

# Documentation

## The Unified Modeling Language

---

Paolo Burgio  
paolo.burgio@unimore.it



**UNIMORE**  
UNIVERSITÀ DEGLI STUDI DI  
MODENA E REGGIO EMILIA

High Performance  
Real Time **Lab**

**DEVELOPERS**

**DESIGNERS**

**PROJECT  
MANAGERS**

**QA**

**SYSADMINS**

**SEEN BY  
DEVELOPERS**



**SEEN BY  
DESIGNERS**



**SEEN BY  
PROJECT  
MANAGERS**



**SEEN BY  
QA**



**SEEN BY  
SYSADMINS**





# What is UML?

---

Born in 1994, standardized in 1998, official version (2.0) in 2005

A *de-facto* design language

- › A semi-standard notation based on a meta-description of entities in a SW system
- › Graphical notations
- › Supports *divide-et-impera*

Useful because

- › Can model different level of abstractions and dev phases: from specs to single classes
- › Works both for top-down and bottom-up
- › Language-independant



# UML taxonomy

---

Three macro-areas

## Entities (a.k.a.: the structure)

- › Classes, interfaces
- › Behavior (FSMs, interaction w/users)
- › Grouping and packaging
- › Notations and general information

## Relations

- › Association
- › Dependency
- › Generalization
- › Implementation

## Diagrams

- › Same object/entity, different perspectives
- › Partial representation, to “see things” under a different light



# UML (standard) diagrams

---

## Structural diagrams

- › Use-cases/scenarios
  - › Notations for classes/objects/packages/components – From OOP
  - › Deployment/components
- } now
- } later
- } won't see these

## Behavioral diagrams

- › Sequence diagrams
- › State diagrams
- › Activity diagrams



# Use-case diagrams



# Use case modeling

---

Describe the interaction between the system and other actors

- › Users, other external systems,....
- › Can be either a picture, or a table (or both)

These are **not** system requirements!

- › We model the expected behavior
- › Also, useful for functional tests/verification

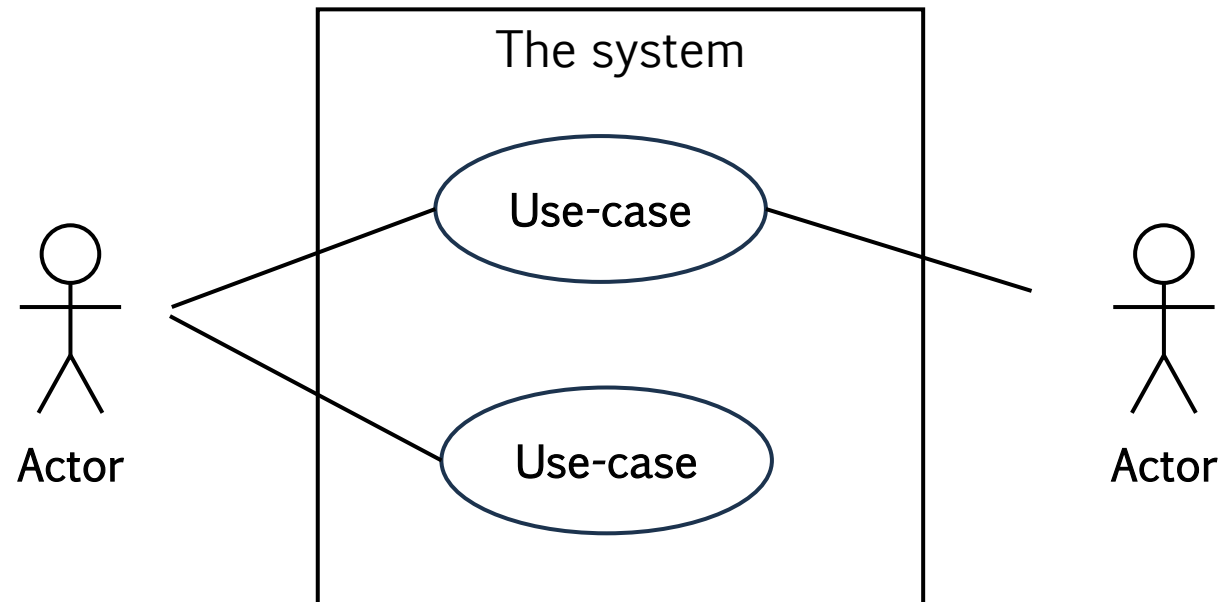
We want to clearly identify

- › The boundaries of the system (behavioral and “physical”)
- › Actors/macro-entities
- › Use-case scenarios

# Graphical notation

---

---



- › For every element, can/shall add a brief description





# The right level of abstraction

---

First, identify the Actors, and model their interaction with the system

- › Remember: actors are **external** to our system!
- › ..even if we might model them internally, they're not under our control

Then, define multiple Scenarios

- › They are a single instance of use-case
  - Define the (sequence of) events that happen in a specific ....scenario 😊
  - Scenario (and their events) define functional, and user assessment tests
- › Distinguish between main scenarios (everything works correctly)
- › ...and secondary scenarios (extensions, or in case of errors)
  - «Optional parts» of the scenario
  - Can become a lot!



# Scenario/UC diagrams

---

Define how the system interacts with the extern

- › Operational conditions (also called “Operational Design Domain”), might also be standardized (see automotive)
- › “Doesn’t work”...but under which conditions? Which scenario?
- › “It works on my laptop” – I **do not want** to hear this sentence anymore, ok?

We typically specify

- › Pre-conditions, and post-conditions (i.e., states change)
- › Guarantees both to be given, and assumed
  - Reliability, both ours and others’, QoS, ...
- › Triggers to events

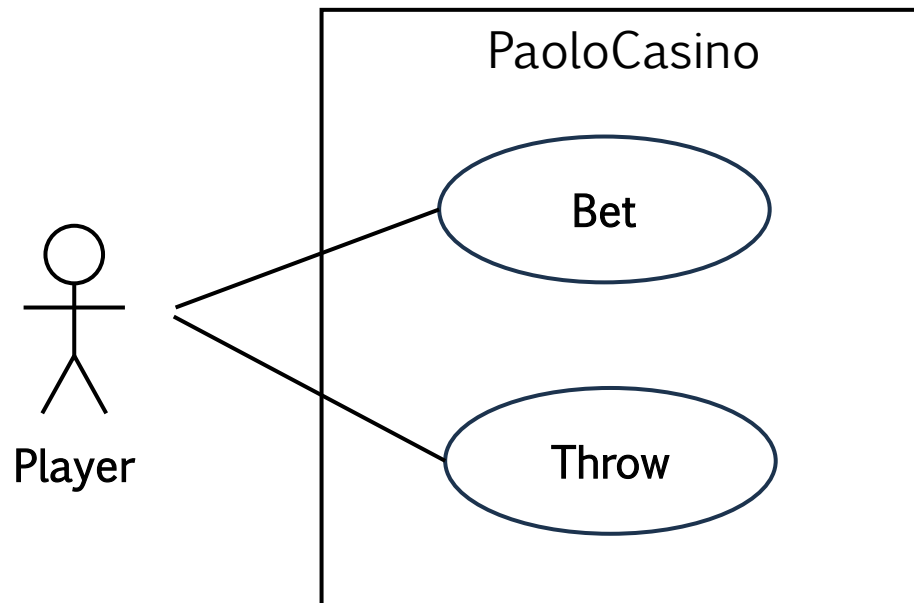


# Example: Paolo's Casino

---

Use-case: users throwing die

- › User shall be able to bet
- › User shall be able to throw die



# Table description

---

More structured, accompanies the image (or the image accompanies it)

- › Unique ID
- › Title
- › Actors
- › Pre-conditions
- › Sequence of events
  - Triggers by actors
  - System responses
- › Postconditions, exceptions
  - Also, state changes (e.g., data storage in DB)



# Table description (cont'd)

---

- › Use case/scenario: UC1
- › Actors: Actors 1 (starter), Actor 2
- › Type: Primary, secondary, essential
- › Description: ...

| Actions              | Responses               |
|----------------------|-------------------------|
| 1. Actor 1, Action X |                         |
| 2. Actor 2, Action Y |                         |
|                      | 3. Response to Action 2 |
| 4. Actor 1, Action Z |                         |
|                      | 5. Response to Action 4 |
| ...                  | ...                     |



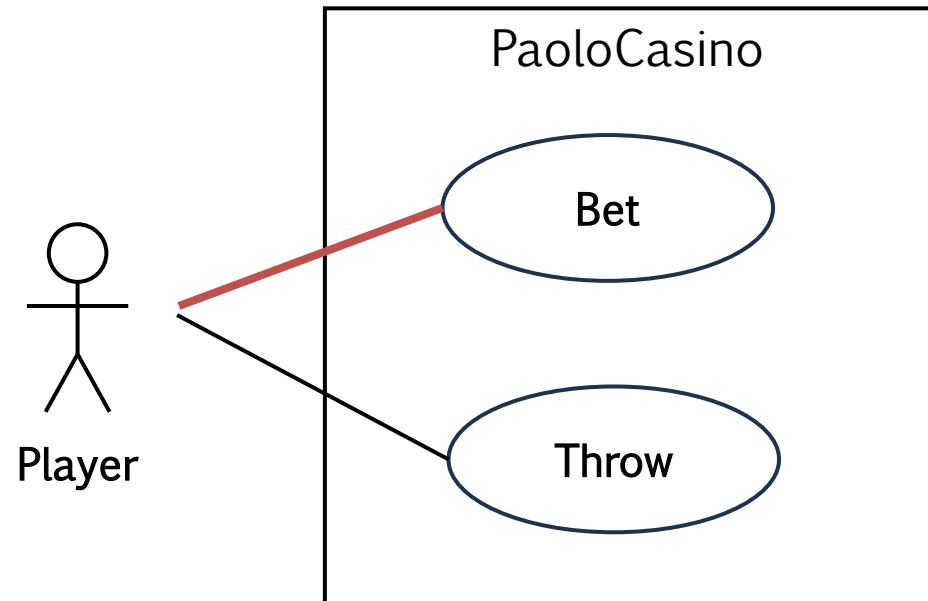
# Paolo's Casino

- › Use case/scenario: [Throwing die] Bet
- › Actors: Player (starter)
- › Type: Essential
- › Description: The player guesses a number, and places a bet with X money

| Actions                                    | Responses (Primary)           |
|--------------------------------------------|-------------------------------|
| 1. Player sets X money, and places the bet |                               |
|                                            | 2. The system accepts the bet |
| Exceptions (secondary)                     |                               |
| 1. The number is not between 0 and 6       |                               |
| 2. The player does not have X money        |                               |
| ...                                        |                               |
|                                            |                               |

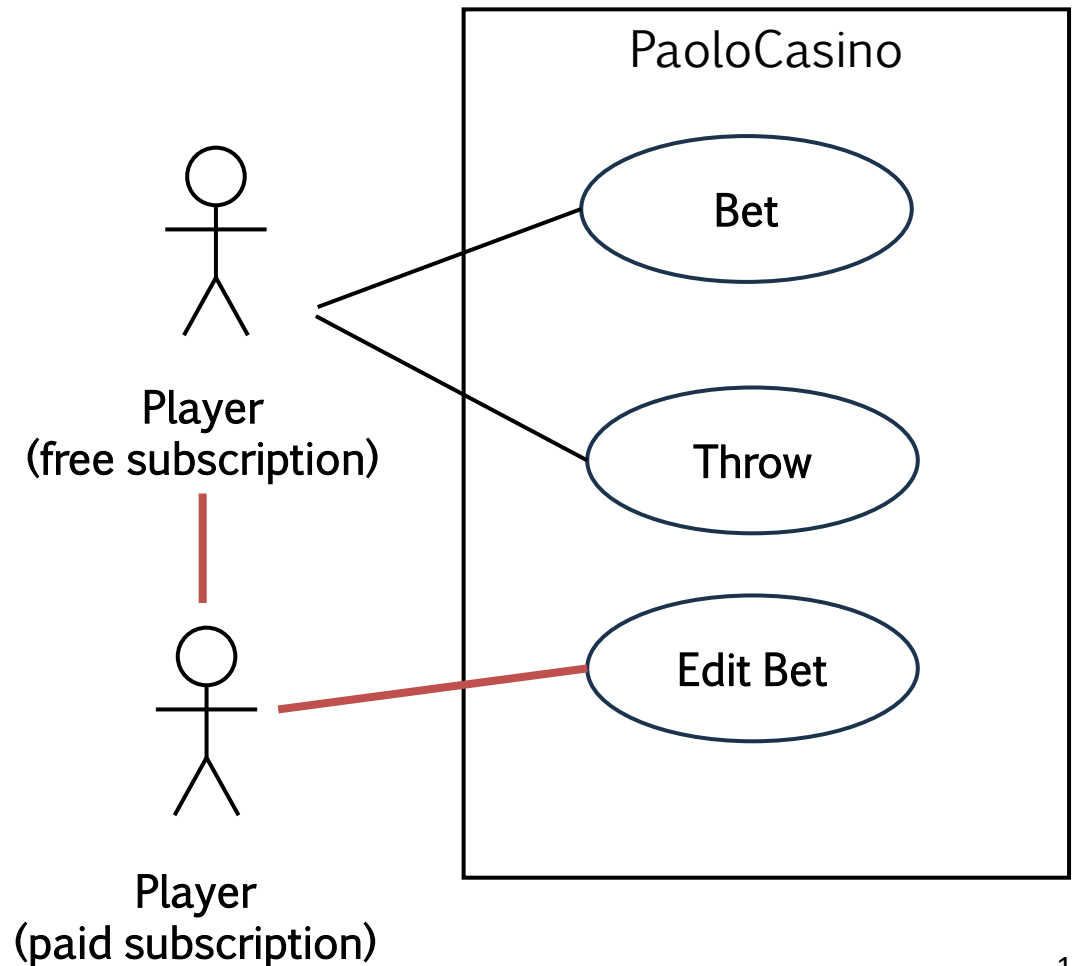
# Relations

- › Association between actors and use cases
- › Generalization between actors and use cases
  - Add feature/characteristics to the parent
- › Inclusion of use-cases
  - <<includes>>
- › Extension of use-cases
  - <<extends>>



