UMLEmb:
UML for Embedded Systems
II. Modeling in SysML

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Outline

Case Study: a Pressure Controlling System

A "client" expects you to deliver the software of the following system:

Specification (from the client)

- A pressure controller informs the crew of a cabin with an alarm when the pressure exceeds 20 bars in the cabin
- The alarm duration equals 60 seconds.
- Two types of controllers. "Type 2" keeps track of the measured values.

Pressure Controller: Assumptions

Modeling assumptions linked to the system

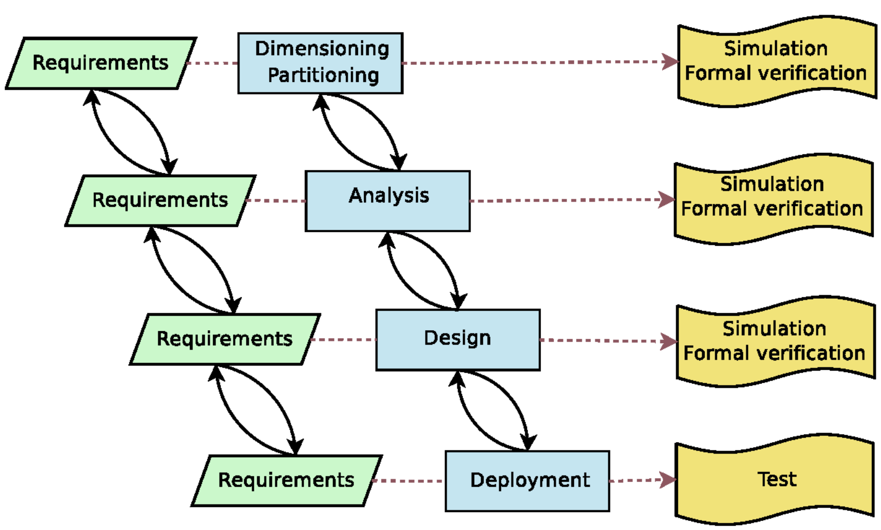
- The controller set up and shutdown procedures are not modeled
- The controller maintenance is not modeled
- Versioning
  - The "keep track of measured value" option is not modeled in the first version of the design

Modeling assumptions linked to the system environment

- The pressure sensor never fails
- The alarm never fails
- The controller never faces power cut

Outline

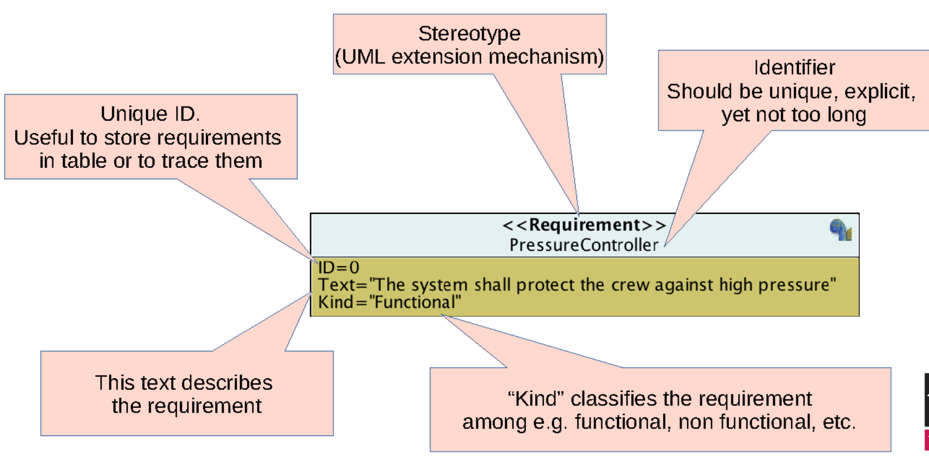
Overview of the V Cycle



Outline

Requirement Node

- **A requirement node identifies a requirement** by:
  - A unique identifier (so as to achieve tracability)
  - A description in plain text
  - A type (functional, non functional, performance, security, . . .).

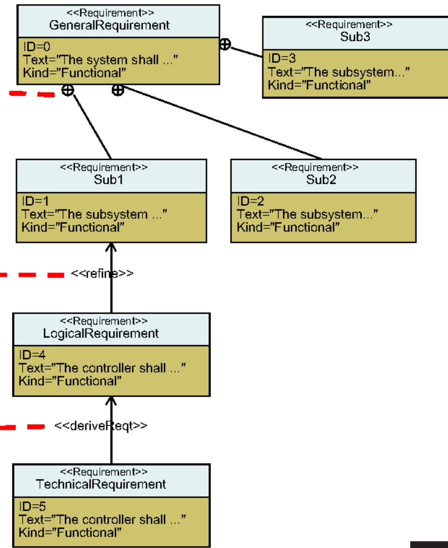


Relations Between Requirement Nodes

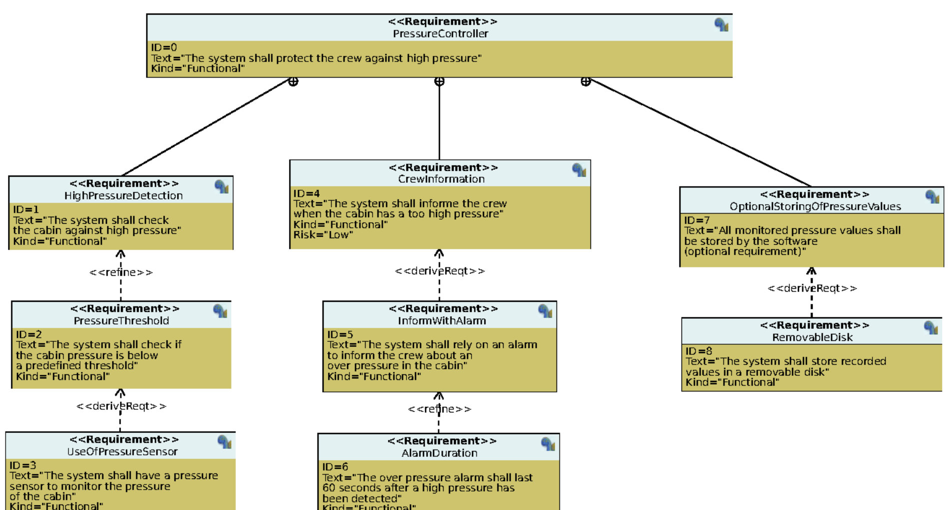
Containment relation
Splits up a compounded requirement into elementary ones

Refinement
Relates two requirements of different abstraction levels

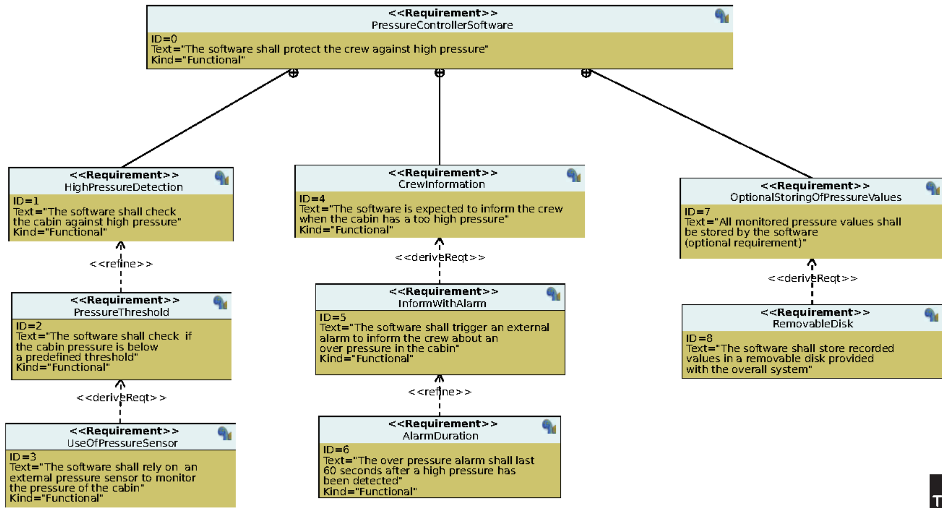
Derivation
Builds a new requirement from the reuse of other requirements



Requirement Diagram - Pressure Controller - System View



Requirement Diagram - Pressure Controller - Software View



Outline

Complex Embedded Systems

- Complex Embedded System = set of SW and HW components intended to perform a predefined set of functions for a given market
- Constraints
  - Right market window
  - Performance and costs

Design Challenges

Complexity

- Very high software complexity
- Very high hardware complexity

Problem

How to decide whether a function should be implemented in SW or in HW, or both?

