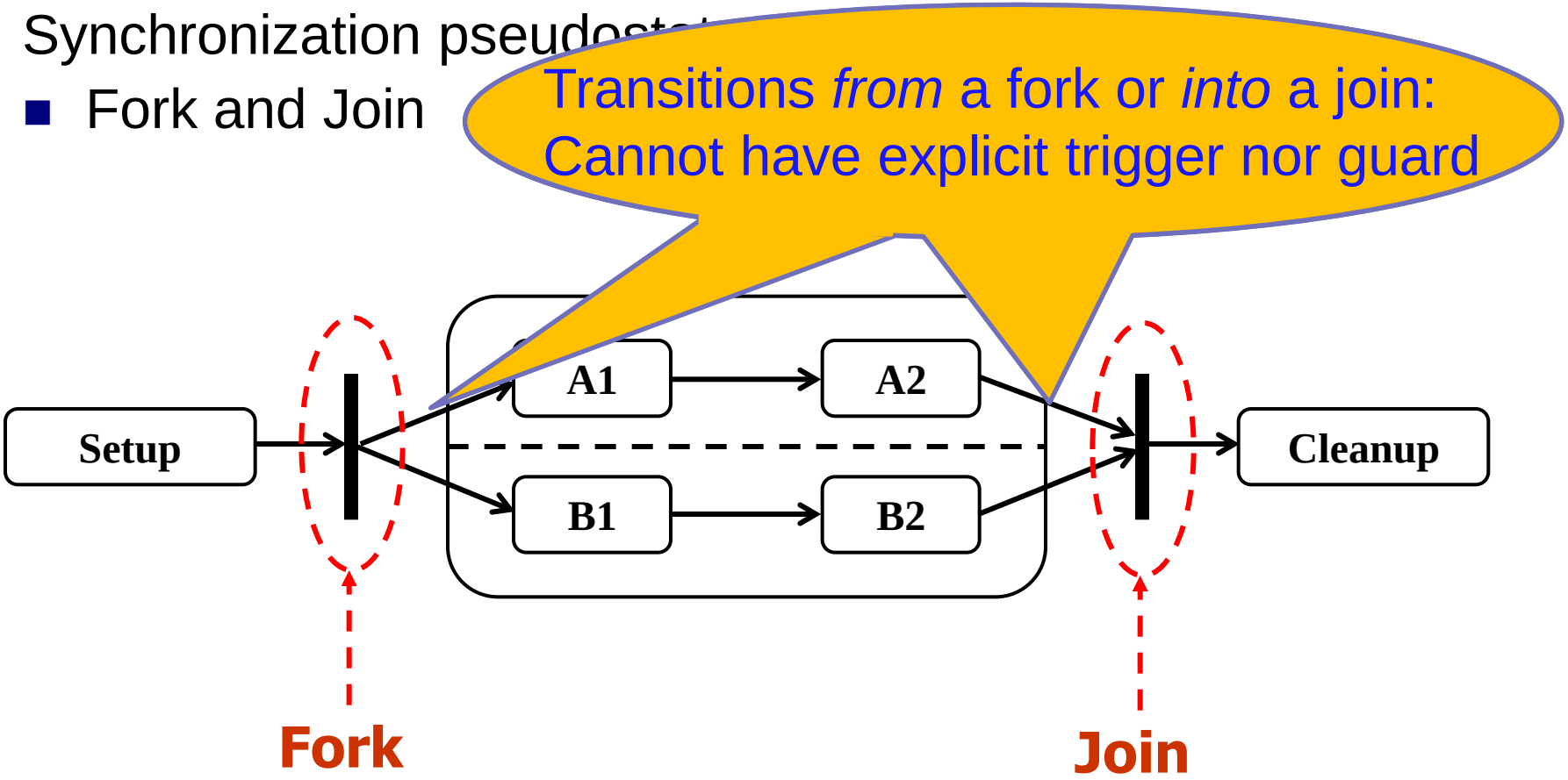
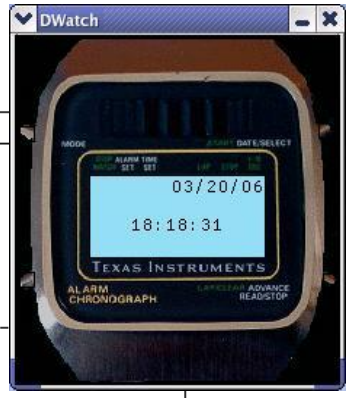
