

# Hybrid Systems

PhD Course, Spring 2001  
Inger Klein,  
Simin Nadjm-Tehrani

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## Organisation and planning

- Course page  
[www.control.isy.liu.se/~inger/hybrid\\_course](http://www.control.isy.liu.se/~inger/hybrid_course)
  - Course goals, literature, web resources, schedule, examination details, etc
- Period: April-June '01
- Examiners:
  - Inger Klein (ISY) and Simin N-T (IDA)

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## Course idea

- To get an overview of the wide and complex area of hybrid systems
- For research students, in both computer science and automatic control
- To get "deep" knowledge in one direction and shallow in others
- Your expectations?

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## Examination

- Seminar presentation of one technical paper, 45 minutes, Not easy!
- Active participation: at least one question formulated *before* the seminar
- Demo of tool: optional extra point

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## This lecture

- What are the main motivations for research in this area?
- Computer science perspective
- Control engineering perspective

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## Instances of hybrid systems

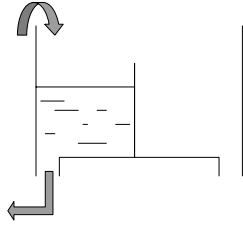
- Physical systems with discrete structural changes
- Composition of a physical system and discrete (state) controllers
- Combination of the two

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## Multi-mode physical system

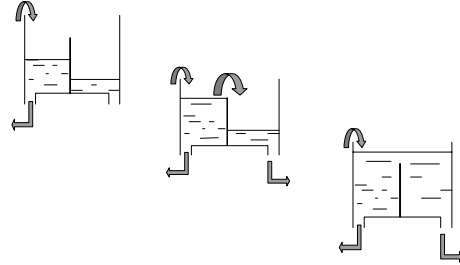


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## Different phases

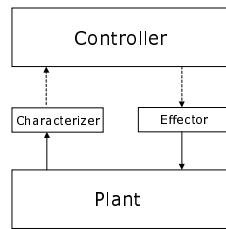


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## Digital control



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## Different instances

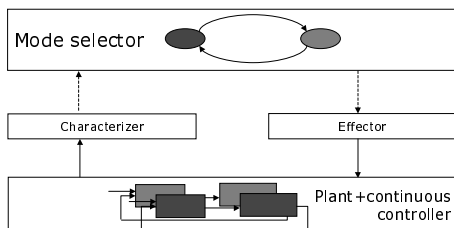
- Where does the complexity lie?
  - Multi-mode controllers
    - e.g. non-linear plant
  - Controllers with complex structure
    - e.g. Asynchronous, hierarchical control
  - Combination of the two

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## Multi-mode controller

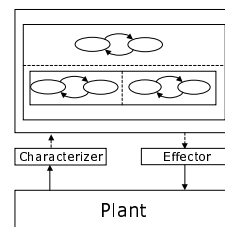


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## Complex controller



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## Simplest models

- Computer scientists:
  - discrete states and one continuous variable: timed models!
- Control theorists:
  - continuous state and one discrete (input) variable: selector, characteriser and effector static mapping

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## Applications

- Not always match these!!!



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## Computer science perspective

- Typical problem: Verification
  - a bad state is never reached
  - a good state is reachable within a certain time bound
- How to solve the infinite space search problem?
- Which approximations?

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## Computer science perspective

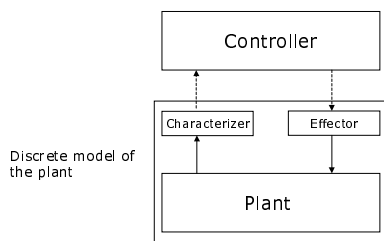
- Well-formedness of the models:
  - Can we exclude the Zeno phenomenon?
  - are models compositional?
  - can we refine the models and keep the verified properties?
  - Can we compose the models and keep (some) verified properties?

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## "Easiest" approximation



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## Complexity barriers

- Even for simplest approximations (constant slope integrators) verification problems undecidable
- Non-algorithmic methods need deep knowledge of applications

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## Other approaches

- Restrict dynamics of the plant
- Impose conservative approximations, e.g. convex hull
  
- Applicability?

## Next ...

- Control engineers perspective