Signals, Instruments, and Systems

Winter Semester 2023-2024

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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, 45h for exercises (labs and lab verification test, preparation time included), and 45h for carrying out and producing requested deliverables for the course project.

2 Grade

The final grade for SIS will take into account the performance in the final written exam as well as that in the *individual* lab verification test and in the *team* course project. Exercises are ungraded but solving them in a thorough way will help the students to be well-prepared for the lab verification test and course project, as well as for the final exam. 50% of the grade will be acquired during the semester, based on the performances in the lab verification test (25%) and course project (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. 50% of the grade will be based on the performance during the final written exam.

3 Reading

Being a pioneering course in the curriculum of environmental and civil engineers, SIS does not have a course book. The lecture notes are the reference for the course. *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 on both the Moodle server and the web pages of the course.

Additionally, complementary reading material will be made available, if appropriate, in electronic format on the 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 an LCD projector and the blackboard, when appropriate. The lectures will be offered exclusively on-site. Lectures will *not* be recorded this year but video material about lectures of the previous edition will be made available to students. While this edition of the course will be roughly aligned with the previous one, changes are possible and we therefore recommend students to attend the lecture of this year in a regular way.

5 Laboratories

The course will involve a total of nine lab exercises lasting three hours as well as a programming self-assessment test. The self-assessment test will focus on the verification of the Matlab and C programming pre-requisites that are necessary for the course and should have been acquired in previous courses. It will take place in the first week of the course. The test is ungraded but will mention points so that students can estimate their preparation in terms of programming. Students are expected to submit their obtained score in an anonymous fashion, via the Moodle server.

All the lab exercises will be also ungraded, without points mentioned on the assignment. 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. While we strongly recommend students to carry out their exercises in the available computer rooms, 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 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.

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 the programming self-assessment test and 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 all the graded assignments, namely lab verification test, course project, and final exam).

Further discussion on specific points of the exercises can happen during office hours. 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, but only for topics of common interest.

6 Lab Verification Test and Course Project

The acquisition of the laboratory content will be verified through two graded assignments: an individual lab verification test (3h, in the computer room, during the exercise session) and a team course project (45 h effort for each student, carried out by a team of *three* students by default, *two* in exceptional cases, in case the total number of students is not divisible by three). The course project effort includes reading the distributed material, implementing, reporting, and demonstrating the obtained solution.

The lab verification test will verify the acquisition of knowledge transmitted during the *first four* laboratories and take place during Week 6. The project assignment will be distributed at the end of Week 10, will verify the acquisition of knowledge transmitted during the *last five* laboratories, and will be concluded during Week 14 (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 course project. The course project will also involve a demonstration of the implemented solution on one of the machines of the on-site computer rooms (logistically it will happen in another room instrumented with the very same type of machine and operating system).

No further assistance outside the specific lab sessions mentioned above will be dedicated to the course project.

7 Course Syllabus

WEEK 1 – September 19 and 21

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
Self-assessment test for Matlab and C programming.

WEEK 2 – September 26 and 28

Lecture
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 3 and 5

Lecture
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 10 and 12

Lecture
Introduction to signal processing – the Laplace transform for continuous-time signals and systems; frequency response, impulse response and transfer function; analog filter analysis and synthesis.

Reading
Lecture notes.

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

WEEK 5 – October 17 and 19

Lecture
Introduction to signal processing – Bode plots; the Z-Transform for discrete-time signals and systems; filter order and type; digital filter analysis and synthesis.

Reading
Lecture notes.

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

WEEK 6 – October 24 and 26

Lecture
Introduction to embedded systems – terminology, main modules (perception, communication, computation, and action); sensor types and performance, power consumption, management, generation, and storage.

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

Lab
Lab verification test in the computer rooms (will involve programming in Matlab).

WEEK 7 – October 31 and November 2

Lecture
Introduction to embedded systems – communication and embedded computation.

Reading
Lecture notes

Lab 5
An introduction to embedded systems programing leveraging the DISAL Arduino node (programming in C/Python/Matlab as appropriate).

WEEK 8 – November 7 and 9

Lecture
From embedded systems to mobile robotics – real-time computing 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 6
Advanced embedded system programing notions leveraging the DISAL Arduino node (programming in C/Python/Matlab as appropriate).

WEEK 9 – November 14 and 16

Lecture
Introduction to mobile robotics - control architectures and positioning systems.

Reading
- Lecture notes

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

WEEK 10 – November 21 and 23

Lecture - AM
Introduction to mobile robotics – localization through odometry.

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), and Ch. 5 (185-191).

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

Course project
Assignment distributed shortly after end of Lab 8 session; tools leveraged will be exclusively Webots.

WEEK 11 – November 28 and 30

Lecture
Introduction to mobile robotics – Localization with odometry augmented with exteroceptive sensing; Kalman filtering.

Reading
- Lecture notes.
- Maybeck P. S. "Stochastic Models, Estimation, and Control", Academic Press, 1979, Ch. 1 (pp.1-16).

- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 4 (pp. 151-154), Ch. 5 (pp. 181-184; pp. 227-244).

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

WEEK 12 – December 5 and 7

Lecture
Stationary and mobile sensor systems for environmental monitoring.

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.
- 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 course project.

WEEK 13 – December 12 and 14

Lecture
Robotic sensor systems for environmental monitoring. Course take home messages. Discussion about the course and student feedback.

Reading
- Lecture notes.
- Ercolani C. and Martinoli A., “3D Odor Source Localization using a Micro Aerial Vehicle: System Design and Performance Evaluation”, *Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, October 2020, Las Vegas, NV, USA, online organization, pp. 6194-6200.
- 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 course project.

WEEK 14 – December 19 and 21

Lecture
No lecture.

Reading

None.

Lab
Course project demonstrations.

Course project
Submission of course project deliverables.