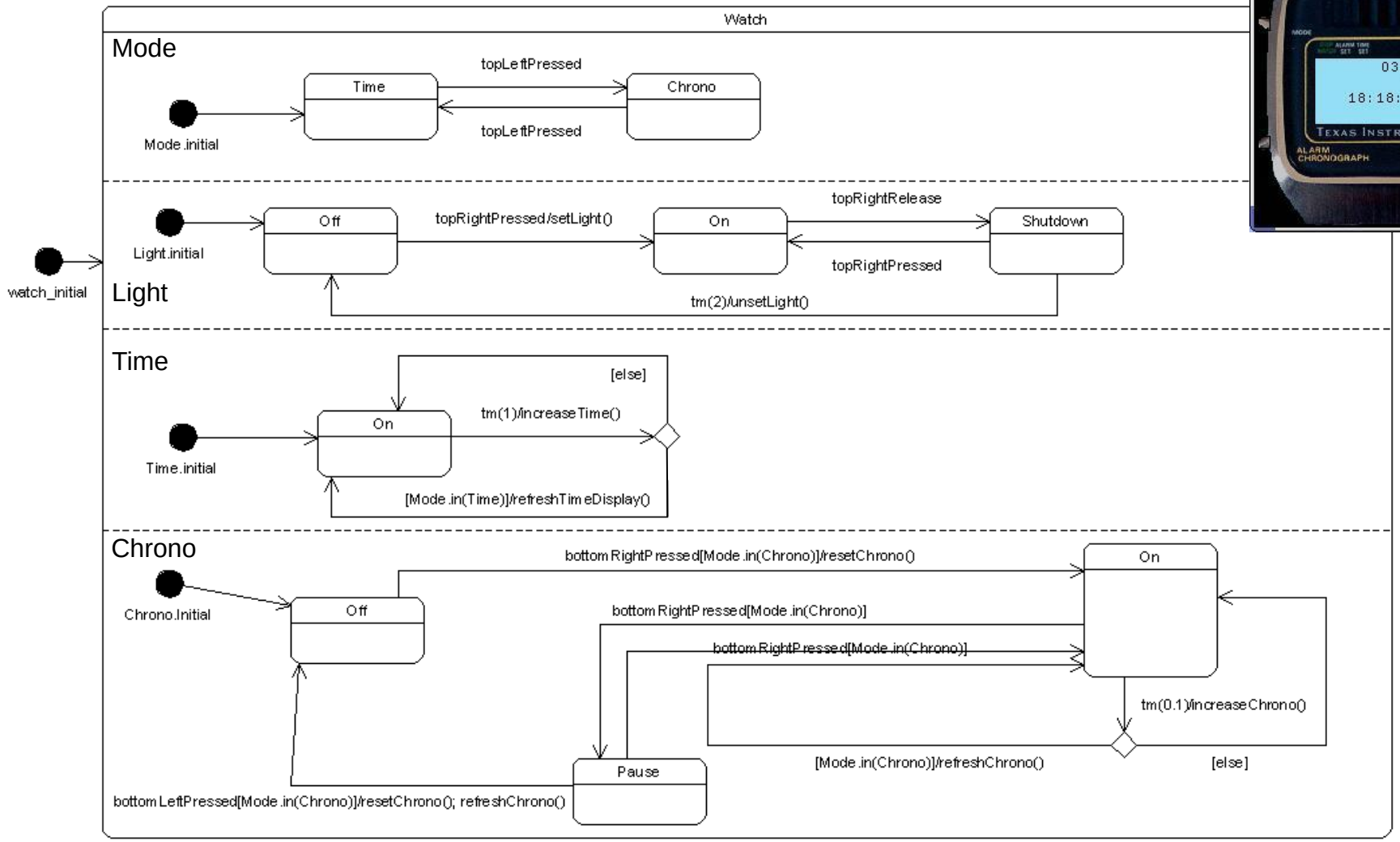


