Documentation
Notations and tools

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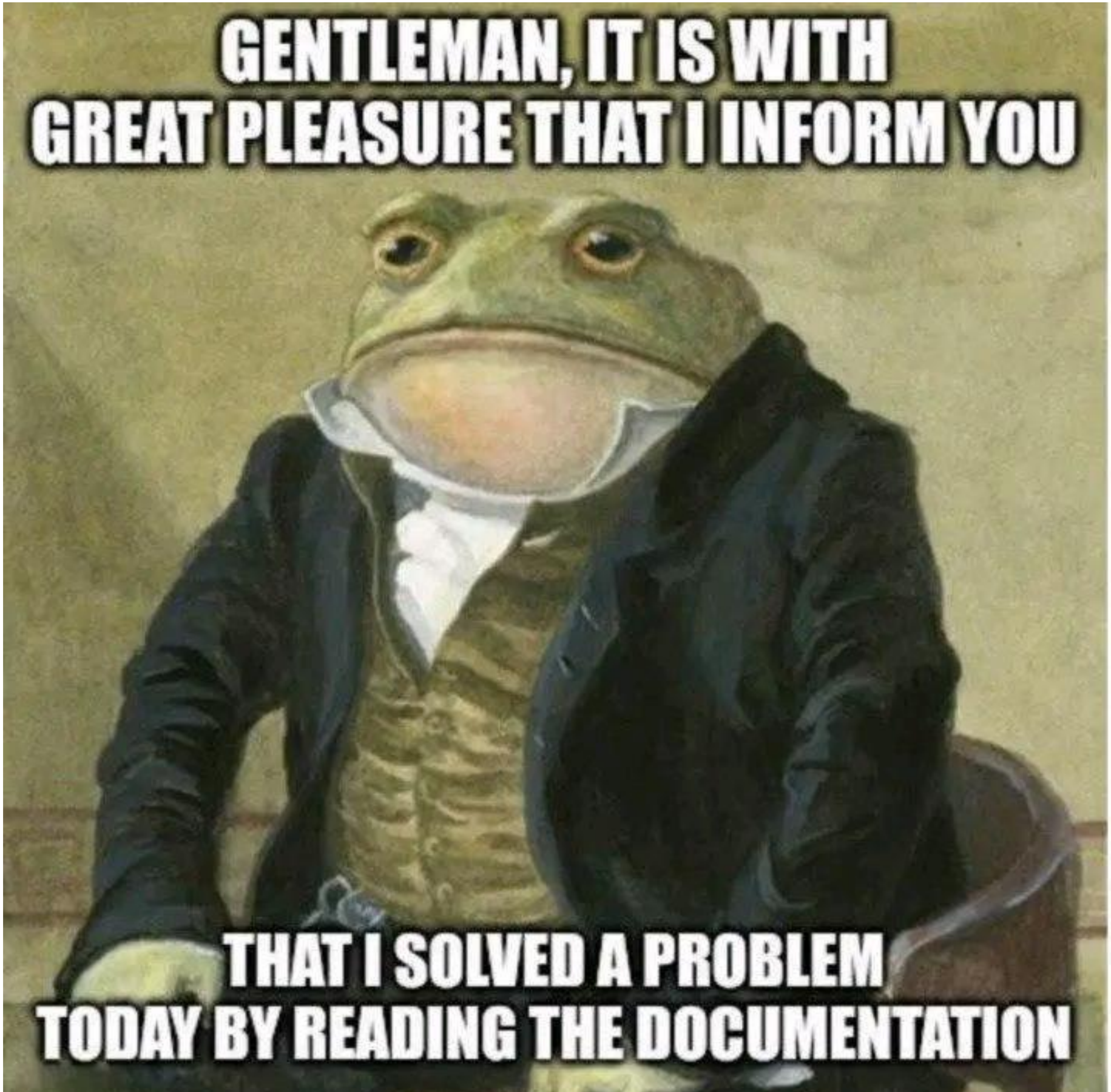
UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA
High Performance Real Time Lab


GENTLEMAN, IT IS WITH
GREAT PLEASURE THAT I INFORM YOU
THAT I SOLVED A PROBLEM
TODAY BY READING THE DOCUMENTATION

Tools and diagrams

Specifications are a **contract** between us and the customer (cit.)

