TOWARDS THE APPLICABILITY OF ALF TO MODEL CYBER-PHYSICAL SYSTEMS

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Agenda

- **Introduction**
  - Motivation
  - Goal
- **Context**
- **Initial approach**
  - Timing and Concurrency
  - Inter-Object Communication
- **Example**
- **Conclusions**

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Motivation

- Cartwright *et al.* (2006) define the following topics as the most important research challenges in CPSs:

(1) Effective methods for **analysis**, simulation and validation of models;

(2) Methods and techniques for guaranteeing real-time properties;

(3) **Modeling languages** for (hybrid) cyber-physical systems.

Goal

- **Problem:** Behavioural definitions in SysML – activity diagrams, sequence diagrams, state machine diagrams, action language, etc...

- **Goal:** specialization to the **action language** for foundational UML (Alf)
  - according to the **synchronous-reactive** Model of Computation
  - for **discrete** behavioural definitions
  - embedded in **SysML** models describing **CPS**s.

*The properties themselves are more difficult to state, were **weaker than** could be achieved in the **synchronous case**, and required **considerable complexity** to be added to the model to ensure that even the weakened properties were true. (Miller et. Al., 2005, section 6.3, pg 23)*

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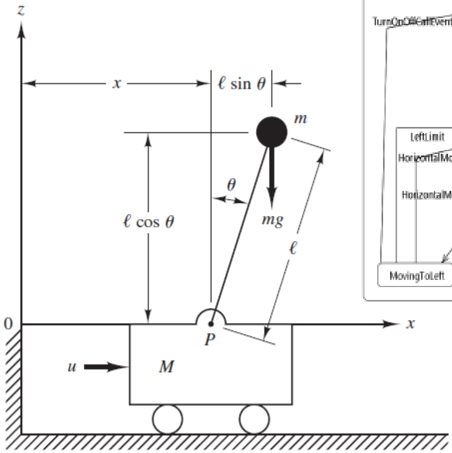
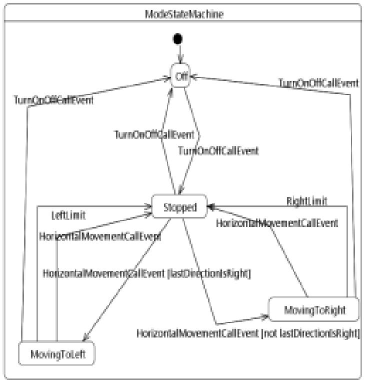
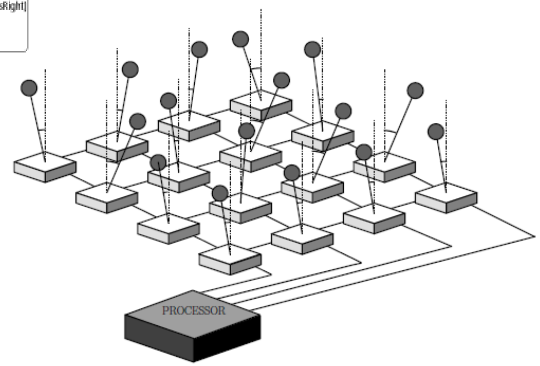
CPSs

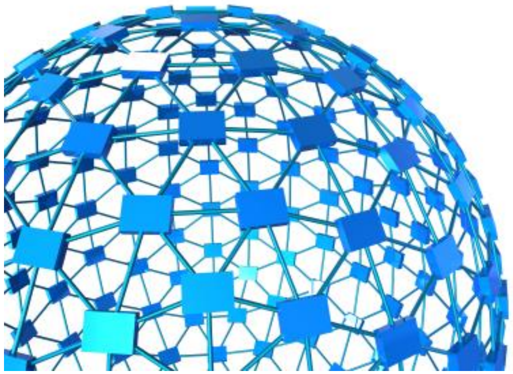


(Ogata, 2009)





