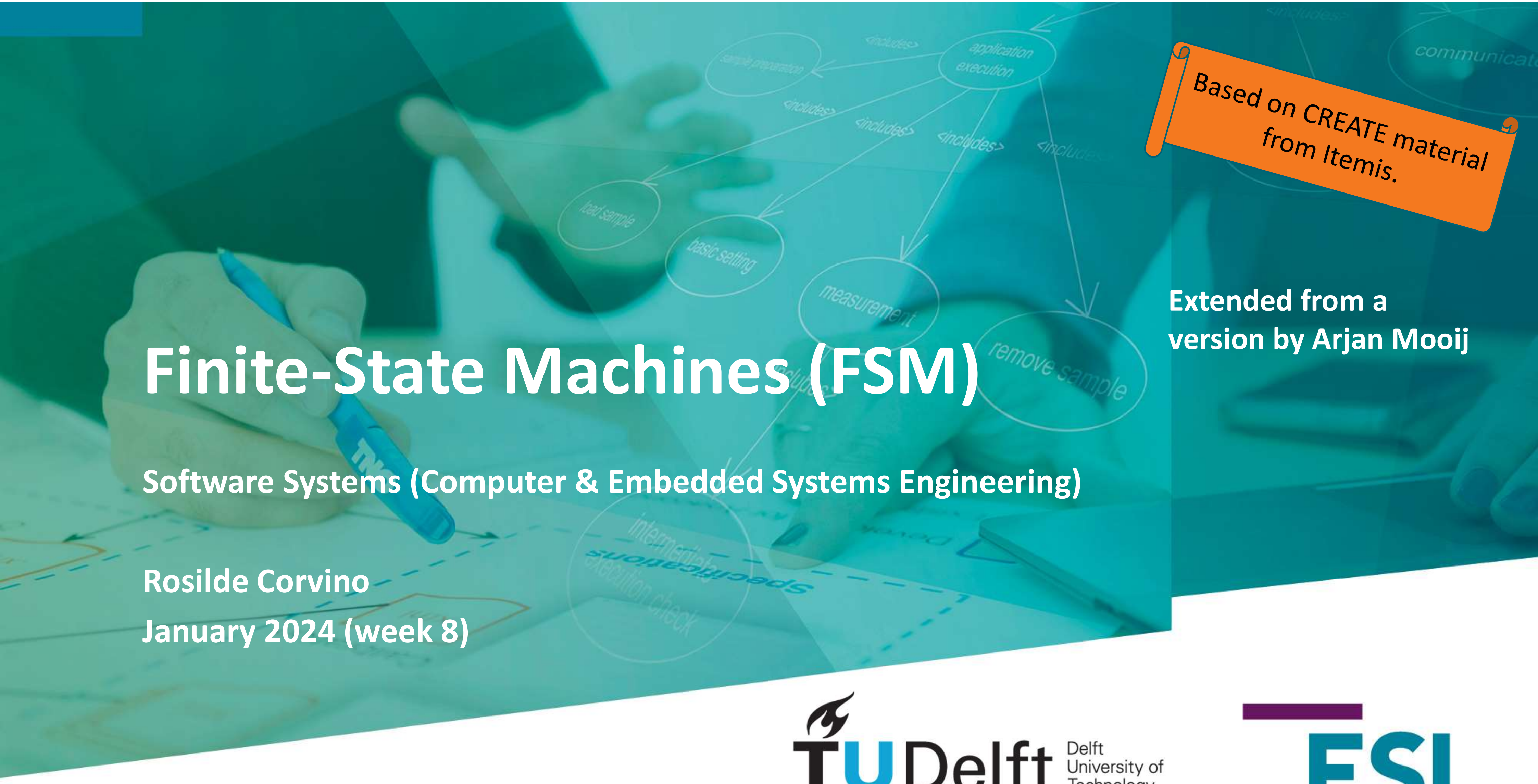


Based on CREATE material from Itemis.

