Cyber-Physical Computation

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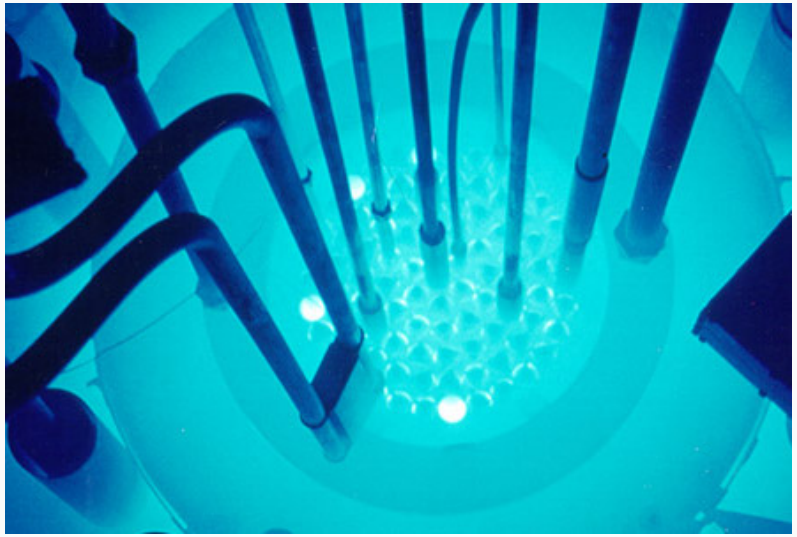
Cyber-Physical systems

Digital devices that interact with their physical environment



Another example of a cyber-physical system

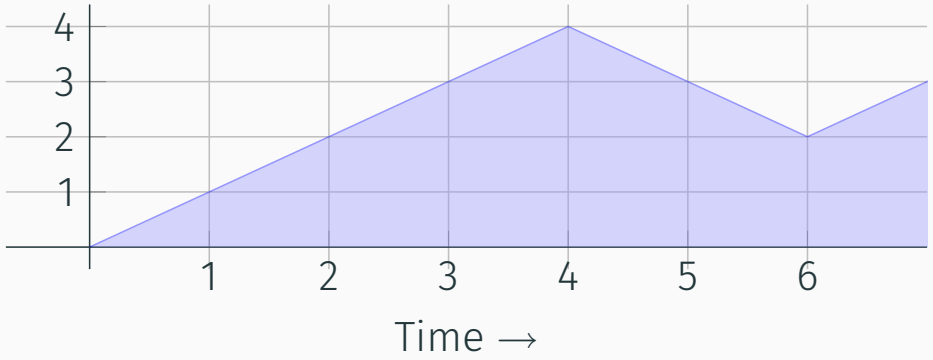
The three ingredients of cyber-physical systems

Concurrency

Communication

Hybrid interaction

Computer Science meets Analysis

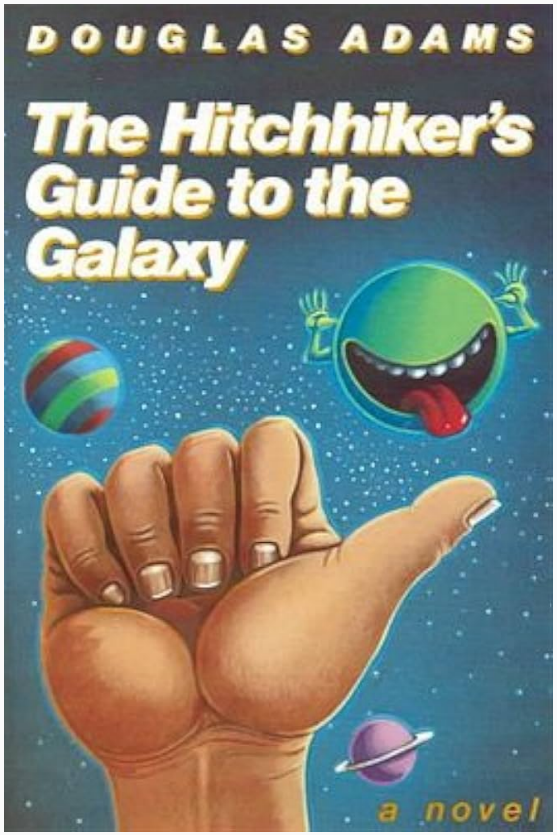



```
while true do {
      if v <= 2
         then v' = 1 for 2
         else v' = -1 for 2
      }
```

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)*

Led to the first models of computation (*circa* 1936)

- Turing machines: state-based, part of automata theory
- λ-calculus: functional, prototypical programming language

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 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 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 basics to the state-of-the-art ...
we will face the turmoils of current limitations ...
and see what challenges lie ahead

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Assessment

Two assignments (about the modelling and analysis of cyber-physical systems)

Materials and contacts

Relevant class material and announcements posted on the website

`https://haslab.github.io/MFP/`

e-mail: nevrenato@di.uminho.pt

office hours: tuesday 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.