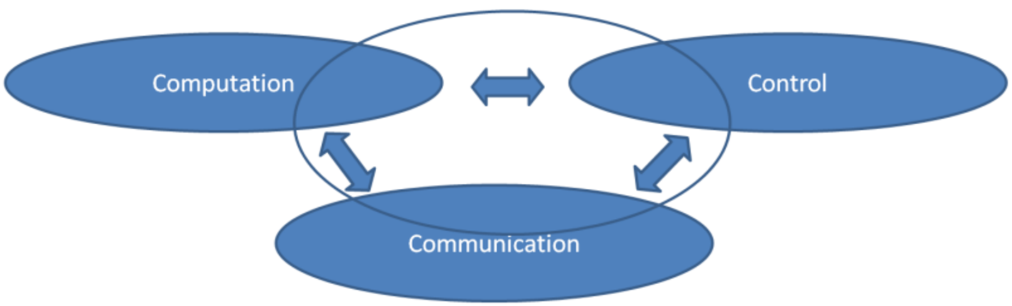
(Zhang *et al.*, 2008)



Hybrid System

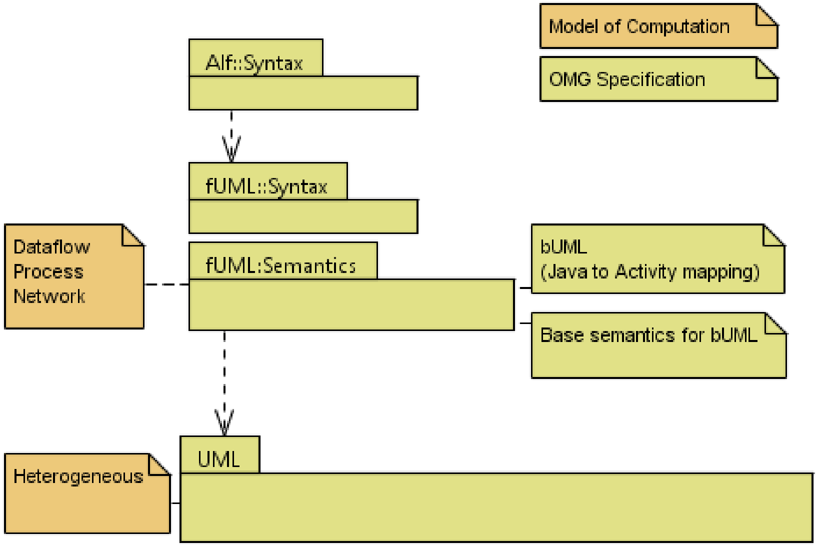
Network

CPSs



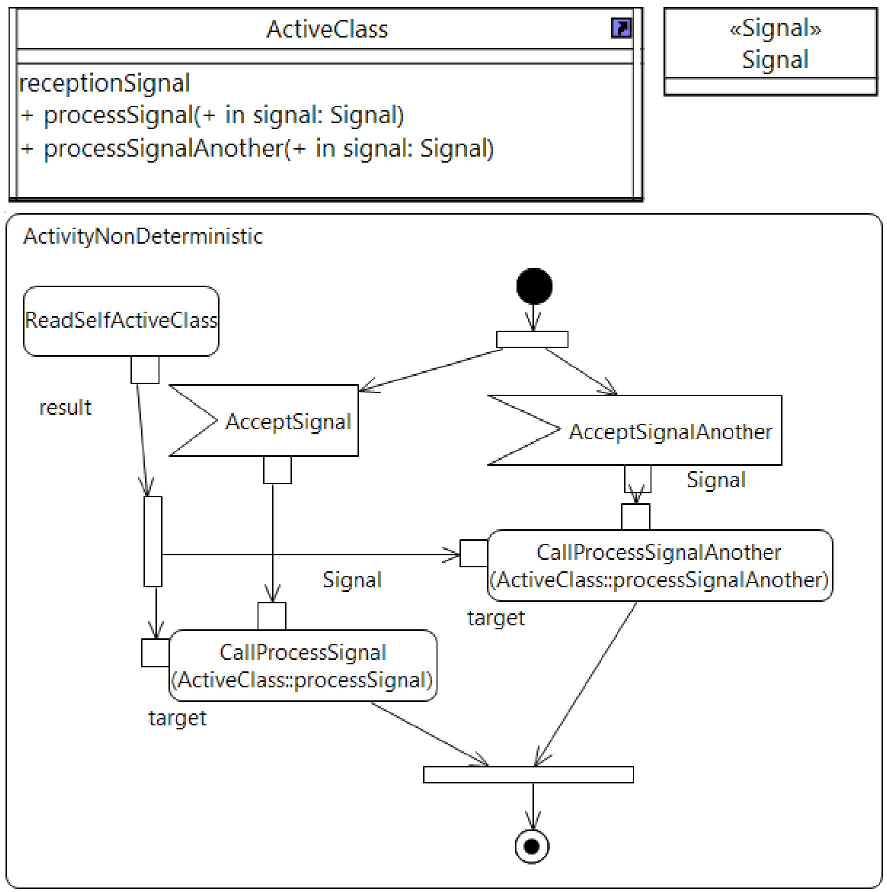
OMG Specifications – fUML and Alf

- **fUML** (Semantics of a Foundational Subset for Executable UML Models) is a subset of UML consisting of the key parts of UML **activities** and **classes** (OMG, 2012).
- **Alf** is the **concrete syntax** for the abstract action language defined by fUML (OMG, 2013).



- fUML, and also Alf, is **not directly feasible to safety-critical systems** (execution model) is **nondeterministic** (Benyahia *et. al.*, 2010).

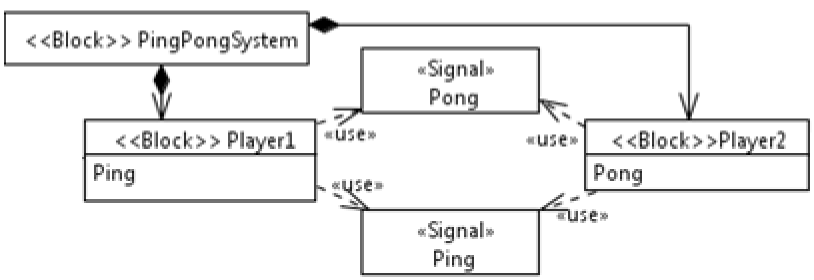
OMG Specifications – fUML and Alf (2/2)

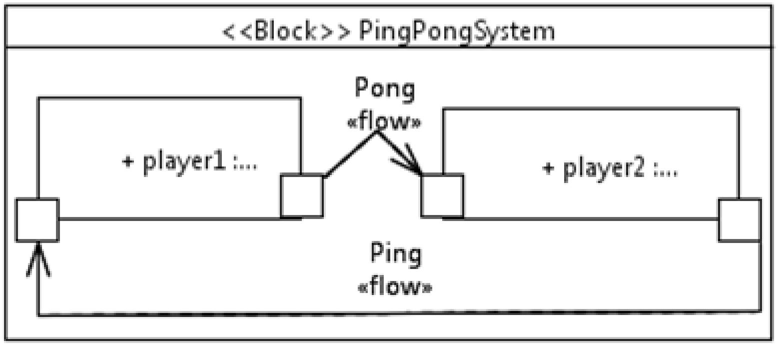



```
                                                   //ACC0
//@parallel
{
    {
        accept( sig:Signal );                      //ACC1
        this.processSignal( sig );
    }
    {
        accept( sigAnother:Signal );               //ACC2
        this.processSignalAnother( sigAnother );
    }
}
```

SysML

- **SysML** (*Systems Modeling Language*) - general-purpose modeling language for systems engineering applications. It reuses a subset of UML, and provides additional extensions to satisfy the necessities of systems engineering, e.g., Requirements Diagram, Parametric Diagram, and allocation.





Synchronous-reactive MoC

- Provides precise behavioural representation using the fundamental model of time as a **sequence of discrete** instants, **computation and communication executed in zero-time**, and **parallel composition as a conjunction** of behaviors (Benveniste *et. al.*, 2003). Solutions can be desynchronized.

