UNIVERSIDAD TECNICA
FEDERICO SANTA MARIA

MECESUP FSM 1204

Summer School on Estimation and Control

Department of Electronic Engineering
Universidad Técnica Federico Santa María
Valparaiso, CHILE
13-17 January, 2014

The Department of Electronic Engineering, Universidad Técnica Federico Santa María (UTFSM), and MECESUP program through the project FSM1204 Internationalization of Ph.D. Programs invites to the Summer School on Estimation and Control.

The Summer School will be held at the Department of Electronic Engineering, UTFSM, Valparaiso, CHILE, between the 13th and 17th of January, 2014. There will be two (independent) mini-courses offered by international speakers:

Course I: Energy Based Modeling and Control of Physical Systems
Prof. Hector Ramirez, University of Franche-Comte, FRANCE
http://goo.gl/zoVW62

Course II: Computational Learning in Dynamical Systems
Prof. Thomas Schön, Uppsala University, SWEDEN
http://goo.gl/405nIf

The School is open to students, academics and the industry at no cost. However, registration is required. Lectures will given be IN ENGLISH

Contact persons:
Registration: Sabrina Rodriguez, sabrina.rodriguez_at_usm.cl
More Information: Prof. Juan I. Yuz, juan.yuz_at_usm.cl

Webpage: http://profesores.elo.utfsm.cl/~jyuz/Summer_School.html

DEPARTAMENTO DE
ELECTRONICA

Summer School on Estimation and Control

Dept. of Electronic Engineering
Universidad Técnica Federico Santa María
Valparaiso, CHILE
13-17 January, 2014

Lecture's Program:

Course I: Energy Based Modeling and Control of Physical Systems
Prof. Hector Ramirez, University of Franche-Comte, FRANCE

Course II: Computational Learning in Dynamical Systems
Prof. Thomas Schön, Uppsala University, SWEDEN

	Monday 13/01	Tuesday 14/01	Wednesday 15/01	Thursday 16/01	Friday 17/01
9:15 - 10:00	Registration & Welcome Ceremony	Course II - L1			
10:00 - 10:15	*Coffee Break*	*Coffee Break*	*Coffee Break*	*Coffee Break*	*Coffee Break*
10:15 - 11:00	Course I - L1	Course II - L1	Course II - L2	Course I - L4	Course II - L4
11:00 - 11:15	*Break*	*Break*	*Break*	*Break*	*Break*
11:15 - 12:00	Course I - L1	Course II - L1	Course II - L2	Course I - L4	Course II - L4
12:00 - 14:00	*Lunch (not provided)*	*Lunch (not provided)*	*Lunch (not provided)*	*Lunch (not provided)*	*Lunch (not provided)*
14:00 - 14:45	Course I - L2	Course I - L3	Course II - L3		Course II - L5
14:45 - 15:00	*Break*	*Break*	*Break*		*Break*
15:00 - 15:45	Course I - L2	Course I - L3	Course II - L3		Course II - L5

Energy based modelling and control of physical systems. A postgraduate course at the Universidad Técnica Federico Santa María, Valparaiso, Chile. 13 - 16 January, 2014.

In the last decade a powerful control theory based on physical balance equations and conservation laws has been developed for electrical, mechanical and electro-mechanical systems. This control theory is based on the principle of conservation of energy providing a clear physical interpretation of control design problems. Particular interest has been given to systems modeled as Hamiltonian control systems. Traditionally these systems arise from the Euler-Lagrange equations of motion, however they have been extended to deal with network models of general physical systems by using the framework of port-Hamiltonian systems (PHS). In network models the system is considered as the interconnection of energy storing elements via basic physical interconnection laws (e.g. Newtons third law or Kirchhof's law) together with energy dissipating elements. PHS theory formalizes the basic interconnection laws together with the power-conserving elements by a geometric (interconnection) structure, and defines the Hamiltonian function as the total energy stored in a system. Thus, PHS have direct physical interpretation since the the physical balance equations are directly derived from the interconnection structure and the physical energy of the system. Models based on energy approaches are very useful tools for engineers, since they are defined in terms of energy, which is a fundamental concept common to all engineering domains. They are also related with other network models, such as bond-graphs.

In this course we study the basic concepts of energy based modelling and their use for the modelling and control of simple and complex physical systems.

- In the first part (2 lectures), we will study models arising from physical balance equations. The port-Hamiltonian model is derived for classes of (linear and non-linear) mechanical, electrical and hydraulic applications and it is shown how models of complex physical systems can be constructed systematically via the interconnecting of simple sub-systems. We will also introduce how this approach may be used for the modelling of multi-energy or multi-physical systems (i.e., systems arising from the interconnection of different physical domains).

- In a second part (1 lecture) we will study how the particular structure of PHS can be use for energy based control design. For this purpose we will study the notion of passive system and specialize it to PHS. We will show how this approach is specially useful when dealing with the control of non-linear systems and how the physical energy is the base for the closed-loop stability analysis (passivity based control).

