Cyber-Physical Computation

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HASLab
HIGH-ASSURANCE
SOFTWARE LABORATORY

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Cyber-Physical Systems

Contents of the course

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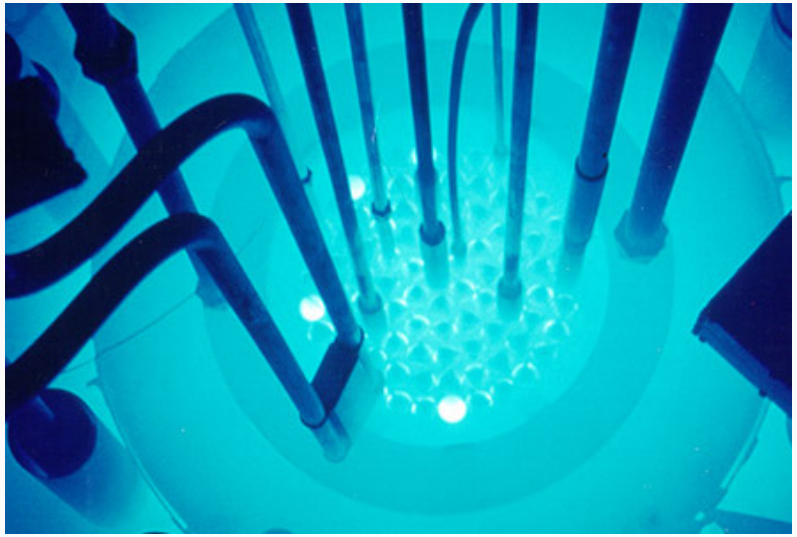
Cyber-Physical Systems

Digital devices that interact with their physical environment



Another example of a cyber-physical system

. . . and yet some other cases

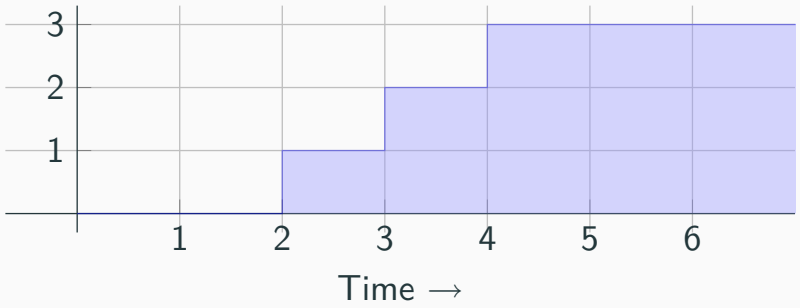
- Semi-autonomous self-driving systems
- (Crewed) spacecrafts

The three ingredients of cyber-physical systems

- Concurrency
- Communication
- Hybrid interaction

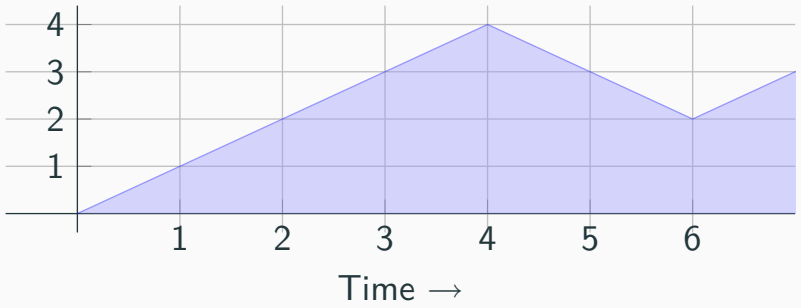
Computer Science meets Analysis

Wait Calls



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

Differential Statements

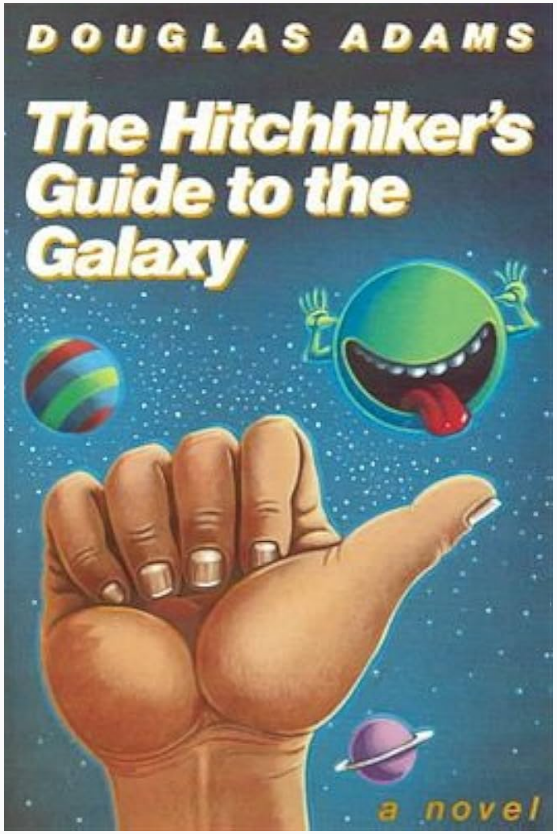


$$\begin{aligned}&\texttt{while}\,(\texttt{true})\,\{\\&\texttt{if}\ \texttt{v} \leq 2\\&\qquad\texttt{then}\ (\dot{\texttt{v}} = 1\ \texttt{for}\ 2)\\&\qquad\texttt{else}\ (\dot{\texttt{v}} = -1\ \texttt{for}\ 2)\ \}\end{aligned}$$

A particle and its orbital trajectory – what can go wrong?

```
x := -1; v := 0; a := 1;
while true do {
      if x <= 0 then a := 1; else a :=-1;
      x' = v, v' = a  for 0.5;
}
```

Cyber-Physical Computation



What is actually computable?

Cyber-Physical Computation

Genesis: David Hilbert and its
Entscheidungsproblem (circa 1928)

Fuelled the appearance of first models of computation (*circa* 1936)

- Turing machines: state-based, part of automata theory
- λ-calculus: function-based, prototypical programming lang

Church-Turing Thesis

Computable if encodable as a Turing machine or (equivalently) as a λ-term

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Contents of the course pt. I

We will study diverse models of cyber-physical computation

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

Contents of the course pt. I

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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 get accquainted with diverse 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

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Assessment

Assessment will consist of

- two individual homeworks (30%)
- two group assignments about the modelling and analysis of cyber-physical systems (70%)

Materials and Contacts

Relevant class material and announcements posted on the website

`https://arca.di.uminho.pt/CyPhyComp2324/`

e-mail: nevrenato@di.uminho.pt

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


Edward A Lee, *Cyber-physical systems-are computing foundations adequate*, Position paper for NSF workshop on cyber-physical systems: research motivation, techniques and roadmap, vol. 2, Austin, TX, 2006, pp. 1–9.


Ragunathan Rajkumar, Insup Lee, Lui Sha, and John Stankovic, *Cyber-physical systems: the next computing revolution*, Proceedings of the 47th design automation conference, 2010, pp. 731–736.