# Generalization between actors

- › Children can participate to all use-cases
- › And add more

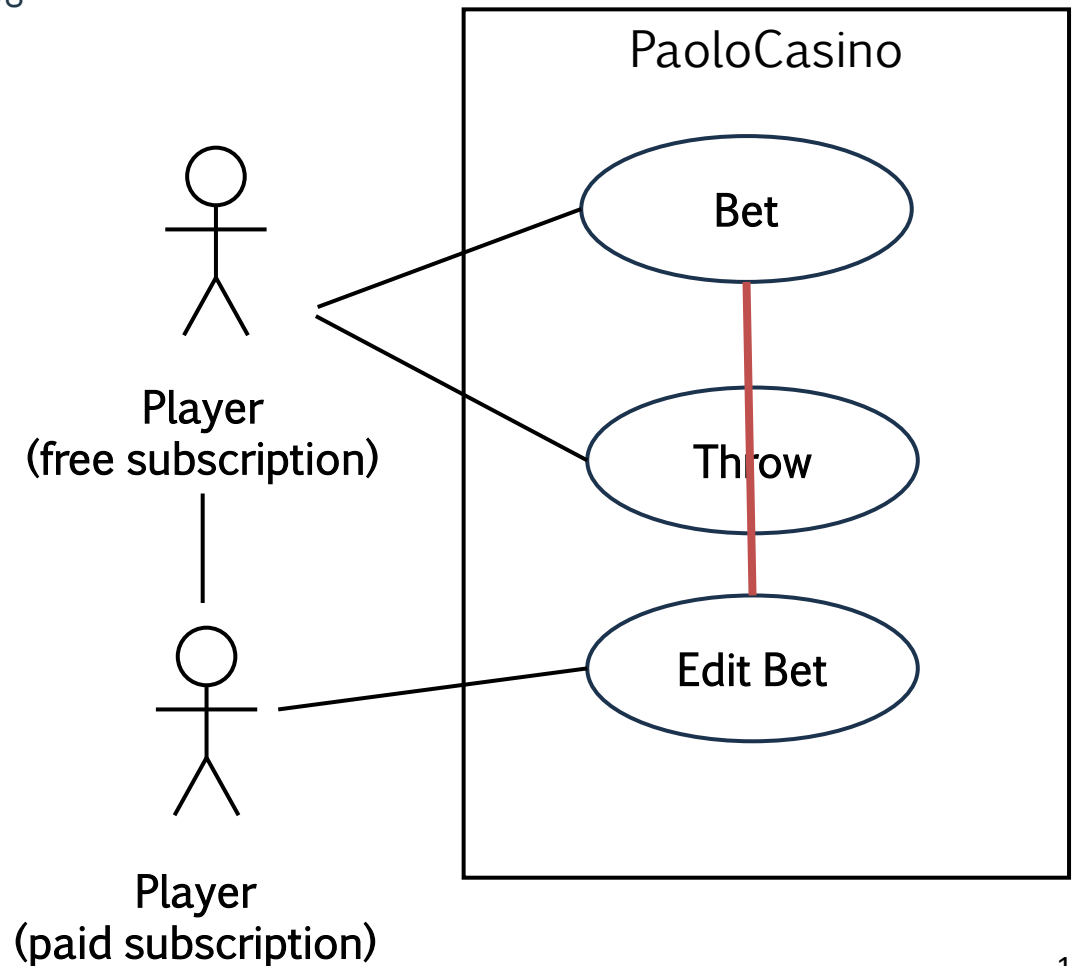




# Generalization between UCs

Can re-define steps and events

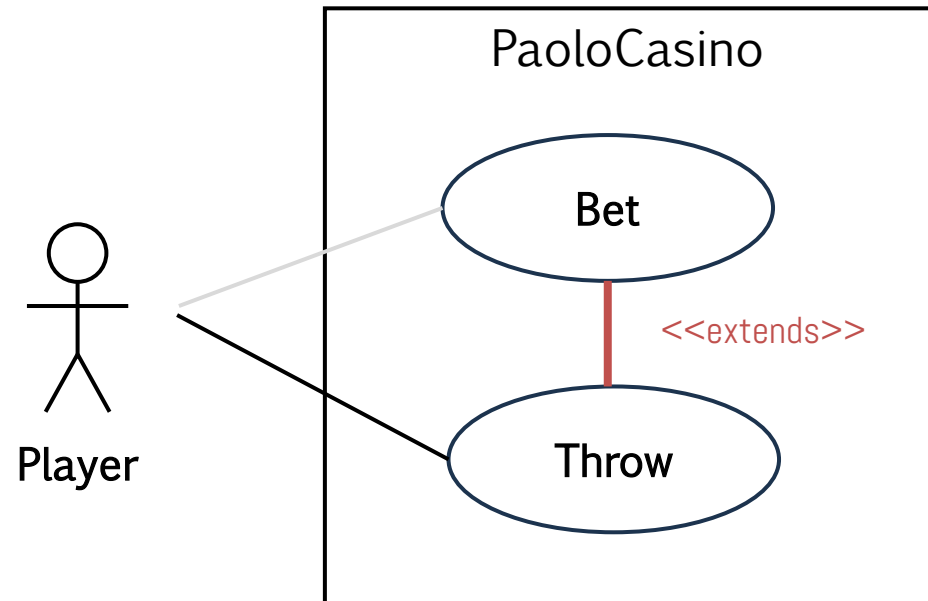
› ..or specialize the existing ones



# Extensions

Used to express dependencies

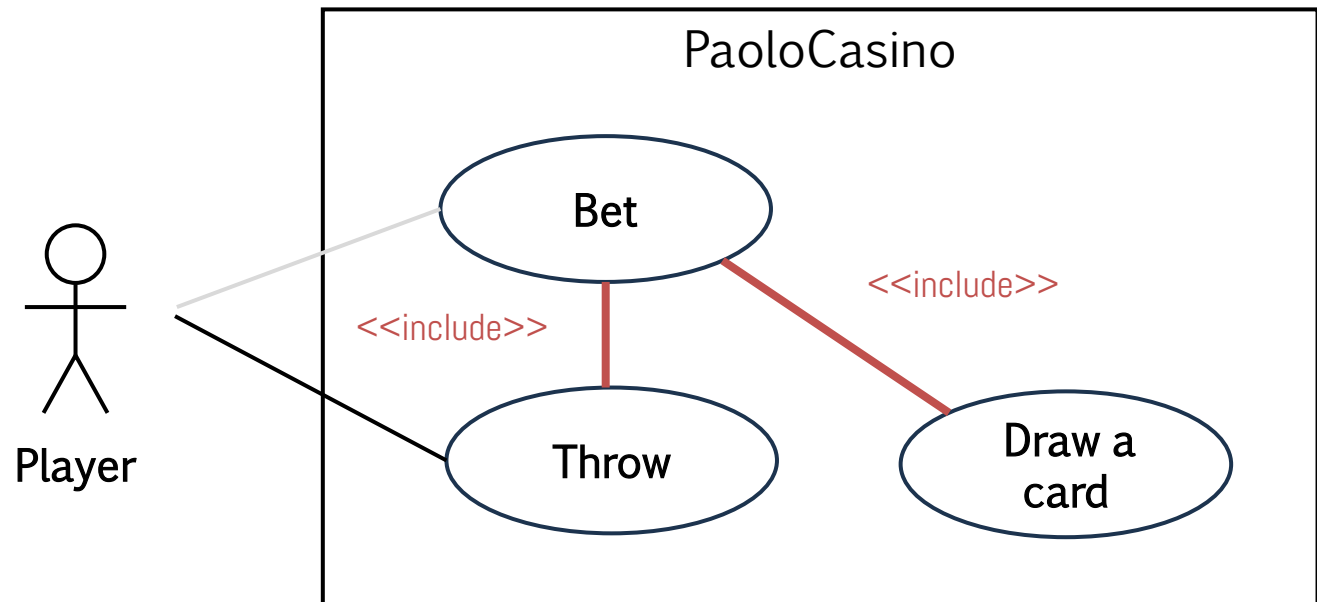
- › First, place the bet, then throw the die
- › Theoretically, Player only “sees” the “throw the die” functionality (button)



# Inclusion

Used to express grouping reuse

- › We can also play/bet with cards, not only with dice





# How do I identify UCs (and scenarios)?

---

Actor-based vs process-based identification

- › For every actor, model the interaction

vs

- › For every interaction, identify the actors

Use case diagrams

- › Are the starting point for system designers
- › Gives a good approximation of the dimension and complexity of the system
- › We can write user guides out of them!

This is an iterative process



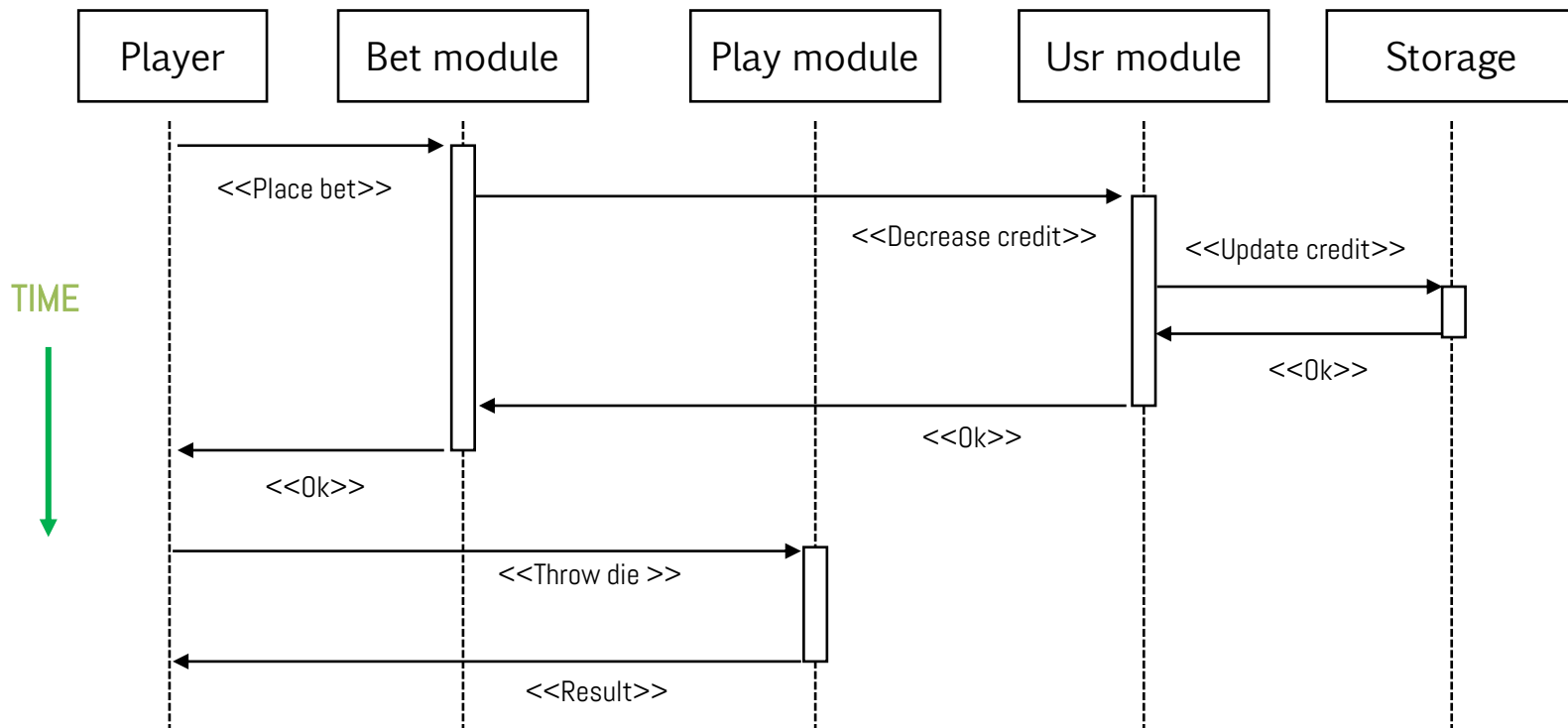
# Sequence diagrams





# Sequence diagrams

- › Focus on Actors, and the data they exchange with the system
- › Describe the interaction, by means of Messages, objects, etc
- › They describe the timeline of a scenario