- We use well-known tools and models

We typically specify/distringuish among:

- Operational diagrams
  - Data flow, UML, models such as FSMs, and Petri Nets
- Descriptive/structural diagrams
  - Entity-Relationship (inspired by DB entities analysis and design)

UML (standard) diagrams

- Structural diagrams
  - Use-cases/scenarios
  - Notations for classes/objects/packages/components – From OOP
- Behavioral diagrams
  - Sequence diagrams
  - State diagrams
  - Activity diagrams

Sorry but… I cannot explain them in this order

We start from specifications, then system design, then implemementation

UML has dedicated slide decks

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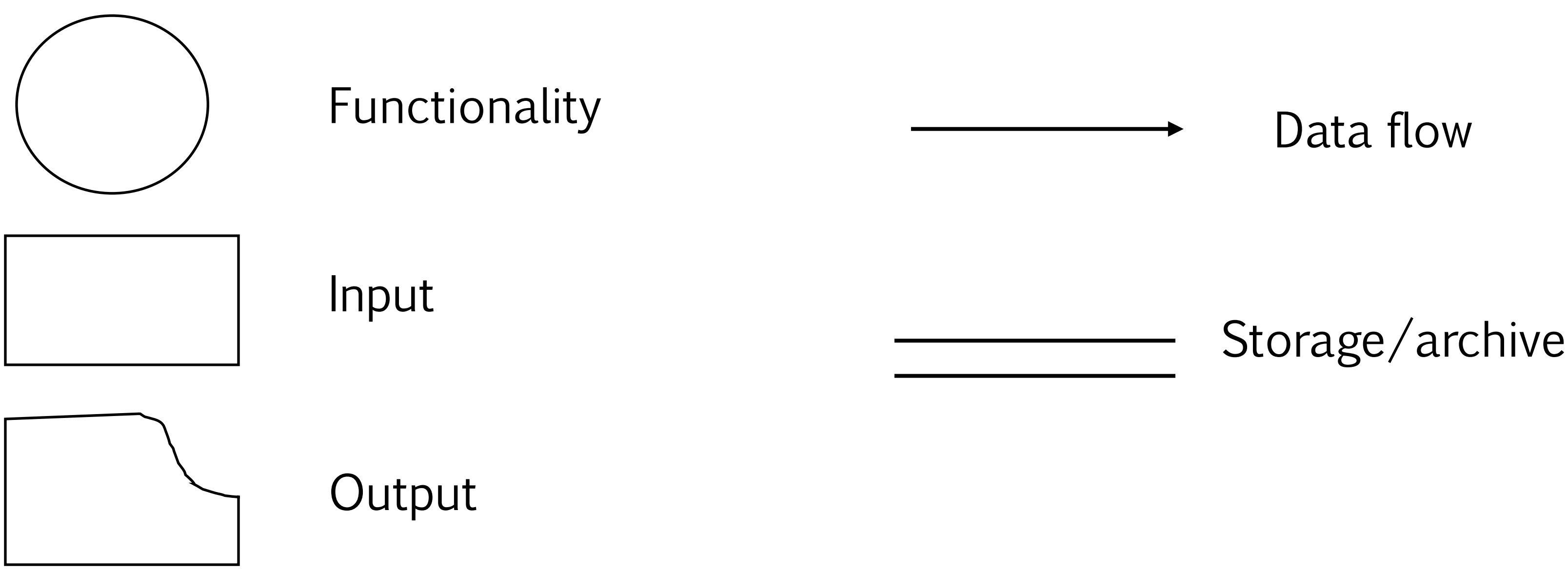
Data Flow Diagram (DFD)

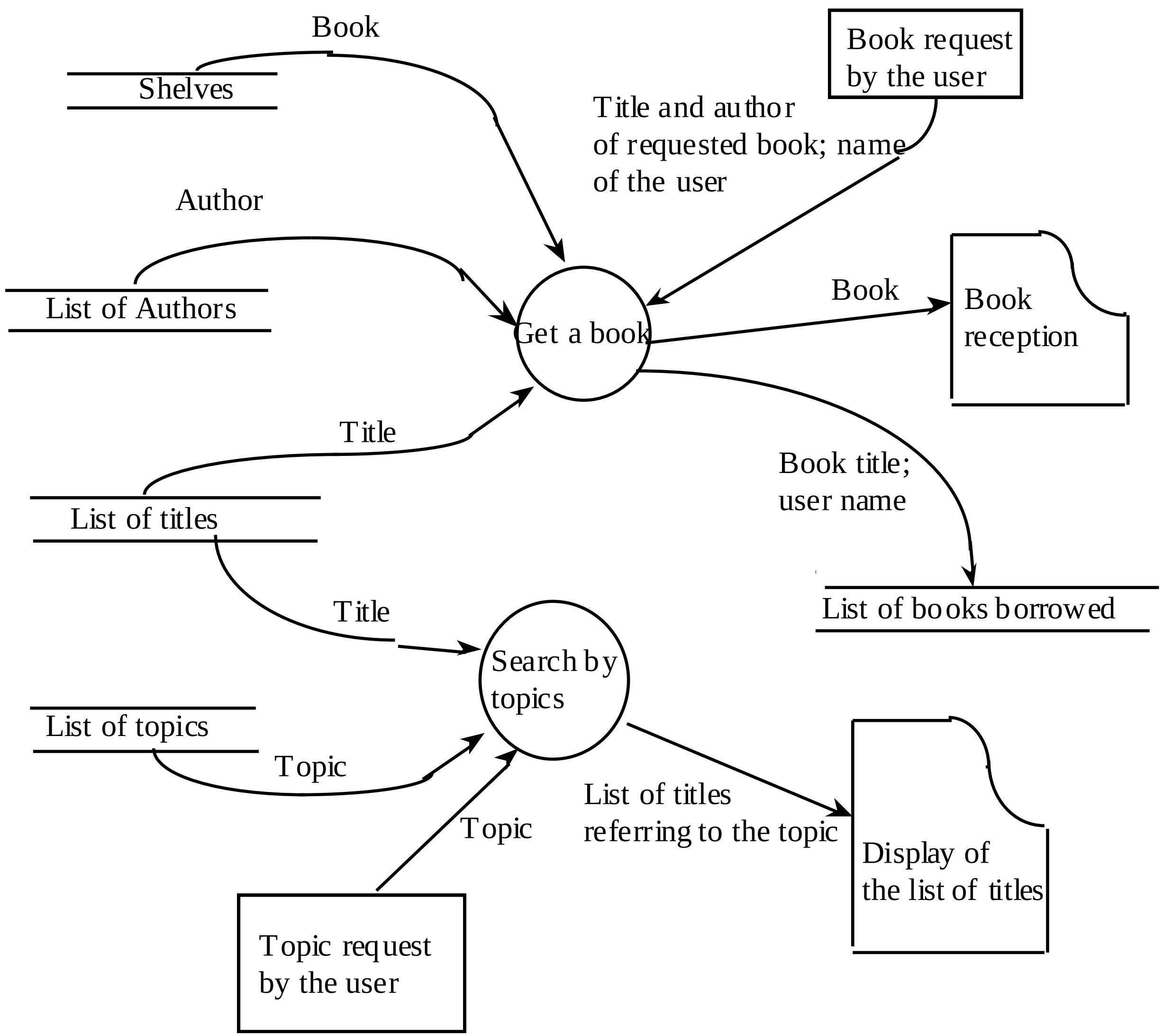
Data Flow Diagrams (DFDs)