Solution

Design Space Exploration!
(a.k.a. "Partitioning")

Design Space Exploration

Design Space Exploration

- Analyzing various functionally equivalent implementation alternatives
- → Find an optimal solution

Important key design parameters

- Speed
- Power Consumption
- Silicon area
- Generation of heat
- Development effort
- ...

Case Study Method Requirements (Partitioning) Analysis Design

Level of Abstraction

Problematic

- Designers struggle with the complexity of integrated circuits (e.g. System-on-chip)
- Cost of late re-engineering
  - Right decisions should be taken as soon as possible ...
  - And quickly (time to market issue), so simulations must be fast

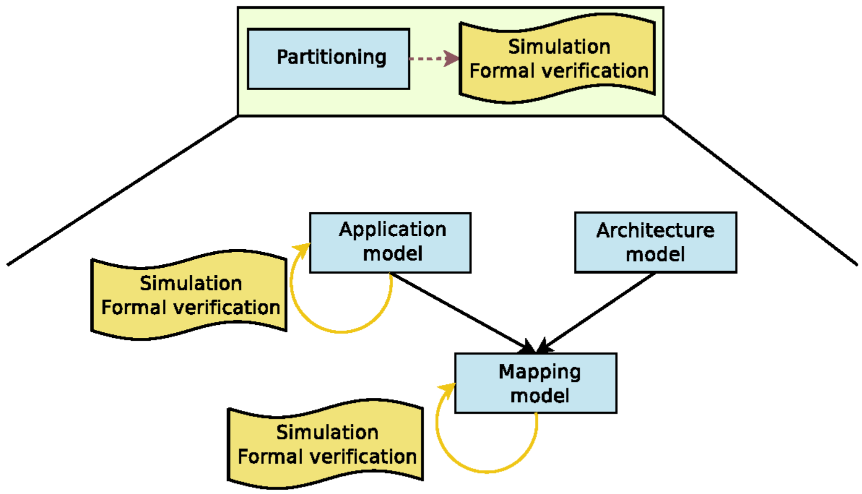
→ System Level Design Space Exploration

- Reusable models, fast simulations / formal analysis, prototyping can start without all functions to be implemented

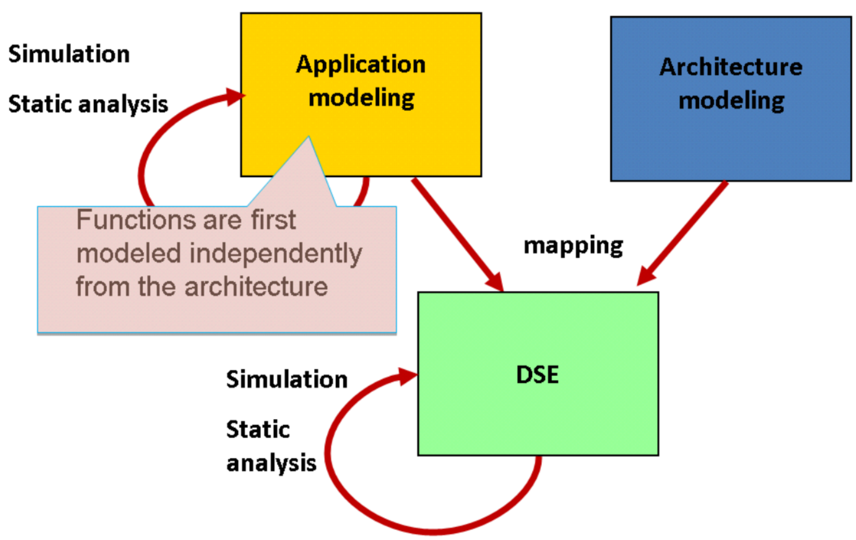
But: high-level models must be closely defined so as to take the right decisions (as usual ...).

Partitioning with the Y-Methododology

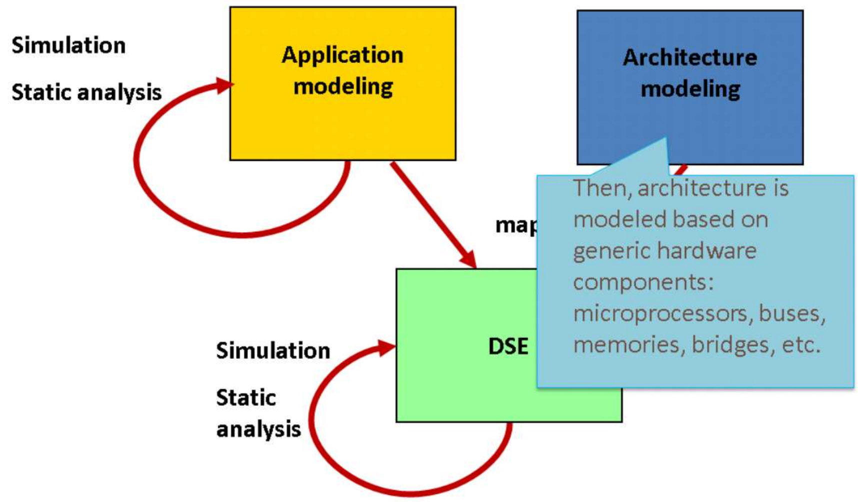
- Example: the DIPLODOCUS methodology



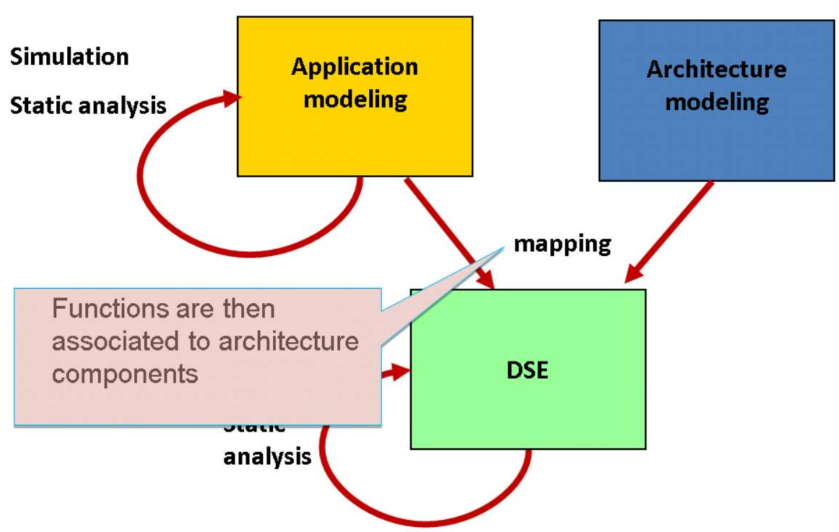
Application Modeling



Architecture Modeling



Mapping



Outline

System Analysis

Analysis = Understanding what a client wants

- So, it does not mean "creating a system", but rather "understanding the main functionalities" of the system to be designed
- Can be performed before or after the partitioning stage

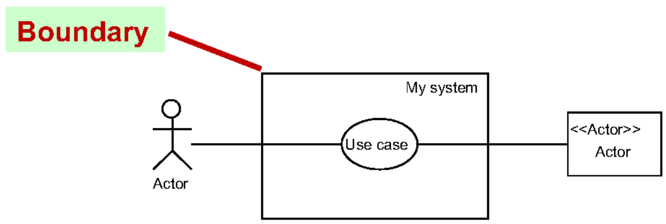
Analysis method

1. System boundary and main functions → *Use Case Diagram*
2. Relations between main functions → *Activity Diagram*
3. Communications between main system entities and actors → *Sequence Diagram*

