Signals, Instruments, and Systems

Winter Semester 2020-2021

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Guest lecturers:	I. Kagan Erünsal (IKE)
Teaching assistants:	I. Kagan Erünsal (Head TA), Cyrill Baumann (TA), Hugo Grall Lucas (TA), Anwar Quraishi (TA), Lucas Pirlet (Help TA), Chloé Udressy (Help TA)
Support staff:	Chiara Ercolani, Faëzeh Rahbar
Course Website:	http://disal.epfl.ch/teaching/signals_instruments_systems/

1 Credits and Workload

Signals, Instruments, and Systems (SIS) distributes 5 ECTS. According to the European Commission guidelines, 1 ECTS is equivalent to up to 30h of workload. Therefore, the total workload for SIS will be about 150h over the whole semester. The approximate breakdown of the workload is 60h for lecture attendance and exam preparation, 30h for exercises (including preparation), and 60 h for carrying out, presenting, and documenting a course project.

2 Grade

The final grade for SIS will take into account the performance in the final written exam as well as in the course project. Exercises are ungraded but solving them in a thorough and individual way will help the students to be well prepared for the course project and the final exam. The final written exam will last 180 minutes and will involve questions focusing on the different topics covered during the course and the exercises. 50% of the grade will be acquired during the semester, based on the performances in the course project (dedicated performance assessment breakdown will be communicated in timely fashion). 50% of the grade will be based on the performance during the final written exam.

3 Reading

Being a new pioneering course in the curriculum of environmental and possibly civil engineers, SIS does not have a course book. The lecture notes are the reference for the course and will be posted regularly on the web site after each lecture.

Additionally, complementary reading material will be made available, if appropriate, in electronic format in the student area of the course (Moodle server). Access to this material will be limited to people enrolled in the class and controlled via username and password. Most of this material is copyrighted and therefore it should be exclusively used for course purposes. Further reading pointers are suggested in the last slide of each lecture.

4 Lecture Notes

Lecture will be given with the help of a LCD projector and a video-conferencing tool for a mixed audience (1/3 on-site and 2/3 on-line), as per EPFL guidelines on flexible teaching.

Lecture with their related questions and answers periods will be recorded and made available after the lecture. Despite higher technical challenges, we have chosen to select a live-streamed mode for our course as we feel this mode will allow for better interaction with students and an increased reactivity for the adjustment of the course content, a particular important feature for this significantly reshaped edition of the course. Various operational details are still open and will be finalized during the first lecture together with the students. *Preliminary* lecture notes will be available on the Moodle server *possibly shortly before* a given lecture (Monday evening usually), in PDF format. *Definitive* lecture notes will be available *after a given lecture* in timely fashion, together with the recording.

5 Laboratories

The course will involve a total of eight lab exercises (six lasting 3h and two 2h). All the lab exercises will be ungraded and no points are therefore mentioned on their assignments. The exercises have been designed such as they are doable in the classroom as well as at home for fulfilling the flexible teaching strategy (1/3 on-site and 2/3 on-line), provided that the corresponding software packages have been downloaded and correctly installed.

The assignments of the exercises will be made available at latest the Wednesday before a given lab session via the Moodle server, in PDF format. At the beginning of each lab session, a mini-tutorial of typically 5-10 minutes will be given by the main designer of the exercise. The corresponding slides will be made available on the Moodle server after the lab session. Official solutions will be distributed for each exercise after a given laboratory session. For the exercises, we encourage the students to take their own personal notes (they will be useful for the course project and the final exam).

Assisted completion of laboratory work and further discussion on specific points of the exercises can happen during on-line office hours. On-line office hours will have to be scheduled upon appointment via the TA mailing list and the Moodle discussion forum will also be leveraged for exercise discussion.

6 Course Project

SIS will involve a 60h course project for each student (this includes reading, implementing, presenting, and reporting). Students will choose a project from a list of approved topics to be distributed during Week 6 of the semester. Projects will be carried out in two-student teams. Every project will be supervised by a teaching assistant. Definitive assignment of course projects will be communicated by the end of the Week 7, based on the preferences expressed by the students in terms of project topic and team mate. During Week 8, a compulsory kick-off session for the implementation of the course projects will be organized, according to the different topics.

Students will be required to submit a brief progress report (not graded) on their project by the end of Week 11, showing a clear understanding of the project topic and its related literature, a concrete implementation plan, familiarization with the needed tools, and preliminary implementation results. This will allow the project supervisor to give feedback to the student team in terms of implementation progress, problem and tool understanding, and time planning. Further details on the final project report and presentation will be communicated in timely fashion.

There will be dedicated office hours for the course project exclusively during the very same time window of the lab sessions (entire lab session or only one hour, with the two other hours used for a laboratory, whose content will be relevant for the course project).

7 Course Syllabus

WEEK 1 – September 15 and 17

Lecture – AM
Organization of the course (team, workload, credits); overview of the course content; introduction to signal processing – signals, time continuity and time discretization, analog and digital signals, baseline concepts.

Reading
Lecture notes.

Lab
None.

WEEK 2 – September 22 and 24

Lecture – AM
Introduction to signal processing – Fourier series and transform, convolution.

Reading
Lecture notes.

Lab 1
Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 3 – September 29 and October 1

Lecture – AM
Introduction to signal processing – sampling, reconstruction, and aliasing.

Reading
Lecture notes.