Describe functionalities (nodes) and data arcs, both input and output

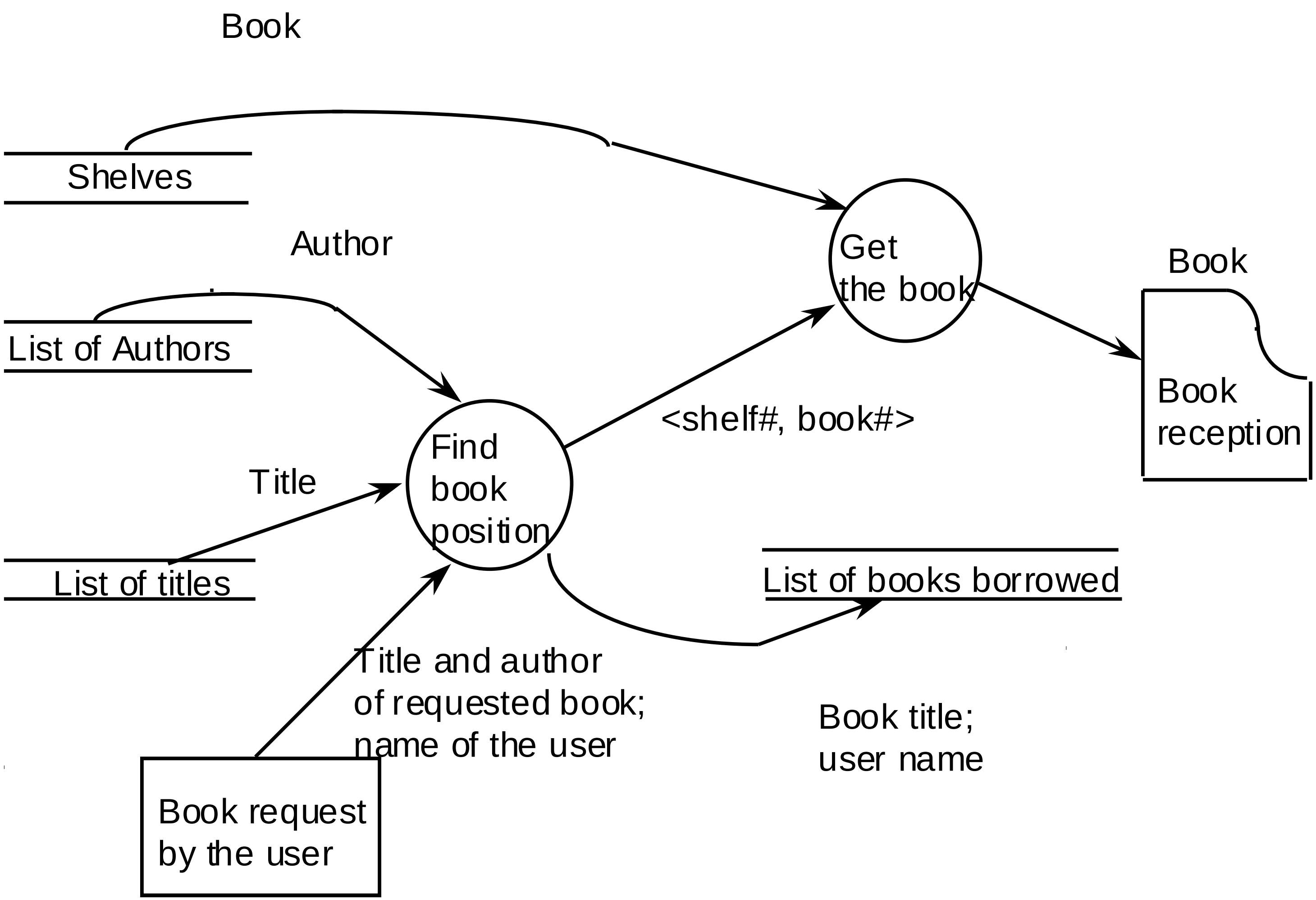
- I show them in B/W, but the recommendation is "play" with shapes to be more "communicative"
- One color per functionality
- Lines can also be dotted/bold(er) etc