- Macro step consists of finitely many micro steps
- Macro steps correspond to reactions of reactive systems, while micro steps correspond with atomic actions

- Languages: Esterel, Quartz, Signal, Lustre, etc…

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Timing and Concurrency

- Time
  - a discrete succession of instants; each instant corresponds to one **macro step**
  - demarcation of macro steps ***@pausable***
    - After each execution of a loop body, it waits for the next **macro step**.
    - All **concurrent behaviors run in lockstep**: they execute the actions inside the loop in zero time, and **synchronize** before next iteration.
- Concurrency
  - concurrent statements (using *@parallel*)
  - multiple active objects

ANNOTATIONS IN THE SPECIALIZED ALF

Annotation	Informal semantics
@delayed	Delayed assignment or *SendSignalAction*
@pausable	Macro step demarcation
@parallel	Computations on each block are carried out concurrently
@nonblocking	*AcceptEventAction* read nonblocking, makes optional signals available

Inter-object communication

- Performed sending signals (*SendSignalAction*) to other active object (not blocking)
- Multicasting was introduced by an active class called ***MessageDispatcher***
  - Work as bus transferring instances of signals between previously registered active objects, which generate events in the target active object.

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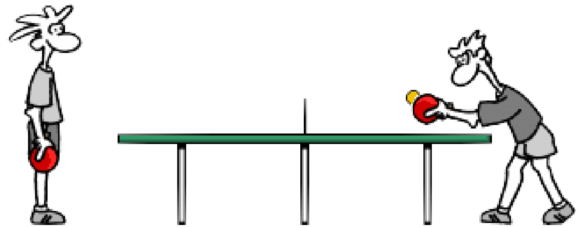
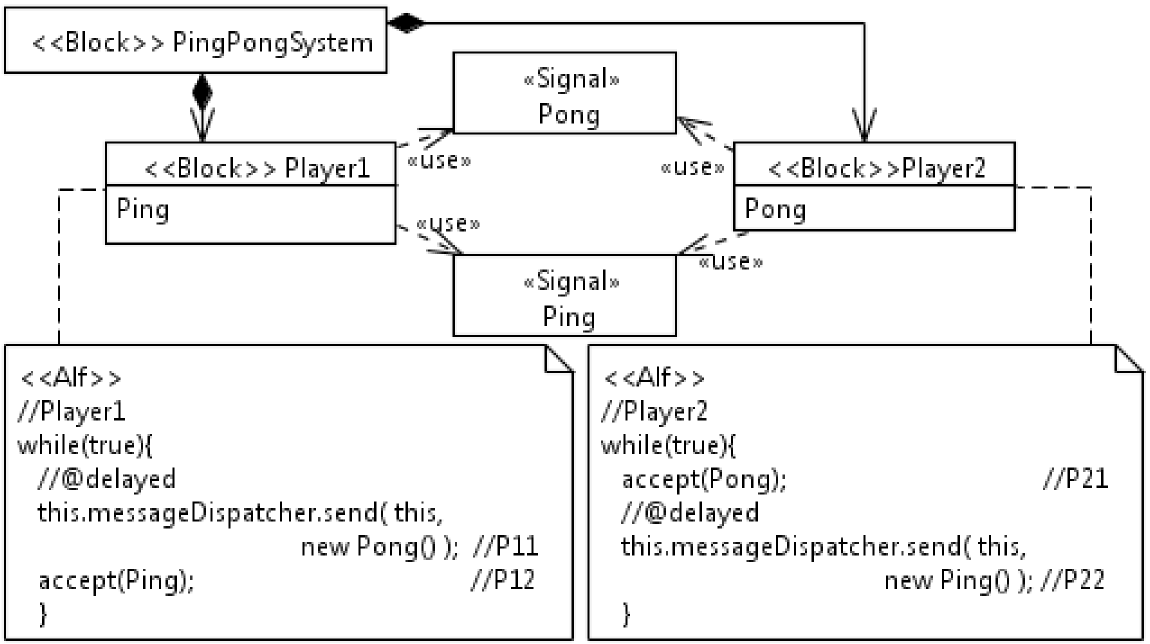
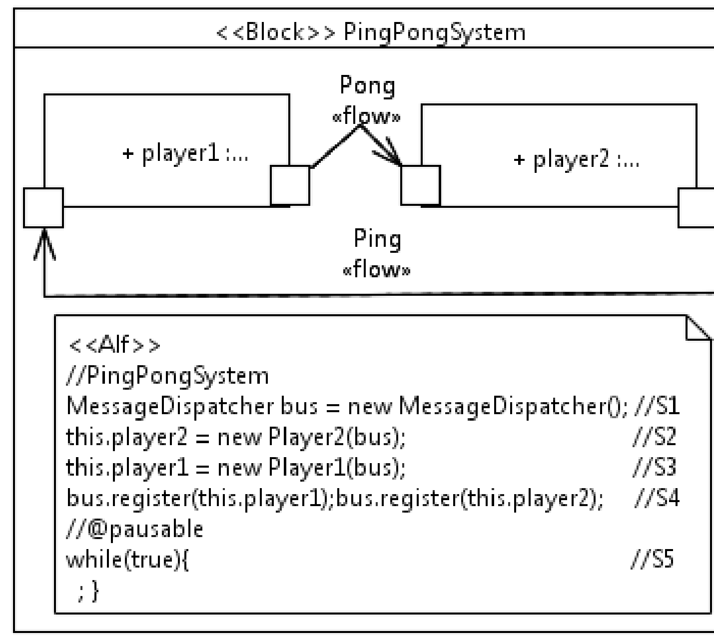
Example – Synchronous Ping Pong