Orthogonal components

Example: a digital watch





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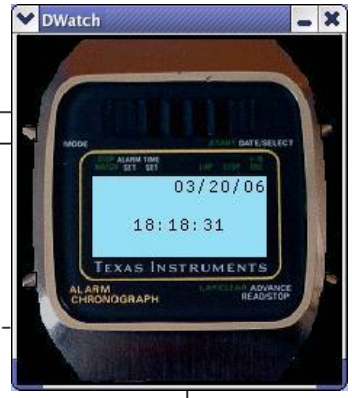
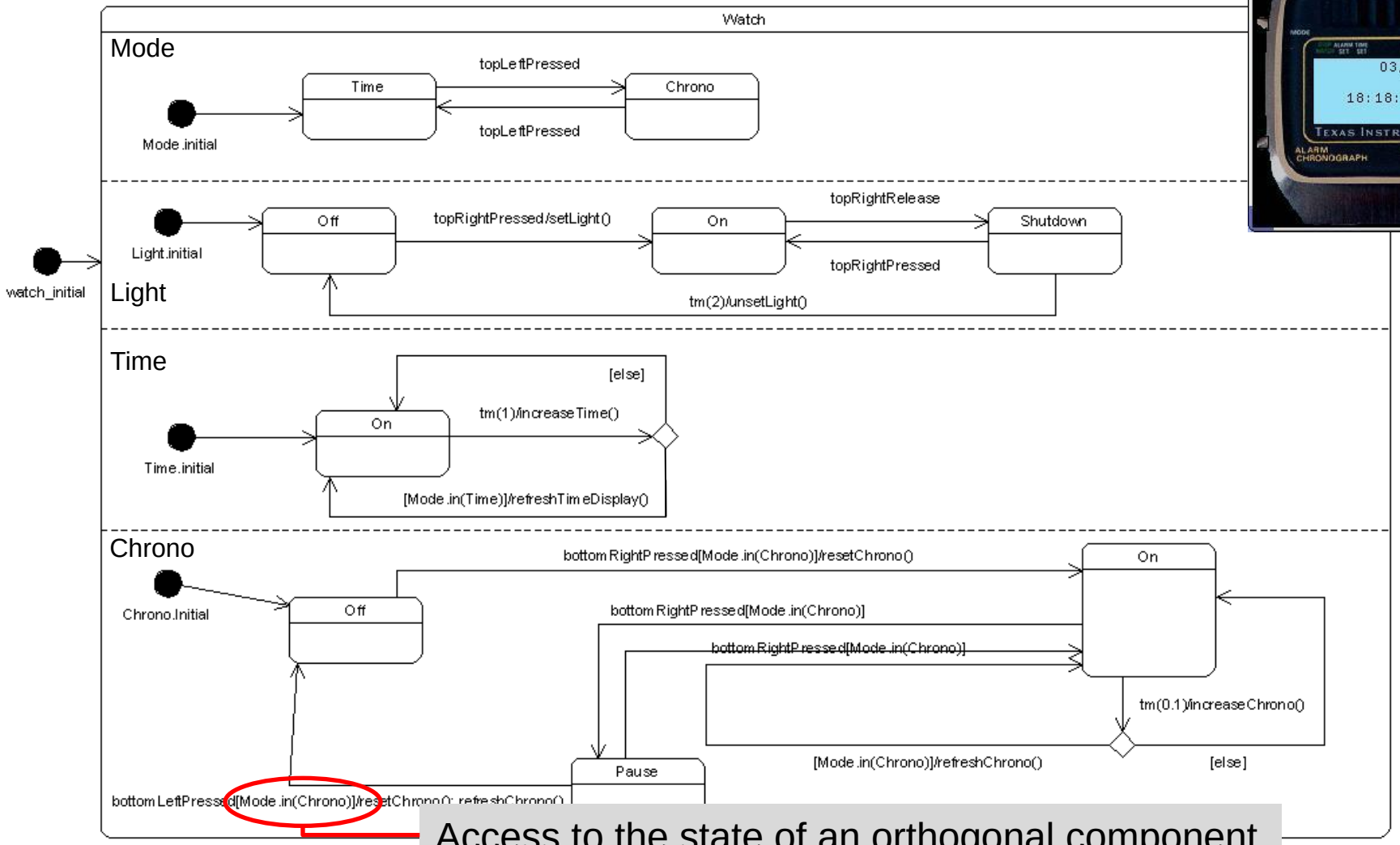