Extended from a version by Arjan Mooij

Finite-State Machines (FSM)

Software Systems (Computer & Embedded Systems Engineering)

Rosilde Corvino

January 2024 (week 8)

An initiative of industry, academia and TNO

Dimensions for each model type

Motivation	When/where to apply the model type?
Concepts	What elements and relations between them are used in the model type?
Notation	How to represent these concepts in a textual/graphical way?
Tool	How to create models using this notation?
Skill	How to determine which concepts to use for your models?

Objectives

At the end of the course, you should be able to:

- Explain the purpose of Finite-State Machines, including several application areas
- Explain the concepts and notations of Finite-State Machines
- Create basic Finite-State Machines to model software-intensive systems

Assessment:

- Modeling assignment using Finite-State Machines (in groups of 2 students)
- Reflection document on Model-Based Development (individual)

Agenda for Finite-State Machines
(Each week the Software Systems course has 2 lecture hours + 4 lab hours)

- **Week 8 Lecture**

30 minutes	Basic Notation and simulation
15 minutes	Basic Modeling skills
15 minutes	Break
15 minutes	Notation and simulation
15 minutes	Modeling skills
15 minutes	Application areas

- **Week 8 Lab**
  - Notation and simulation
  - Modeling skills

What do you already know about FSM?

- **What is an FSM?**
  - It is a mathematical model of computation.
  - It is an abstract machine that can be in exactly one of a finite number of states at any given time.
- **What parts (or type of logic) do you need to realize an FSM?**
  - Combinatorial and sequential logic
- **How many types of FSM do you know?**
  - Mealy / Moore
- **What is the main difference between them?**
  - Mealy's output depends on input and current state
  - Moore's output depends only on the current state
- **What are possible problems with simple FSM representations?**
  - Explosion of the number of states and transitions in certain cases

Motivation

Finite-State Machines are a very practical way to describe behavior:

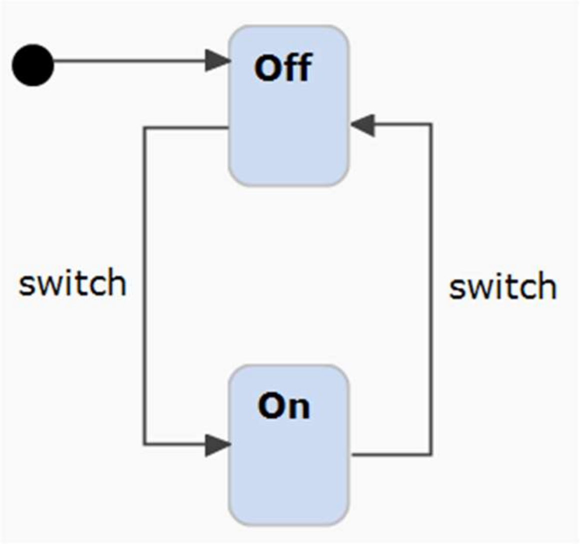
- User workflow
  - In which environment will the system be used?
  - E.g., passport renewal (submit application, background check, printing process, delivery, etc.)
- System behavior
  - What is the logic that the system should implement?
  - E.g., guarantee the safety of traffic lights
- Communication protocols on interfaces
  - How should concurrent components interact with each other?
  - E.g., only send messages (or call methods) in a specific order (e.g., after initialization)

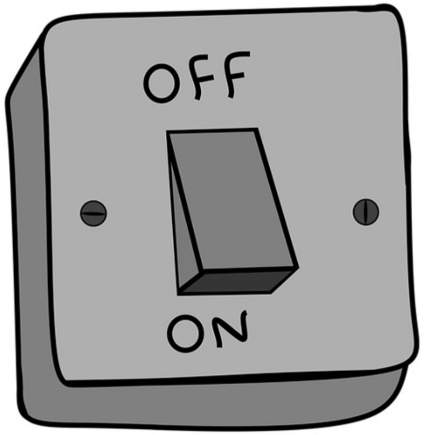
Note: Finite-State Machines are called State Machine Diagram in UML