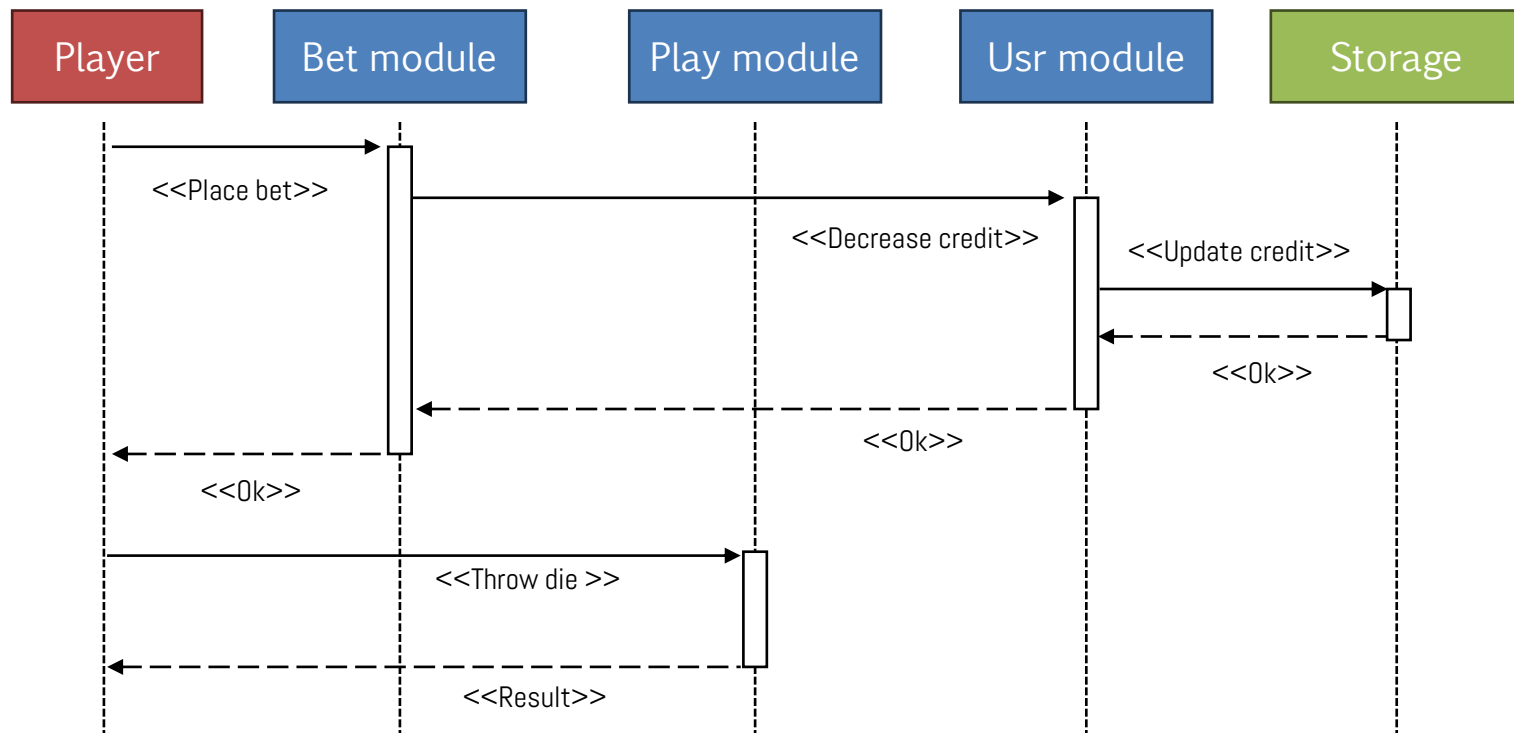




# Sequence diagrams (cont'd)

Objects are entities, in our system

- › Represented as a rectangle
- › Can be **Actors**, **Modules**, Classes, **DBs**....

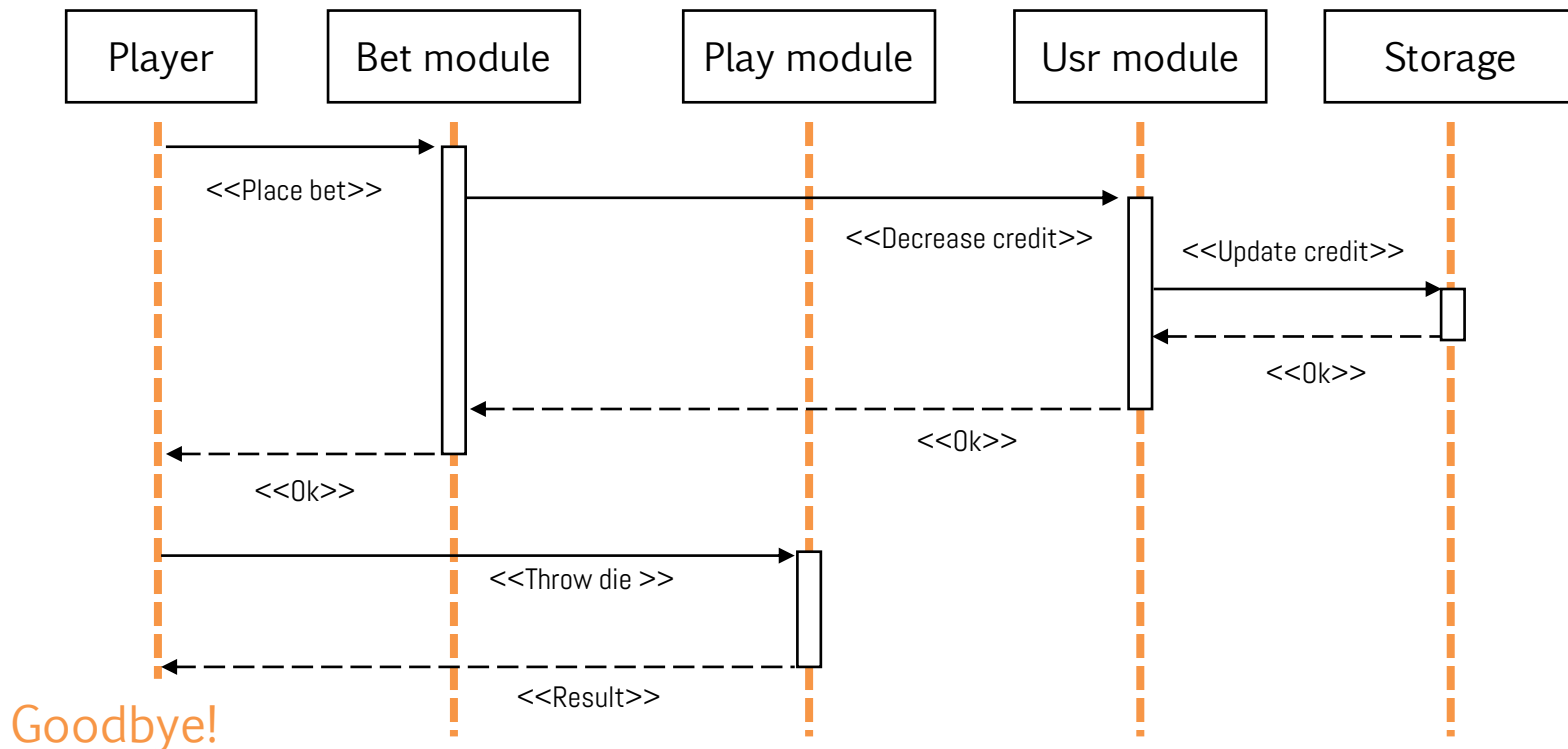




# Sequence diagrams (cont'd)

Lifetime represents when an entity exists

- › For classes and objects, it is extremely meaningful
- › Especially, if you don't have implicit memory mgmt, e.g., non-OO languages



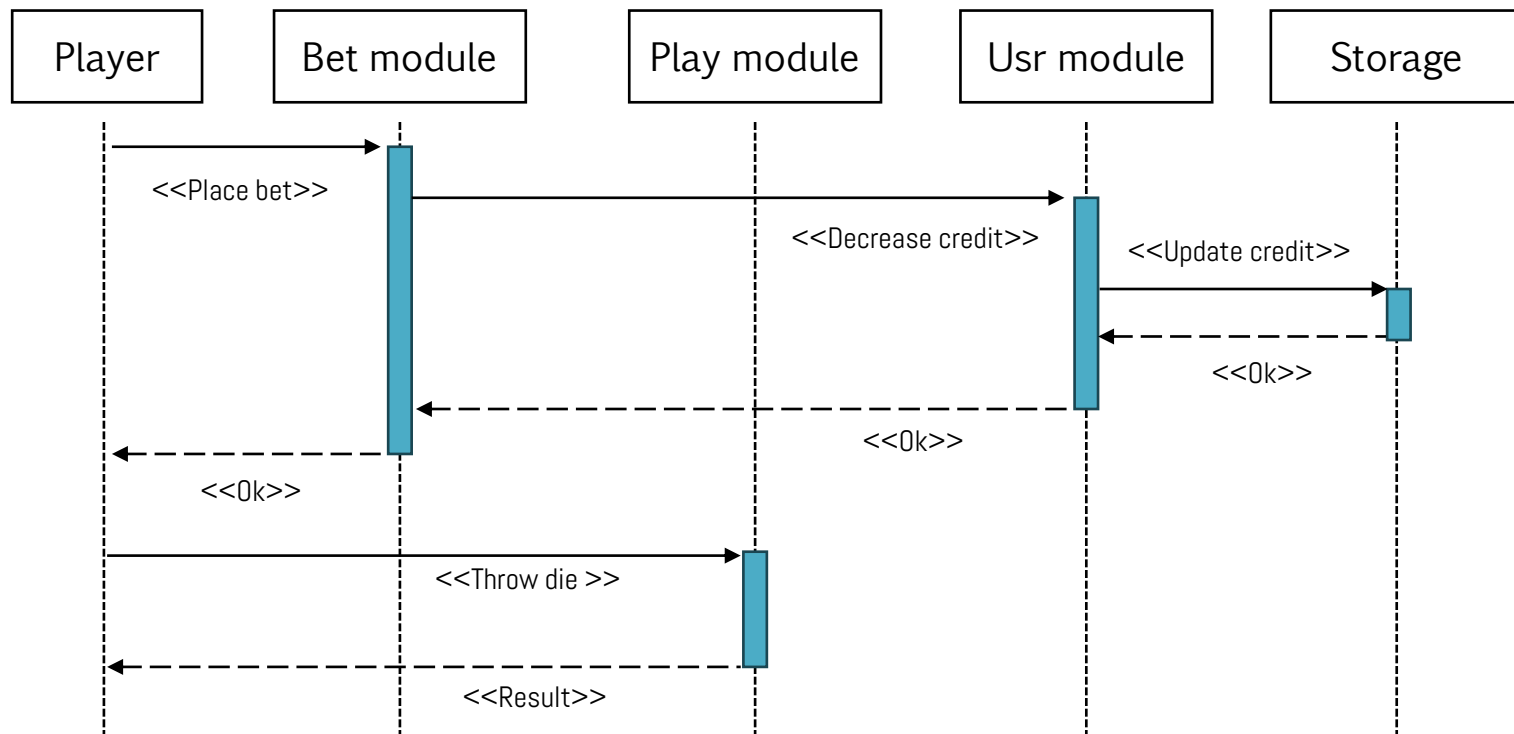




# Sequence diagrams (cont'd)

## Focus of control

- › Rectangle on the lifeline
- › The objects **synchronously locks** the interaction