Access to the state of an orthogonal component

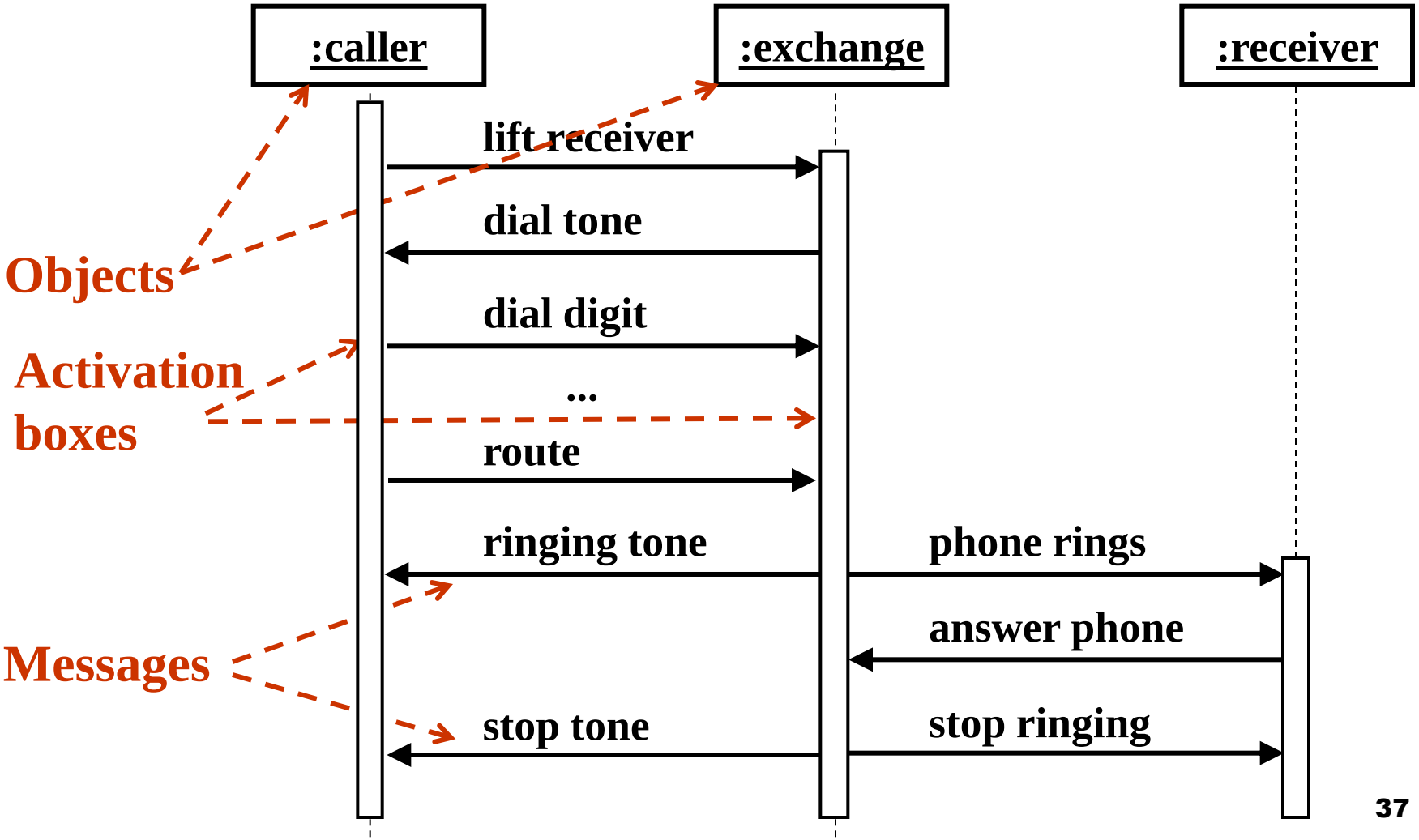
State transition diagram

- Select two classes from your project and build their state transition diagrams.

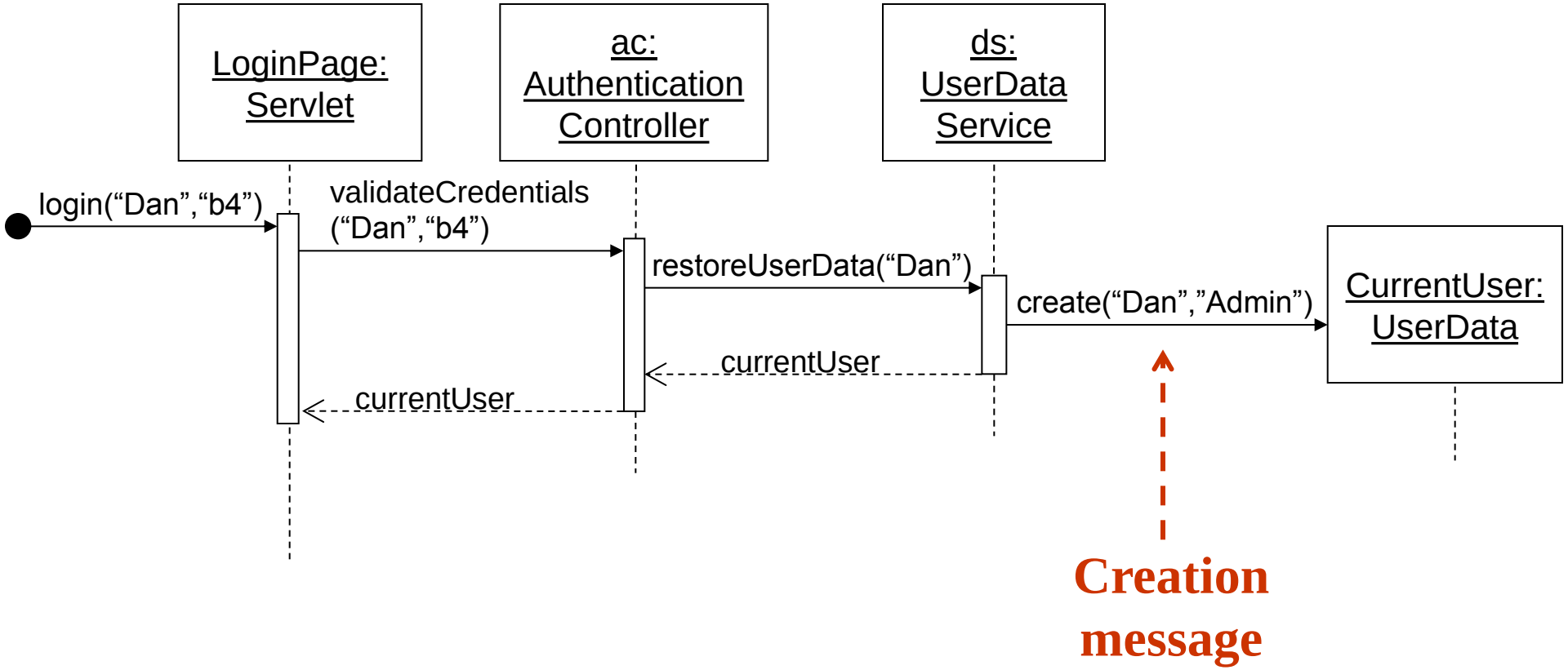
Sequence diagram

- Represents a sequence of messages that are activated by and sent to **a set of objects**.
- Each object has a lifeline represented vertically.
  - Time evolution is represented downwards.
  - Message invocation: arrows joining lifelines.
  - Activation boxes.