Notation and simulation

Finite-State Machines (FSM)

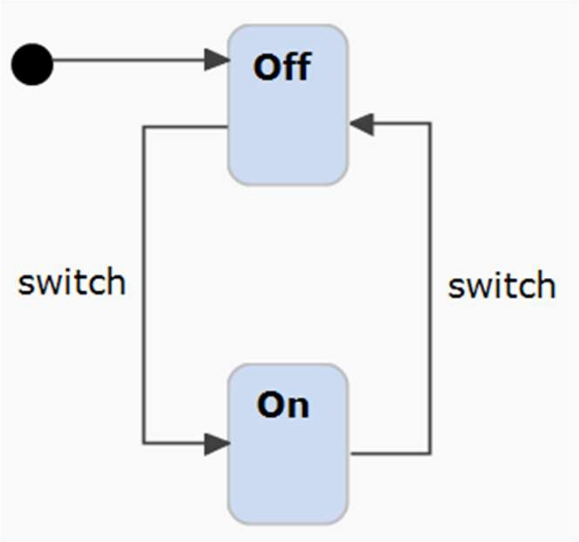
What would the elements in this Finite-State Machine mean?





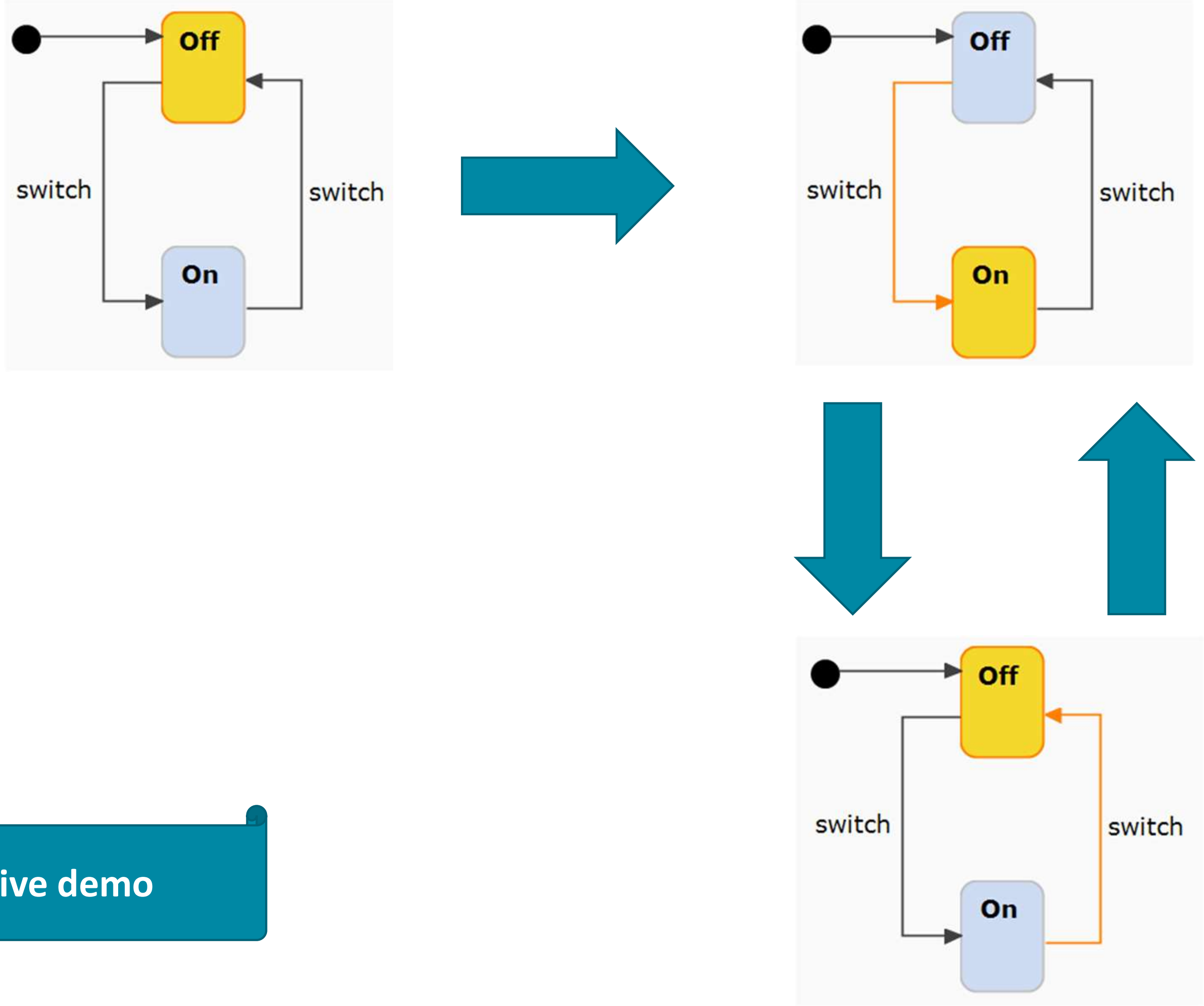
Think → Pair → Share

States, transitions and events



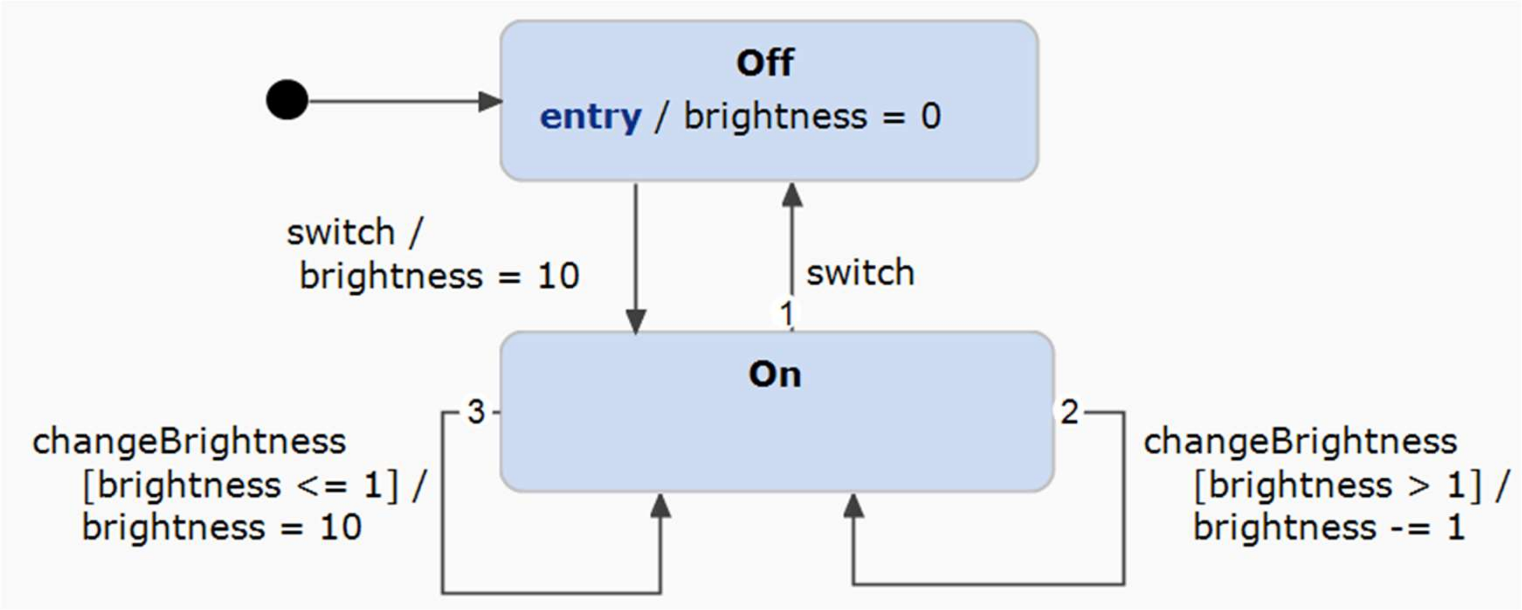
- **State**
  - Represents a possible mode of a system
    - Where the system is executing an activity or waits for an event.
  - Each state can be active or inactive
  - Visualization:
    - Normal state: Rounded rectangle (with a name)
    - Initial state: Indicated by an entry point
    - Entry Point: Filled black circle (without a name)
- **Transition**
  - Represents a possible state change
  - Visualization: Arrow from the source state to the target state (with an event trigger)
- **Event**
  - Represents a possible element on the interface of the system