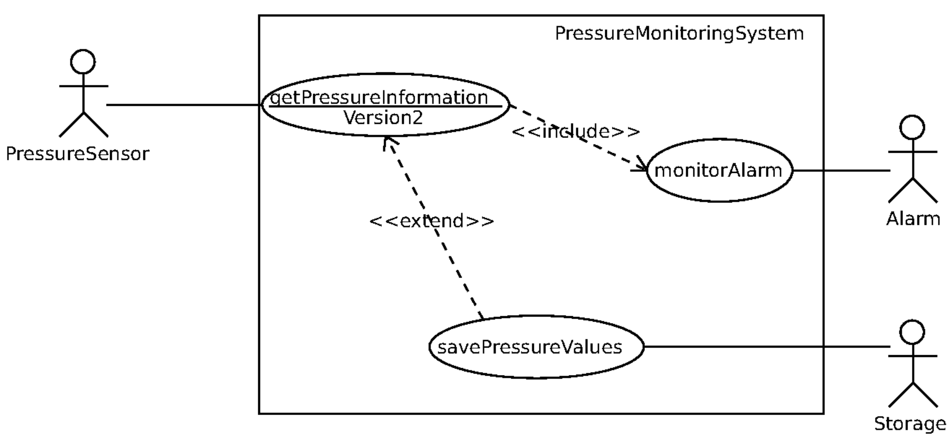
Use Case Diagram: Method

- **Shows what the system does and who uses it**

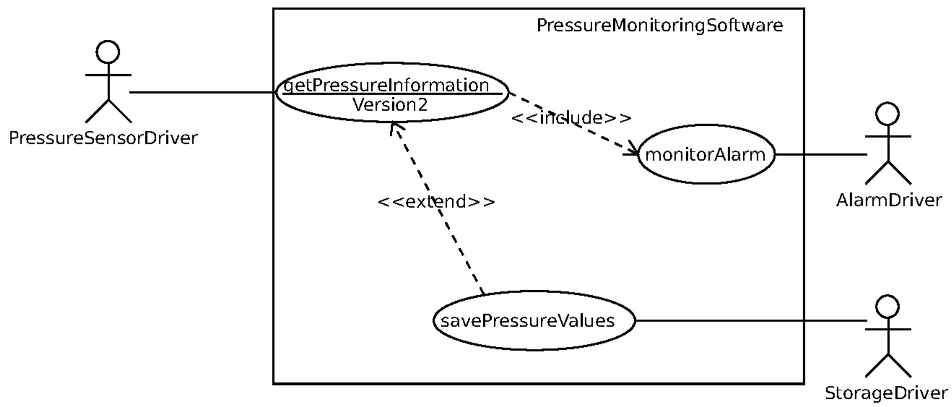
1. **Define the boundary of the system**
   - Inside of the rectangle → What you promise to design
   - Outside of the rectangle → System environment (= Actors)
     - **This is not part of what you will have to design**
2. **Name the system**
3. **Identify the services to be offered by the system**
   - Only services interacting with actors
4. **Draw interactions between functions and actors**



Use Case Diagram - Pressure Controller - System View

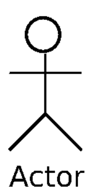


Use Case Diagram - Pressure Controller - Software View

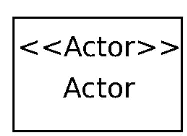


Actors

- **Syntax 1**: Stickman



- **Syntax 2**: <<Actor>>

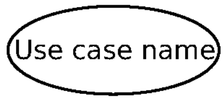


Method

- An actor identifier is a substantive
- An actor must interact with the system

Use Case

- **Syntax**: ellipse with exactly one use case

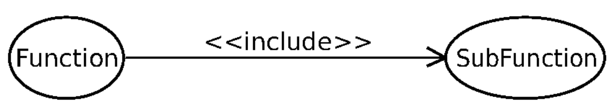


Method

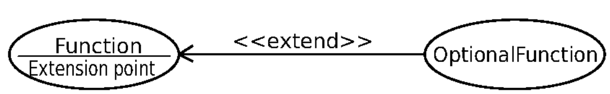
- A use case is described by a verb
  - The verb should describe **the point of view of the system**, not the point of view of the actors
- A use case diagram must **NOT** describe a step-by-step algorithm
  - A use case describes a high-level service/function, not an elementary action of the system

Use Case to Use Case Relations

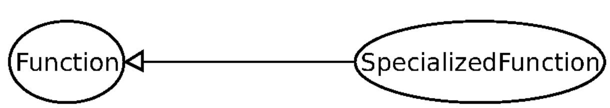
- **Inclusion**
  - A function mandatorily includes another function



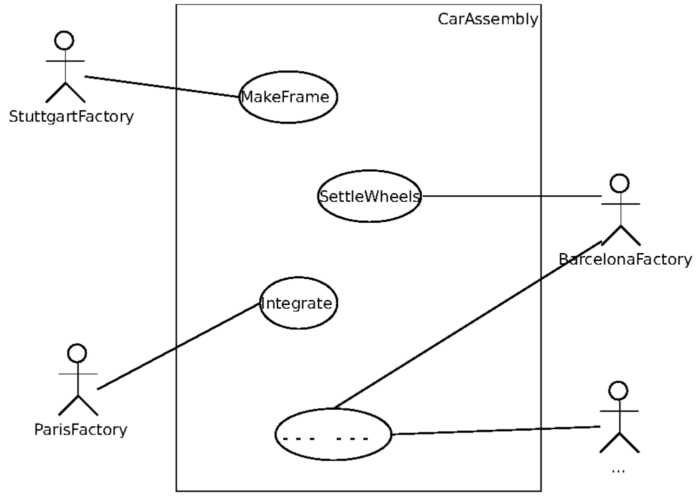
- **Extension**
  - A function optionally includes another function