Sequence diagram

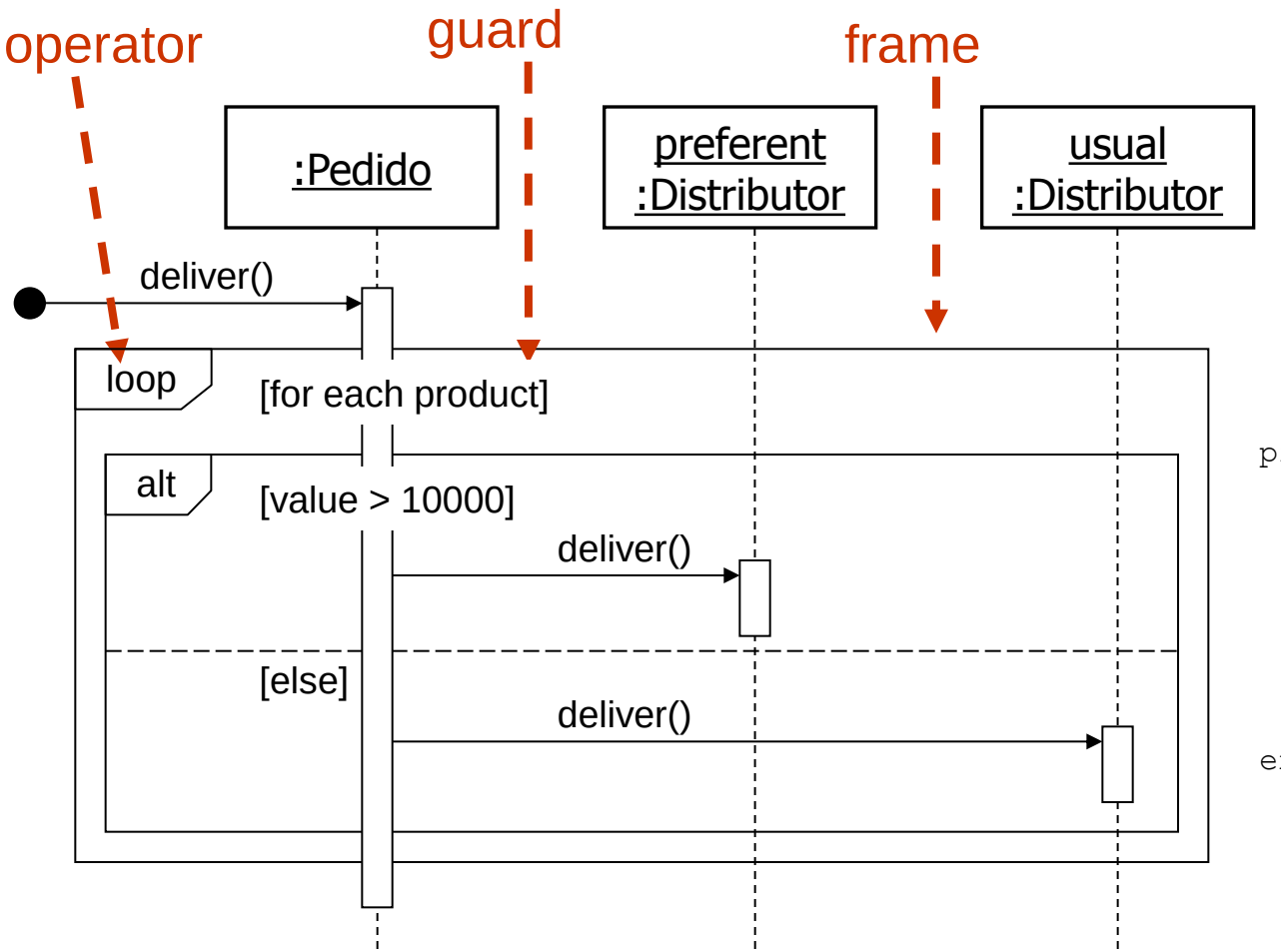


Sequence diagram



Sequence diagram

Operators




```
procedure deliver()
   foreach product:
      if product.value>10000
         preferent.deliver()
      else
         usual.deliver()
      end if
   end for
end procedure
```