Simulation



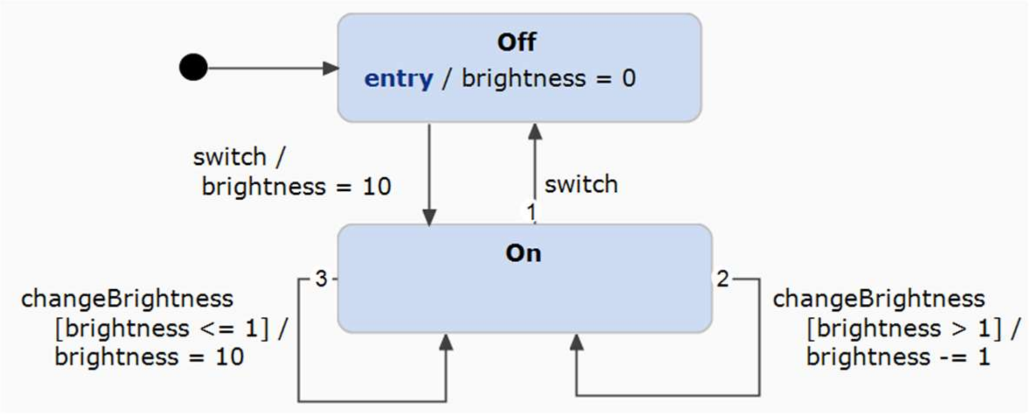
Live demo

What would the elements in this Finite-State Machine mean?



