EQ2401 Adaptive Signal Processing

2020, Period 3 – 7.5 ECTS credits

The course will be given in English

Course homepage(s)

Canvas: https://kth.instructure.com/courses/17672

Course directory: https://www.kth.se/student/kurser/kurs/EQ2401?l=en

KTH Social: https://www.kth.se/social/course/EQ2401/

Registration

Remember to register yourself to the course by using KTH My Pages.

Goals

This course teaches adaptive signal processing algorithms for extracting information from noisy signals. The emphasis is on recursive, model based estimation methods for signals and systems whose properties change in time. Applications in, for example, communications, control and medicine are covered.

After completing the course, the student should be able to:

- Design and apply optimal minimum mean square estimators and in particular linear estimators. To understand and compute their expected performance and verify it.
- Design, implement and apply Wiener filters (FIR, non-causal, causal) and evaluate their performance.
- Design, implement and apply the different adaptive filters to given applications.
- Analyze the accuracy and determine advantages and disadvantages of each method.
- Use the theoretical understanding to do troubleshooting, e.g., in cases the observed performance is not as expected.
- Report the solution and results from the application of the filtering techniques to given problems.

Syllabus

The course presents the fundamentals of adaptive signal processing; mean-square estimation, Wiener filters. Introduction to adaptive filter structures and the least squares method. State space models and optimal (Kalman) filtering. Stochastic gradient, LMS (least mean squares), and RLS (recursive least squares) methods. Analysis of adaptive algorithms: Learning curves, convergence, stability, excess mean square error, mis-adjustment. Extensions of LMS and RLS.

Prerequisites

EQ1220 Signal theory/ EQ1270 Stochastic Signals and Systems (Stochastic processes)
(EQ2300 Digital Signal Processing)

Organization

- Lectures 13*2 h
- Tutorials 8*2 h
- Voluntary Homework, 6 problem sets
- Computer exercises (not scheduled, self study)
- Two mandatory take-home projects, 1.5 credit units each (ECTS)
- Written exam 5 h, 4.5 credit units (ECTS)

The course language is English.

Literature

- Lecture notes: Adaptive Signal Processing, Hjalmarsson & Ottersten
- Collection of Problems in Adaptive Signal Processing
- Computer Exercises in Adaptive Signal Processing

The above material is available to purchase at EECS Service Center Lindstedtsvägen 3, floor 4, when the course begins.

The KTH "Collection of Formulas in Signal Processing" as used in our previous courses may be useful. (It can be downloaded from the course homepage under the link: "Course material.")

Instructions for the projects are handed out on the release dates. They will also be available on the course homepage under "Assignments."

Course responsible/Lecturer

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Lectures

There are 13 lectures scheduled. Before each lecture we recommend that you read the corresponding pages in the lecture notes. After each lecture we recommend you to look at the corresponding exercises for self study. Please note that very little time is scheduled for problem solving in class (see below). We rather encourage you to try to solve these problems outside class and discuss them with your fellow students. If there still are questions remaining, you are of course welcome to make an appointment with us.

Tutorials

There are 8 problem solving seminars scheduled. The problems that will be covered are in the list of Lecture/Tutorial content.

Voluntary Homework

As part of the course we will hand out weekly sets of homework problems. In total there will be 6 such sets. They are not mandatory and you can choose not doing them. If you do hand them in in due time, we will grade them and provide brief feedback. If most of it is correct you will also get 0.5 bonus points towards the exam. Hence, in total you can get maximum 3 points on top of your exam score. However, the main motivation should be the help to get started in doing problem solving early on in the study period. Problem solving is indeed an important part of this course.

Individual (handwritten) solutions should be handed in before the deadline via the homepage in Canvas. The problem sets will be made available under "*Assignments*."

Computer exercises

An important part of the course is the computer (matlab) exercises included in the course material. We have not scheduled any specific times for these in the computer labs. However, we strongly encourage you to use the computers to learn the subject matter. Questions are of course welcome. Please make an appointment or send an email.

The computer exercises are also extremely useful as a preparation for the project assignments.

Matlab functions and data files that are needed are available from the course homepage under "Course material."

Project assignments (mandatory)

Two projects in which you will solve "typical" application problems are included in the examination. Instructions are handed out during the course. The release dates and deadlines for reporting are given under "Assignments."

Schedule

Specific dates, times and locations are given in the official schedule of the course in TimeEdit. Detailed (preliminary) contents are given in the following table.

	Content	Chapters/Problems
Lecture 1	Introd. to Estimation	1,2,3
Lecture 2	Estimation cont., Wiener Filtering	3, 4.1 - 4.3
Tutorial 1	Estimation/Wiener Filtering	1.4, 1.5, 1.10
Lecture 3	Wiener, One-step ahead Prediction	4.4, 4.5
Lecture 4	State-space models, Kalman Filtering	5,6.1-6.4
Tutorial 2	Wiener filtering/Prediction	2.1, 2.3, 2.17
Lecture 5	Kalman Filtering	6.5-6.13
Lecture 6	Spectral Estim./ Equalization/ Noise cancellation.	7
Tutorial 3	State-Space Systems/ Kalman Filtering	3.4, 3.1, 3.26, 3.18
Lecture 7	Adaptive filtering: steepest descent	8, 9

Lecture 8	LMS	10
Tutorial 4	Kalman/Adaptive filtering	3.5, 3.25, 4.1 (3.22)
Lecture 9	LMS cont'd, applications	10, 11
Lecture 10	RLS	12
Tutorial 5	LMS	4.12, 4.6, 4.18, 4.10
Lecture 11	RLS cont'd	12
Lecture 12	Adaptive filtering as Kalman filtering, review	13
Lecture 13	Extensions to Kalman filtering and LMS	extra material
Tutorial 6	RLS	4.14, 4.20, 4.33
Tutorial 7	walkthrough, questions	catch up problems, old exam
Tutorial 8	walkthrough, questions	Old exam

Exam

The exam consists of five exercises with a maximum score of 50p. It is graded by A-F. Normally, 23p is required to pass. If you get 21-22p, you will get the FX grade and you will be offered the possibility to do complementary examination for the E-grade. See further the old exams under “Course material” at the homepage.

The following are allowed aids on the exam:

1. Lecture notes in adaptive signal processing, Hjalmarsson & Ottersten
2. "Collection of formulas in Signal Processing" EECS, KTH

3. BETA Mathematics Handbook

Notice that it is NOT allowed to have written notes in the books and that no other material or electronic equipment is allowed.

Final exam is in March (see schedule for detailed information).

Re-exam is in June (see schedule).

Remember to register in time before the exam by using My Pages.

Supplementary information

In this course, the EECS code of honor applies, see:
https://www.kth.se/en/eecs/utbildning/hederskodex.