Example of DFD



Example of DFD (cont'd)



DFD are not standardized

Pros: they are extremely simple, and everyone uses them

Cons:

- Informal, not standardized
- I typically use a variant with additional symbols
- They are not operational: they cannot, specify “control flows (`if`, `or`, `switch`,...)

Unified Modeling Language (UML)

UML

See the dedicated slide decks

- 05 - Unified Modeling Language.pptx

Finite state machines

Modeling stateful systems: an example

E.g., an elevator, reacts to multiple events

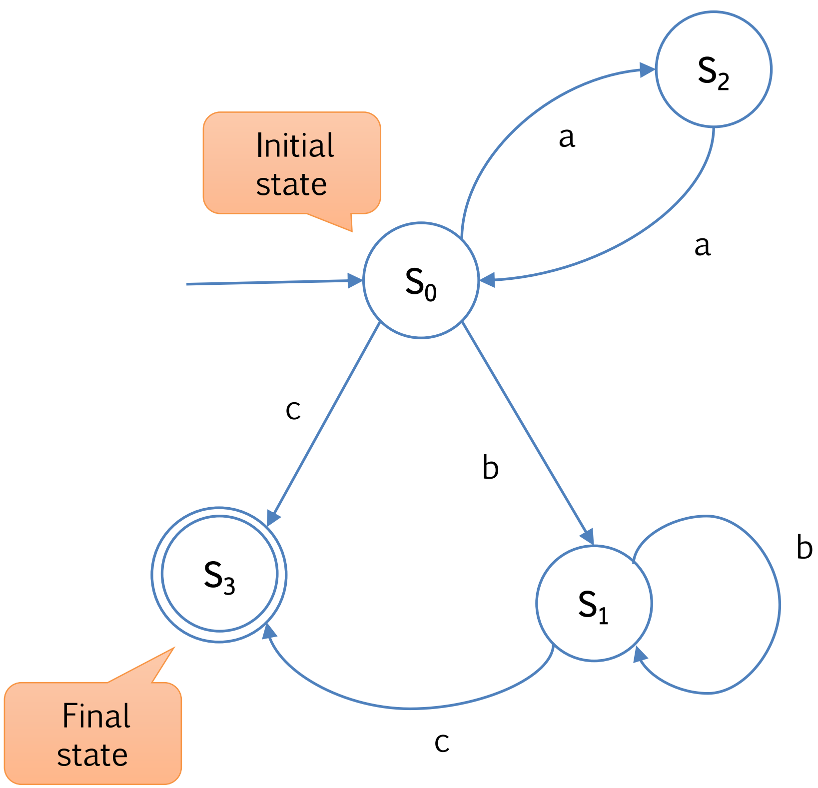
- Typically in idle state
- If you are press the button, the door opens
- You select the floor, doors close
- Then, it reaches the floor (feat. velocity control)
- Then, it opens the door, which subsequently closes after X seconds

This behavior is controlled by a **finite state automations/machine**

Finite State Machines/Automata

Example problem

- Identify even sequences of *a* (even empty), followed by one, or more, or no, *b*, ended by *c*



Given an <u>alphabet</u> that models a set of inputs

And validation rules for <u>producing</u> the sequence (aka: <u>words</u>)

Define FSA as

- S: a non-empty states set
- $s_0 \in S$: initial state
- $S_f \subseteq S$: final states set
- $t: S \times V \rightarrow S$: states transaction func

Exercise

Let's code!