- **Inheritance**
  - A "child" function specializes a "parent" function

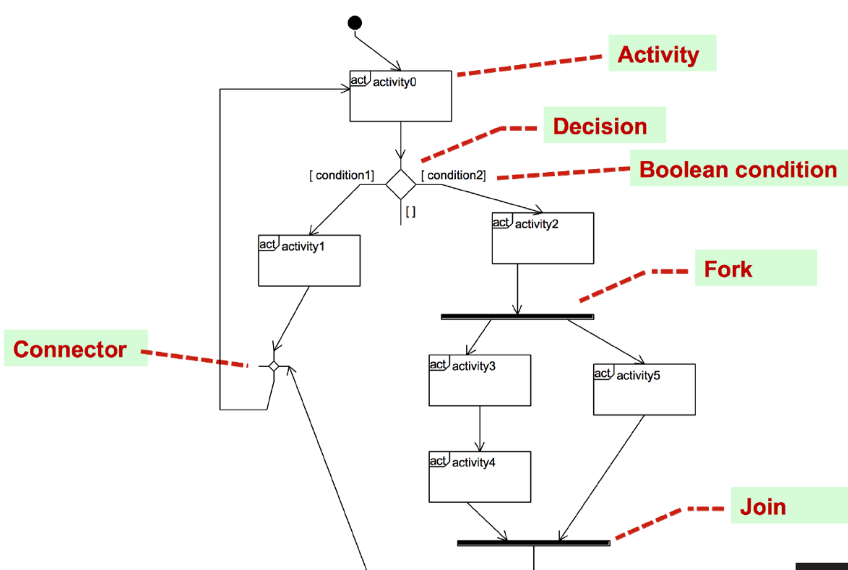


Location-Driven Use Case Diagram

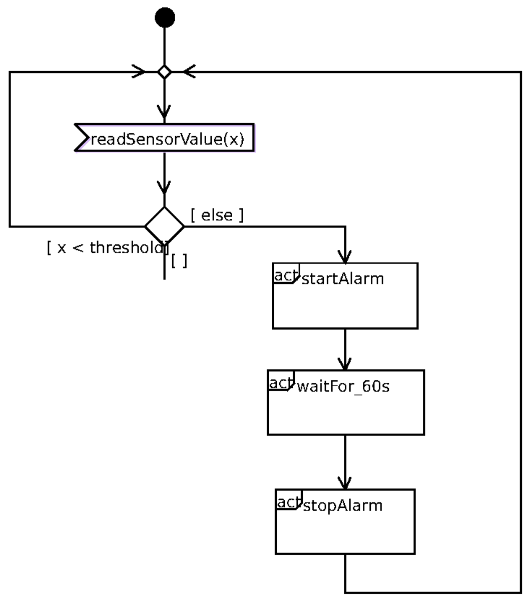


Activity Diagram - Syntax

Shows functional flows in the form of succession of actions

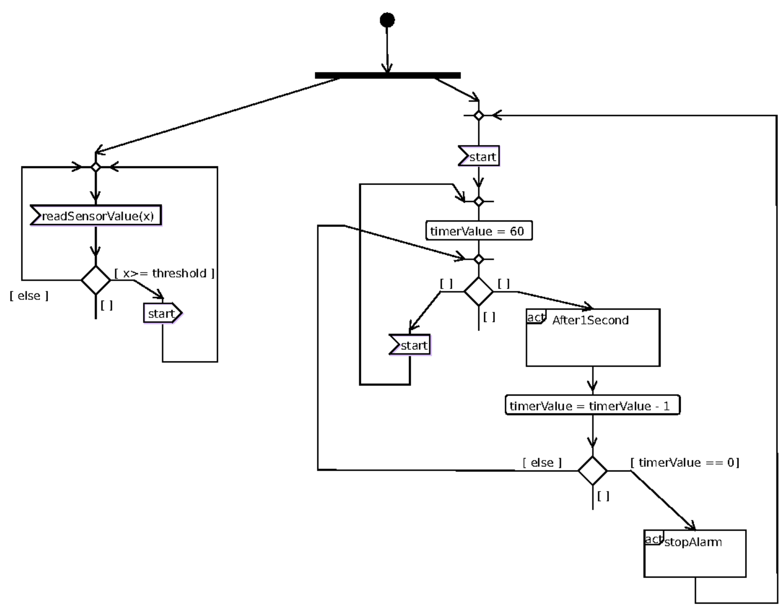


Activity Diagram - Pressure Controller

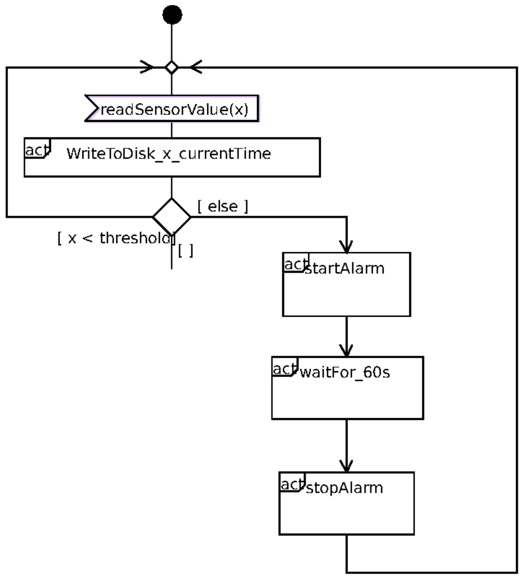


Case Study Method Requirements (Partitioning) Analysis Design

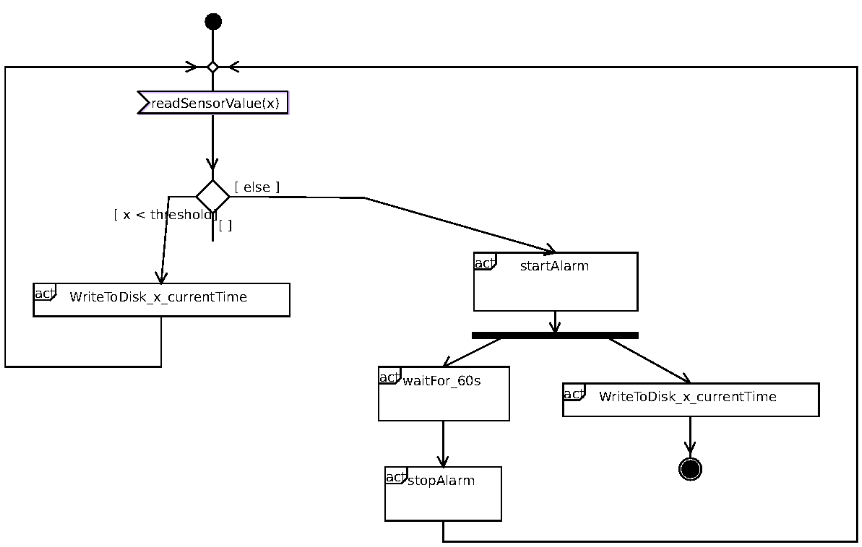
Activity Diagram - Pressure Controller



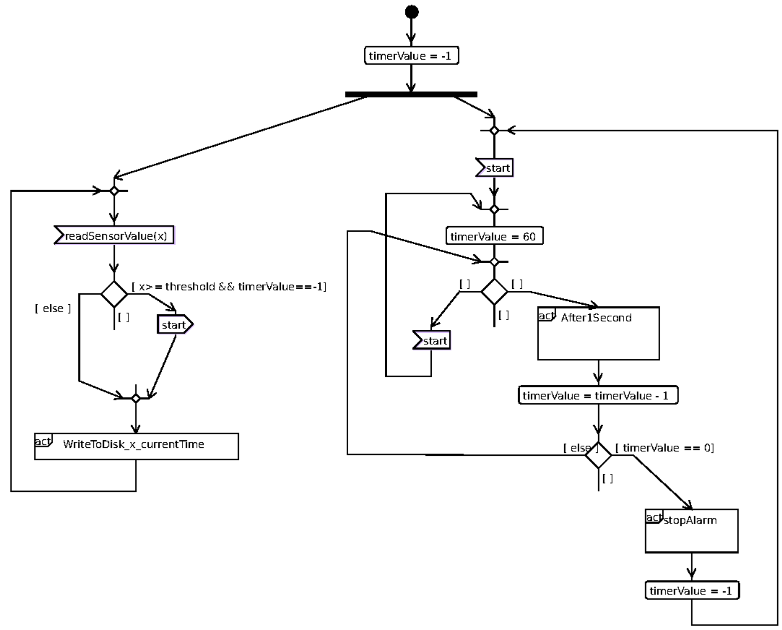
Activity Diagram - Pressure Controller



Activity Diagram - Pressure Controller

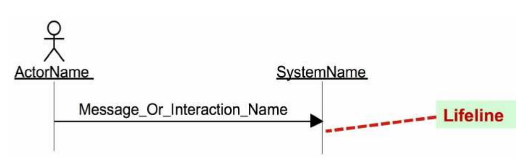


Activity Diagram - Pressure Controller

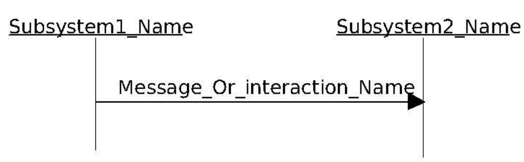


Sequence Diagram

- **An actor interacting with a system**

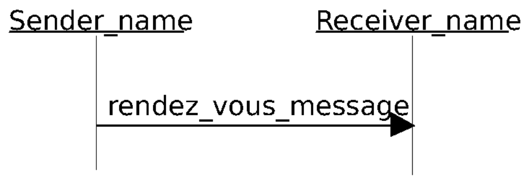


- **Two interacting "parts" of the system**

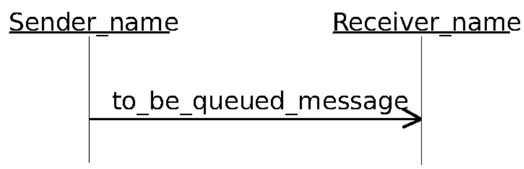


Sequence Diagram - Messages

- **Synchronous communication** (black arrow)



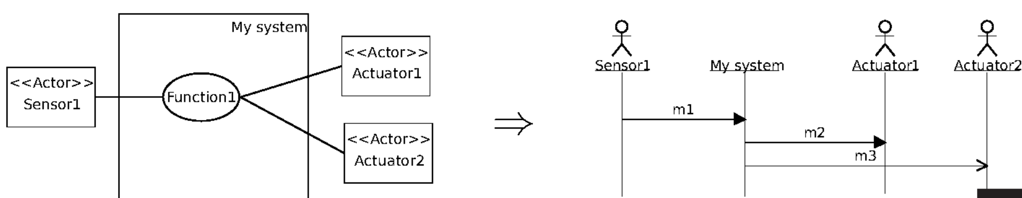
- **Asynchronous communication** (regular arrow)



Using Sequence Diagrams

Method

- A sequence diagram depicts one possible execution run, **NOT** the entire behavior of the system
- **NO message between actors**
- All actors must be defined in the use case diagram
  - WARNING: Coherence between diagrams

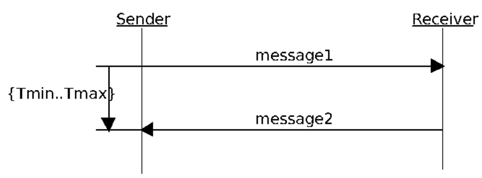


Sequence Diagram - Time (1/2)

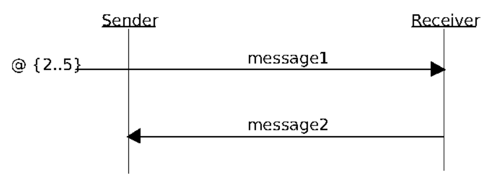
Semantics

- One global clock (applies to the entire system)
- Time uniformly progresses (lifelines are read top-down)
- Causal ordering of events on lifelines
  - Time information must be explicitly modeled

