Signals, Instruments, and Systems

Winter Semester 2021-2022

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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, 40h for exercises (including preparation), and 50 h for carrying out and producing requested deliverables for homework.

2 Grade

The final grade for SIS will take into account the performance in the final written exam as well as that in the two graded homework assignments. Exercises are ungraded but solving them in a thorough and individual way will help the students to be well-prepared for the homework and the final exam. 40% of the grade will be acquired during the semester, based on the performances in the homework (the first homework assignment will count for 15% of the grade, the second homework assignment for 25%). The final written exam will last 180 minutes and will involve questions focusing on the different topics covered during the course and the exercises. 60% 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 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

Lecture will be given with the help of a LCD projector and a video-conferencing tool for a mixed audience (on-site and 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 selected a live-streamed mode for our course as we feel this mode allows 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. Similar to a previous edition partially run in such mode, we will involve student representatives for improving the liaison between the on-line and the on-site audience during lectures. *Preliminary* lecture notes will be available on the Moodle server *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 nine lab exercises lasting 3 hours. All the lab exercises will be ungraded and no points are therefore mentioned on their assignments. The exercises have been designed and tested such as they are doable in the two computer rooms available for the course on campus, leveraging a Linux operating system (Ubuntu 20.4). Most of the exercises can be also carried out on personal machines, provided that the corresponding software packages have been downloaded and correctly installed on the specific operating systems (not necessarily Linux). While we will make available some instructions on the Moodle server for this purpose, as the current flexible teaching conditions allow any student to attend on-site exercises, we will not offer any assistance for the deployment of such tools on private machines. Moreover, it is not foreseen to distribute hardware at home for laboratories involving additional hardware.

The assignments of the exercises will be made available at latest by Wednesday (mid-day) 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 a teaching assistant. 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 homework and the final exam).

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 Homework

SIS will involve a 50h homework effort for each student (this includes reading the distributed material, implementing, reporting, and demonstrating the obtained solution). Homework assignments will be carried out in two-student teams. Their purpose is to verify the acquisition of the notions transmitted during lab sessions with a series of concrete synthesis exercises.

The course will involve two homework assignments. The first homework will be distributed in Week 7, will verify the acquisition of knowledge transmitted during the first six laboratories, and will be due at the beginning of Week 9, after about 10 days (an exact schedule will be communicated in timely fashion). During Week 8 there will be no dedicated exercise but the lab session will offer assistance for the homework. The second homework will be distributed in Week 11, will verify the acquisition of knowledge transmitted during the last three laboratories (but some notions of the previous laboratories will be of course still leveraged), and will be due at the end of of Week 13, after about 17 days (an exact schedule will be communicated in timely fashion). During Week 12 and 13 there will be no dedicated exercises but the lab sessions will offer assistance for the homework. The second homework will also involve a demonstration of the implemented solution on one of the machines of the on-site computer rooms (logistically it might happen in one of the two allocated computer rooms or in another room instrumented with the very same type of machine and operating system).

No further assistance outside the dedicated lab sessions mentioned above will be dedicated to the homework.

7 Course Syllabus

WEEK 1 – September 21 and 23

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 28 and 30

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 – October 5 and 7

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 12 and 14

Lecture – AM

Introduction to signal processing – additional transforms (Discrete-Time Fourier Transform, Laplace Transform, Z-Transform); impulse response and transfer function; frequency response and Bode plots; analog filter analysis and synthesis.

Reading
Lecture notes.

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

WEEK 5 – October 19 and 21

Lecture - AM
Introduction to signal processing – filter order and type; digital filter analysis and synthesis.
Introduction to embedded systems – terminology, main modules (perception, communication, computation, and action); sensor types and performance.

Reading
- Lecture notes.
- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 4 (pp. 89-98).

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

WEEK 6 – October 26 and 28

Lecture – AM (online)
Introduction to embedded systems – power and communication.

Reading
Lecture notes.

Lab 5
An introduction to embedded systems programing leveraging the DISAL Arduino node.

WEEK 7 – November 2 and 4

Lecture – AM
Introduction to embedded systems – control, real-time programming, and sensor 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*, November 2008, Raleigh, NC, USA, pp. 43-56.

Lab 6

Advanced embedded system programing notions leveraging the DISAL Arduino node.

Hwk 1
Assignment distributed shortly after end of Lab 6 session.

WEEK 8 – November 9 and 11

Lecture – AM
Introduction to mobile robotics - simple control architectures and high-fidelity simulation.

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

Lab
Assistance for Hwk1.

WEEK 9 – November 16 and 18

Lecture – AM
Introduction to mobile robotics - localization 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. 5 (181-191).

Lab 7
Introductory Webots lab; programming in C but use of Matlab when appropriate.

Hwk 1
Submission of homework deliverables before lecture Week 9.

WEEK 10 – November 23 and 25

Lecture - AM
Introduction to mobile robotics - localization in presence of uncertainties and corresponding estimation methods in 1D.

Reading
- Lecture notes
- Siegwart R. and Nourbakhsh I. R., "Introduction to Autonomous Mobile Robots", MIT Press, 2004, Ch. 4 (pp. 145-151 and 151-154), Ch.5 (pp. 227-233).
- Maybeck P. S. "Stochastic Models, Estimation, and Control", Academic Press, 1979, Ch. 1 (pp.1-16).

Lab 8
Odometry lab in Webots; programming in C but use of Matlab when appropriate.

WEEK 11 – November 30 and December 2

Lecture – AM and IKE
Introduction to mobile robotics – filtering methods for 2D localization and C programming refresher.

Reading
- Lecture notes.
- Siegwart R. and Nourbakhsh I. R., "Introduction to Autonomous Mobile Robots", MIT Press, 2004, Ch. 5 (pp. 191-200; 212-214; 227-244).

Lab 9
Odometry augmented with exteroceptive sensing + Kalman filtering lab in Webots; programming in C but use of Matlab when appropriate.

Hwk 2
Assignment distributed shortly after end of Lab 9 session.

WEEK 12 – December 7 and 9

Lecture – AM
Sensor systems for environmental monitoring: programmable instruments with different mobility (static sensing, mobile sensing, robotic sensing).

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*, February 2017, Uppsala, Sweden pp. 12-23.

Lab
Assistance for Hwk2.

WEEK 13 – December 14 and 16

Lecture – AM
Sensor systems for environmental monitoring (continuation). Course take home messages. Discussion of the course evaluation by the students.

Reading
- Lecture notes.
- Quraishi A., Bahr A., Schill F., and Martinoli A., "Autonomous Feature Tracing and Adaptive Sampling in Real-World Underwater Environments," *Proc. IEEE Int. Conf. on Robotics and Automation*, May 2018, Brisbane, Australia, pp. 5699-5704.

Lab
Assistance for Hwk2.

Hwk 2
Submission of homework deliverables by the end of the week (including week-end).

WEEK 14 – December 21 and 23

Lecture
Hwk2 demonstrations.

Reading
None.

Lab
Hwk2 demonstrations.