Implement the FSM that understands whether a word has the following form

"Identify even sequences of a (even empty),

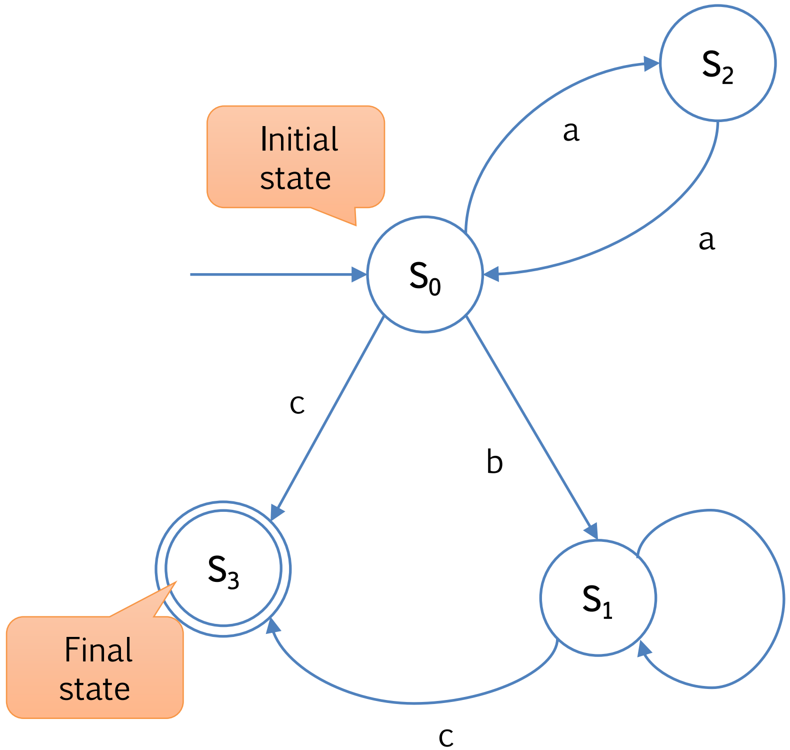
followed by one, or more, or no, b, ended by c"

Use the language that you want

- You just need IFs, CASE-SWITCH, recursion, tables
- Receive the target word from stdin
- Hint: start simple...

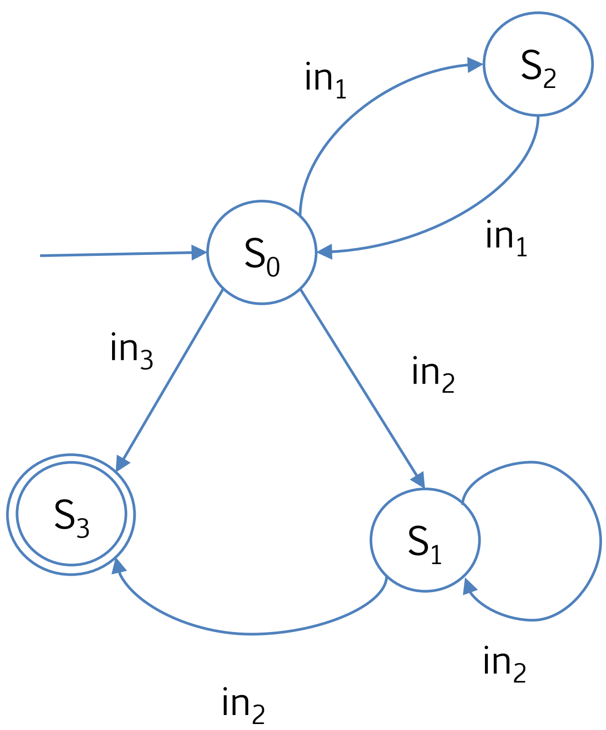
What's missing?

- In case of error => default error state
- Typically implicit in state diagrams



A generic FSM

- Till now, we only saw machines that can recognize a **word** from a language
  - I say “word”, you might want to understand “sentence”
- Let’s now see how a machine can actually **produce** an output



The Machine of Mealy

- When crossing an edge, produce an output

< I, O, S, mfn, sfn >

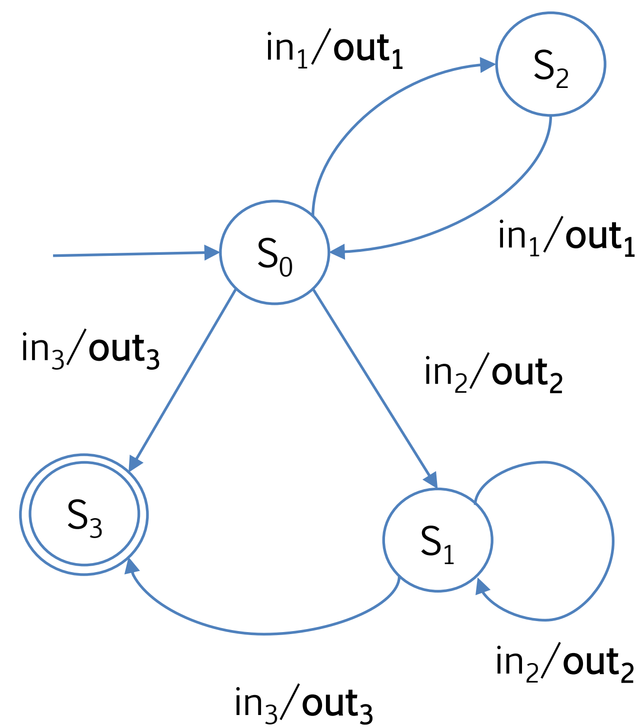
`I` : (finite) set of Input symbols

`O` : (finite) set of output symbols

`S` : (finite) set of states (s_0 initial state)