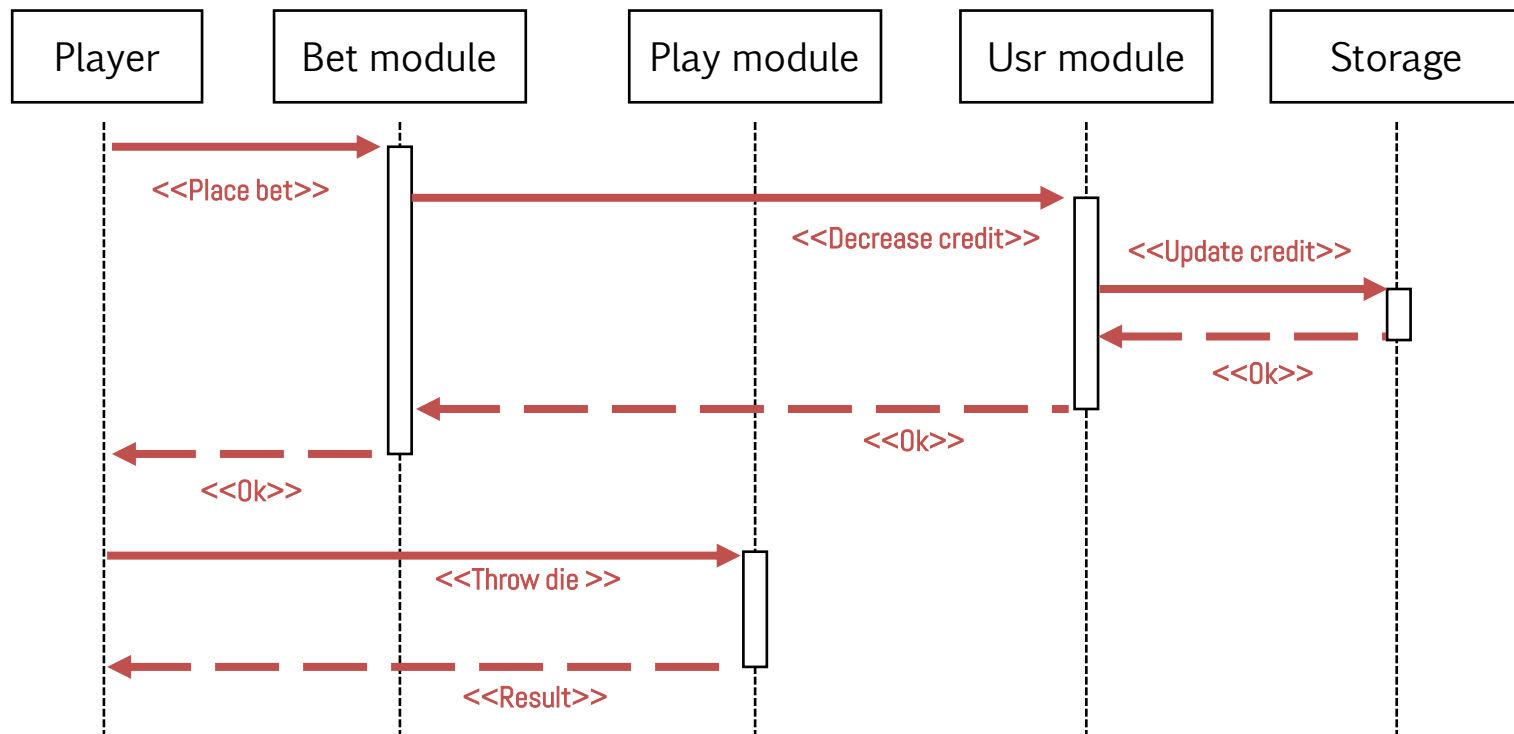




# Sequence diagrams (cont'd)

## Stimula

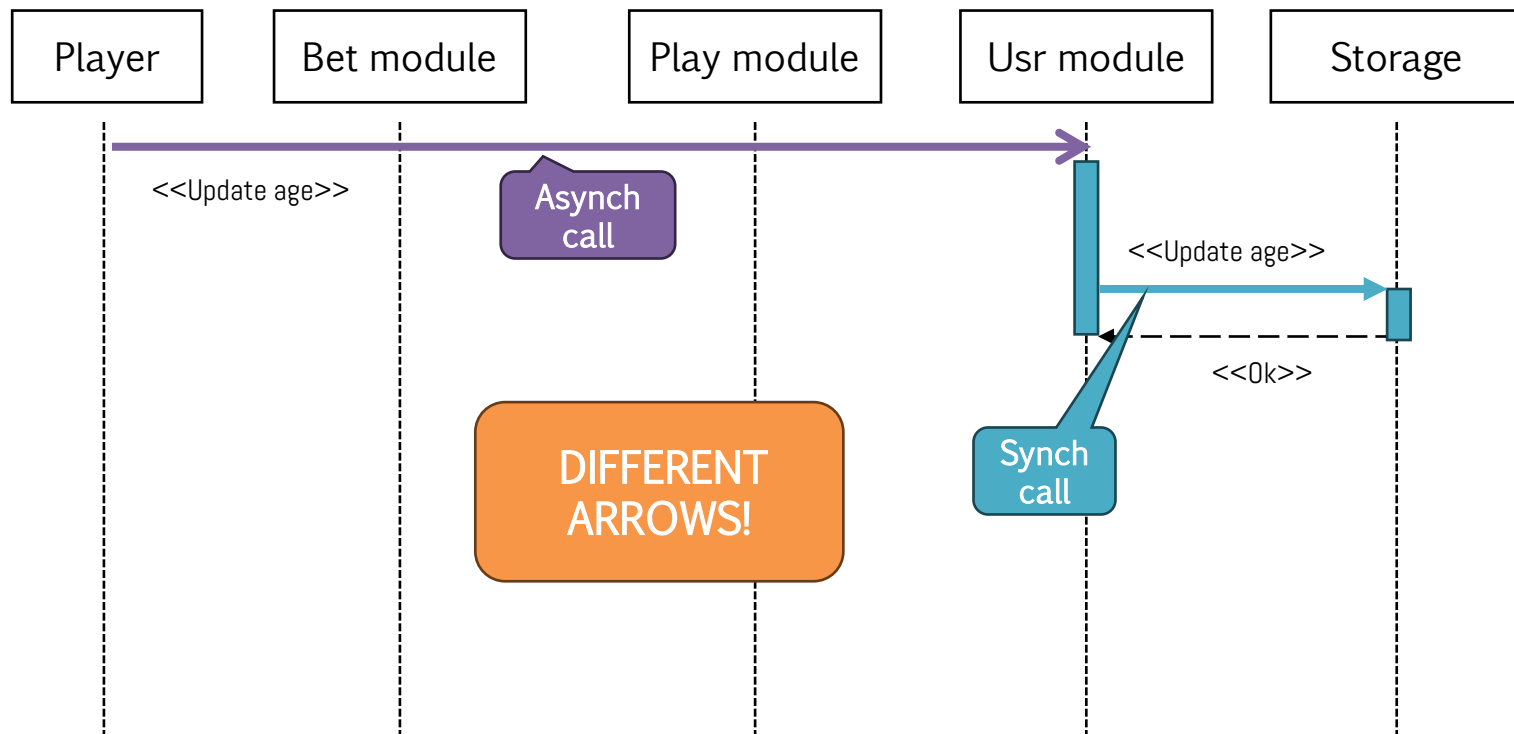
- › Represent calls, invocations (with brief description)
- › For synchronous calls, dotted arrows are the return/response
- › Not necessary to model also the transferred data



# Sequence diagrams (cont'd)

Asynchronous focus of control

- › Fire and forget semantics
- › Ex: update user age





# Stimula and messages

---

Stimula abstract messages, who represent/trigger **Actions**

- › **Call/Invokation**, e.g., of a function, an endpoint etc
- › **Return**
- › **Send** a signal or a message
- › **Create** or **destroy** objects

Message can be aggregated onto sequences

- › To model complex interation / state changes
- › In this case, might be useful to use numbering to explicit sequencing/ordering



<<1. Place bet>>



<<2. Throw die >>



# Types of messages

---

- › Constructors, destructors
  - For objects
- › Read/query
- › Update
- › Collaborate / trigger an action
- › Iterative (e.g., to specify that the entity on which we work is a list of items such as Java Arrays, Dictionaries, Lists)
- › Marked with \*

Example: HTTP verbs

- › POST, GET, UPDATE/PATCH, DELETE (CRUD)
- › But also PUT, OPTIONS, ...



# Homework

---



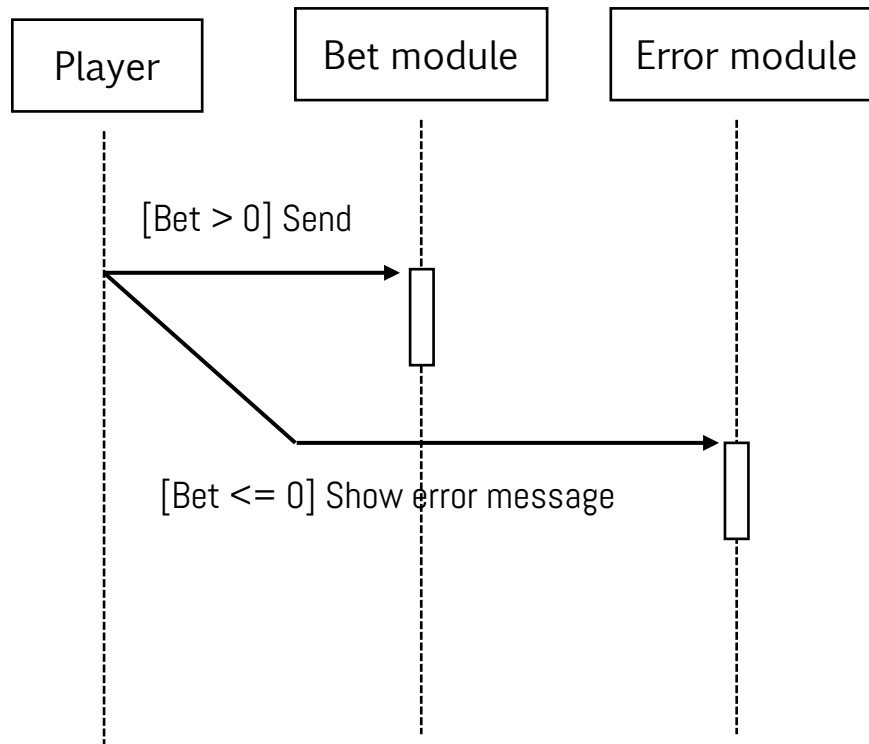
Write the sequential diagram of a simple web server

- › That supports all HTTP verbs on a sample endpoint
- › `https://<myserviceurl>/me`
- › E.g., handle user infos



# Conditional execution

- › IFs are represented as []

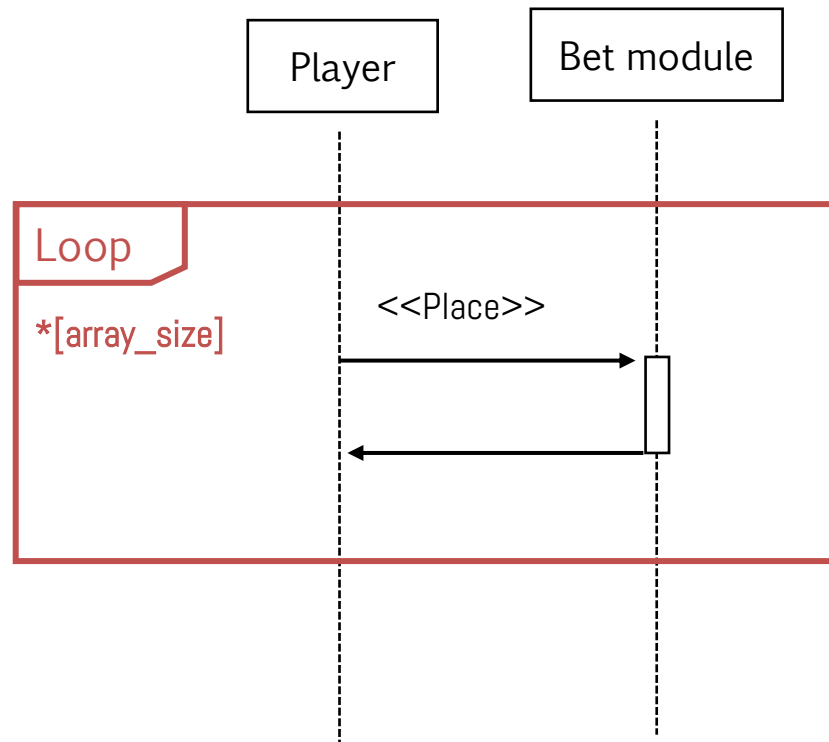




# Loops

Loops are represented as `*[]`, and squares

- › E.g., Place multiple bets by a list



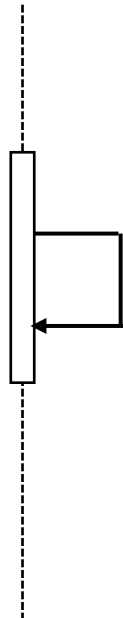




# Recursion

---

Some  
module





# State diagrams



# Stateful entities

---

State diagram to represent the lifecycle of an entity, typically classes/objects, by means of

- › Events and Actions
- › States
- › Transitions
- › Guards

State defined as:

*a consistent, meaningful set of attributes of an entity/object, that affects its behavior*

- › Initial and end pseudo-states
- › Initial state after creation/boot, etc
- › End state might not exist (for persistent entities)

# Graphical representation

By standard, a rounded square

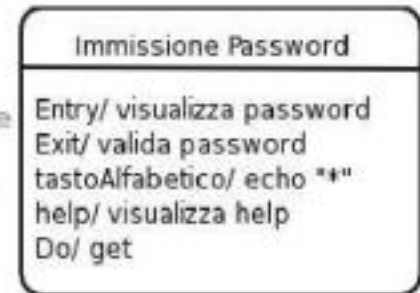
› (fill with useful information/state/behavior)

nome dello stato

azioni di ingresso e di uscita

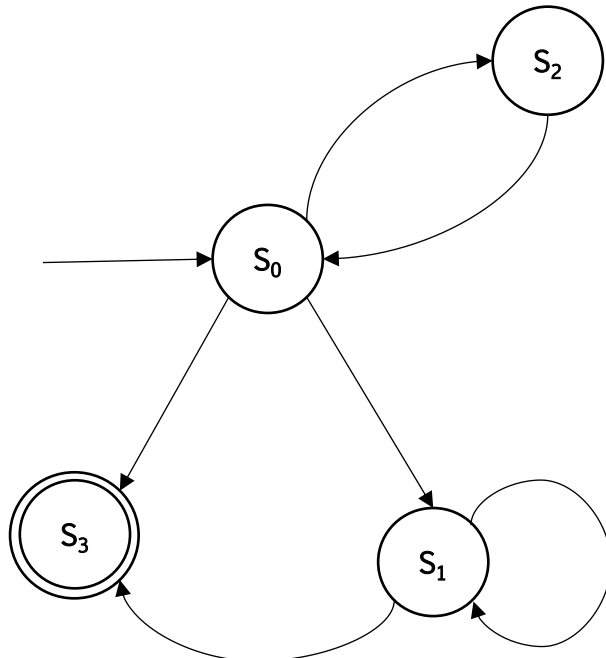
transizioni interne

attività interna



Sintassi dell'azione: **evento/ azione**

Sintassi dell'attività: **Do/ attività**



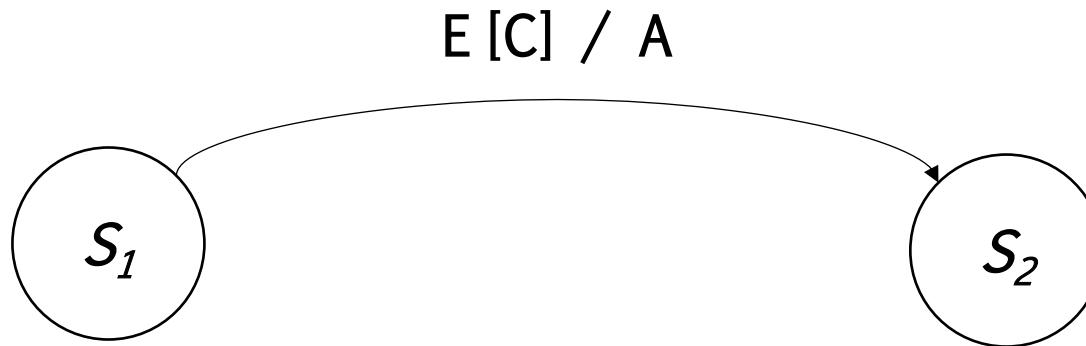
Or (non-standard) circles/ovals

› Useful when we don't have many details

› System-wide

# Arcs - State transitions

---



This means:

- › If we are in State **S1**
- › And Event/Trigger **E** happens
- › If Condition/Guard **C** is satisfied
- › Then we execute Action **A**, and we enter State **S2**



# Transitions and guards

---

event [parameters] [guard] / action

- › Events can have parameters
- › Guards are conditions that “block” the transition, if not satisfied
- › Action is a (typically small) piece of computation task that is executed as soon as transition is triggered
  - States can also contain (more complex) activities!