- **Relative dates**

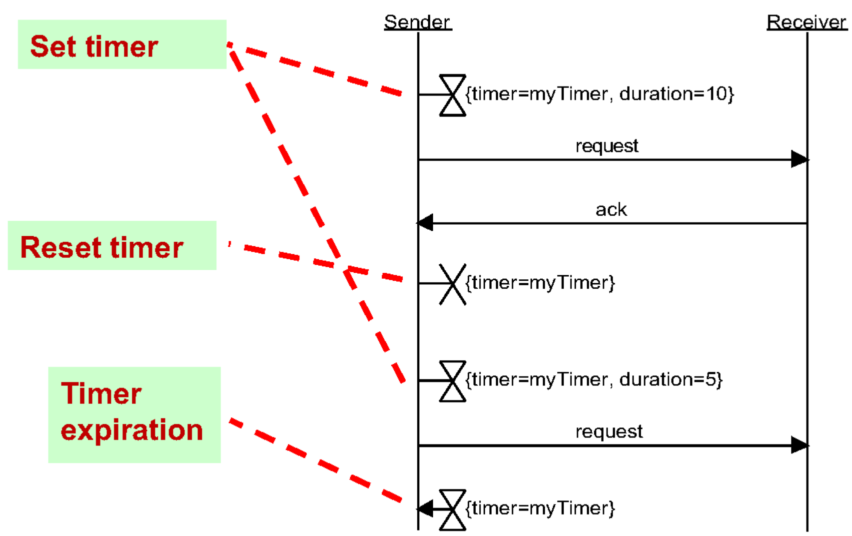


- **Absolute date**



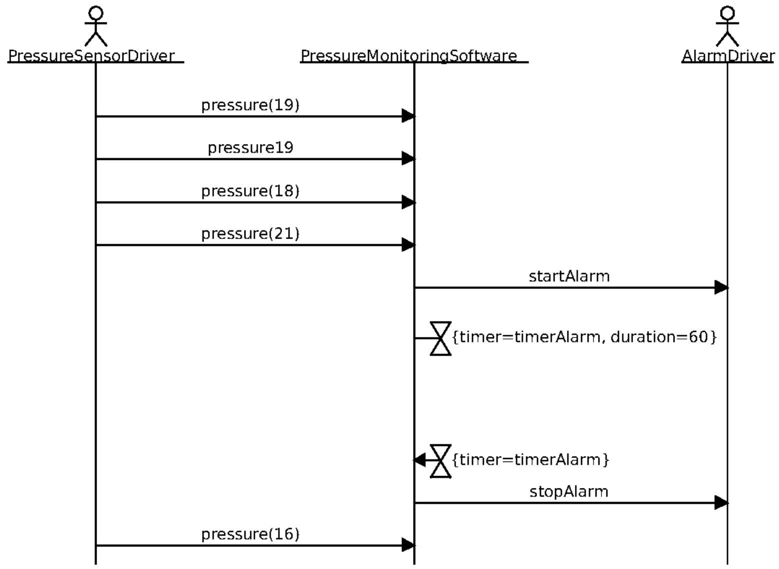
Sequence Diagram - Time (2/2)

- **Timers**



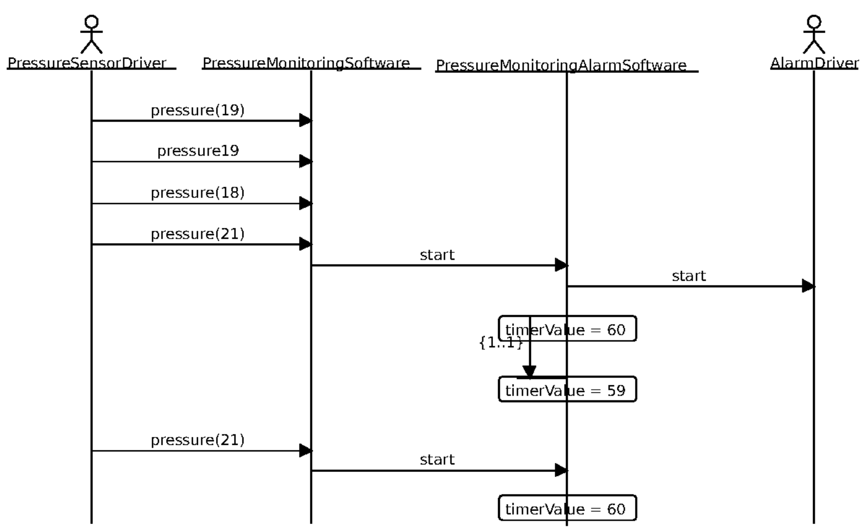
Sequence Diagram - Pressure Controller

Nominal trace



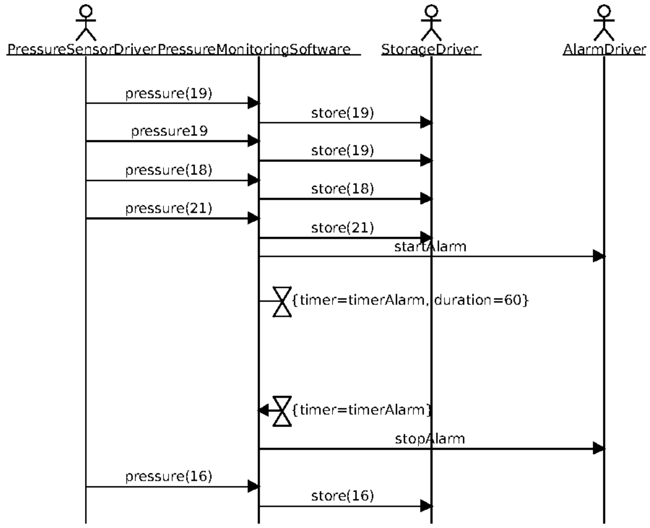
Sequence Diagram - Pressure Controller

Advanced trace



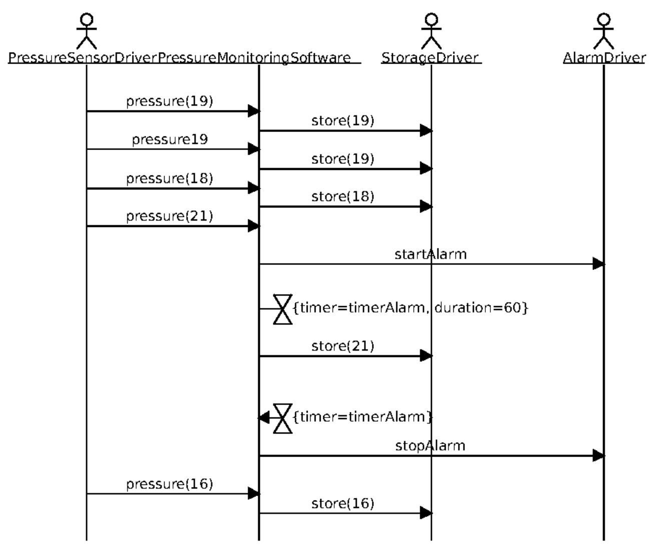
Sequence Diagram - Pressure Controller

Nominal trace - version 2 (save before alarm)



Sequence Diagram - Pressure Controller

Nominal trace - Version 2 (save after alarm)



Outline

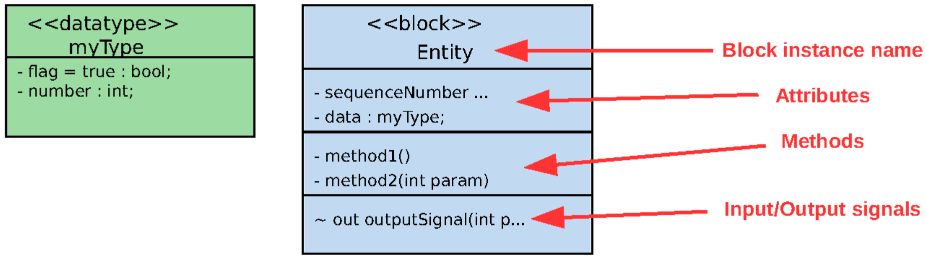
System Design

Design = Making what a client wants

So, it means "inventing a system", "creating a system" that complies with the client requirements.

