

1. Cyber-Physical Computation: Introduction

Renato Neves José Proença

CPC 2022/2023

Cyber Physical Computation

CISTER – ISEP, Porto, Portugal

U.Minho, Braga, Portugal

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

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



Universidade do Minho

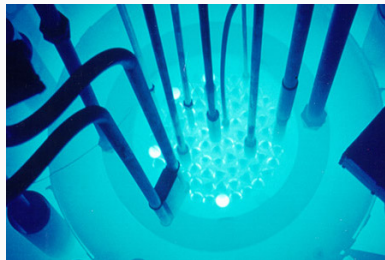


Cyber-Physical Systems

Cyber-Physical Systems



Computational devices that interact with their physical environment

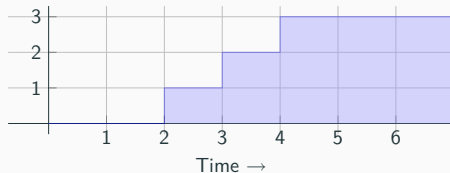


Another example of a cyber-physical system



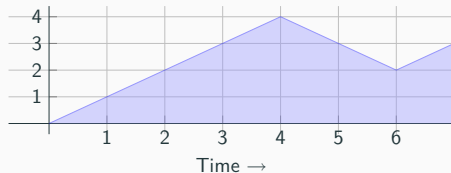
Computer Science meets Analysis

Wait Calls



```
(wait 2); x := x + 1; (wait 1) ...
```

Differential Statements



```
while (true) {  
  if  $v \leq 2$   
    then ( $\dot{v} = 1$  for 2)  
    else ( $\dot{v} = -1$  for 2) }
```

Contents of the module

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

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

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

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

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

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

We will also get acquainted 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

- 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

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

- nevrenato@di.uminho.pt
- pro@isep.ipp.pt

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

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

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.