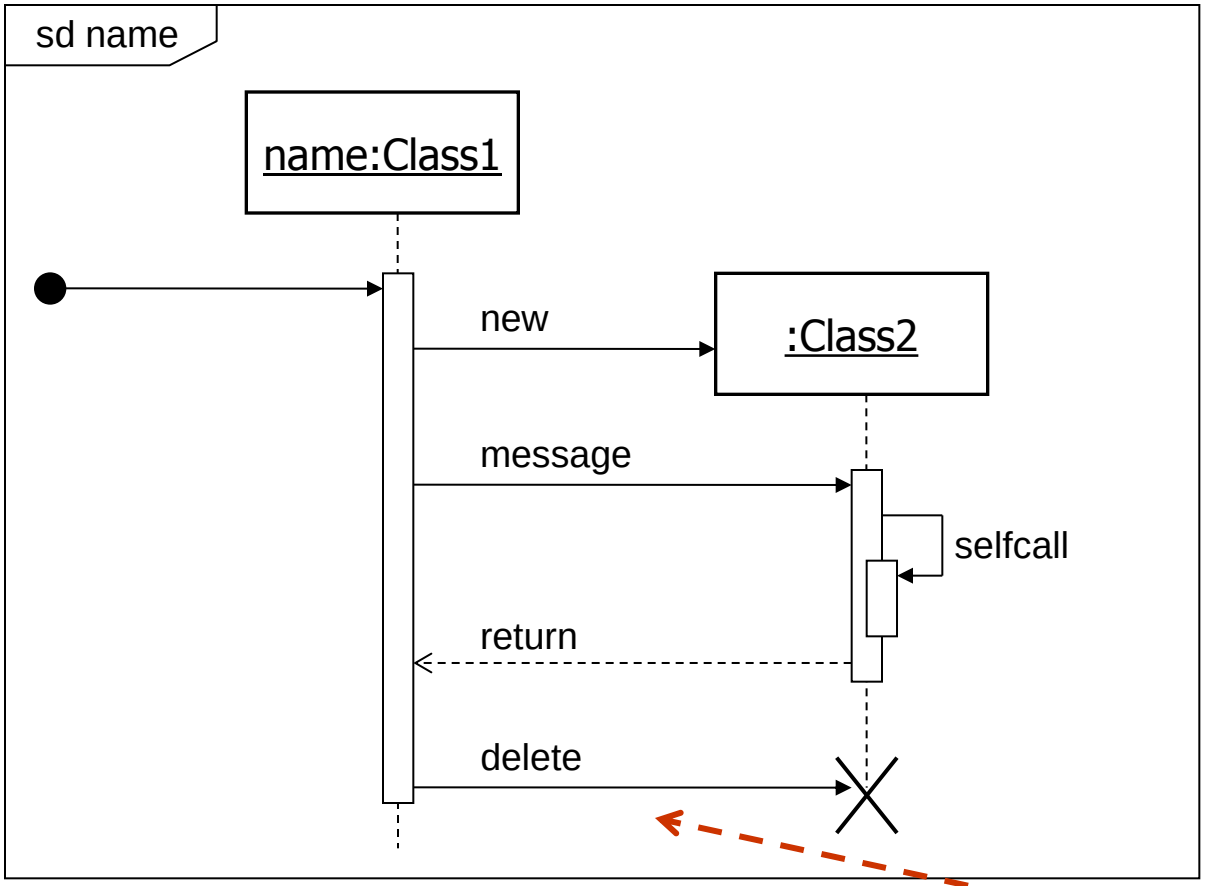
Sequence diagram

Operators

- Combined fragments, operators:
  - **Alternative (*alt*)**: selection (by means of a guard) of an interactión. Múltiple fragments, only the one that satisfies the guard is executed.
  - **Option (*opt*)**: equivalent to an *alt* operator with just one fragment. It is executed if the guard is satisfied.
  - **Loop (*loop*)**: the fragment is executed several times. The guard indicates how to iterate.
  - **Negative (*neg*)**: defines an invalid interaction.
  - **Parallel (*par*)**: each fragment is executed in parallel.
  - **Critical region (*critical*)**: there can be only one process executing the fragment at each instant.
  - **Sequence diagram (*sd*)**: encloses a sequence diagram.
  - **Reference (*ref*)**: the frame refers to an interaction that is defined in another diagram. It covers the lines involved in the interaction. It can include parameters and a return value.