- System architecture → *Block Definition Diagram and Internal Block Diagram*
  - In AVATAR, they are merged in one diagram that contains:
    - The definition of blocks
    - The interconnection of these blocks
- Behaviour of the system → *State Machine Diagram*
  - One state machine diagram per block

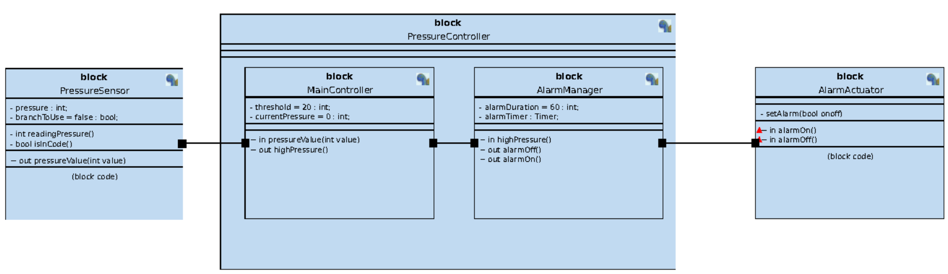
(Instance) Block Diagram: Syntax of Blocks



Note

- Upper-case and lower case characters
- Attributes are *private* elements
- Signals have the *package* access right
  - Package = a block + its sub-blocks

(Instance) Block Diagram: Connecting Blocks

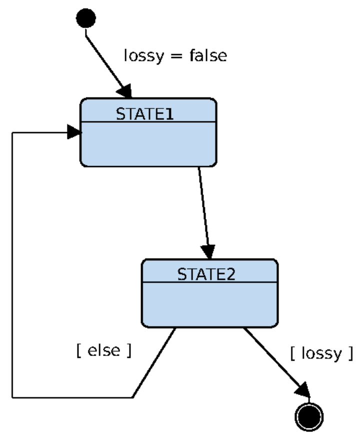


- Ports are connected to allow the state machines of blocks to exchange signals
- A block instance may nest one or several block instances

State Machine - States and Transitions

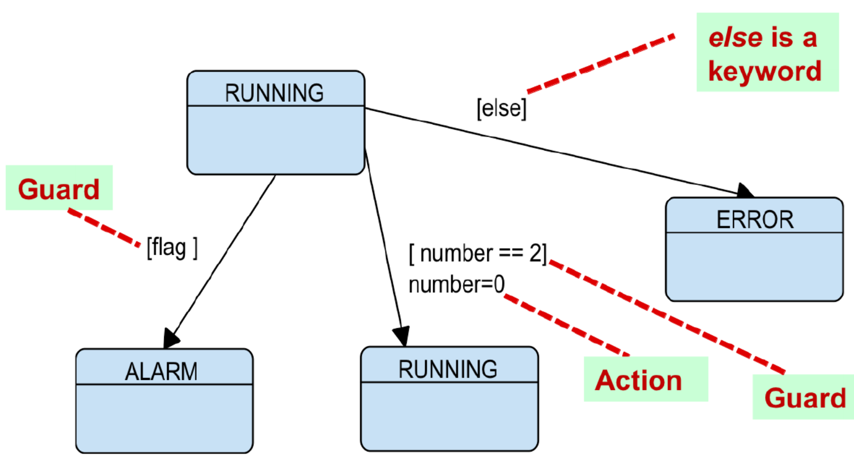
Note

- No parallelism
- States can have several output transitions



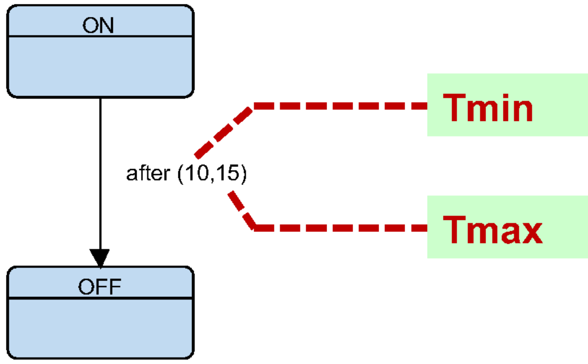
State Machines - Guards

- A transition guard contains a *boolean expression* built upon boolean operators and attributes



State Machines - Time Intervals

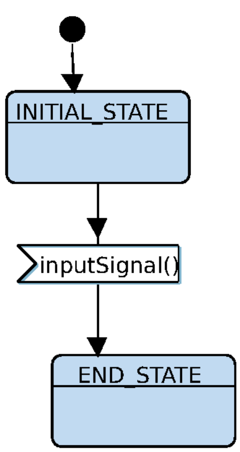
- *after* clause with a [Tmin, Tmax] interval



- A transition with no *after* clause has de facto an **after**$(0, 0)$ clause, which means the transition may be fired "immediately"

State Machine - Inputs (1/3)

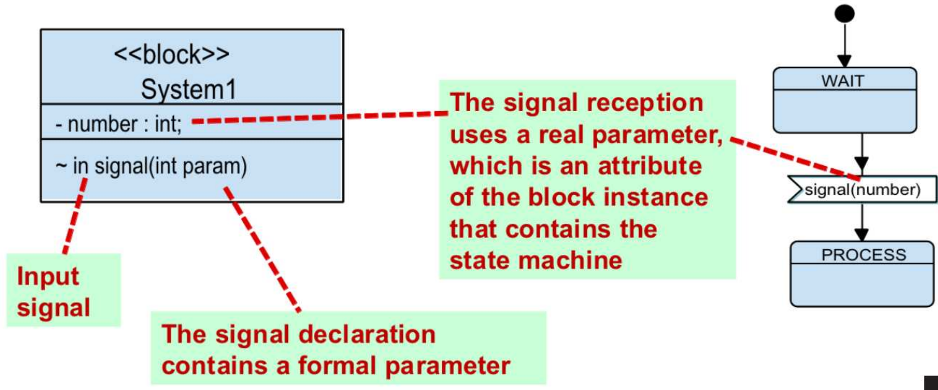
- A signal reception is a **transition trigger**



- The transition between INITIAL_STATE and END_STATE is triggered by a signal reception
- **Asynchronous communication**
  - FIFO-based
  - The transition is fired if $size(FIFO, inputSignal) > 0$
- **Synchronous communication**
  - The transition is fired whenever a rendezvous is possible
- Signals can convey parameters

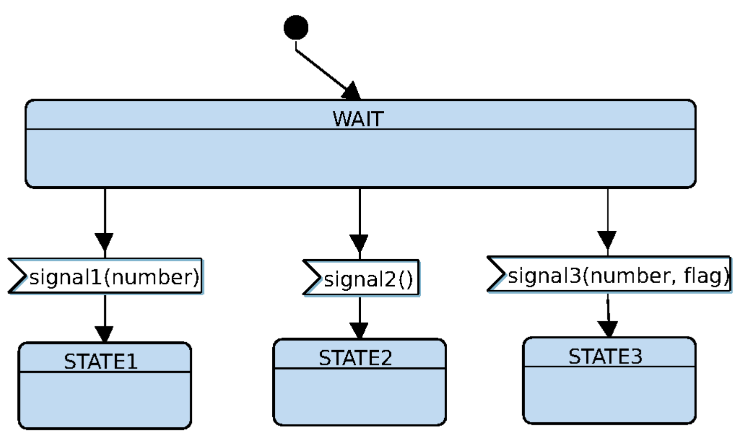
State Machine - Inputs (2/3)

- Signal parameters, if any, are stored in attributes of the block instance that receives the signal



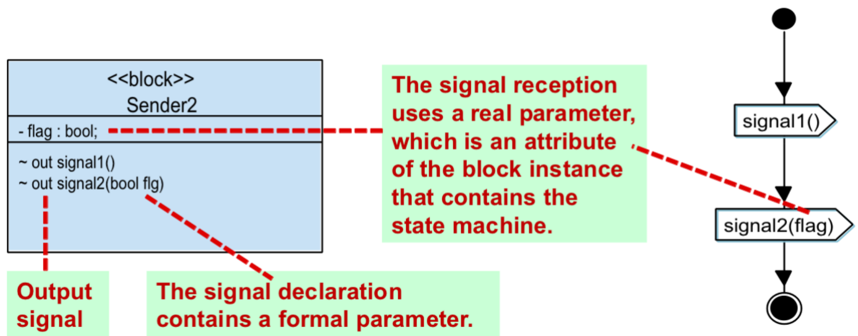
State Machine - Inputs (3/3)