Think → Pair → Share

Variables, guards, and effects

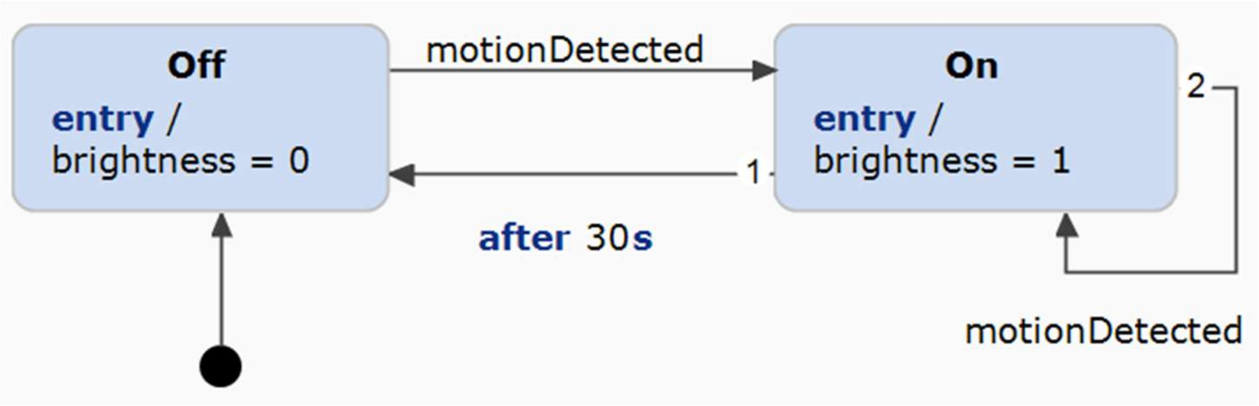


- **Variable**
  - Stores some data that can be changed
    - (Model may no longer be finite state)
- **Effects:**
  - Assignment to a variable
  - Raise an event (syntax: **raise** event)
  - Sequential composition(syntax: effect1 ; effect2)
- **Transition reaction:**
  - Executed when the transition is taken
  - Syntax: trigger [guard] / effect
    - Guard is a condition that enables the transition
- **State reaction:**
  - Syntax:
    - **entry** / effect Executed when the state is entered
    - **exit** / effect Executed when the state is exited
    - event / effect Executed when no outgoing transition can be taken
- **Priorities on the outgoing transitions of a state**

Simulation

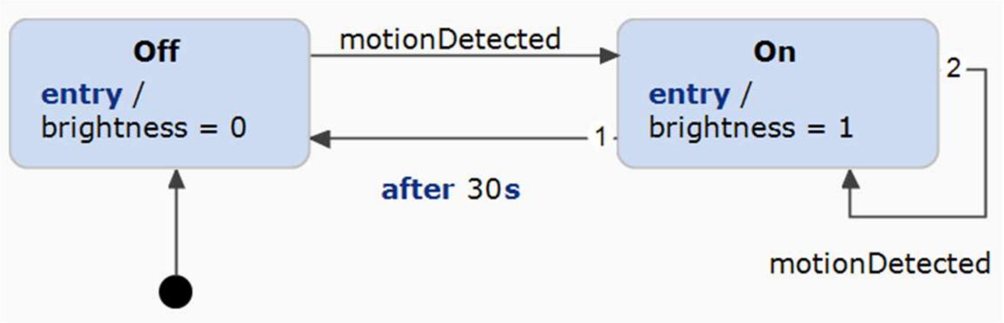
Live demo

What would the elements in this Finite-State Machine mean?



Think → Pair → Share

Triggers



- **Single event trigger**
  - Trigger when the event is raised
  - Syntax: ev1
- **Multiple event trigger**
  - Trigger when one of the event is raised
  - Syntax: ev1, ev2
- **Time trigger**
  - Trigger after given amount of time
  - Syntax: after 30s

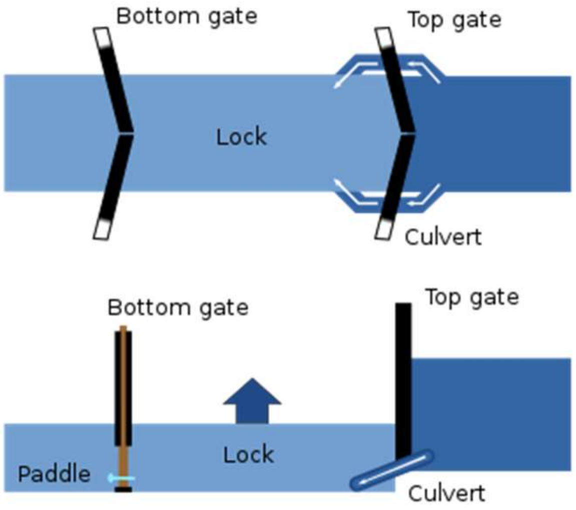
Simulation

Live demo

Modeling skills

Finite-State Machines (FSM)

Creation of an FSM



https://en.wikipedia.org/wiki/Lock_(water_navigation)

Ship lock:

- Two gates: bottom and top
- Two valves: bottom (paddle) and top (culvert)

Why would it be interesting to model this?

Safety constraints:

- At most one gate or valve open at a time
- Gates can only be opened when the water levels match

Let’s model the behavior of the lock in terms of the gates and valves!