`mfn: I x S` → `O` machine/output function

`sfn: I x S` → `S` state transition function



The Machine of Moore

- When in a state an edge, produce an output

`< I, O, S, mfn, sfn >`

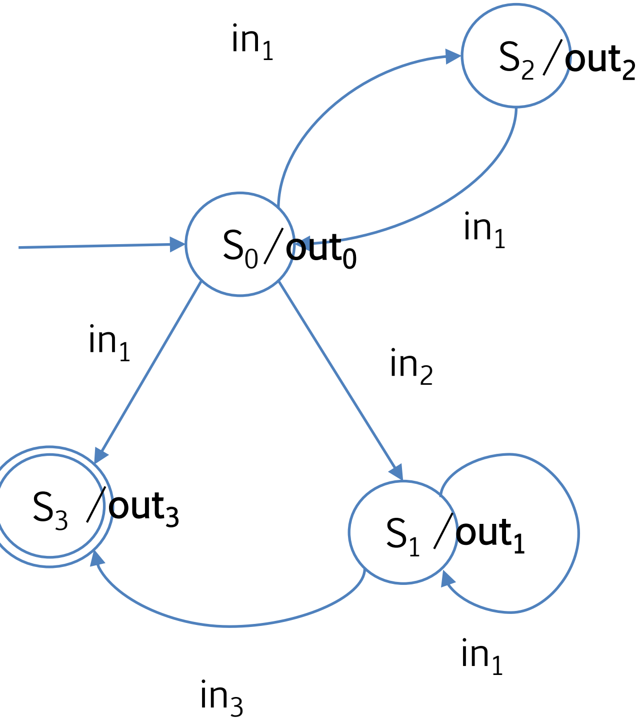
`I` : (finite) set of Input symbols

`O` : (finite) set of output symbols

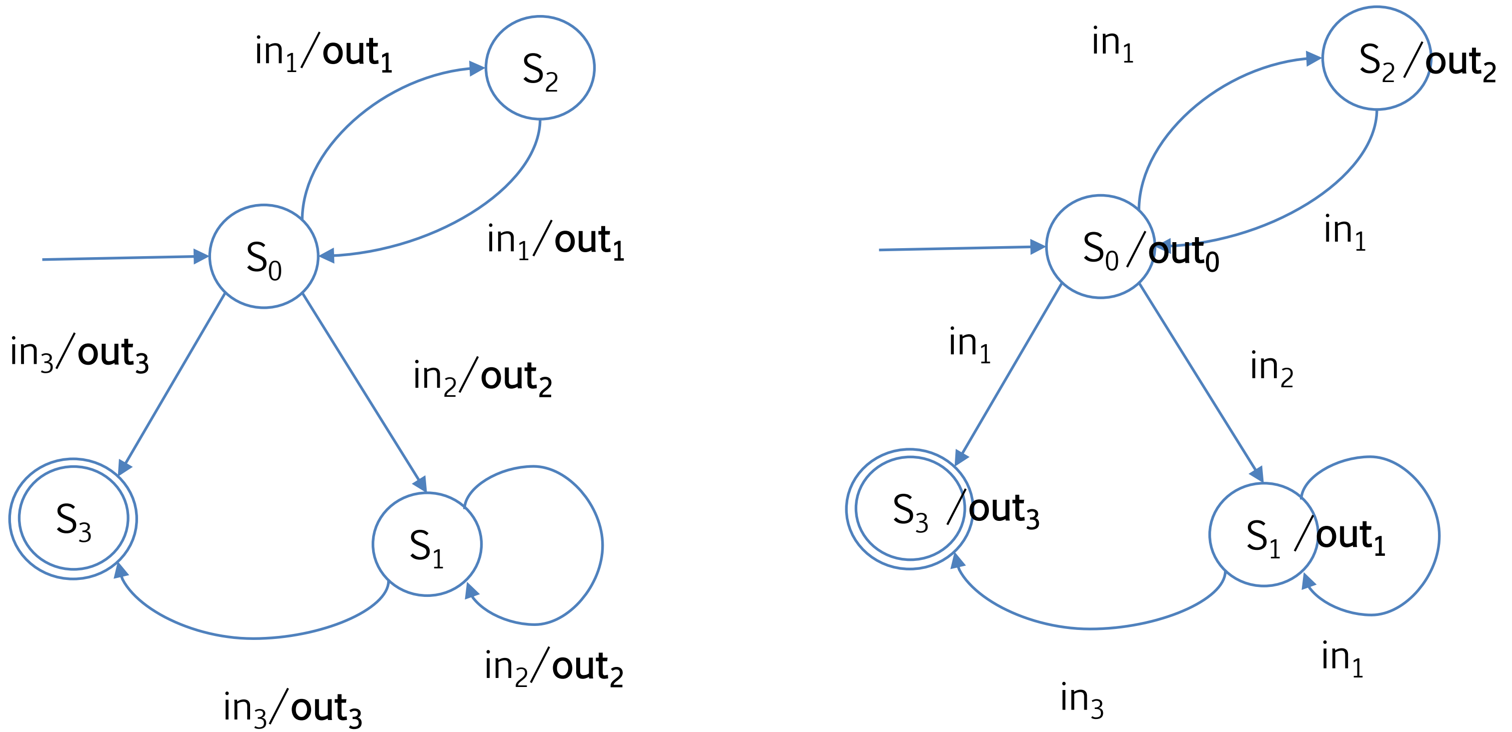
`S` : (finite) set of states (s_0 initial state)

