AVDELNINGEN FÖR SYSTEMTEKNIK
UPPSALA UNIVERSITET
Bengt Carlsson September 8, 2014

COURSE PROGRAM
- Empirical Modelling (EM)

Teachers

Name:	**Tasks:**
Bengt Carlsson	Examiner, lectures
Johan Wågberg	Problem solving session, Lab and project superv.
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Course literature

Modellbygge och Simulering[1] , Ljung och Glad, Studentlitteratur, 2004.

Additional material, including "A note on linear regression", by B Carlsson, "Beskrivning av signaler i frekvensdomänen" by B Carlsson and a text on "Recursive Identification". Most of the material will be available from the course homepage:

`http://www.it.uu.se/edu/course/homepage/empmod/vt14`

but also Studenportalen will be used for some non-public material.

[1]The book is also available in English: "Modeling of Dynamic Systems", Ljung and Glad, Prentice Hall.

Course layout

The course consist of three parts

1. The theory of model building with emphasis on Empirical Modelling (also called System Identification). As a compliment some guest lectures from industry are also included.

2. Laboratory work (computer labs and one process lab)

3. Project work: Both a group project and an individual task.

What is Empirical modelling?

Empirical modelling/System identification deals with the problem of building mathematical models of dynamic systems based on observed data (measurements) collected from a system. This is a basic scientific methodology. Since dynamic models of systems are used in almost all disciplines, empirical modelling has a very broad application area.

Reading advices

The book used in the course is quite easy to read and presents different aspects on how to build mathematical models.

- Chapter 1-3 gives a general overview of models and how to obtain models from simple experiments.

- Chapter 4 - Physical modelling. This part is not used in the course but may serve as a valuable reference when you need to build a model based on physical principle. Chapters 6-9 are not used in the course.

- Chapters 10, 11, 12, and 14 are very important for the course.

- Chapters 13, 15, and 16 - may be read briefly.

- Appendices. Background material.

The additional material will give important background material and extension to the course book.

Guest lectures

Modelling and control problems are central in many environmental and energy processes. As a compliment to the theory and project, three guest lectures are included in the course. It is expected that all course participants attend these lectures.

- Linda Åmand from IVL Svenska Miljöinstitutet presents some work on Multivariate methods. *Date*: 2014-09-04.
- Linn Saarinen from Vattenfall Research and Development(Älvkarleby) gives an overview of how they are using modelling and control strategies. *Date*: 2014-09-18
- Tomas Smed from Forsmark nuclear power plant will give a guest lecture on how they are using empirical modelling and automatic control strategies at the plant. *Date*: 2014-10-01

Examination forms

The examination consists of several parts. In order to pass the course (Mark 3) the following three requirements must be fulfilled:

1. Passed laboratory work (Process lab in week 41 and one compulsory Computer lab (No 5) and attendance in the guest lectures.
2. A compulsory homework assignment (inlämningsuppgift). The assignment is required to be given in before starting with the process lab.
3. Oral and written project presentation. In order to get mark 3 the default project exercises must have been solved and presented in a satisfactory way. You must also show that you have *understood the theory* presented in the course (for example when you describe the results and motivate your modelling choices). The project work consists of two parts:
    - One **individual** task where you should estimate "your best" model from a given data set. The result should be documented on 1-2 pages.
    - A **group** project (4 students/group) where a number of modelling tasks should be done.

In order to get mark 4 the following additional requirements must be fulfilled:

- The written group project report is of high quality and submitted before the dead-line.
- One or several extra tasks have been solved.

Finally there is an **optional** exam (Mon 20 Oct 2014). If you pass the exam the mark from the project work is increased with one unit. The exam is based on the problem solving sessions [2] L1-L6.

Individual task "The System Identification Competition"
Data from an unknown (for you) system will be provided and your task is to find the system!

Group project work
The project is conducted as as a team work of 4 students and the project results will be presented both orally and in a written report. See the course plan. A detailed project description will be given out later in the course.

Most of the project work will be done using the program Matlab and in particular the toolbox "System identification". The computer laboratory work (see p 5) will give important experience for the project work.

The (deafult) project consists of three problems, which illustrate how system identification can be used for different energy applications. Data from real energy systems will be used.

In the basic project you will study the following issues:

- *Modelling of a solar heating system.* Performance of different modelling techniques applied to data from a small scale solar heating system are compared.
- *Identification of wind speed dynamics* Spectral estimation using different parametric and non-parametric methods is applied to analyse the data.
- *A study of a special method for emprical modelling/system identification*

Several possible extra tasks exist, see examination forms for a motivation why to do an extra task!. The project group may also suggest an (extra) project task by themselves which is likely to be approved if it is "reasonable". One example of (a pre defined) extra task is:

- *Electric power consumption modelling.* Identification and prediction of electric consumption using weather data.

