VII. Specifications (I)

Laurea Triennale in Informatica – Corso di Ingegneria del Software I – A.A. 2006/2007
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Objectives

- To discuss the importance of models for the definition of specifications
- To show formalisms that can be used to define system models
- To discuss properties and compare such formalisms
- To provide examples

Topics

- To distinguish among formal and informal specifications
- Operational vs. Descriptive Models
- Introduce some operational model:
  - Data Flow Diagrams (DFD)
  - Finite State Machines (FSM)
  - Petri Nets (PN)

- The material that will be discussed today and tomorrow is covered by [GJM] Chapter 5 and/or [Som] Chapters 8,10

How to increase Specification Qualities

- Spec should be: **Clear, Unambiguous, Understandable**
- Should not be: Contradictory or **Inconsistent, Incomplete**

- Models are description of the system abstracting away unimportant details, so to make the system "tractable"

- **Formal** specifications vs. **Informal** specifications
  - Use of formalisms make spec precise and augment automatic verification possibilities
  - Informal spec more flexible, leave more decision space to the implementer

- **Semiformal** often we use notation which semantics has not been defined so precisely (e.g. UML)

Formal Spec and Verification

- Formal specs are a powerful tool for **making easier many development phases** in particular for analysis and verification purpose
- Just some keyword:
  - Model Checking
  - Model Based Testing
  - Simulation and prototyping

Operational vs. Descriptive Specification

- **Operational specification** describe the system in term of the expected behaviour generally providing a model

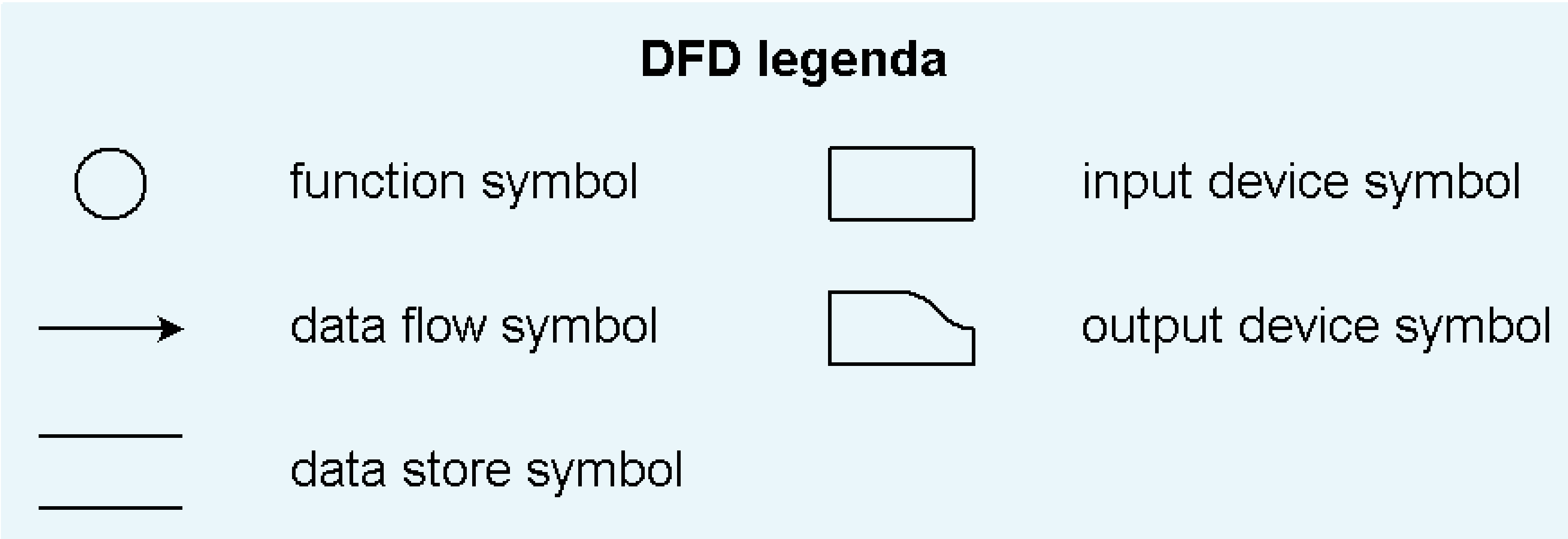
- **Descriptive specifications** describe the system in term of desired properties for the system

