1. Cyber-Physical Computation: Introduction

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Cyber Physical Computation

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https://lmf.di.uminho.pt/CyPhyComp2223/

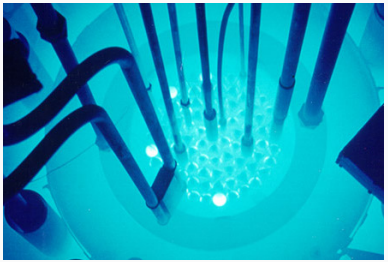
https://haslab.github.io/MFP/PCF/2223/

Universidade do Minho

Cyber-Physical Systems

Cyber-Physical Systems

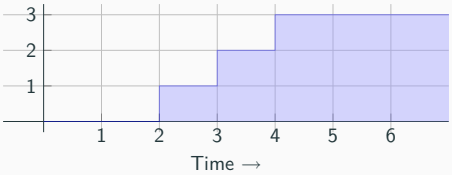
Computational devices that interact with their physical environment



Another example of a cyber-physical system

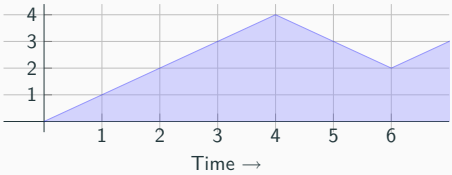
Computer Science meets Analysis

Wait Calls



$(\texttt{wait}\ 2)\,;\ \texttt{x} := \texttt{x} + 1\,;\ (\texttt{wait}\ 1)\ \ldots$

Differential Statements



$$
\begin{aligned}
&\texttt{while}\ (\texttt{true})\ \{\\
&\quad \texttt{if}\ \texttt{v} \leq 2\\
&\qquad \texttt{then}\ (\dot{\texttt{v}} = 1\ \texttt{for}\ 2)\\
&\qquad \texttt{else}\ (\dot{\texttt{v}} = -1\ \texttt{for}\ 2)\ \}
\end{aligned}
$$

Contents of the module

Cyber-Physical Computation

Genesis: David Hilbert and its
Entscheidungsproblem *(circa 1928)*

The problem fuelled the appearance of the first two models of computation ...

- Turing machines (*circa* 1936): state-based computation, part of automata theory
- λ-calculus (*circa* 1936): function-based computation, can be seen as a prototypical programming language

Contents of the module pt. I

We will study a myriad of models for cyber-physical computation

- timed automata,
- a hybrid while-language,
- λ-calculus extended with computational effects (monads!)

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and often make detours through the mathematical foundations of automata and programming language theory.

Contents of the module pt. II

We will also get accquainted with a number of tools

- Uppaal – verification of real-timed systems modelled by (networks of) timed automata
- Lince – agile analysis of cyber-physical systems modelled by a hybrid while-language
- Haskell – a platform to study λ-calculus with effects

How deep will we go into the rabbit hole?

Our learning path will intersect theory and practice,
from the very basics to the state-of-the-art —
we will face current limitations and see what challenges lie ahead

Syllabus

- CSS: a simple language for concurrency
  - Syntax
  - Semantics
  - Equivalence
- Timed Automata
  - Syntax
  - Semantics (composition, Zeno)
  - Equivalence
  - UPPAAL tool
    - Specification
    - CTL and Verification
- A simple C-like language
  - Syntax
  - Semantics (operational)
- Hybrid-language: adding differential equations
  - Syntax
  - Semantics
  - Lince tool
    - Specification
    - Analysis
- Monads: semantics with computational effects

Logistics

Useful information

Relevant class material and announcements will be posted on the website periodically

https://lmf.di.uminho.pt/CyPhyComp2223
https://haslab.github.io/MFP/PCF/2223

E-mail

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Office hours (please send an email the day before if you wish to meet):

- *Renato Neves:* Wednesday afternoon
- *José Proença:* Thursday morning

Assessment

Assessment will consist of

- 30% – an individual test at the end;
- 40% – a group assignment involving the use of the Uppaal model checker and of Haskell; and
- 15% + 15% – two sets of individual exercises to do at home.