`mfn: S` → `O` machine/output function

`sfn: I x S` → `S` state transition function



What's the difference?



What's the difference?

Mathematically equivalent

- One can be transformed in another

..but..

- Mealy can potentially have different outs, to different inputs/transitions
  - Less states, if output depends on inputs one can add an edge to the machine
- Moore potentially keeps the output stable for all the state
  - Moore requires more states, in case out depends on input and not only on state

Exercise

Let's code!

- Implement the automata that understands whether a words is from L

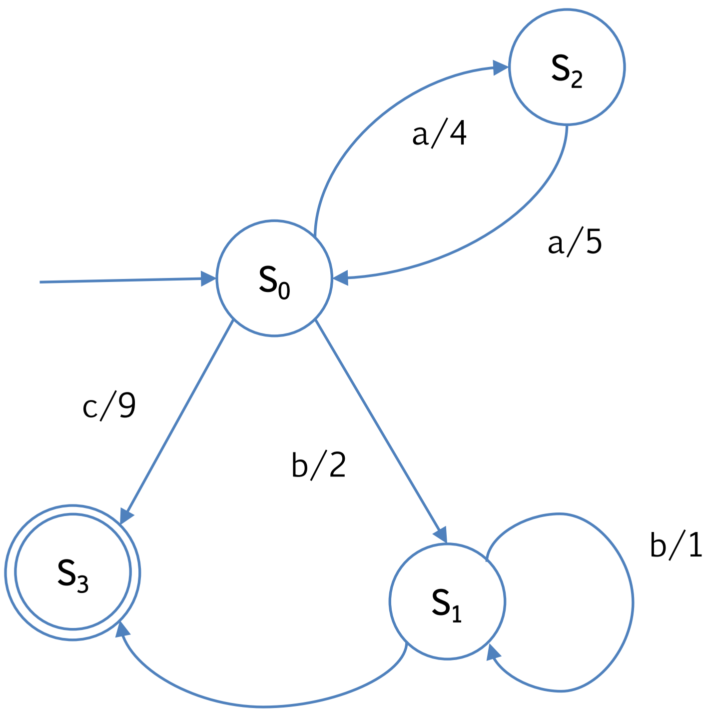
"Identify even sequences of a (even empty),

followed by one, or more, or no, b, ended by c"

- ..and writes the corresponding number (I choose them randomly)
- Mealy? Moore? You choose
  - Here, I show Mealy

Hint

- If not already done, use tables for state/output transactions



More formalism

`< I, O, S, mfn, sfn >`

`I` : (finite) set of Input symbols

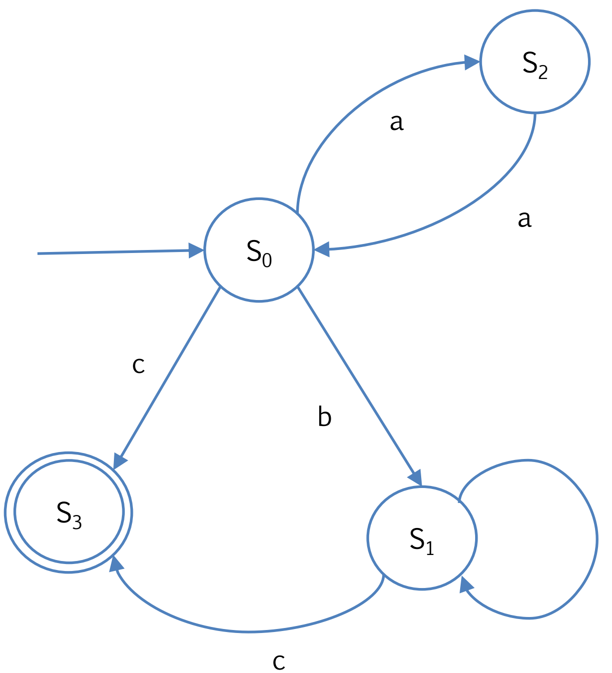
`O` : (finite) set of output symbols

`S` : (finite) set of states

`mfn`: `I x S` → `O` machine function

`sfn`: `I x S` → `S` state function

- Partly already seen
- Has memory
- Memory is a limitation



Automate..the automata production process

At the end of the day, we just need to model the grammar, and them!