- An example from mathematics:
  - Take a string of length “r” and fix at one of its extreme a pencil. Then fix the other extreme to a sheet using a pin. Now tightening the string move the pencil over the sheet describing a circle.
  - $x^2 + y^2 = r^2$
  - **which one is a descriptive or an operational specification?**

Operational Specifications – DFD

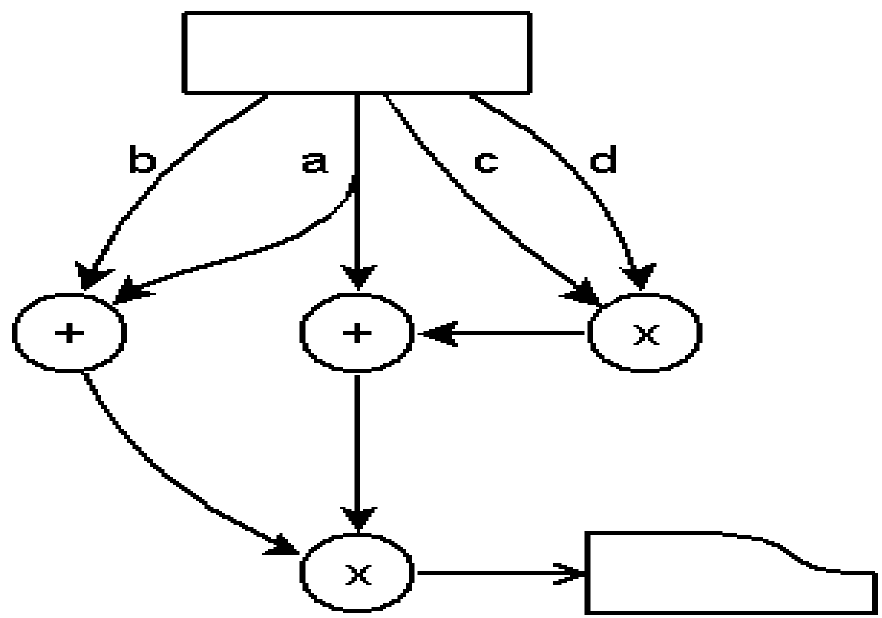
- Data Flow Diagrams:
  - Used to specify functions of a system and how **data flow** from functions to functions
- Systems are seen as collections of **functions that manipulate data**
  - Data can be **stored** in repositories
  - Data can **flow**
  - Data can be **transferred** from and to the external environment