Lab 2
Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 4 – October 6 and 8

Lecture – AM
Introduction to signal processing – additional transforms (Discrete-Time Fourier Transform, Laplace, z-Transform); transfer functions, impulse and step responses; filter analysis and synthesis.

Reading
Lecture notes.

Lab 3
Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 5 – October 13 and 15

Lecture - AM
Introduction to signal processing – filter analysis and synthesis; introduction to programmable instruments and embedded systems; the e-puck miniature robot as example of embedded system.

Reading
- Lecture notes.
- Siegwart R. and Nourbakhsh I. R., "Introduction to Autonomous Mobile Robots", MIT Press, 2004, Ch. 4 (pp. 89-95).

Lab 4
Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 6 – October 20 and 22

Lecture – IKE
Refresh of C programming background: good practices in C programming (e.g., multi-file project organization, syntax indentation and commenting, use of debugging tools), similarities and differences between compiled (e.g., C) and interpreted (e.g., Matlab) languages.

Reading
Lecture notes.

Lab 5
Refresh of C concepts previously learned and exercise of good practices in C programming.

Course project
Distribution of course project list and request preferences.

WEEK 7 – October 27 and 29

Lecture – IKE and all TAs
(1h, IKE) Introduction to realistic simulation (Webots), C programming in this environment, basic concept of perception-to-action loop, controller, sensor & actuator, communication channel modeling.
(1h, all TAs) Solving last installation problems and carrying out operational tests for the Webots simulator on the students' machines.

Reading
- Lecture notes
- Michel O., "Webots: Professional Mobile Robot Simulation". *Int. J. of Advanced Robotic Systems*, **1**: 39-42, 2004.

Lab 6
Introduction to Webots lab (programming in C but use of Matlab when appropriate)

Course project
Assign projects.

WEEK 8 – November 3 and 5

Lecture – AM
Introduction to embedded systems – communication and mobility.

Reading
- Lecture notes
- Mondada F., Bonani M., Raemy X., Pugh J., Cianci C., Klaptocz A., Magnenat S., Zufferey J.-C., Floreano D., Martinoli A., "The e-puck, a Robot Designed for Education in Engineering". *Proc. of the 9th Conference on Autonomous Robot Systems and Competitions,* May 2009, Castelo Branco, Portugal, Vol.1, pp. 59-65.

Lab
Kick-off and assistance for course project.

Course project
Compulsory course project guided kick-off session.

WEEK 9 – November 10 and 12

Lecture – AM
Introduction to localization techniques in mobile robotics and positioning systems.

Reading
- Lecture notes
- Siegwart R. and Nourbakhsh I. R., "Introduction to Autonomous Mobile Robots", MIT Press, 2004, Ch. 3 (pp. 47-53), Ch. 4 (pp. 145-151), Ch. 5 (181-191).

Lab 7
(2h) Odometry lab in Webots (programming in C but use of Matlab when appropriate)
(1h) Assistance for course project.

WEEK 10 – November 17 and 19

Lecture - AM
More on localization techniques and filtering in mobile robotics: coping with uncertainties and fusing exteroceptive and proprioceptive sensing.

Reading
- Lecture notes
- Siegwart R. and Nourbakhsh I. R., "Introduction to Autonomous Mobile Robots", MIT Press, 2004, Ch. 4 (pp. 151-154), Ch. 5 (pp. 191-200; 212-214; 227-244).
- Maybeck P. S. "Stochastic Models, Estimation, and Control", Academic press, 1979, Ch. 1 (pp.1-16).

Lab 8

(2h) Odometry augmented with exteroceptive sensing (programming in C but use of Matlab when appropriate).
(1h) Assistance for course project.

WEEK 11 – November 24 and 26

Lecture – AM
Traditional field instruments for environmental engineering (wind, temperature, humidity, etc.); energy management in field instruments; advanced field instruments for environmental engineering: wireless sensor nodes and networks.

Reading
- Lecture notes.
- Barrenetxea G., Ingelrest F., Schaefer G. and Vetterli M., "The Hitchhiker's Guide to Successful Wireless Sensor Network Deployments". *Proc. of the 6th ACM Conference on Embedded Networked Sensor Systems* (SenSys 2008). Raleigh, NC, USA, 5-7 November 2008.

Lab
Assistance for course project.

Course project
Compulsory progress verification milestone through the submission of an ungraded intermediate report (literature read, concrete implementation plan, tool familiarization, preliminary implementation results).

WEEK 12 – December 1 and 3

Lecture – AM
Advanced field instruments for environmental engineering: mobile sensor nodes.

Reading
- Lecture notes
- Marjovi A., Arfire A., and Martinoli A., "Extending Urban Air Quality Maps Beyond the Coverage of a Mobile Sensor Network: Data Sources, Methods, and Performance Evaluation". *Proc. of the International Conference on Embedded Wireless Systems and Networks* (EWSN 2017), Uppsala, Sweden, 20-22 February, 2017.

Lab
Assistance for course project.

WEEK 13 – December 8 and 10

Lecture
Advanced field instruments for environmental engineering: robotic sensor nodes. Introduction to Distributed Intelligent Systems (follow-up master course) and course take home messages. Discussion of the course evaluation by the students.

Reading
None

Lab
Course project assistance.

Course project
Final reports will be due on Sunday December 13.

WEEK 14 – December 15 and 17

Lecture
Course project defenses.

Reading
None.

Lab
Course project defenses.