`I` : (finite) set of Input symbols

`O` : (finite) set of output symbols

`S` : (finite) set of states

`mfn: I x S → O` machine function

`sfn: I x S → S` state function

Several tools to support the design

- Matlab Stateflow, UML

Several grammar interpreters to rely the burden of writing FSM code

- FSF's GNU Bison – Included in GCC
- YACC – Yet Another Compiler-Compiler

FSMs/Automata and UML

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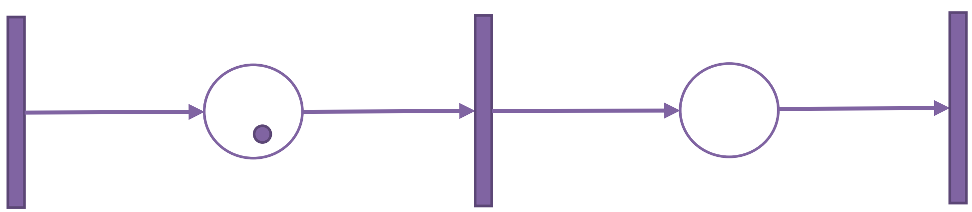
Petri nets

Petri nets - definition

Model application behavior through a directed bipartite graph

- **Transitions** triggered by **events** (*bars*)
- **Places**, i.e., conditions (*circles*)
- *Arcs* connect only places to transitions (or vice-versa), and specify which places are **pre- or post-conditions** for events
- Every place collects **tokens** (*dots*) which might trigger an event (if multiple events are triggered in the same net, which fires first is non-deterministic



Model distributed systems, discrete events dynamic systems

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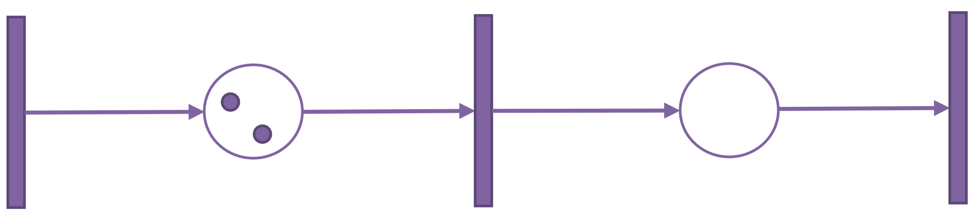

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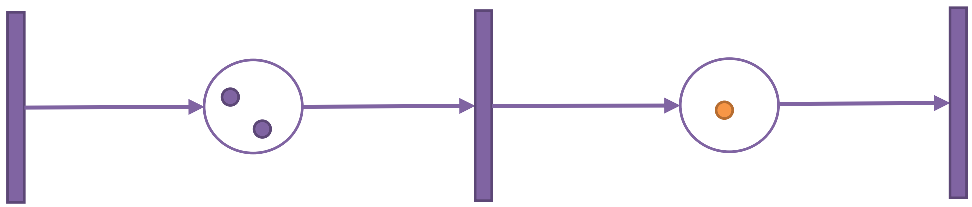

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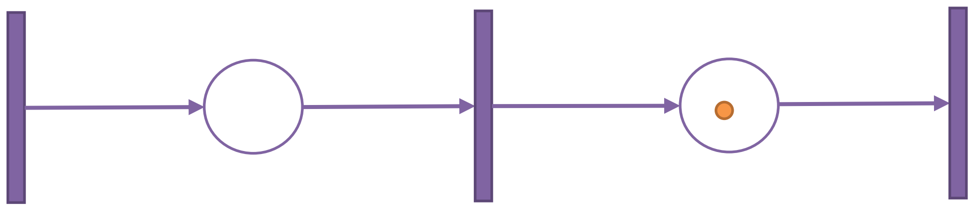

Model distributed systems, discrete events dynamic systems

(Marking) Petri net - formalism

- S: finite set of states
- T: finite set of transitions
- $W: (S \times T) \cup (T \times S) \rightarrow \mathbb{N}$ multiset of arcs
- M: (marking) a mapping $S \rightarrow \mathbb{N}$ that assigns to each place a number of tokens
- M_0: initial marking

A tuple (S, T, W, M_0)

Subject to:

- S and T are disjoint
- No arc can connect two states or two transitions among them

How they execute

- firing a transition t in a marking M consumes $W(s, t)$ tokens from each of its input places, and produces $W(t, s)$ tokens in each of its output places
- a transition is *enabled* (it may fire) in M if there are enough tokens in its input places for the consumptions to be possible, i.e. if and only if $\forall s : M(s) \geq W(s, t)$

References

Course website

- http://hipert.unimore.it/people/paolob/pub/ProgSW/index.html
- http://hipert.unimore.it/people/paolob/pub/Industrial_Informatics/index.html

Book

- I. Sommerville, "Introduzione all ingegneria del software moderna", Pearson
  - Chapter 3
- Alessandro Fantechi, «Informatica Industriale», Città Studi Edizioni

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