DFD – graphical notation

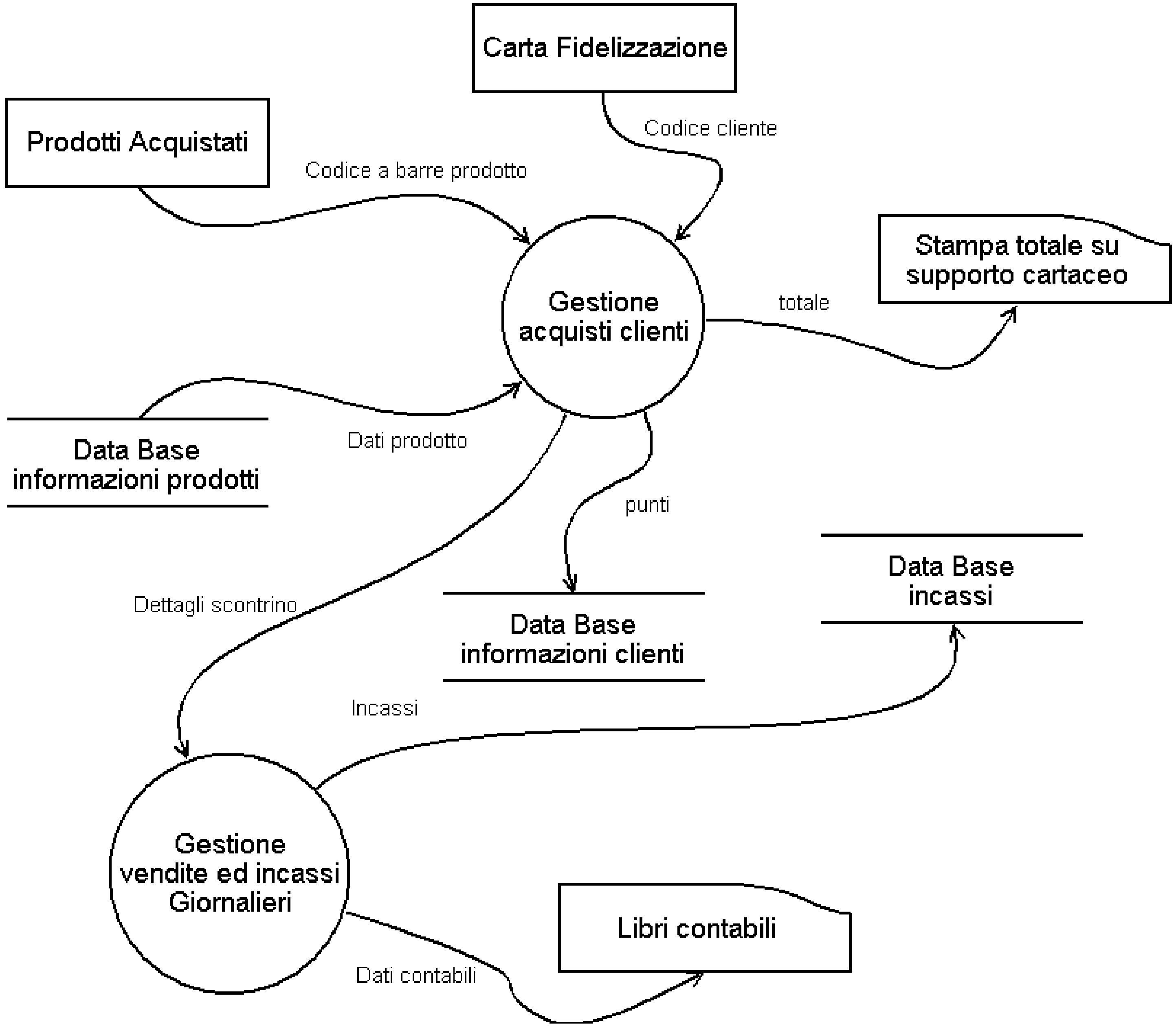


- Example – a simple arithmetical function:

(a+b)*(a+c*d)



DFD – a supermarket example (I)

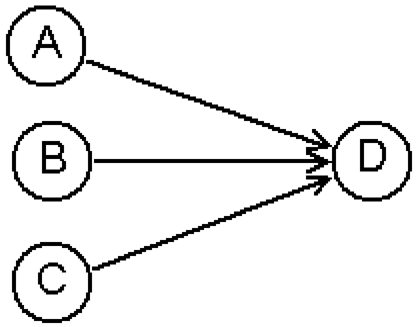


DFD – a supermarket example (II)

- The functionality "gestione acquisti cliente" is certainly a macro **activity that could be split**
- In case of supermarket wants to apply discounts for some products, in a certain period, to some clients, how these information could be introduced in the system?

DFD Characteristics

- DFD is certainly a **semi-formal** notation
- **Lack of precise semantics**:
  - Function definition can be defined more precisely using more formal description
- No concept of **control** in such kind of diagrams
  - Diagrams do not specify how data are used and output are produced
- **Synchronization** between functions is not specified



When the function D should start?

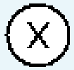
How to overcome DFD weakness

- Use of **complementary notation** to express those aspects that are not adequately described by DFD
- Augment the DFD introducing **mechanisms that allow to express the missing aspects**
- **Revise the traditional definition** of DFD to make it fully formal

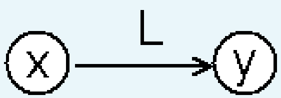
Operational Specifications – FSM

- A Finite State Machine (FSM) is an abstract automaton that permits to describe the control flow of a system
- Mathematically FSM are defined by:
  - A finite set of states Q
  - A finite set of input I
  - A transition function **δ:** Q x I --> Q
- A simple switch can be described by the following FSM:
  - Q = [On, Off]
  - I = [Switch]
  - **δ =** [(On,Switch) --> Off,
(Off,Switch) --> On]