- From the same state it is possible to wait for several signals
  - Asynchronous communication: the first signal in the input queues triggers the transition
  - Synchronous communication: The first ready-to-execute rendezvous triggers the transition



State Machine - Ouputs

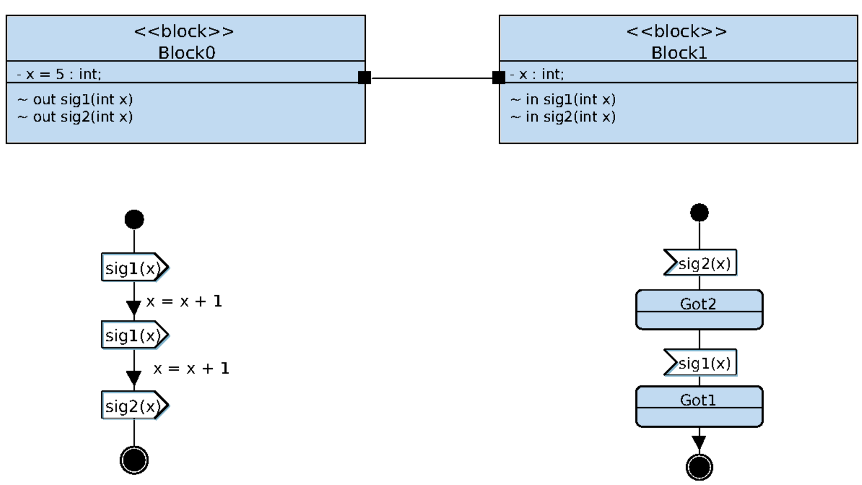
- A block instance can send signals with several parameters
  - Constant values may not be used as real parameters → use attributes instead



- A block instance cannot send two or several signals in parallel but it can send two or more signals in sequence

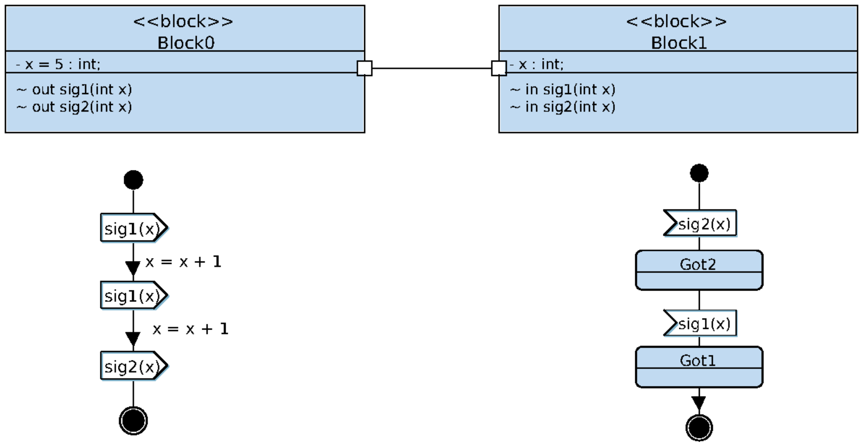
Synchronous Communications

- Sender and receiver synchronizes on the same signal
- Data exchange from the writer to the reader



Non-Blocking Asynchronous Communications

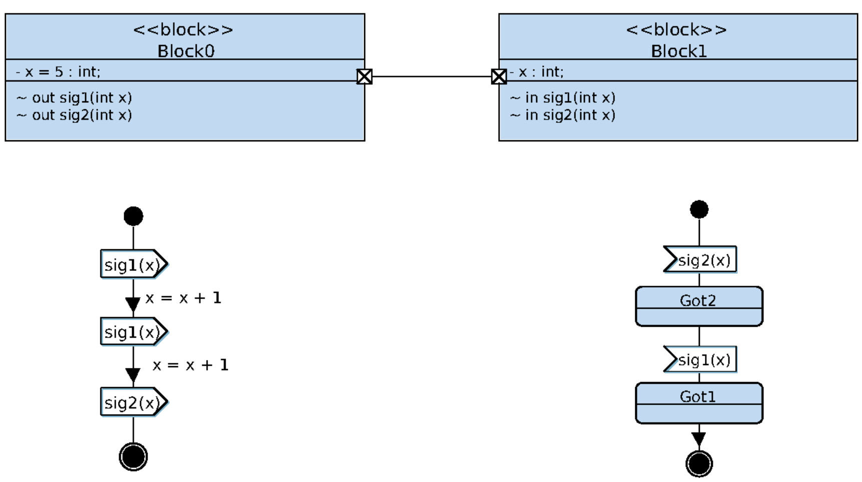
- One FIFO per signal association
- Writing is **NOT** blocked when the FIFO is full
  - Bucket approach when FIFO is full: new messages are dropped
- Example: we assume a FIFO of size 1



Case Study Method Requirements (Partitioning) Analysis Design

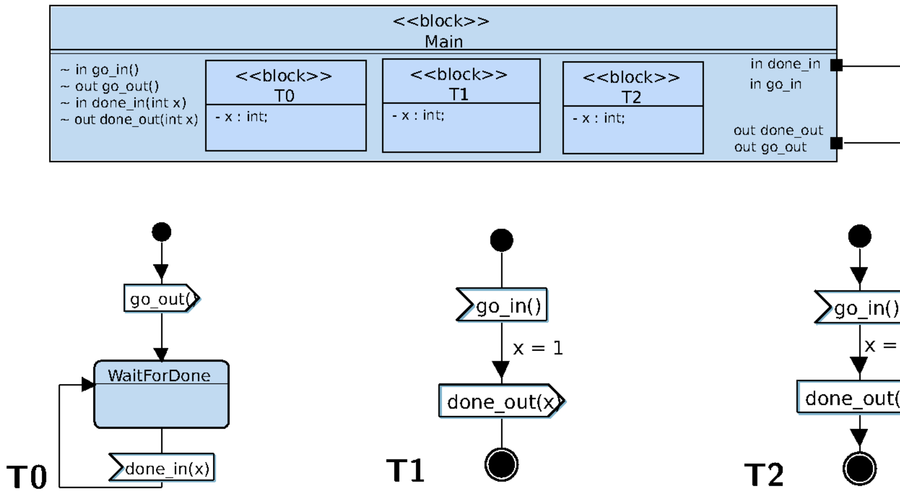
Blocking Asynchronous Communications

- One FIFO per signal association
- Writing is blocked when the FIFO is full
- Example: we assume a FIFO of size 1



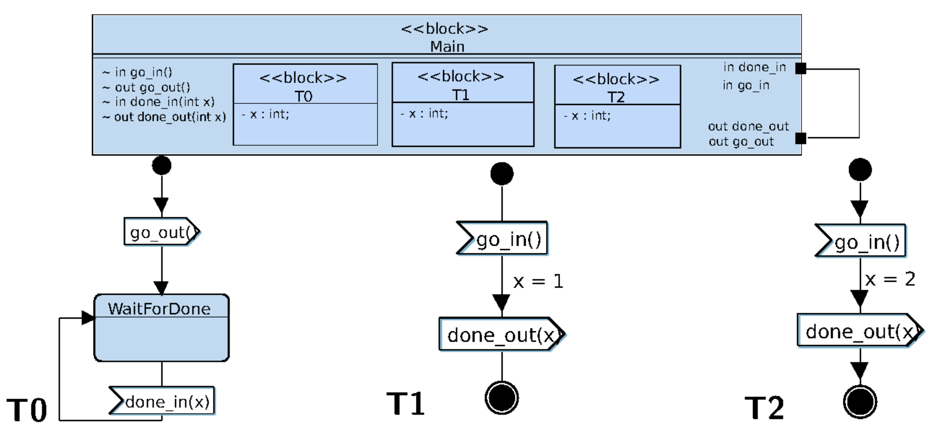
State Machine - Advanced I/O

- Signals declared by a block may be used by its sub-blocks



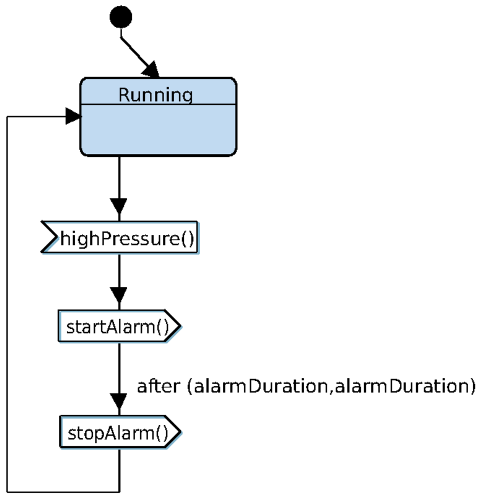
Broadcast Channel

- All blocks ready to receive a signal sent over a broadcast channel receive it
- So, what happens if the channel below is now set to *broadcast*?