# Events

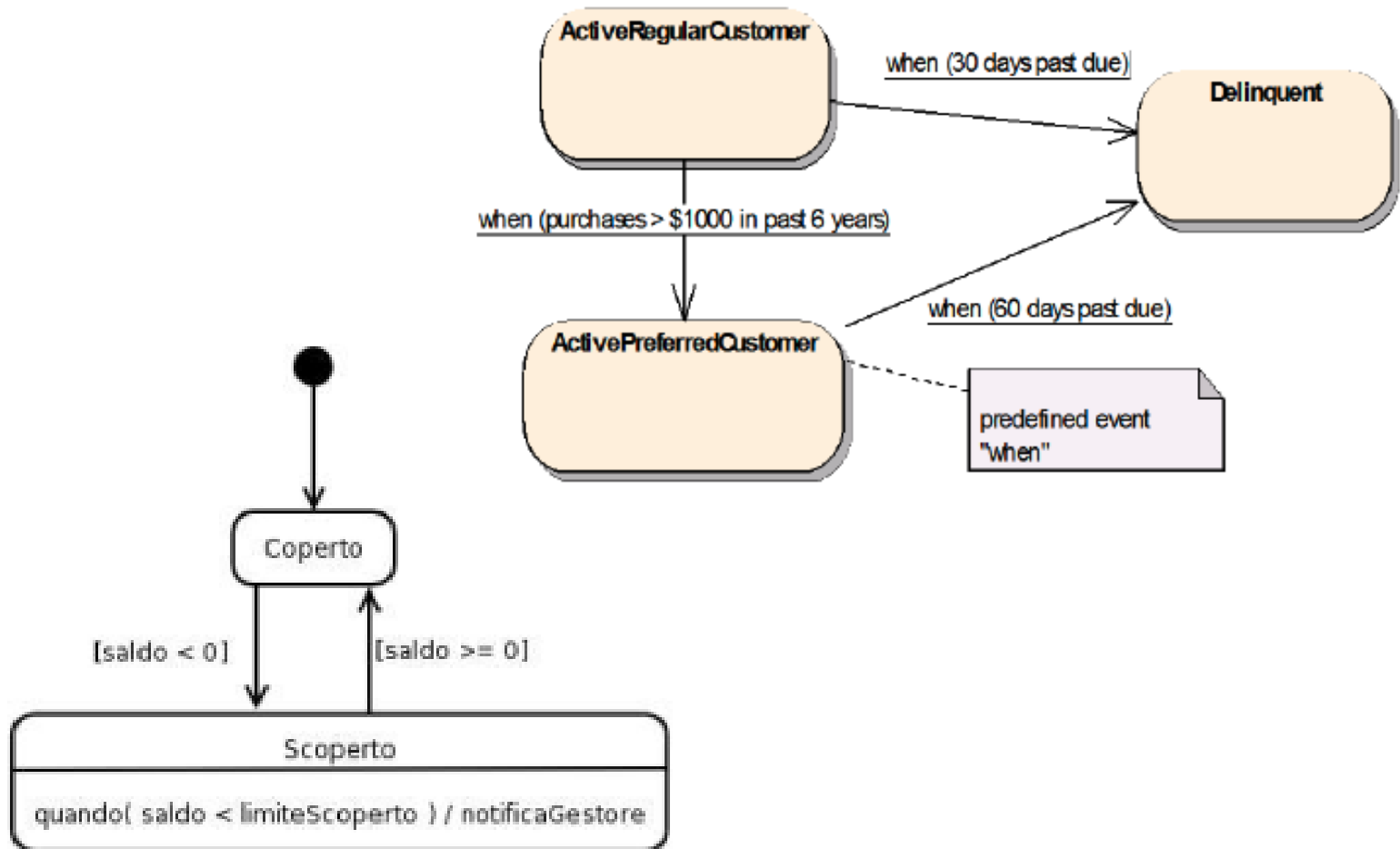
- › Trigger state transitions
- › In Sequence Diagrams, modeled as Message
- › Together with States, trigger object responses (Mealy vs. Moore...)



They can be:

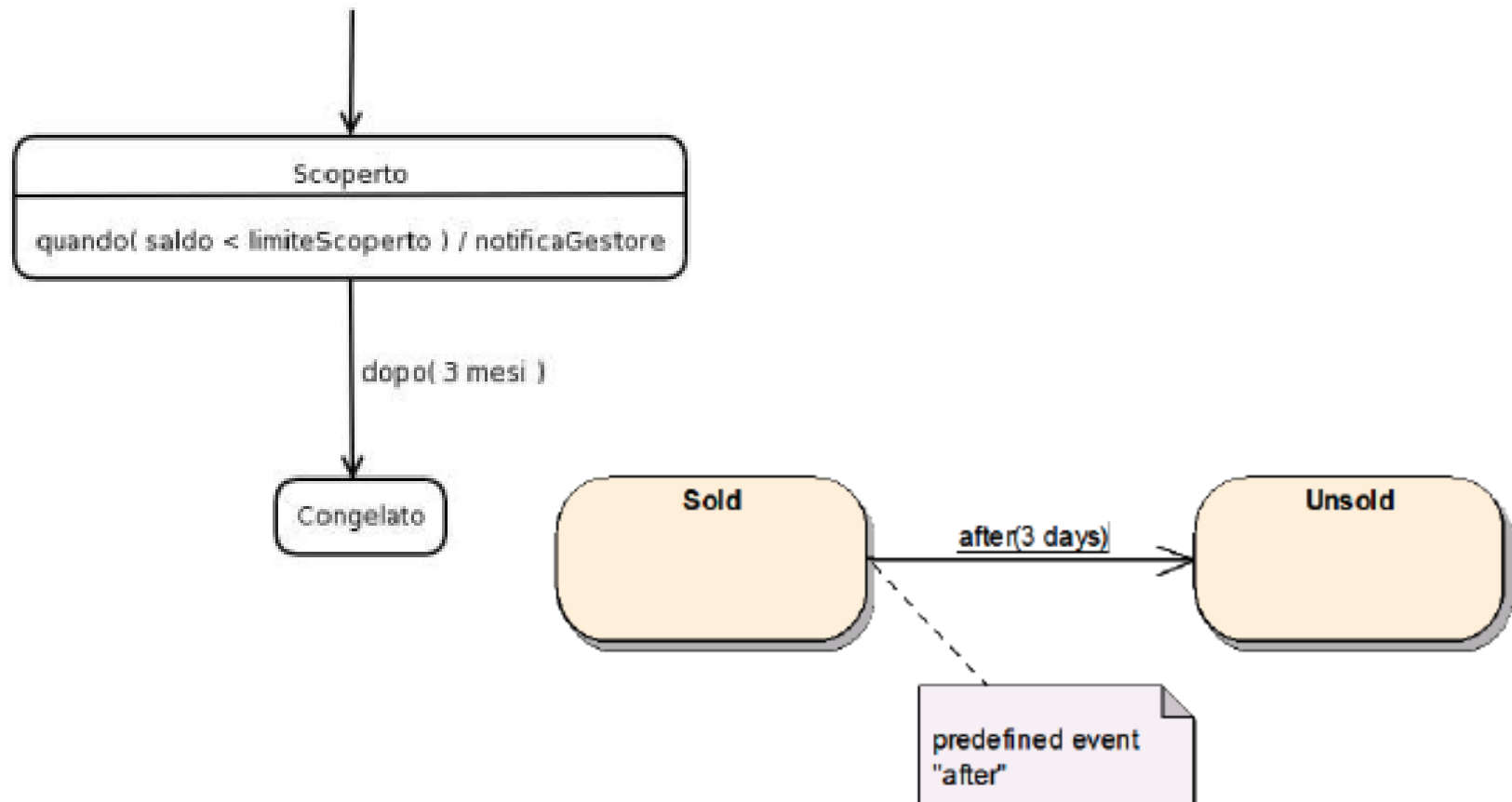
- › Synchronous method invocation ("call")
- › Asynchronous method invocation ("signal")
  - ex: throw exception, interrupts
- › A condition turning true or false ("change event")
- › An expired timer/counter ("elapsed time event")

# Change events





# Time events





# Activities and Actions

---

- › Inside states, there can be

## Activities

- › Non-atomic
- › (Typically) they do not alter object state

## Actions

- › Smaller, atomic
- › They alter the object state



# Actions

**Entry:** executed as soon as the object enters a given state

› entry/action name

**Exit:** executed as soon as the object exits from a State, due to a transition

› exit/action name

**Do:** executed as soon as the object is in a State

› do/action name

**Include:** invokes a «submachine», another state diagram

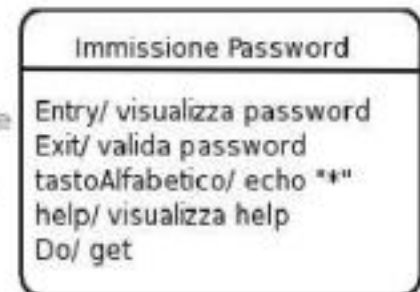
**Event:** actions happen as a response to an Event/trigger

nome dello stato

azioni di ingresso e  
di uscita

transizioni interne

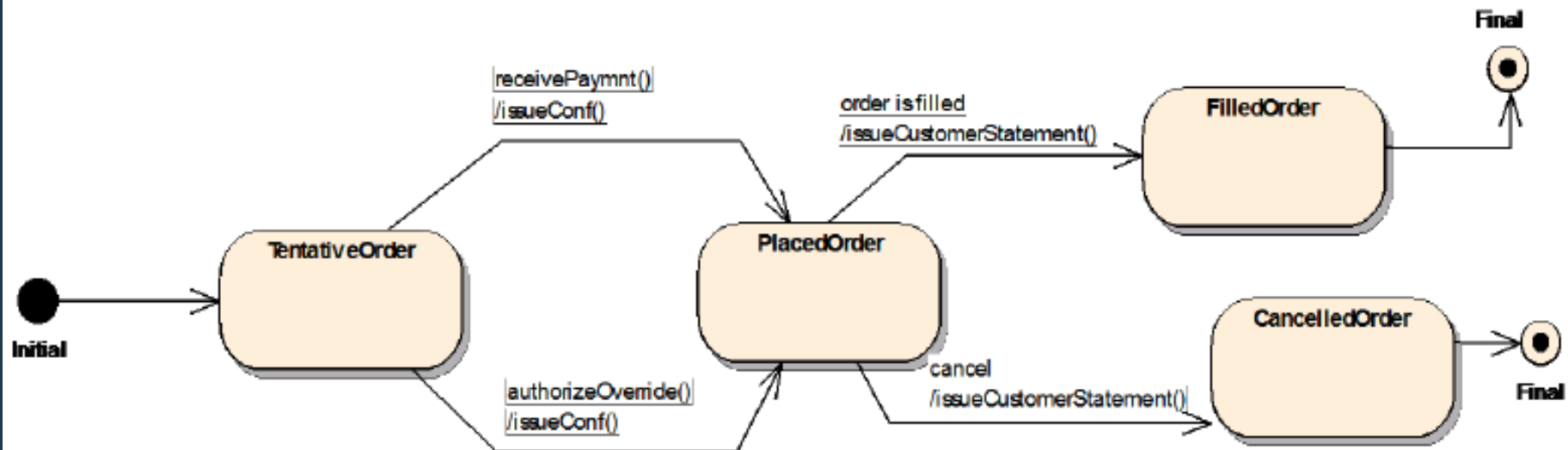
attività interna



Sintassi dell'azione: **evento/ azione**

Sintassi dell'attività: **Do/ attività**

# Actions: example





# Actions: sequence

---

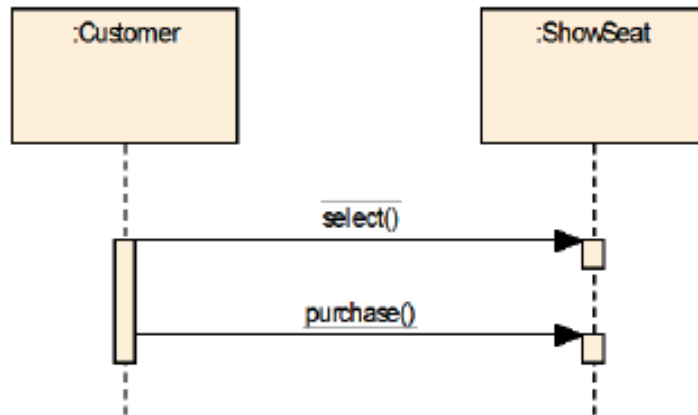
When an event triggers a transition

- › Executing activities are interrupted ("gracefully", we hope...)
- › Run the Exit action of the «old» state
- › Run the Event action
- › Run the Entry action of the «new» state
- › Run Do actions of the «new» state

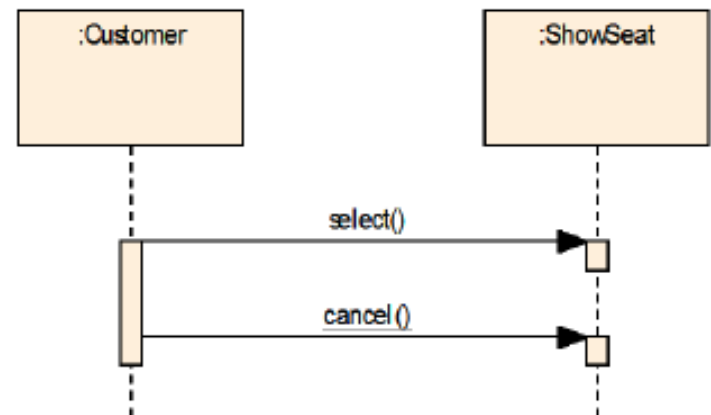
# Actions: success vs. failure

- › 2 scenarios (modeled in sequence diagrams)