FSM Symbols legenda

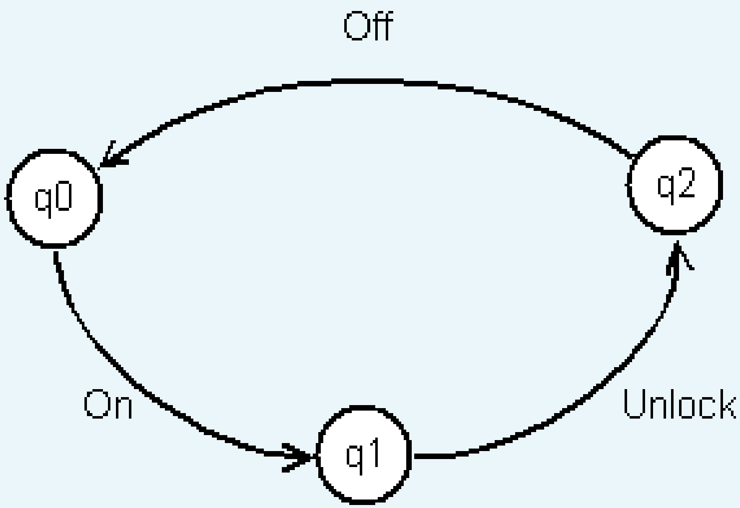


State symbol representing state X



Transition from state "x" to "y" after input "L" has been provided

- A simple example of an electrical equipment including a safety mechanism:



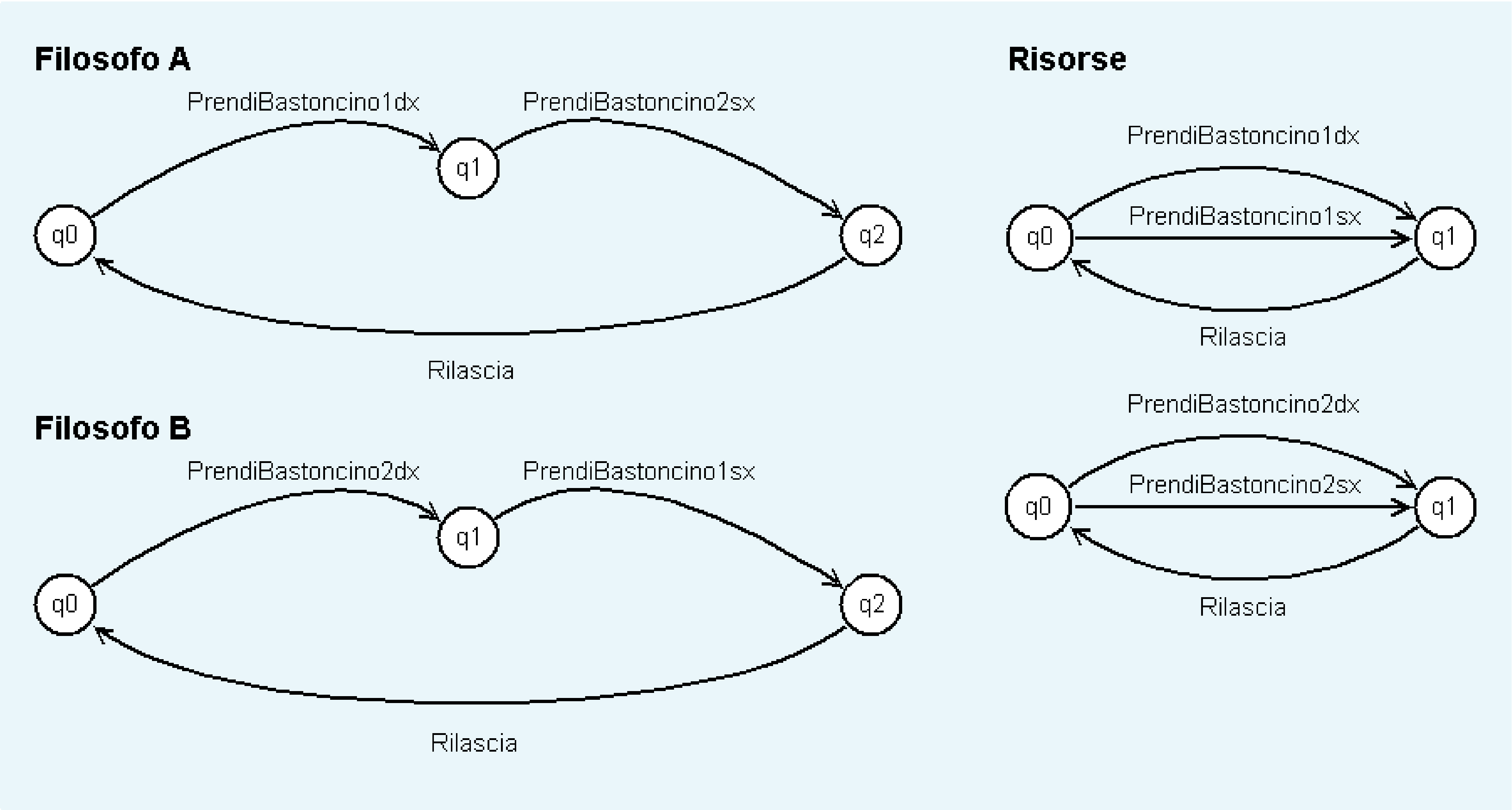
Q=[q0,q1,q2]
I=[On,Off,Unlock]