Creation of an FSM

Goal of the model: **safe operating procedure of the gates and valves**

Events:

- **Depend on the gate/valve interface** → **perhaps first model their interface behavior!**
  - For the valves we rely on time
  - For the gates we rely on sensors that confirm certain positions
- **User interactions:**
  - Start the next swap
  - (Possible extension: interrupt a swap?)

Two kinds of state:

- **Stable system situation: e.g., gate open**
- **Instable stable situation: e.g., valve open**

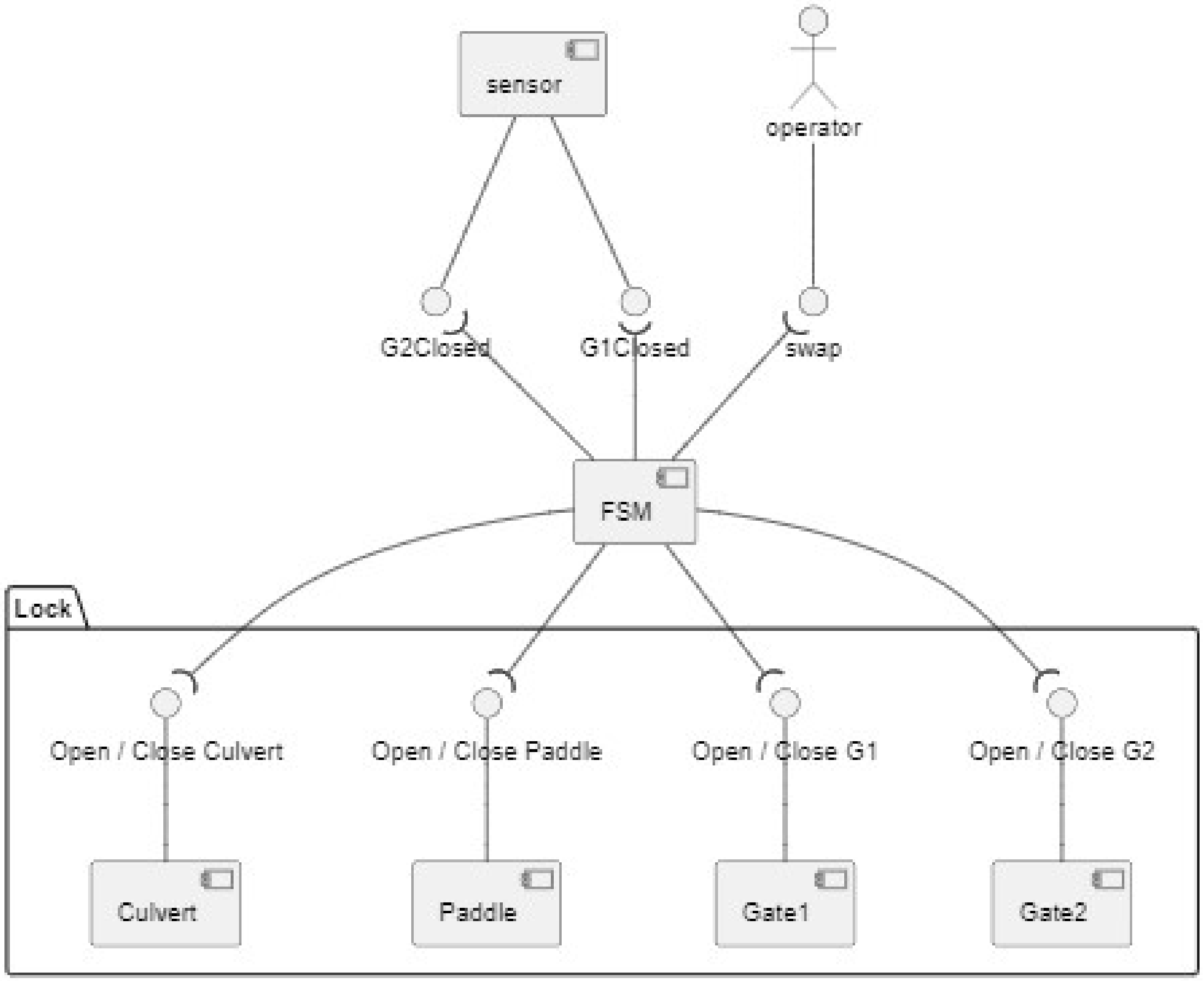
Think → Pair → Share

Components:

- **Gate 1 (bottom), gate 2 (top), paddle, culvert**

External interface:

- **Input from an operator: swap**
- **Input from a sensor: G1Closed, G2Closed**
- **When G1 is closed: output OpenCulvert**
- **When the lock is full: output CloseCulvert, OpenG2**
- **When G2 is closed: output OpenPaddle**
- **When the lock is empty: output ClosePaddle, OpenG1**



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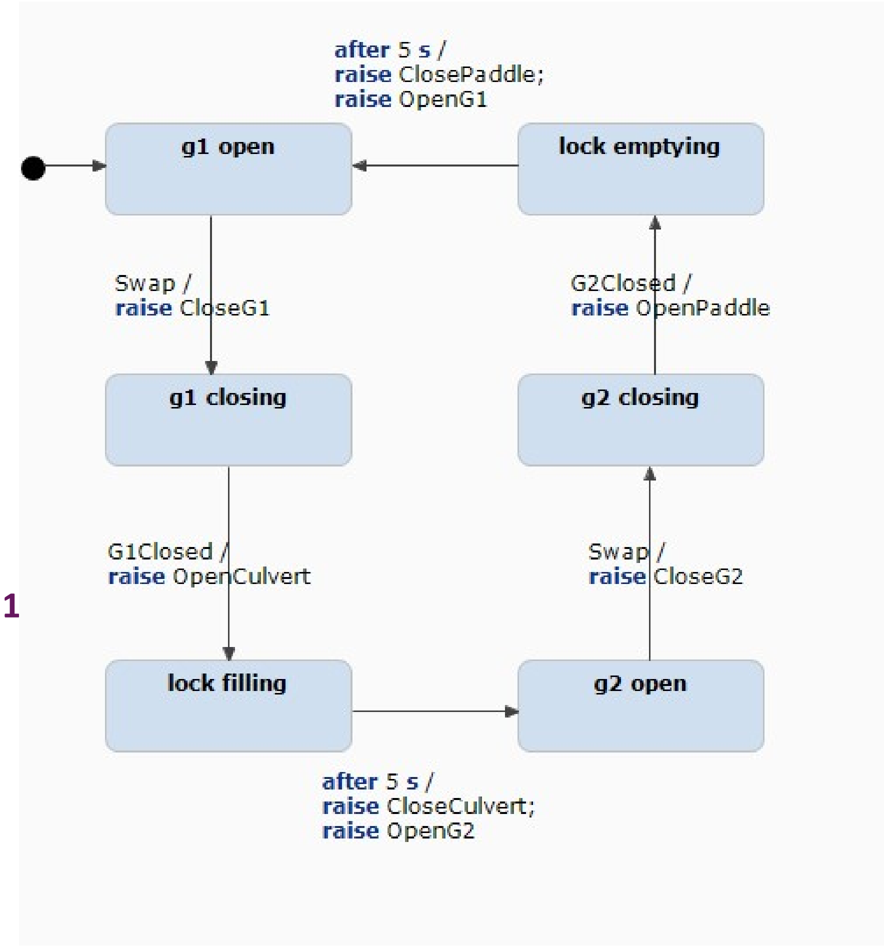
after 5 s /
raise ClosePaddle;
raise OpenG1
g1 open
lock emptying
Swap /
raise CloseG1
G2Closed /
raise OpenPaddle
g1 closing
g2 closing
G1Closed /
raise OpenCulvert
Swap /
raise CloseG2
lock filling
g2 open
after 5 s /
raise CloseCulvert;
raise OpenG2