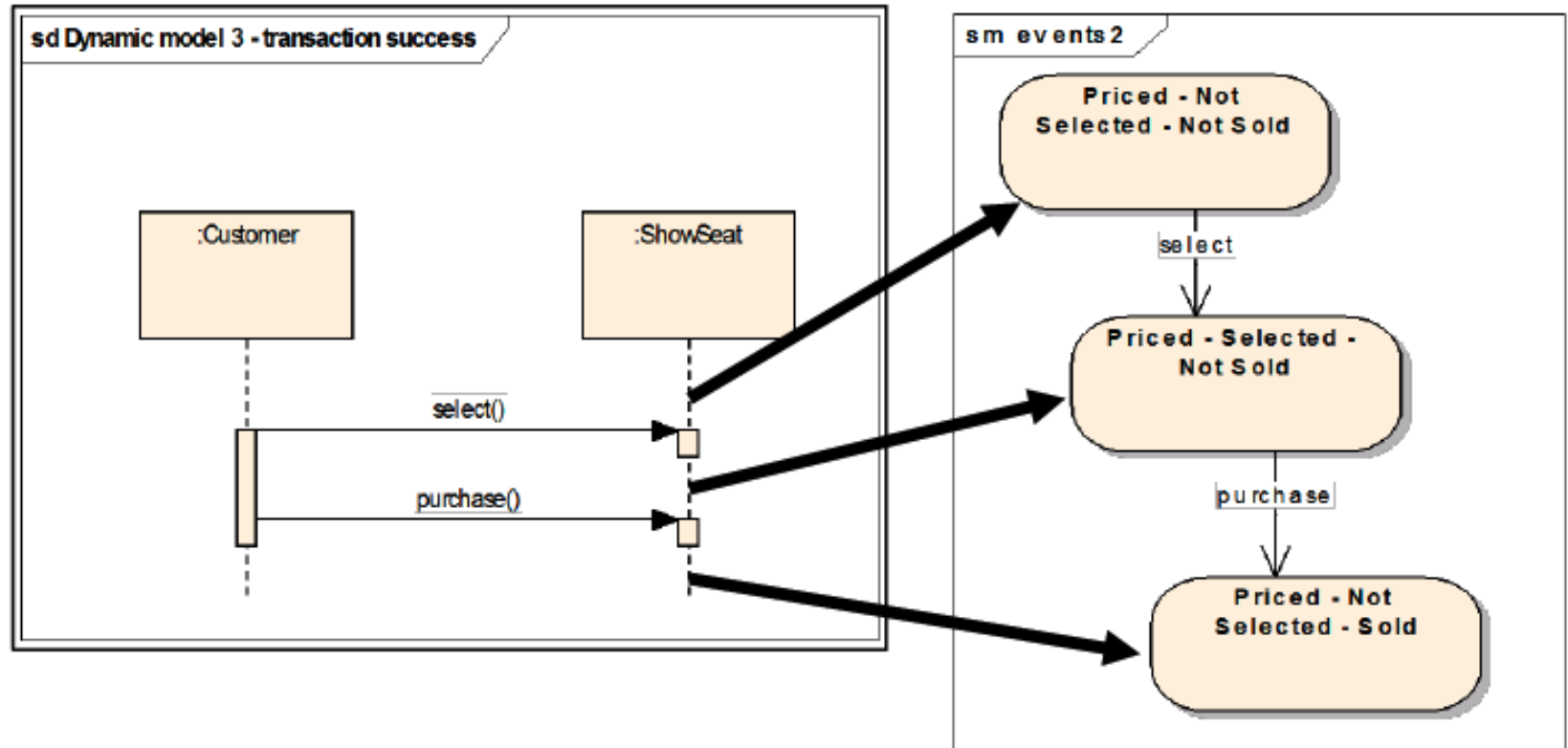
sd Dynamic model 3 - transaction success



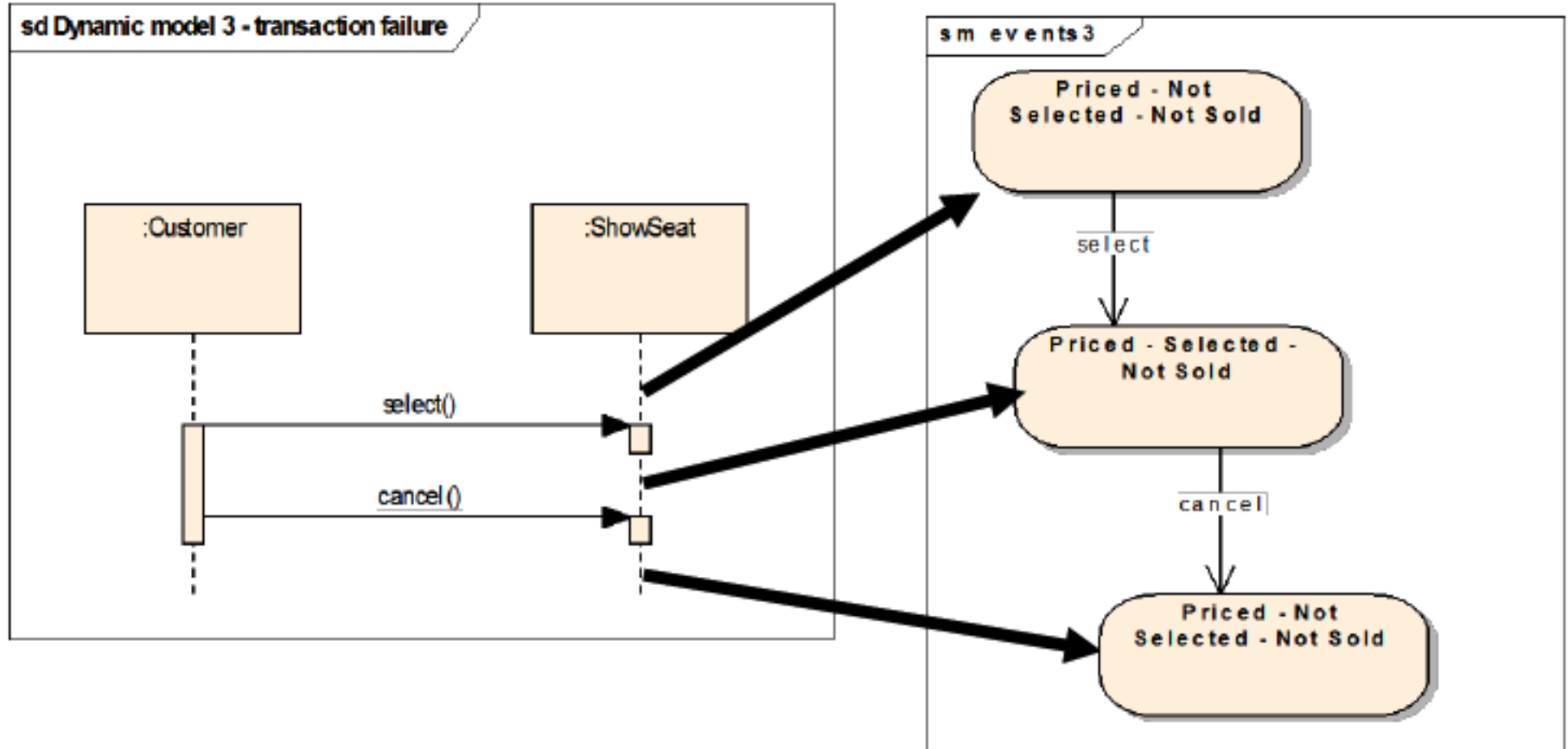
sd Dynamic model 3 - transaction failure



# Action: success scenario

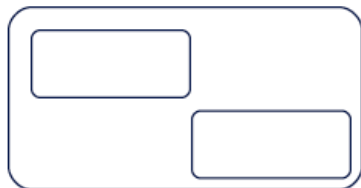
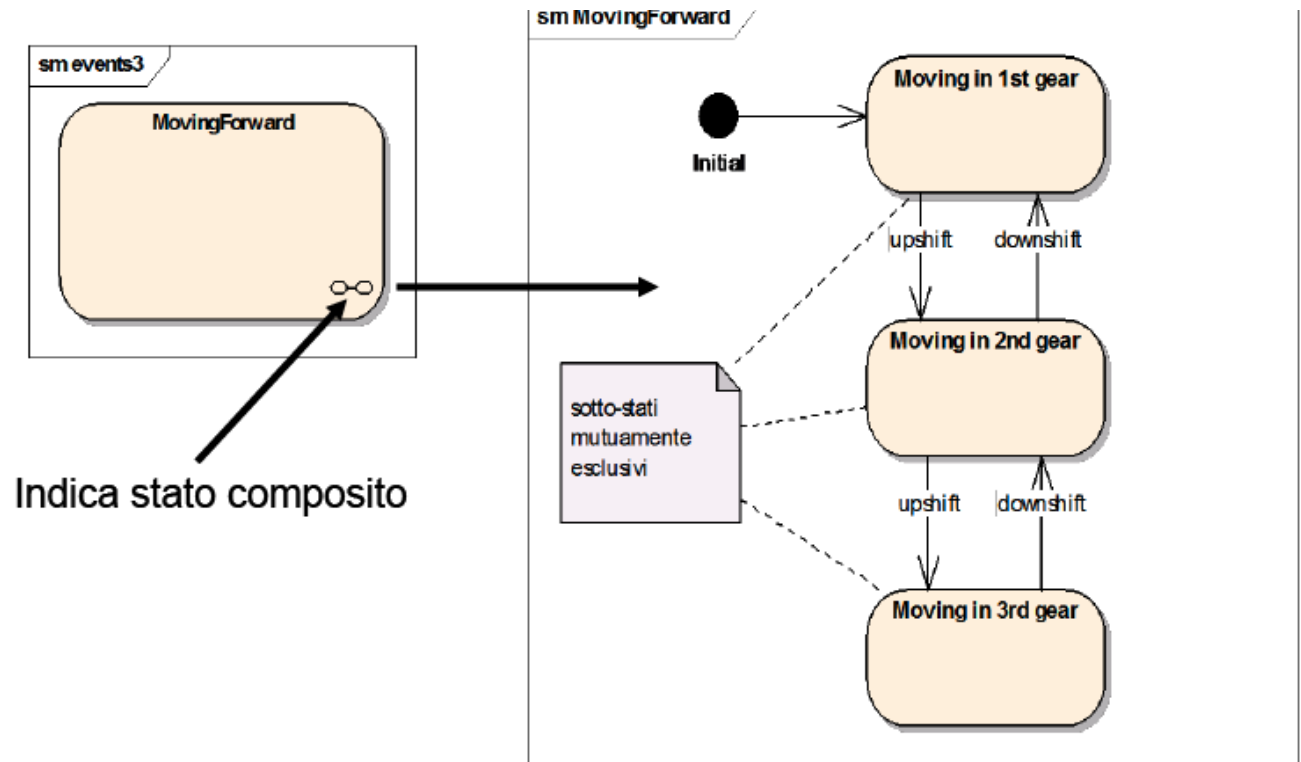