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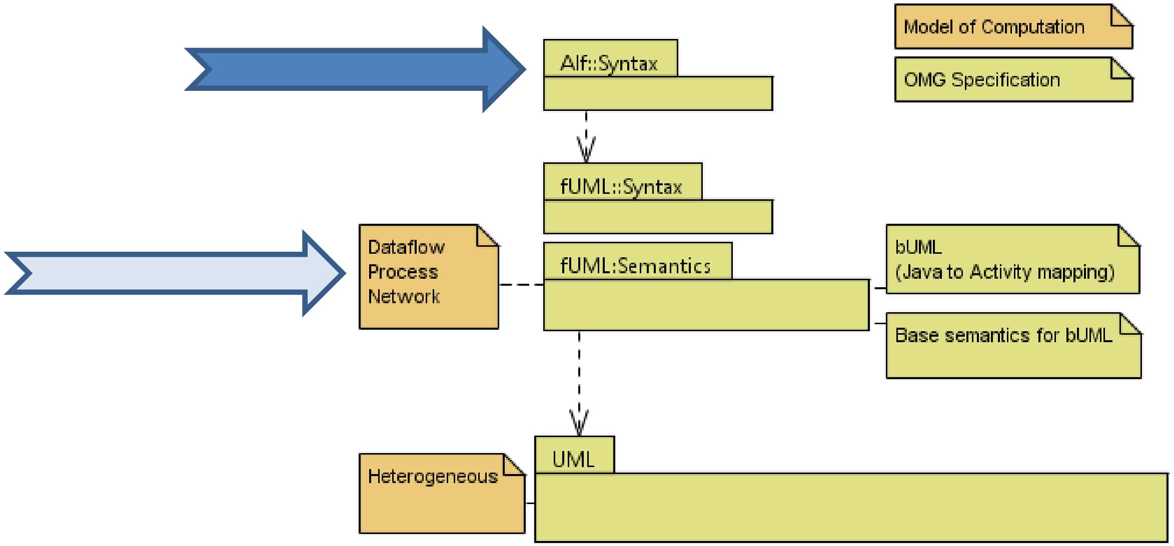
Conclusions

• ***Specializing*** well-known vendor-independent specifications (Alf and SysML) can provide an understable set of languages for modeling, analysing, and verifying of CPSs.

• Such a set of languages **can** enable **formal** verification for **discrete** parts of CPS.



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