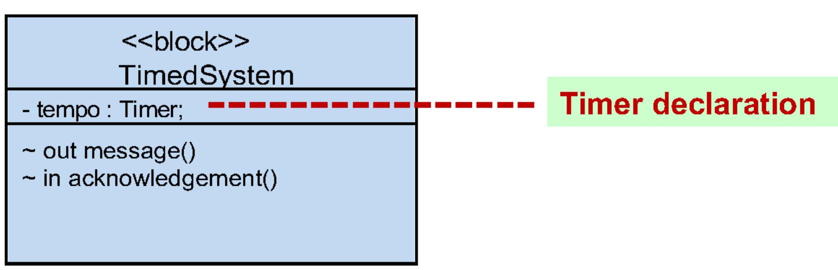
State Machine Diagram - Pressure Controller

- Shows the inner functioning of the *Controller* block instance



State Machines - Timers (1/3)

- **A timer must be declared as an attribute of the block instance which uses it**
  - Unlike attribute declarations, a timer declaration cannot contain an initial value
    - Use the *set* operator to initialize the duration of a timer
  - The signal issued by the timer at expiration time does not need to be declared



State Machines - Timers (2/3)

Set

- The "set" operation starts a timer with a value given as parameter
- The timer is based on a global system clock

Reset

Prevents a previously set timer to send an expiration signal

Expiration

- A timer "timer1" sends is a signal named "timer1" to the block instance it belongs to
- ⇒ A timer expiration is handled as a signal reception

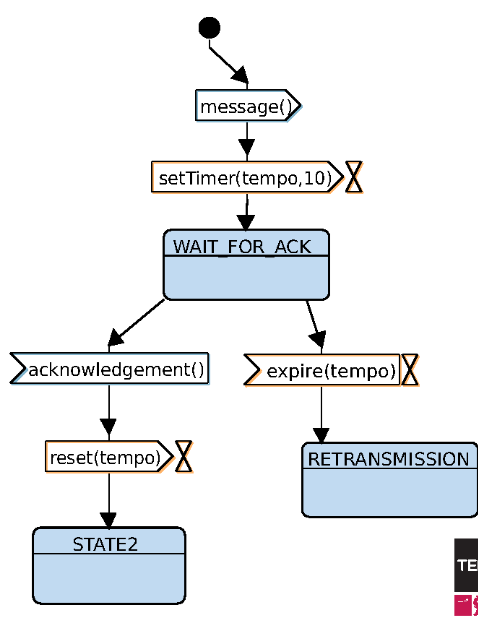
State Machines - Timers (3/3)

"Temporally limited acknowledgement" with timers

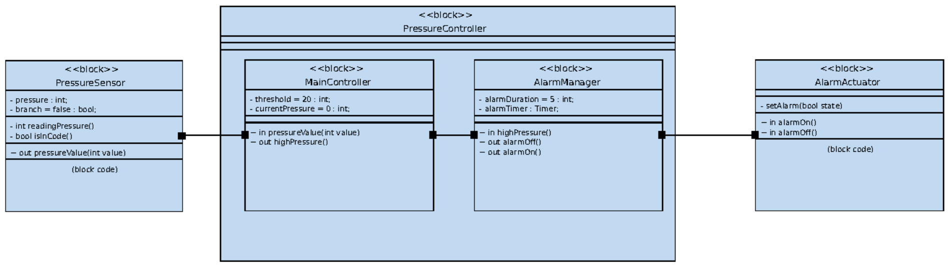
A block instance may take decisions depending on the signal which arrives first: either a "normal" signal or a timer expiration

Question

Could we use an *after* clause instead of the *tempo* timer?

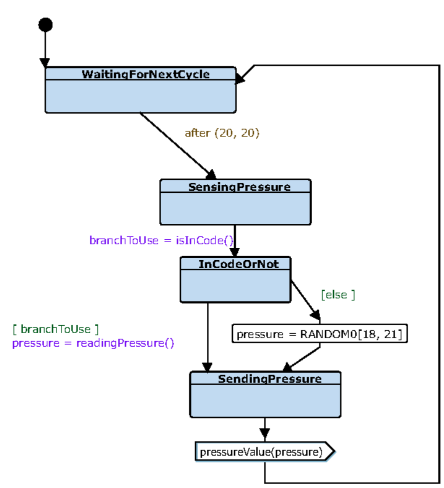


Pressure Controller



TELECOM Paris IP PARIS

Pressure Controller: States Machines



Pressure Sensor

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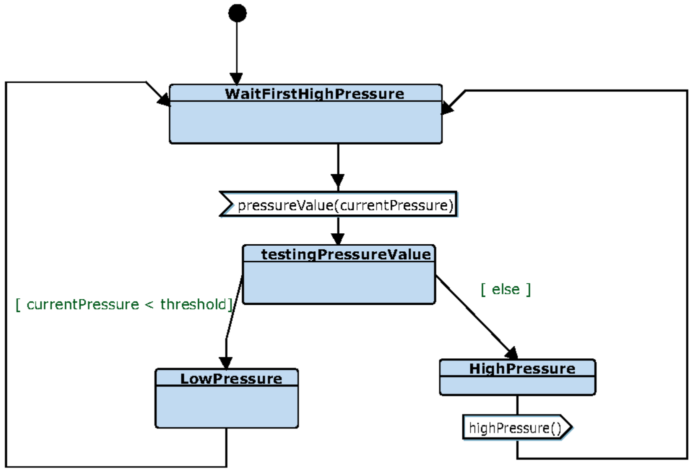
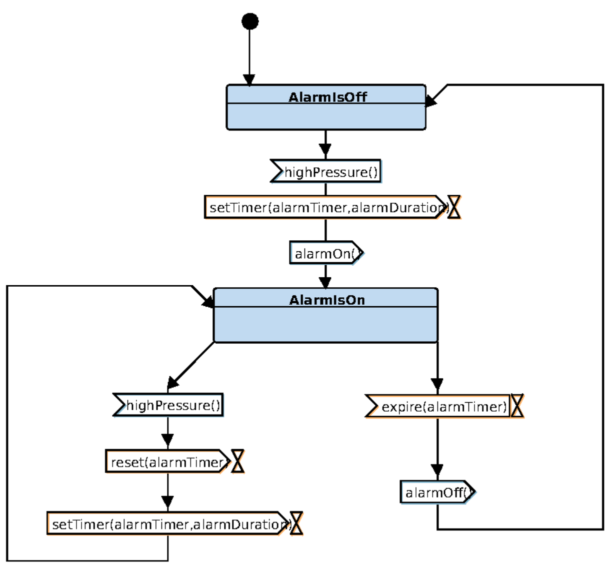
Pressure Controller: States Machines



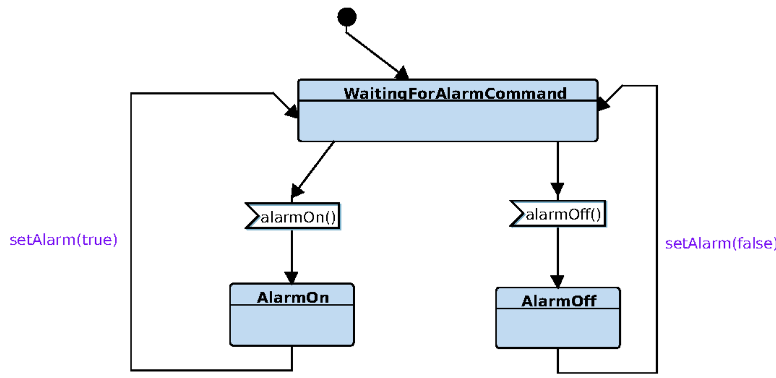
Main Controller

Pressure Controller: States Machines



Alarm Manager

Pressure Controller: States Machines



Alarm Actuator

How to Make "Good" Models?

Practice, Practice and Practice!!!

- Knowledge of various diagrams capabilities
- Accurate understanding of the system to model
- "Reading" your diagrams, reading diagrams of your friends, reading diagrams on Internet
- **Experience is a key factor**

→ **Make exercises!**