δ = [(q0,On) $\longrightarrow$ q1,
(q1,Unlock) $\longrightarrow$ q2,
(q2,Off) $\longrightarrow$ q0]

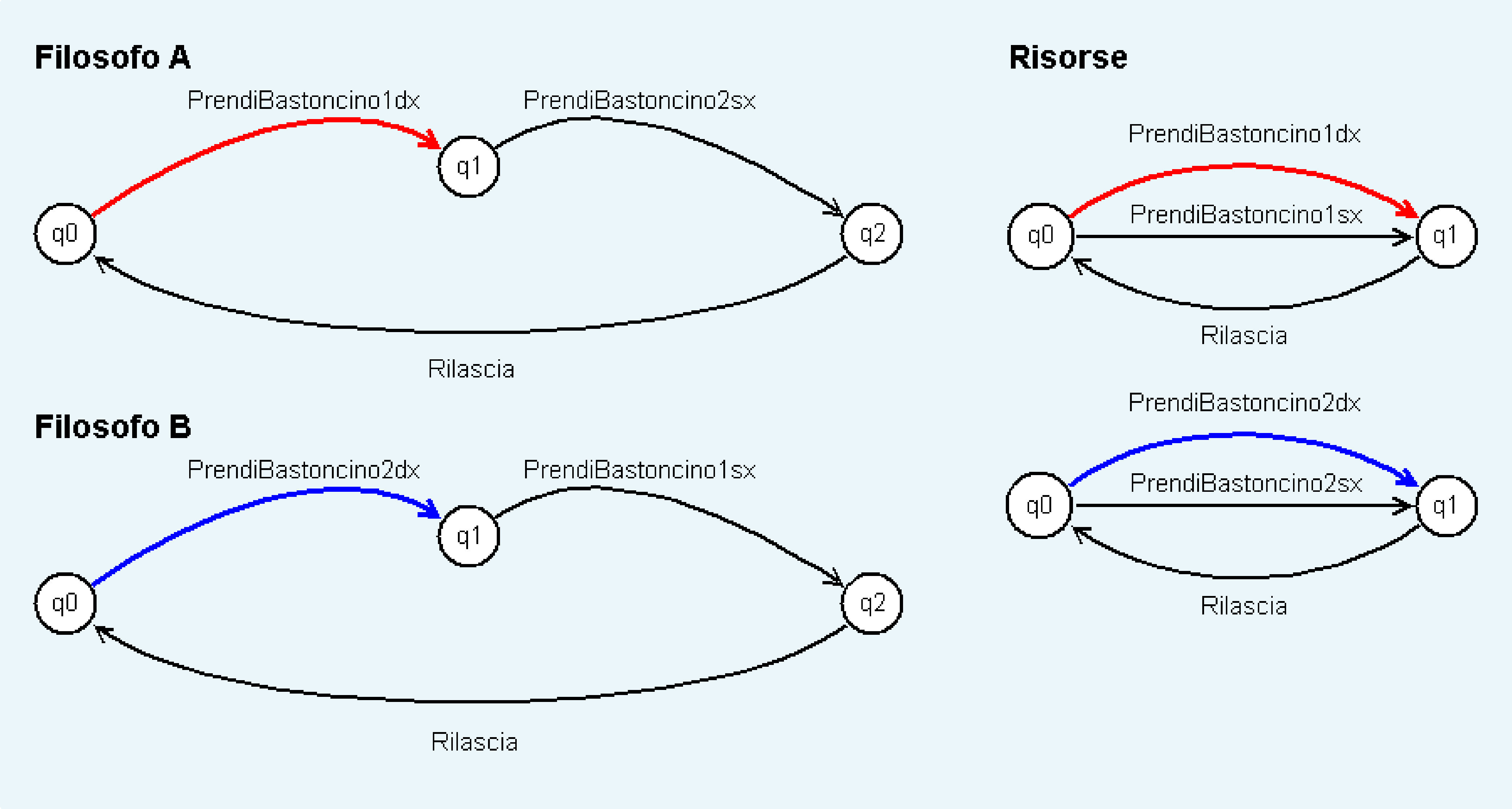
FSM with Input and Output

- A Finite State Machine (FSM) extension permits to distinguish among input and output data
- Mathematically I/O FSM are defined by:
  - A finite set of states Q
  - A finite set of input I
  - A finite set of output O
  - A transition function **δ:** Q x I --> Q x O
- How FSM can be composed originating a system FSM?
  - Resulting machine have a number of state given by the product of the number of states for each composing machine
  - We take a simple (and a bit simplicistic) approach