# Action: failure scenario



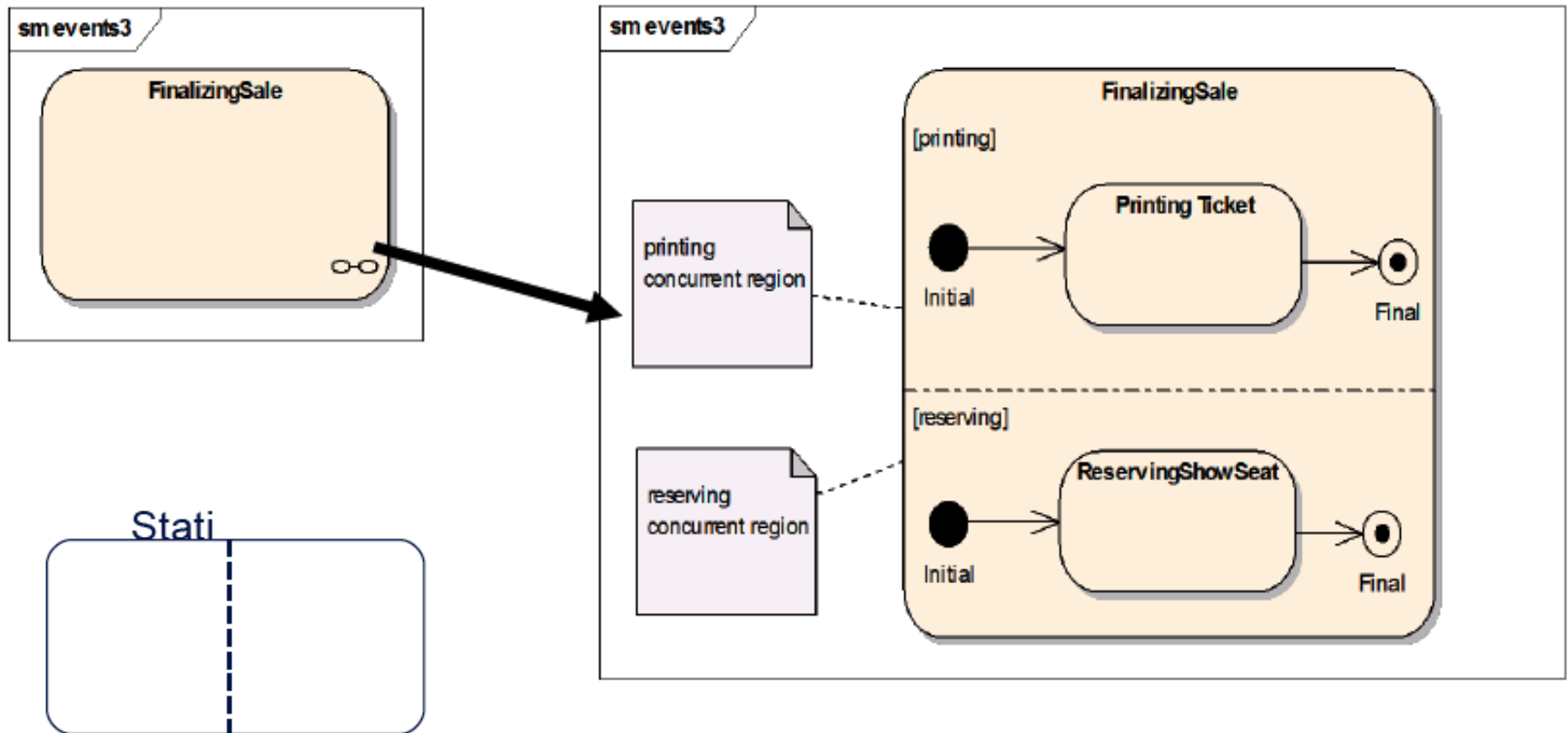


# States and mutual exclusion

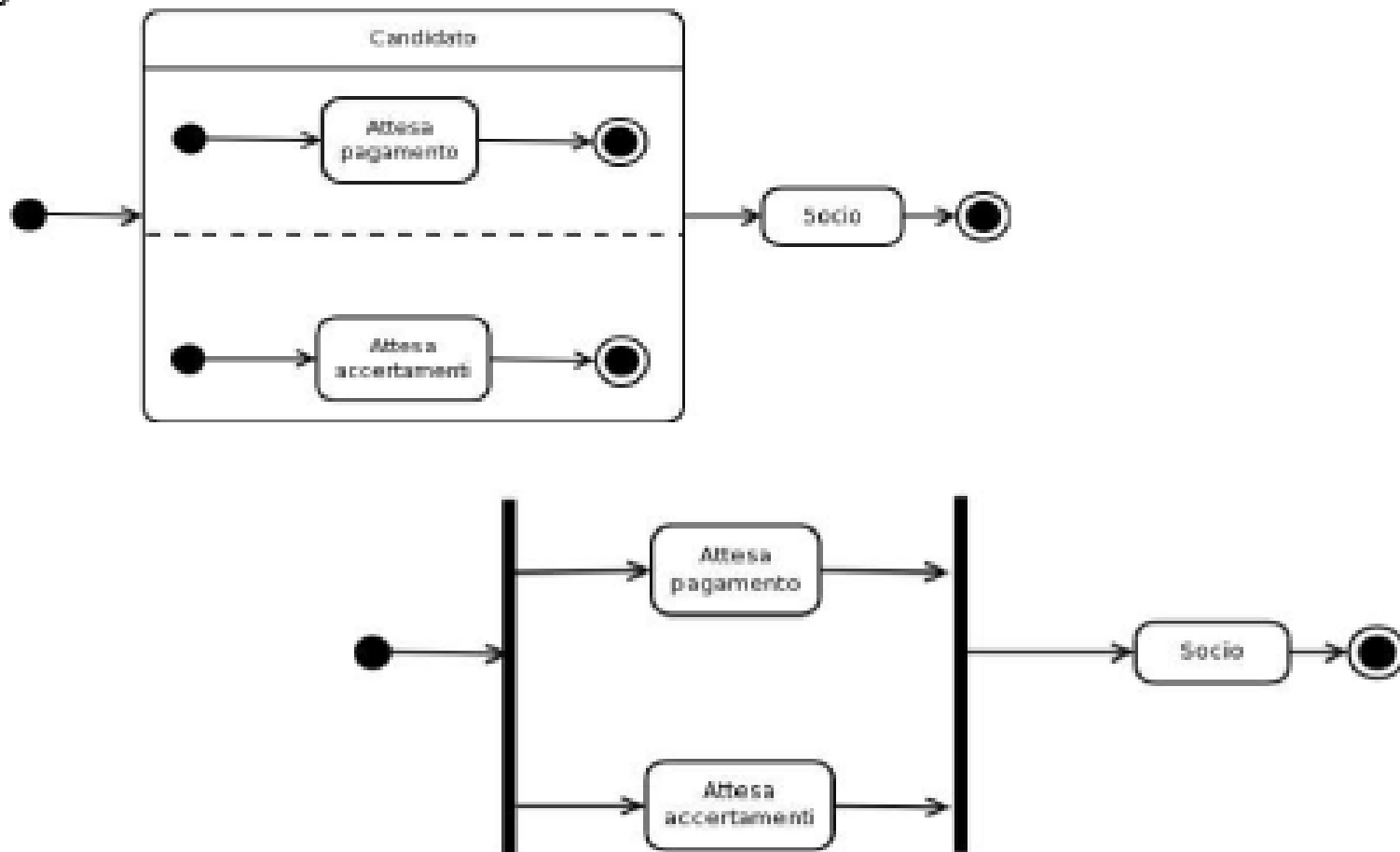


- › Or decomposition (of sub-states)

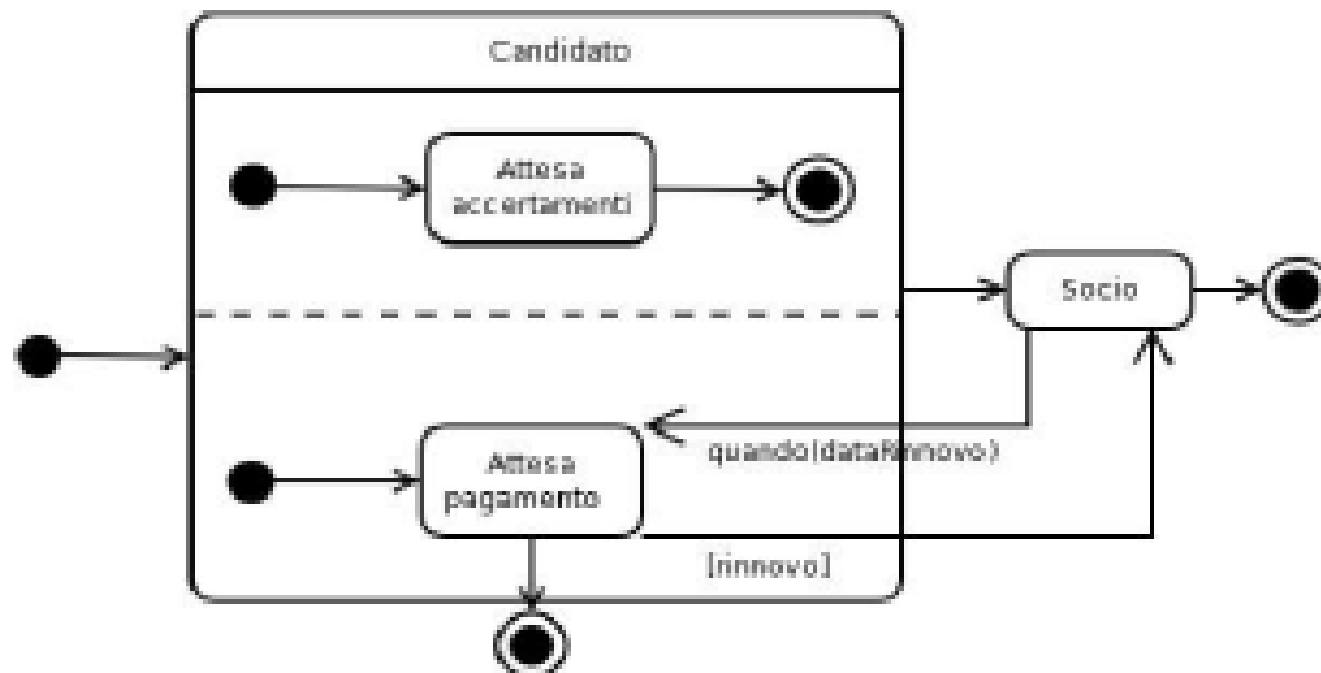
# Concurrent states



# Alternative states/scenarios

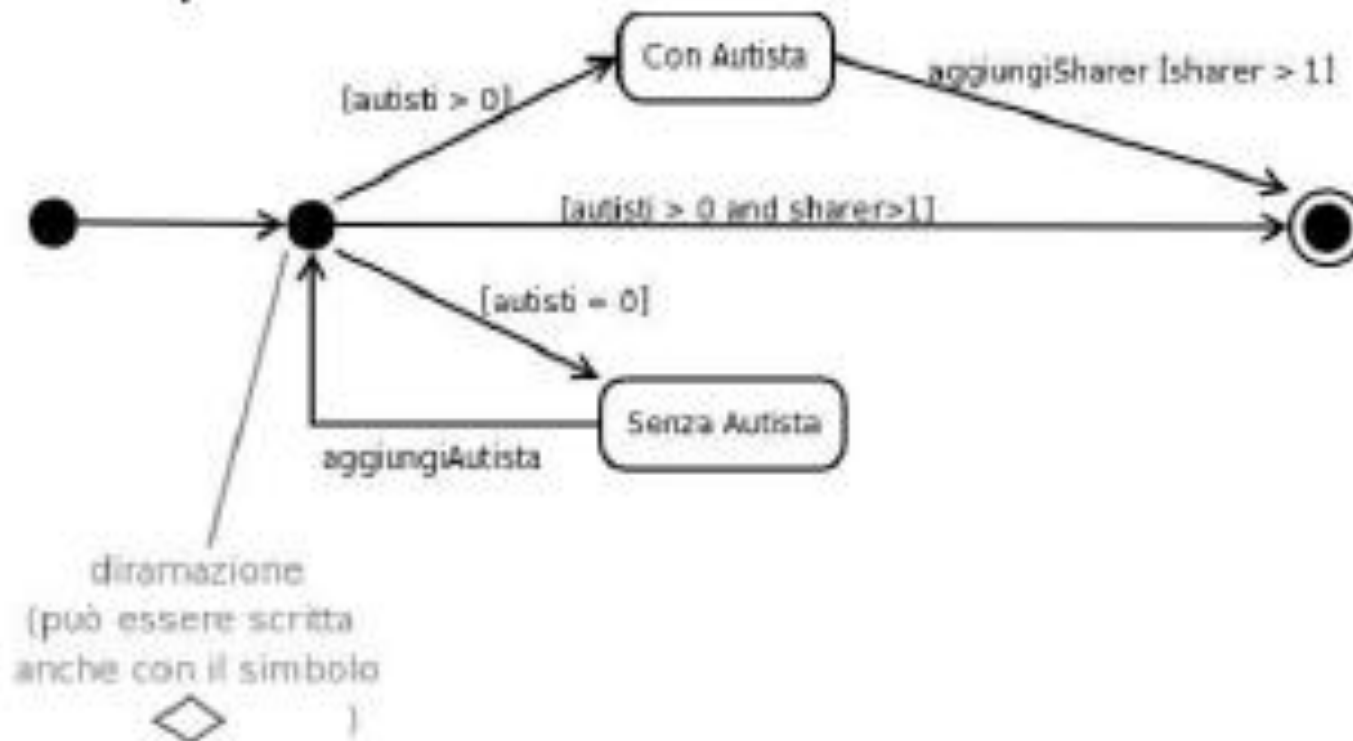


# Composite states



# Conditional branching

- › Same trigger/event, different conditions, bring to different states





# Activity diagrams



# Activity Diagrams in a nutshell

---

Model the behavior of any entity in the system, for every state

- › “Object-Oriented” flow diagrams
- › They include (timing and spatial) dependencies
- › Give more detail of activities (and sub-activities) happen in every state, under inputs

# Actions, and transitions

**Action states** are atomic activities

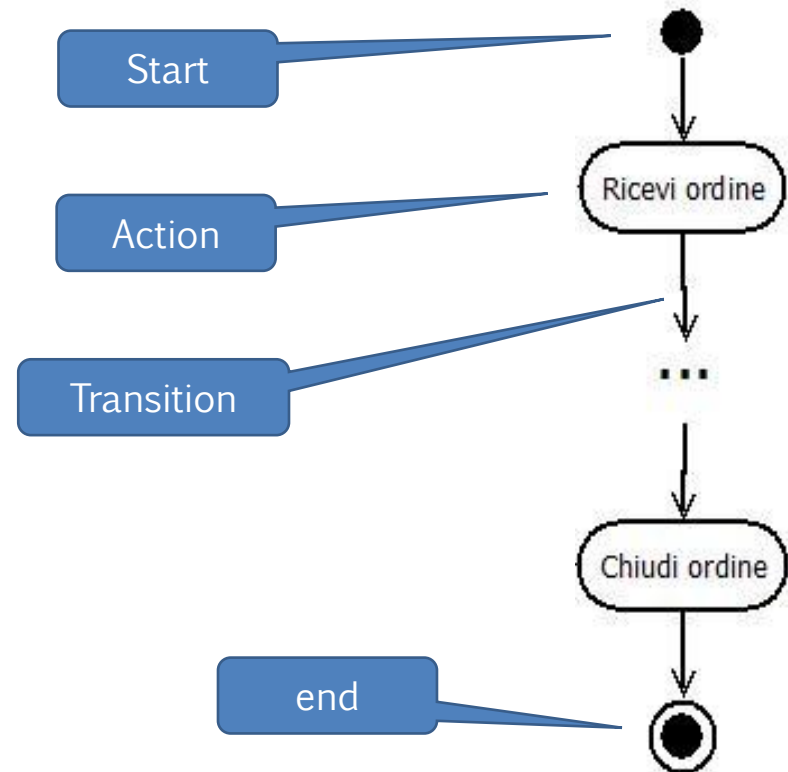
- › Cannot be split
- › Cannot be interrupted (preempted)
- › (In the model) happen instantly