Group project work - Wastewater treatment
Students which has taken Reglerteknik II and the course Wastewater treatment have the possibility to chose a project combining knowledge from these

[2] Even if you plan to not do the exam, the sessions L1-L6 may be worthwhile to attend since a lot of the theory will be illustrated by using simple pen-and-paper problems.

courses. The project is to use a Kalman filter to estimate the oxygen transfer rate in a batch experiment. This problem is of high relevance in order to find how, for example, different detergents affect the wastewater.

Group project work - Nuclear power plant
Students which has a background and/or an interest in nuclear power engineering may replace the sub project "Modelling of a solar heating system" with a sub project devoted to modelling the stability margin in a nuclear power plant.

Laboratory work

Two kinds of laboratory work are conducted in the course

1. Computer labs. Five computer labs are included in the course. Each lab, has a scheduled 2h time slot for supervision, but you may need more time to go through all exercises. The first four labs are non-compulsory (but are strongly recommended since they will train you in how to solve the project tasks). Date and location for the computer labs for your program can be found on the schedule.

   The labs illustrate important concepts of System Identification and how to use Matlab (The System Identification Toolbox) for solving advanced modelling tasks. To be able to use the computers in the PC lab you must have a valid UpUnet-S account, see www.student.uu.se/upunets/.

   The m-files for doing the labs can be downloaded from the course homepage. If you want to do the labs on your own computer you will need Matlab and the System Identification toolbox.

2. Process lab. The process lab will start with a 2h demo where you will get data from a lab process. After the demo lab you will use the data for estimate models and use model validation techniques.

Laboratory material will be given out later. Note that the labs have tasks which should be done in advance (*förberedelseuppgifter*) and that it is required that the homework assignment is submitted before starting with the process lab.

Course plan, version September 8, 2014

Explanations: Bold face= compulsory, (*)=primarily (but everyone is welcome!) for students which have not read *Reglerteknik II.*

Nm.	Tid	Innehåll
F1.	Tu 2/9, 15^{15}	Course introduction. Ch 1-3.
F2.	We 3/9, 10^{15}	Linear Regression.
F3.	Th 4/9, 15^{15}	Guest lecturer: Linda Åmand, IVL.
F4. (*)	Fr 5/9, 13^{15}	Introduction to discrete time systems and stochastic processes
F5.	Mo 8/9, 10^{15}	Beskrivning av signaler i frekvensdomänen
F6.	Tu 9/9, 13^{15}	Ch 10-11
F7.	Fr 12/9, 15^{15}	Parameter estimation in dynamic models - Ch 12
F8 (*)	Må 15/9, 10^{15}	Numerical illustration of some methods
L1.	Tu 16/9, 8^{15}	Exerc 1
F9.	We 17/9, 13^{15}	Parameter estimation cont'd -Ch 12
F10.	Th 18/9, 8^{15}	Parameter estimation cont'd - Ch 14
F11.	Th 18/9, 13^{15}	Guest lecture:Linn Saarinen, Vattenfall
L2.	Fr 19/9, 8^{15}	Exerc 2
B1	Fr 19/9	Computer lab 1 (2h)
F12.	Mo 22/9, 8^{15}	Non linear models (Ch 13), summary of system identification.
F13.	Tu 23/9, 10^{15}	Kick-off Project
F14	We 24/9, 8^{15}	Webinar by Prof Lennart Ljung
B2.	We 24/9	Computer lab 2 (2h)
B3.	Mo 29/9	Computer lab 3 (2h)= project help in the PC lab
F15.	Tu 30/9, 10^{15}	Recursive identification (theory for **B5**, Lecture by K. Pelckmans)
F16.	We 1/10, 8^{15}	Guest lecture: Thomas Smed, Forsmarks kraftgrupp
L3.	Th 2/10, 8^{15}	Exerc 3
B4.	Fr 3/10	Computer lab 4 (2h)
B5.	Mo 6/10	Computer lab 5 (2h)
Process lab.	w41	Process lab 2h/participant
L4	Mo 13/10, 13^{15}	Exerc 4
L5	Tu 14/10, 8^{15}	Exerc 5
L6.	We 15/10 8^{15}	Repetition (before exam)
Exam	Mo 20/10	See Examination forms
F17	23-24/10,	Project presentations (2h/participant)