Warsaw University of Technology
Faculty of Electrical Engineering
Institute of Control and Industrial Electronics
Division of Control

System Identification and Control

Semester 7 (3^{rd} year) B.Sc. in Electrical Engineering Course

Module Descriptor

Module Leader: Bartlomiej Beliczynski

Associate Module Tutors: Maciej Twardy

STRUCTURE

Subject	**Hours/week**			**Weeks**	**Total**
	Lecture	**Lab**	**Total**		
System Identification and Control	2	1	3	15	45

PRE-REQUISITE KNOWLEDGE

Foundation of matrix algebra, Laplace, Fourier and ***Z*** transform, state space and transfer function description of dynamic system, some Matlab and Simulink knowledge.

SUMMARY OF CONTENT

The aim of this module is to provide the student with an understanding of various models of dynamic systems its mutual relationships, and equip the student with the necessary knowledge to estimate parameters of linear dynamic system, model the system basing on data collected from experiments and use identification results for control.

OBJECTIVE

On completion of this module, the student should be able to:

- Understand and apply various types of dynamic system models for modelling real data,
- Understand identification experiments and collect appropriate data,
- Estimate parameters of linear dynamic model,
- Use identification in order to control the plant

TEACHING/LEARNING STRATEGY

Lectures will be used to introduce theory and background knowledge, with lab sessions to support this. The lectures are designed to stimulate students' thinking and generate their activity during problem statement, discussing possible ways of solving it and searching for solution. Consequently, no or little ready-made solutions are presented to the students and almost no hands-out are given to them. It is intended to conduct the lectures with high level of interaction with students. Two tests are only partly designated to check the students knowledge accumulation. Their main goal is however to create a framework for individual thinking exercise being major factor of learning and cognitive processes. Later the lecturer marks the tests, and then the solutions are discussed in details with the students and additionally commented. This is an important part of teaching/learning strategy.

Lab sessions are used for experiments and demonstrations, which illustrate the theory and provide the students with "hands-on" experience. During the lab sessions, there is a time for question stated by students and often the student's requirements and interest stimulate exercises.

SYLLABUS

The taught syllabus will cover the following areas:

Mathematical Background: Singular Values Decomposition, pseudoinverse, least squares solution of the linear matrix equation, recursive solution.

Models of Dynamical Systems: continuous and discrete models, equivalence of continuous and discrete-time models for different classes of input signals, input/output and state-space models, ARMAX models.

Parameters Estimation of Linear Dynamical System: Application of nonrecursive and recursive methods to parameters estimation of linear dynamical systems, extension and modification of the least squares methods.

Function Approximation and Dynamical System Modelling: neural network based function approximation, regularisation methods, NARMA models and approximation of nonlinear dynamical systems.

Illustrative Examples and Applications: adaptive systems.

READING LIST

Recommended Texts:

Further Texts:

1. *T.Soderstrom and P.Stoica: System Identification, Prentice Hall, 1994. There is Polish translation published by PWN in 1997.*
2. *E.Chong, S.Zak: An Introduction to Optimization. Wiley Interscience Pub., 2008.*
3. *G. Goodwin and P Sin: Adaptive Filtering, Prediction and Control. Prentice Hall, 1984.*
4. *J.N. Juang: Applied System Identification, Prentice Hall, 1994.*

DETAILED DESCRIPTION

LECTURES:

The lecture will cover the following topics:

1. An introduction: theories and applications contributing to the field.
2. Review and enlarging of mathematical background: symmetrical matrices, symmetrical eigenvalues problem, quadratic forms, nullspace and range of matrix.

3. Geometrical definition of pseudoinverse, orthogonal projection matrices.
4. Singular Values Decomposition and its link to pseudoinverse and basis of null space and range of matrix.
5. Approximate solutions of the matrix equation Ax=b: Least Squares Solution.
6. Recursive solutions of the matrix equation Ax=b: Recursive Least Squares Method.
7. Continuous and discrete models of dynamical systems: equivalence of continuous and discrete-time models for different classes of input signals, input/output and state-space models, ARMAX models.
8. Application of nonrecursive and recursive methods to the parameters estimation of linear dynamical systems.
9. Extensions and modifications of least squares methods with application to dynamical systems: exponential data weighting, covariance resetting orthogonal projection to parameters space, UDU factorization.
10. Neural network based function approximation: universal approximation, best approximation, incremental approximation, regularisation methods.
11. NARMA and NFIR models and approximation of nonlinear dynamical systems based on neural networks.
12. Identification and adaptive control systems.
13. Additional comments, review and conclusions.

TUTORIALS:

DEMONSTRATIONS:

PROJECTS:

LABS:

Lab sessions are designed to support the lectures by means of solving selected problems and doing simulation experiments. The experiment topics are usually suggested by tutor but implemented, tuned and run by the students. Topics of the lab exercises may vary according to students' actual needs and interest. We use very flexible and powerful Matlab/Simulink environment. The students, in a limited period of time, are able to write a program and provide certain analysis or simulations. There is always a time devoted to questions from both sides and discussions. Usually contents of the lab is the following:

* Matlab/Simulink - a guided tour

  The tour will be guided through selected Matlab/Simulink features such as: operation on matrices, accuracy, complex data, graphics, m-functions, debugging, simulation environment, creating and masking Simulink blocks.

* Basic operations of linear matrix algebra

  This exercise is aiming to make students familiar with some abstract concepts such as eigenvalues and eigenvectors, null space and range of a matrix, quadratic forms, pseudoinverse, projection matrices and Singular Values Decomposition. All these terms and concepts will be further used.

* Least squares and recursive least squares solutions to linear matrix equation

  The students will investigate properties of error function while solving a set of linear equations. Various aspects of ordinary Least Squares (LS) and Recursive Least Squares (RLS) methods will be discussed and compared. All necessary operations and m-functions the students will write themselves.

* Various models of dynamic systems

  Various models of dynamic systems will be investigated: continuous and discrete time, discrete equivalence of continuous dynamics in particular step response equivalence, selection of sampling time, frequency responses and conversion between different representations.

* Estimation of parameters of linear plant

  Identification experiment will be set-up in Simulink and collected data will be processed via LS (RLS) methods to estimate parameters of discrete model of the plant.

* Neural networks based function approximation

  Function will be represented by a set of input/output pairs. One hidden layer network will be taught.

* An example of adaptive control system

  Plant with variable gain will be controlled.

ASSESSMENT METHODS AND RULES:

For each student, there will be one, final mark for this module. It will be calculated based on separate assessments for the lecture and lab. The lecture will be weighted by 65% and the lab 35%. Participation in lectures is not obligatory. However during semester, two tests will be conducted. A number of students may be exempted from the exam based on good results of the tests. However every student is fully entitled to take the exam and overwrite any previous record. Lab assessment is based on the record of participation and the student performance during lab hours. No homework, no reports are required. Two absences are tolerated.