Special states

- › Start/end state

**Transition**

- › When Action states ends





# Branching/Merging

## Branching based on condition

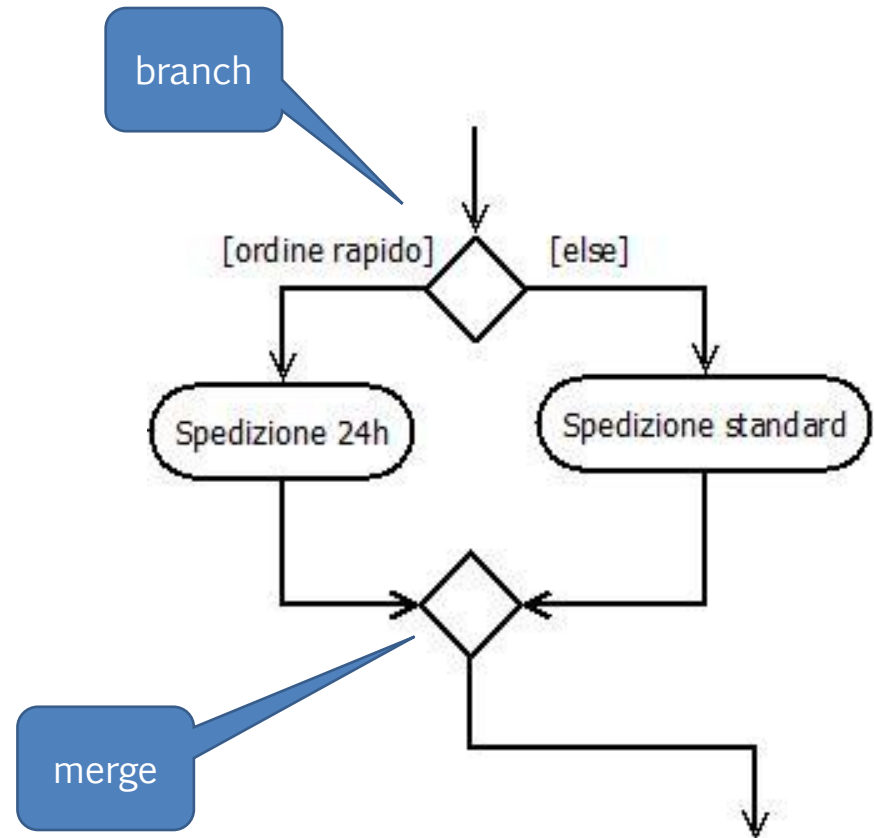
- › Captures IF-ELSE semantics
- › Rhombus: one-to-many

## Merging

- › Rhombus: many-to-one

## Important

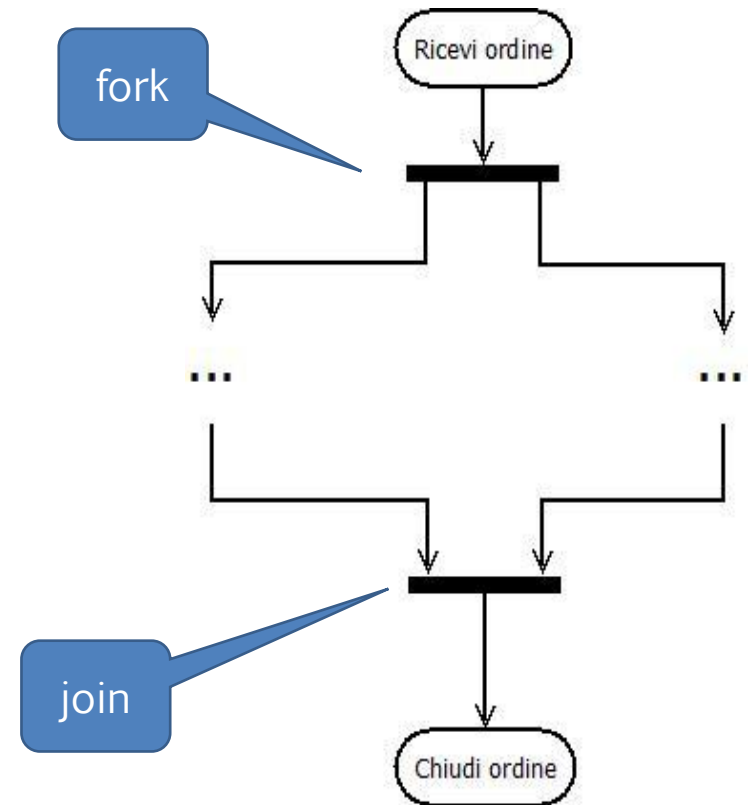
- › You do not have to model the whole application!
- › Choosing the right abstraction level, lets you cut the clutter



# Fork/Join

Model concurrent actions

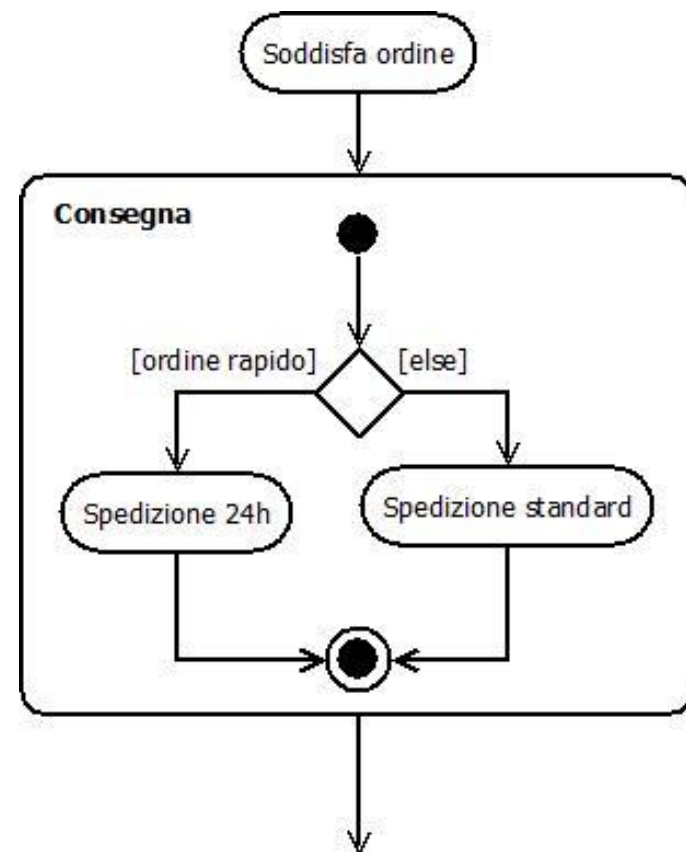
- › Implemented with parallel threads/processes..
- › Join point represent
- › (We'll go back to this..)



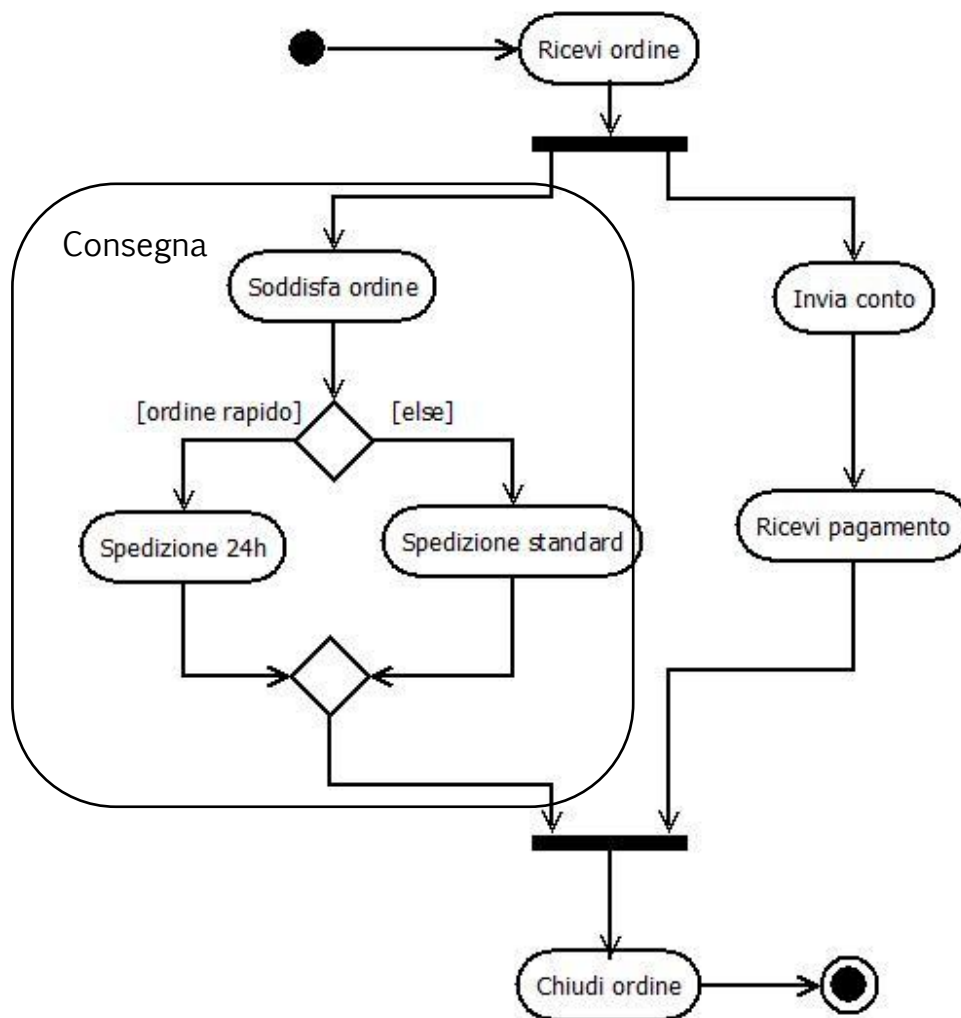
# Sub-activity states

Group activity states /subdiagram into macro functionalities

- › Non atomic
- › Can be interrupted
- › Non-zero execution time



# The full example





# Swimlanes

---

Group activities into areas

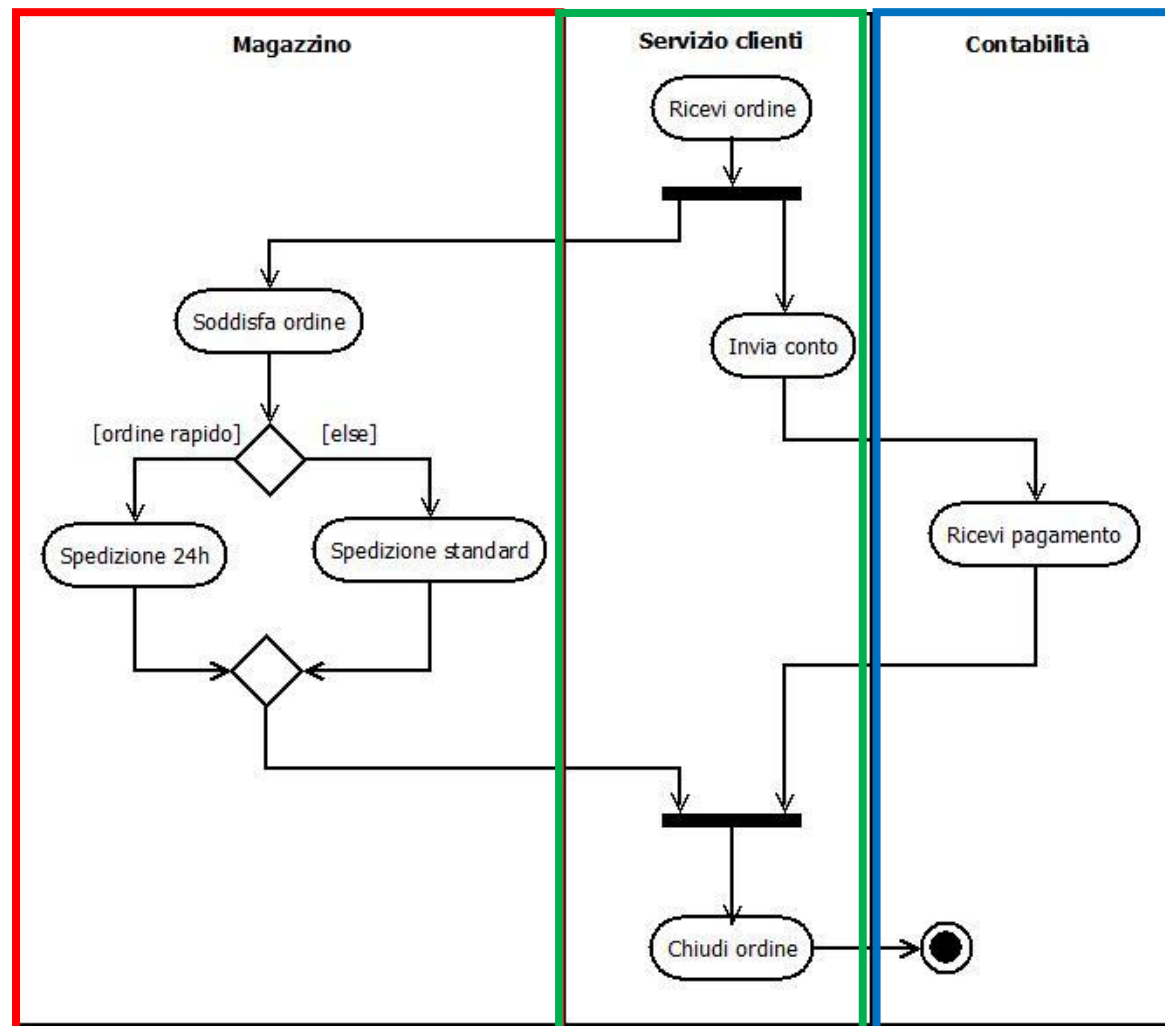
- › Partition the activity diagram

*What do we model with areas?*

- › Use cases
- › Classes/Objects
- › Components
- › Business units
- › Roles

# Swimlanes: example

› Here, areas = business units





# From Activity diagrams to Sequence diagrams

---

- › Activity diagrams identify scenarios, and we can/must write a Sequence diagrams for each of them!
- › Can use areas to model scenarios/use cases



## Course website

- › <http://hipert.unimore.it/people/paolob/pub/ProgSW/index.html>

## Book

- › I. Sommerville, "Introduzione all ingegneria del software moderna", Pearson
  - Chapter 3

## My contacts

- › [paolo.burgio@unimore.it](mailto:paolo.burgio@unimore.it)
- › <http://hipert.mat.unimore.it/people/paolob/>
- › <https://github.com/pburgio>