Sequence diagram

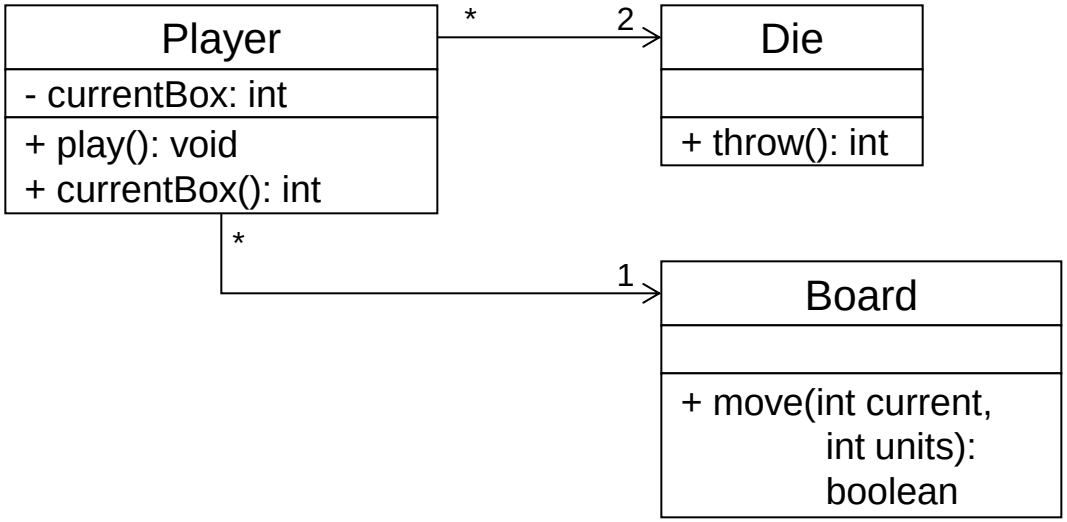
Operators



Sequence diagram

Exercise

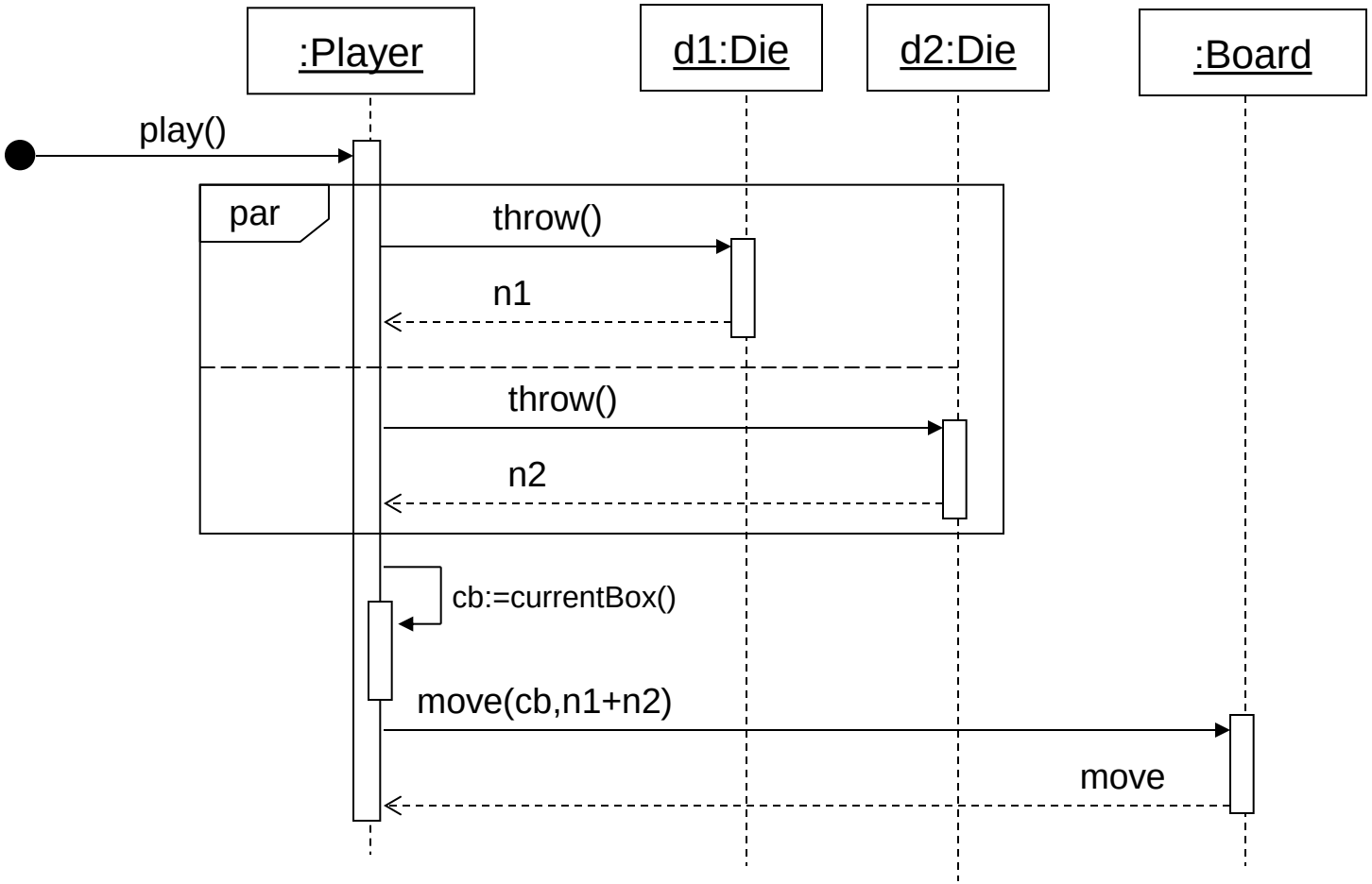
- Specify the sequence diagram of the “play” operation defined in the Player class for the ludo(*) game.



(*) ludo=parchís.