FSM – Thinking Philosophers (I)



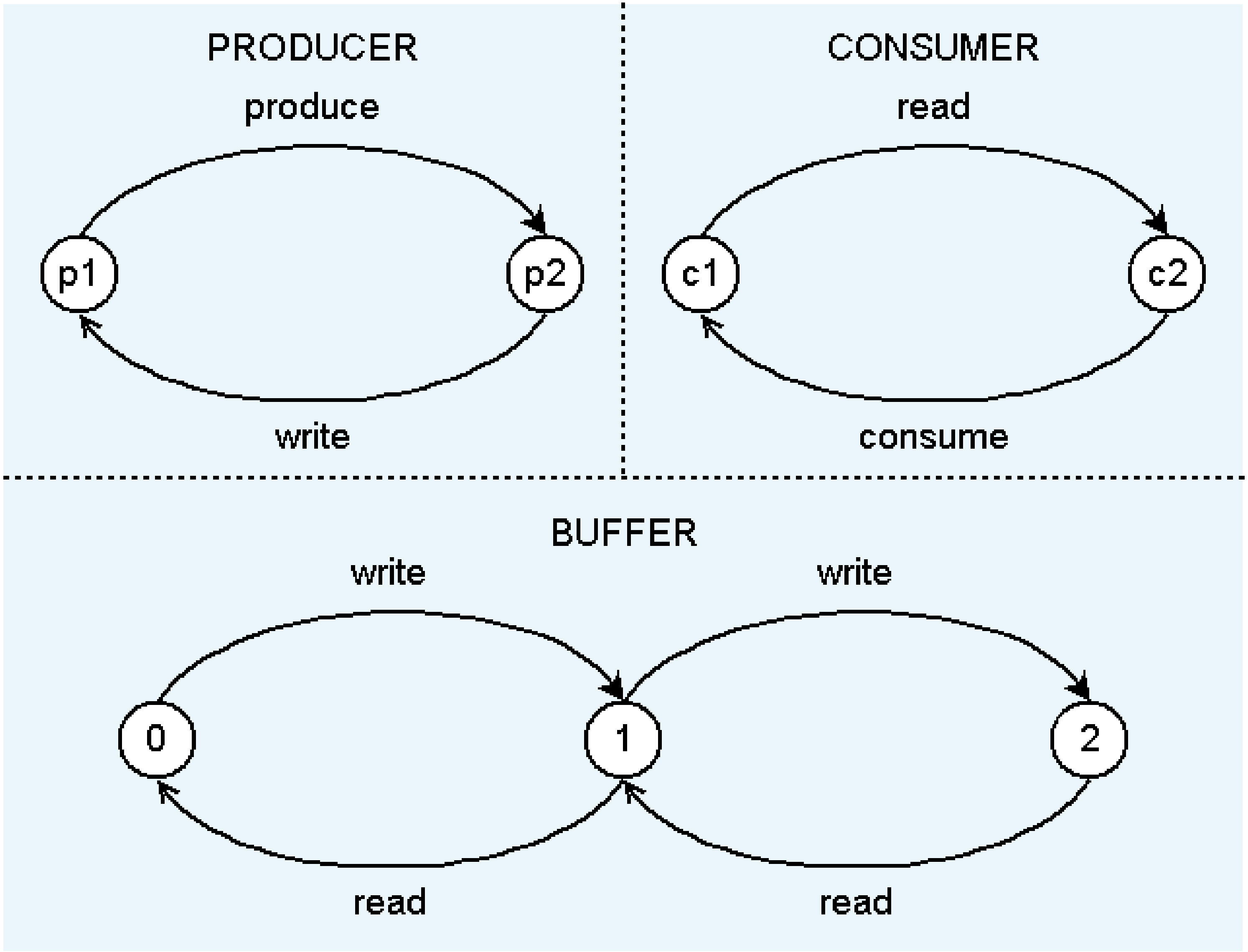
FSM – Thinking Philosophers (I)



