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Workshop: Hybrid Systems

Nordic Informatic Network in Agricultural Sciences

Workshop for PhD students

Tune Landboskole, November 28-29 2002.

Invitation

The workshop is aimed at research students and researchers which study complex dynamical phenomena as found in life sciences and in highly non-linear and multimodal control tasks. The purpose is to introduce *hybrid systems*, a novel modelling framework for such systems.

Hybrid Systems are dynamical systems which change irregularly between smooth evolutions and discrete transitions. Some examples from the control domain are a driving wheel hitting black ice, a robot detecting an obstacle, or a gearbox with quick shifts; examples from biology are protein synthesis and cell transformations, e.g. within the immune system. Typically, the smooth evolutions are modelled by differential equations and the discrete transitions by state machines (automata).

The basic theory has evolved during the recent decade in an interplay between control theory and computer science. Control theory has supplied the framework for modelling smooth evolutions by means of differential equations with algebraic constraints, while computer science has supplied automata theory that gives a framework for modelling discrete transitions. In recent years, modelling tools have been developed together with techniques for determining interesting properties such as stability or optimality.

The workshop introduces the fundamental theory, starting with automata, then quickly proceeds to examples and exercises using modelling tools, such that participants get an operational understanding of the framework. We assume that participants are familiar with modelling of dynamical systems by means of ordinary differential equations.

The workshop is directed to:

- PhD students in agricultural, biological or biochemical sciences who have to model complex phenomena.
- PhD students in control engineering or theory who wants to apply hybrid systems in their work.

The workshop is organised by the DINA Research School as part of the Nordic cooperation in NINA, Nordic Informatic Network in Agricultural Sciences. The workshop language will be English.

We are looking forward to seeing you at Tune Landboskole!

Anders. P. Ravn
Aalborg University

url: http://www.dina.dk/phd/w/w11/

Erik Jørgensen
Peter Sestoft
Dina Research School

Workshop: Hybrid Systems: Program

Thursday 28 November

11.00 Arrival and accommodation.

12.00 Lunch

13.00 **Introduction and presentation of participants**
Erik Jørgensen, Dina Research School.

13.15 **Lecture: Hybrid Systems.**
A quick introduction by example to: automata, timed automata and hybrid automata
Anders P. Ravn, Aalborg University

We introduce the concept of a state machine or automaton and illustrate how it is used to model simple systems , where the dynamic behaviour consists of discrete state transitions. The model is then extended with timers or local clocks that measure the time spent in states. They can be reset at a transition, and a transition can be dependent on a clock value. Finally we generalize the concept of timers to flow variables that evolve according to a differential or differential algebraic set of equations.
At the end of the lecture, we shall briefly indicate constructs for hierarchical composition of state machines: Substates and Superstates, Sequential composition, and Parallel Composition with communication.

13.50 Break.

14.00 **Lecture: An Application Case Study from Control Engineering**
An application to a trajectory following problem for an outdoor vehicle.
Jan Dimon Bendtsen, Aalborg University

This lecture discusses an application of hybrid systems design taken from nonlinear control, namely the problem of trajectory tracking for a four-wheel steered, four-wheel driven mobile robot. The purpose of the robot is to drive autonomously between waypoints, starting from rest and stopping when the next waypoint is reached. The robot is modelled as a non-holonomic dynamic system subject to pure rolling, no-slip constraints. Under normal driving conditions, a nonlinear trajectory tracking feedback control law based on dynamic feedback linearization is sufficient to stabilize the system and ensure asymptotically stable tracking. However, when the velocity of the robot becomes very small, or the wheel configurations approach certain singular points, the feedback linearization scheme tends to fail due to these singularities. It is therefore necessary to switch to other modes of control when the robot is sufficiently close to the singularities. We will show how these transitions are derived systematically from the model, and present a hybrid automaton containing the different continuous-time control laws derived above in each mode

14.30 **Lecture: An Application Case Study from Biology**
Application of automata to modelling of a T cell in immunology
Na'aman Kam, Weizmann Institute, Israel

15.30 Coffee and Tea.

16.00 **Modelling Exercises on Computers.**

17.30 **Discussion of results**

17.45 Dinner.

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Workshop: Hybrid Systems: Program

19.00 **Lecture: Analyzing Properties of Hybrid Systems**
Analyzing automata: reachability, invariants, timed and hybrid extensions.
Rafael Wiesniewski, Aalborg University

In this lecture we shall continue with the notion of hybrid automaton. The focus is on a class of rectangular automata, which is a generalization of timed automata. In particular we shall analyse the following control problem. Given a set of possible control modes, together with the plant behaviour resulting from each model the control problem is to find a switching strategy between control modes that keeps the plant output out of unsafe state. The central issue is whether such a control problem can be solved algorithmically.

19.35 **Modelling Exercises, (continued)**.

21.45 Coffee, tea and sandwiches.

Friday 29 November

7.30 Breakfast.

8.00 **Discussion of Results from Exercises** .

8.35 Break.

8.50 **Lecture: Advanced Modelling of Biological Systems**
Application in genetics - studying *Caenorhabditis elegans*
Na'aman Kam, Weizmann Institute, Israel

9.30 Coffee and tea.

10.00 **Lecture: Abstraction and Refinement of Models**
Anders P. Ravn, Aalborg University

When models get too complex, we need to abstract from detail, and conversely, when the model is too superficial we have to refine some part of it.
Abstraction and refinement are introduced as a precise notion of a simulation relation between automata. The intuition is, that whenever the refined or detailed automaton does a transition to a target state, then the corresponding abstract state makes a transition to a new abstract state corresponding with the target state. Note that the abstract automaton may stay in a state, while the detailed automaton does a number of steps, as long as the states passed, all correspond to the abstract state

10.45 Break.

11.10 **Discussion and Closing**
Erik Jørgensen, Dina Research School.

12.00 Lunch and Departure.

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Practical information

Time From Thursday noon, November 28, till Friday 1 pm, November 29, 2002.

Venue Tune Landboskole, Grevevej 20, DK-2670 Greve, Denmark. Refer to the travel information on the web-page.

Accommodation Single rooms with shower and WC.

Board Full board starting with lunch on November 28 and ending with lunch on November 29.

Price The Dina Research School pays for participation including accommodation and meals. Travel costs are paid by the Department of the PhD student (except for accepted Nordic participants where NorFA covers the travel costs). Other participants pay directly to Tune Landboskole (approximately 1300 DKK)

Target group Ph.D. students whose projects are based on a problem from the agricultural or biological sciences, no matter whether the student has a background in biological or computer science. Others may attend at their own cost.

Conditions for participation Active participation in discussions and exercises is expected.

Further information Dina Research School, Erik Jørgensen, is available for further information. Use e-mail: Erik.Jorgensen@agrsci.dk

Registration Send an e-mail to the research school with information about name, address and whether or not you are a PhD student.

Deadline for registration As soon as possible and no later than November 12, 2002.

Experts of the Dina Research School

Computer Science:	Peter Sestoft, Department of Mathematics and Physics, KVL
Statistics:	Rasmus Waagepetersen Department of Mathematical Sciences, AAU
Numerical science:	Per Grove Thomsen, Informatics and Math. Modeling, DTU

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