- In the third and final part (1 lecture) we will shortly introduce some ongoing lines of research: The use of energy based methods for the modelling and control of irreversible thermodynamic systems and systems described by partial differential equations (infinite dimensional systems). These problems will be developed using two practical applications: a chemical reaction in a continuous stirred tank reactor and a DNA-manipulation process.

Pre-requisites:

Undergraduate courses in linear dynamical systems. Some basic notions on control are useful but not necessary.

Bibliography:

[1] A.J. van der Schaft, L2-Gain and Passivity Techniques in Nonlinear Control, Lect. Notes in Control and Information Sciences, Vol. 218, Springer-Verlag, Berlin, 1996, p. 168, 2nd revised and enlarged edition, Springer-Verlag, London, 2000 (Springer Communications and Control Engineering series), p. xvi+249.

Lectures

Each lecture is split into blocks of 45 minutes, with a 15 minute break in between.

- Monday January 13/01

  1. Balance equations, conservation laws, and passive systems. [10:15 – 12:00]
  2. Port-Hamiltonian systems. [14:00 – 15:45]

- Tuesday January 14/01

  3. Passivity based control of port-Hamiltonian systems. [14:00 – 15:45]

- Thursday January 16/01

    4. Ongoing research applications: The CSTR and a class of DNA-manipulation process. [10:15 - 12:00]

Contacts

- Hector Ramirez, UFC, FEMTO-ST, Besançon France. e-mail: hector.ramirez@femto-st.fr
- Juan Yuz, UTFSM, Valparaiso Chile. e-mail: juan.yuz@usm.cl

Héctor Ramirez Estay
Assistant Professor, University of Franche-Comté
Besançon, France

Héctor Ramírez is assistant professor at the faculty of sciences and technologies at the University of Franche-Comté and researcher at the department of automatic control and micro-mechatronic systems at the FEMTO-ST research institute in Besançon. He made his Ph.D. in the frame of a Chilean-French collaboration and received in 2012 the degrees of Doctor in Electrical Engineering Sciences and Doctor in Automatic Control from the Universities of Concepción and Lyon, respectively. In 2009 he received the degree of Master in Electrical Engineering Sciences and in 2006 the Electronic Civil Engineer professional title, booth from the University of Concepción. He held a postdoctoral research position at the FEMTO-ST research institute from June 2012 to September 2013, working on modeling and control of micro-mechatronic systems described by partial differential equations with dynamic boundary conditions.

He teaches automatic control and modeling of dynamical systems at undergraduate and graduate levels. His research interest are in the fields of non-linear control and modeling using passivity based methods. He is currently working on modeling and control of irreversible thermodynamic systems using port-Hamiltonian system theory and control of distributed parameter systems on 1D spatial domains using semi-groups.

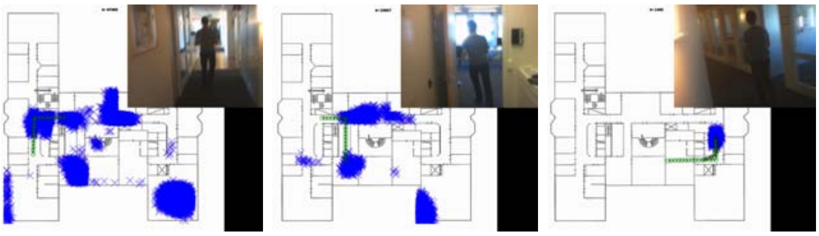
More info at: https://sites.google.com/site/hramirezestay/

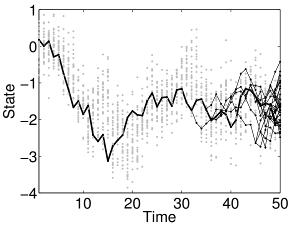
Computational learning in dynamical systems

Given at Universidad Técnica Federico Santa María (UTFSM), Valparaíso, Chile in January 2014.

Thomas B. Schön (thomas.schon@it.uu.se, `user.it.uu.se/~thosc112`)
Department of Information Technology, Uppsala University, Sweden

The aim of this course is to show how we can make use of measured data in learning and performing inference in probabilistic models of nonlinear dynamical systems. More specifically we will introduce sequential Monte Carlo (SMC) methods and Markov chain Monte Carlo (MCMC) methods and show how these can be used to solve challenging nonlinear system identification and state estimation problems. SMC methods (such as the particle filter and the particle smoother) have been developed over the last two decades, but it is only over the last five years that they have been used to develop new and interesting solutions to the nonlinear system identification problem.





Day 1 (January 14, 09.15 - 12.00) – Introduction, modelling and strategies

- Course introduction and probabilistic state space models
- Strategies for state and parameter learning in nonlinear dynamical systems (i.e. nonlinear state estimation and nonlinear system identification)

Day 2 (January 15 at 10.15 - 12.00) – EM and MCMC explained via linear sys. id.