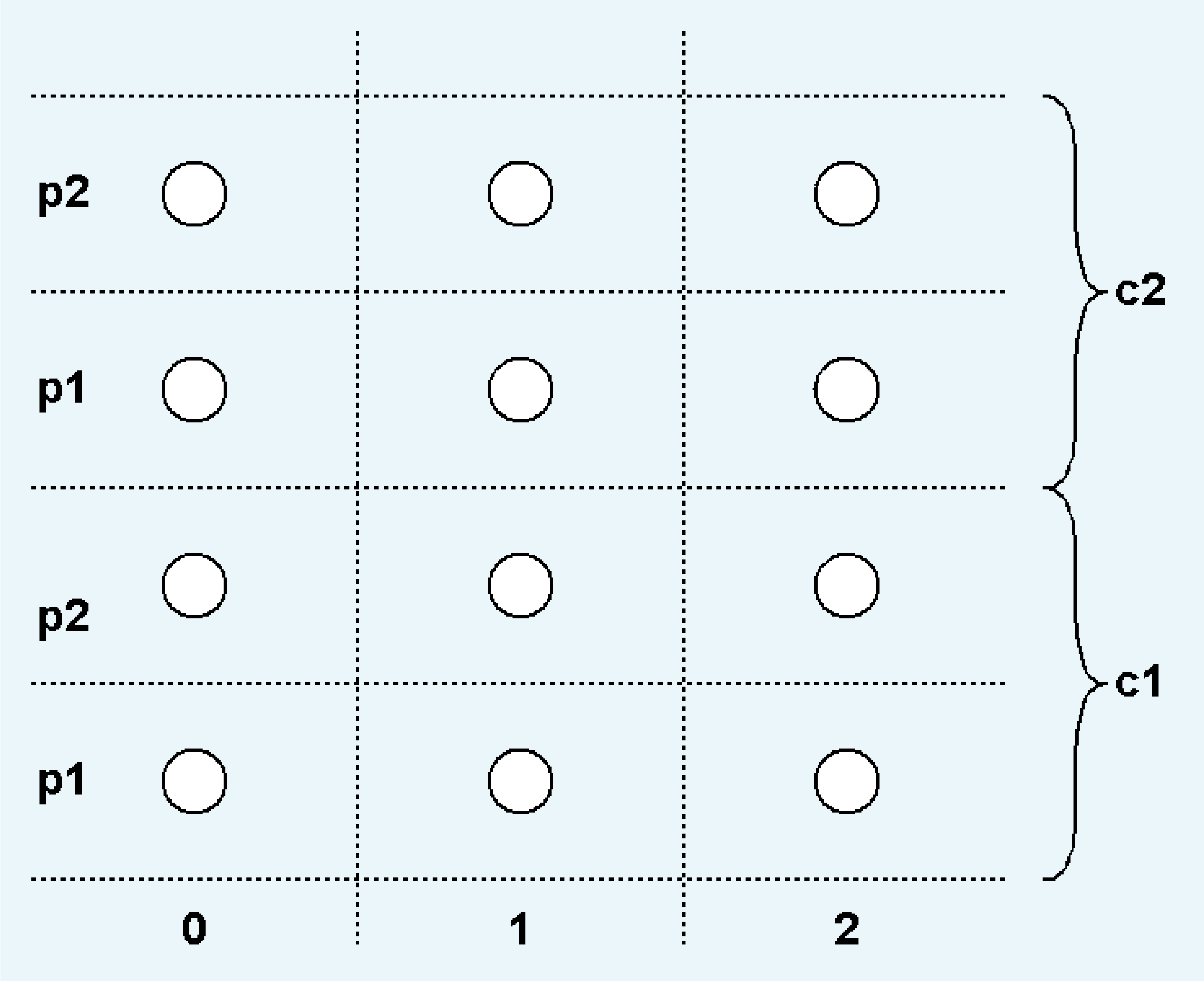
FSM and continuous systems

- FSM can store a finite quantity of information (**Finite-memory devices**)
- FSM can be cumbersome to describe even "finite" systems requiring to formally express details that sometimes are **easier to understand using natural language**
- In practice computer always have a finite memory but number of states is unmanageably large.
- How to manage these situations:
  - Ignore details
  - Complement diagrams with natural language comments
  - Change model (LTS, PN, ...)
  - Enrich FSM (i.e. Introduce a language to annotate transitions)