Sequence diagram

Exercise



Sequence diagram

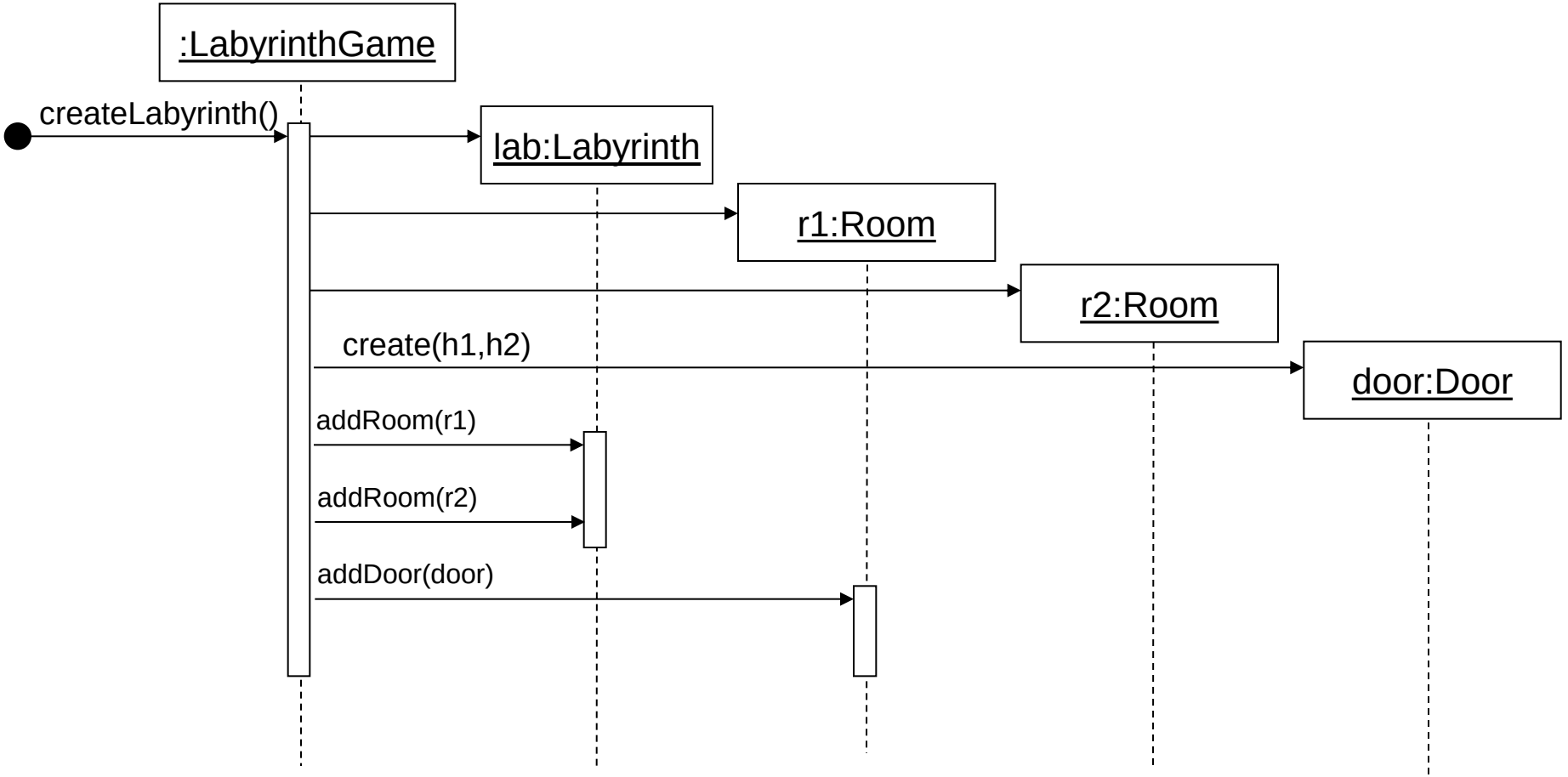
Exercise

Specify the sequence diagram for the method “createLabyrinth”

```
public class LabyrinthGame {
   public Labyrinth creteLabyrinth () {
      Labyrinth lab = new Labyrinth();
      Room r1 = new Room();
      Room r2 = new Room();
      Door door = new Door(r1, r2);
      lab.addRoom(r1);
      lab.addRoom(r2);
      r1.addDoor(door);
      return lab;
   }
}
```

Sequence diagram

Exercise



Sequence diagram

- Select two relevant scenarios from your project and build their sequence diagrams.
  - You can select some of the scenarios from the use cases.

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Requirements Traceability

- At the end of the design phase, it is necessary to check whether the current project requirements, elicited in the analysis phase, are being met.
- A Requirements Traceability Matrix helps correlating requirements and functional elements created in the solution domain.

	Functional Elements			
Requirements	Class1.method1	Class1.method2	…	ClassN.methodM
Requirement 1	X	X		
Requirement 1.1		X		
…				
Requirement N	X			X
Requirement N.M				X

Requirements Traceability

- Create a Requirements Traceability Matrix for your project.
  - This matrix will be later on updated and re-submitted after the coding phase

Bibliography

There are many books and manuals about UML2.0. Here you can find some of them:

- Class diagrams:
  - Using UML. Stevens&Poley. Addison Wesley. 1999. Chapters 5 y 6.
  - UML Distilled, 3rd Edition. Fowler. Addison Wesley. Chapter 3.
- Object diagrams:
  - UML Distilled, 3rd Edition. Fowler. Addison Wesley. Chapter 6.
- State transition diagrams:
  - Using UML. Stevens&Poley. Addison Wesley. 1999. Chapter 11.
  - UML Distilled, 3rd Edition. Fowler. Addison Wesley. Chapter 10.
- Sequence diagrams:
  - UML Distilled, 3rd Edition. Fowler. Addison Wesley. Chapter 4.