- Derive the expectation maximization (EM) algorithm
- The Monte Carlo idea
- Markov chain Monte Carlo methods and their use in Bayesian system identification

Day 2 (January 15 at 14.00 - 15.45) – Particle filters

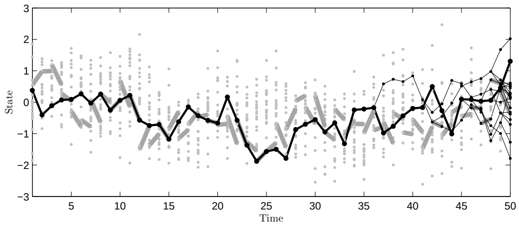
- Introduce importance sampling and rejection sampling
- Derive the particle filter (most common SMC sampler)

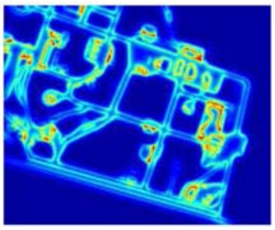
Day 3 (January 17 at 10.15 - 12.00) – Particle smoothers, ML nonlinear sys. id.

- Derive particle smoothers (PS)
- Maximum likelihood (ML) nonlinear system identification using EM and PS

Day 3 (January 17 at 14.00 - 15.45) – Bayesian nonlinear system identification

- Particle Markov chain Monte Carlo (PMCMC)
- Bayesian nonlinear system identification using SMC and MCMC





Course website: `user.it.uu.se/~thosc112/CLDS_UTFSM/`

Welcome!

Extended summary

The overall aim in this course is to provide an introduction to the theory and application of computational methods (some of them only a couple of years old) for inference and learning in nonlinear dynamical systems. More specifically, the computational methods we are referring to are sequential Monte Carlo (SMC) methods (including particle filters and particle smoothers) for nonlinear state inference problems and expectation maximization (EM) and Markov chain Monte Carlo (MCMC) methods for nonlinear system identification. Our final algorithms are typically nonstandard combinations of the methods mentioned above.

After a brief introduction we will define the models we are working with; probabilistic models, almost exclusively on state space form. We will then turn to the general strategies of solving different state estimation problems (both filtering, prediction and various smoothing problems). This involves deriving general expressions for computing filtering, prediction and smoothing densities for the states in nonlinear dynamical models. The basic strategies employed in both maximum likelihood (ML) and Bayesian system identification are then reviewed.

It is our firm belief that even if you aim at solving nonlinear problems, you should always make sure that the method under study is capable of solving basic linear problems first. If that cannot be done, the method does not stand a chance in solving the nonlinear problem either. Furthermore, a good understanding of linear models is important in order to be able to understand nonlinear models. This course is about how to deal with nonlinear models, and it is expected that the participants have some knowledge of linear theory from before. However, to instill confidence in what we are doing we will provide a few examples where well known solutions like the Kalman filter and standard linear smoothers emerge as the result. We will throughout the course introduce the methods by answering simple questions related to linear models and then (most importantly) show that the methods are capable of tackling challenging nonlinear problems as well.

The linear models serve the purpose of being a testing ground, where we can introduce the EM and the MCMC methods in such a way that we can focus on the methods. However, when this has been done we leave the linear models behind and turn our attention to the more challenging nonlinear models instead. The SMC methods (focusing on the particle filter and the particle smoother) will be introduced and the basic theory is provided. We will also show how the particle filter has been used to solve some nontrivial nonlinear filtering problems we have been working on in applied projects together with various industrial partners. Several particle smoothers are also introduced.

Finally, we will show how the methods introduced above can be used to solve various problems in nonlinear system identification. We start by showing how to compute ML estimates using EM (involving particle smoothers and nonlinear optimisation) and we will illustrate how this can be used to solve various problems, including some Wiener identification problems. Finally, the recent (and exciting) development referred to as the particle MCMC (PMCMC) methods will be introduced. Using PMCMC we are capable of solving nonlinear Bayesian system identification problems by a nontrivial combination of MCMC and SMC methods.

Prerequisites: Basic undergraduate courses in linear algebra, statistics, signal and systems. Linear estimation theory including the Kalman filter is helpful, but not necessary.

Invited lecturer

Professor Thomas B. Schön

Department of Information Technology, Uppsala University, Uppsala, Sweden.

Thomas B. Schön is Professor of the Chair of Automatic Control in the Department of Information Technology at Uppsala University. He received the PhD degree in Automatic Control in Feb. 2006, the MSc degree in Applied Physics and Electrical Engineering in Sep. 2001 and the BSc degree in Business Administration and Economics in Jan. 2001, all from Linköping University. He has held visiting positions with the University of Cambridge (UK) and the University of Newcastle (Australia). He is a Senior member of the IEEE. Based on the impact of his PhD thesis it won the best PhD thesis award 2013 by The European Association for Signal Processing (EURASIP). He received the best teacher award at the Institute of Technology, Linköping University in 2009.

Schön's main research interest is nonlinear inference problems, especially within the context of dynamical systems, solved using probabilistic methods. He is active within the fields of machine learning, signal processing and automatic control. He pursues both basic research and applied research, where the latter is typically carried out in collaboration with industry. More information about his research can be found on his website:

`user.it.uu.se/~thosc112/research/research-overview.html`