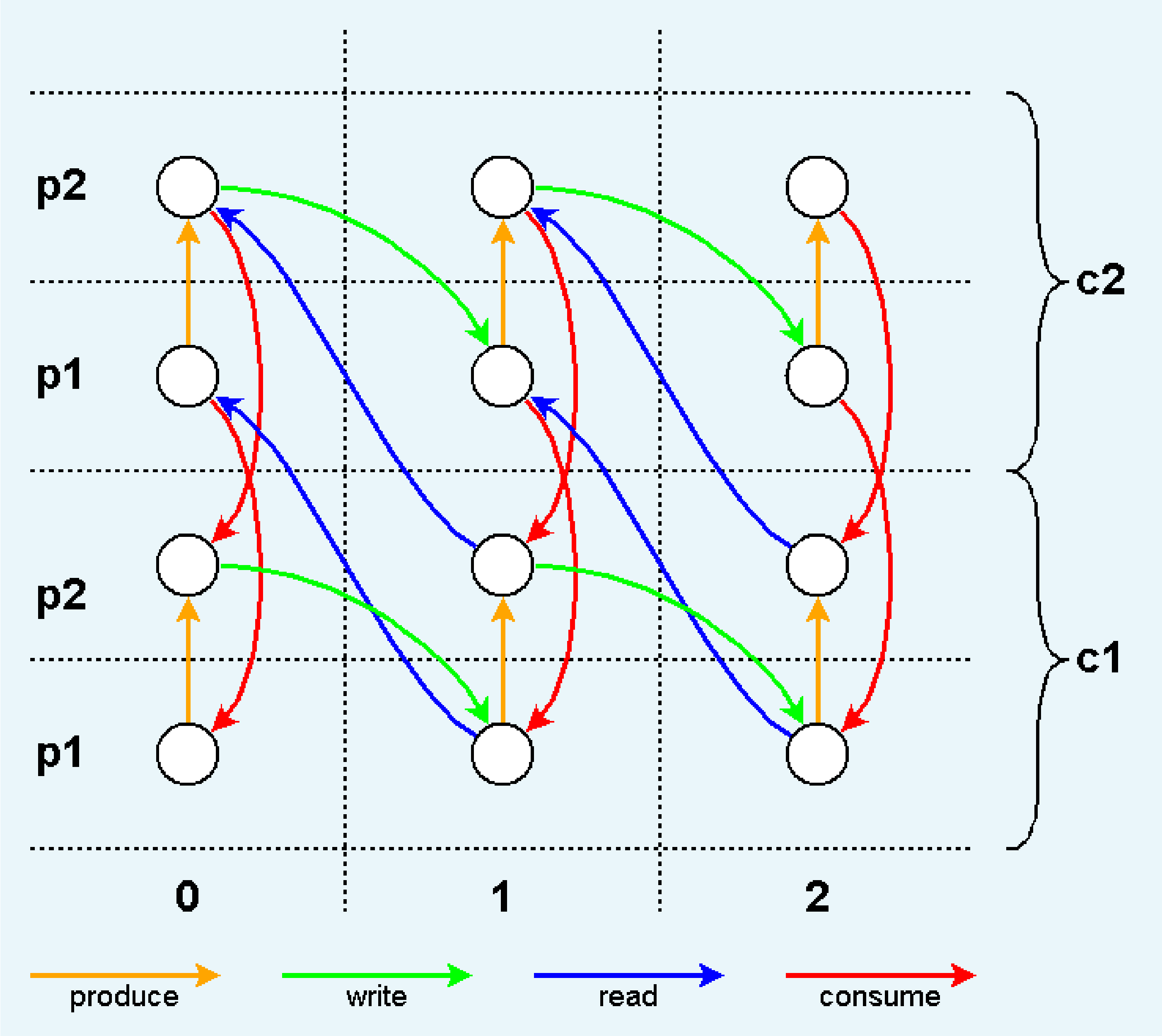
FSM for a Producer/Consumer System



Deriving the Parallel Machine



The Buffered Producer/Consumer System



FSM limitations

- Composing machines the **number of states raise drastically**
- We could leave the FSM are they are defined for the subsystems and use composition rules.
- Still some problem persist
  - The system must be **always in a unique state and can perform only one action at any instant of time**
- FSM permit to express only **synchronous interactions**
  - Not really adequate to describe general concurrent systems

FSM Exercises

- FSM for a two switch lighting systems

- Two lamps and one button
  - Different alternatives to model the same system

Key points

- On today lesson we introduced and discussed:
  - Models to describe software systems have been introduce
  - Properties that permit to classify different modelling language
    - Operational vs. Descriptive
    - Formal vs. Semiformal vs. Informal
  - Data Flow Diagram (DFD)
  - Finite State Machine (FSM)