

Signals, Instruments, and Systems

Winter Semester 2022-2023

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Guest lecturers:	Chiara Ercolani (CE), Wanting Jin (WJ)
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Support staff:	Lucas Wälti
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 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 *individual* lab verification test and in the *team* homework. Exercises are ungraded but solving them in a thorough way will help the students to be well-prepared for the lab verification test and homework, as well as for the final exam. 40% of the grade will be acquired during the semester, based on the performances in the lab verification test (20%) and homework (20%). 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 an LCD projector and the blackboard, when appropriate. The lectures will be offered *either* on-site (most of the lectures) *or* on-line (three hours of lecture are currently planned in this mode). No mixed on-line and on-site attendance will be supported. 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 well-aligned with the previous one, changes are possible and we therefore recommend students to attend the lecture of this year in a regular way. *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.

5 Laboratories

The course will involve a total of nine lab exercises lasting three 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 22.04). 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 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, homework, 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 Homework

The verification of 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 homework (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 homework 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 six* laboratories and take place during Week 8. The homework will be distributed in Week 11, will verify the acquisition of knowledge transmitted during the *last five* laboratories, 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 homework 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 dedicated lab sessions mentioned above will be dedicated to the homework.

7 Course Syllabus

WEEK 1 – September 20 and 22

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 27 and 29

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 4 and 6

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 11 and 13

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 18 and 20**Lecture – AM (on-line) and CE (on-site)**

Introduction to signal processing – filter order and type; digital filter analysis and synthesis; C programming refresher.

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 25 and 27**Lecture – AM (online)**

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

Reading

Lecture notes.

Lab 5

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

WEEK 7 – November 1 and 3**Lecture – AM**

Introduction to embedded systems – communication and real-time programming.

Reading

Lecture notes

Lab 6

Advanced embedded system programming notions leveraging the DISAL Arduino node (programming in C/Python/Matlab as appropriate).

WEEK 8 – November 8 and 10**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

Lab verification test in the computer rooms.

WEEK 9 – November 15 and 17**Lecture – AM**

Introduction to mobile robotics - localization and positioning systems. Short discussion of indicative course evaluation by the students.

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/Python when appropriate.

WEEK 10 – November 22 and 24**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/Python when appropriate.

WEEK 11 – November 29 and December 1**Lecture – WJ**

Introduction to mobile robotics – filtering methods for 2D localization.

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/Python when appropriate.

Hwk

Assignment distributed shortly after end of Lab 9 session.

WEEK 12 – December 6 and 8**Lecture – AM**

Stationary and mobile sensor systems and networks 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 hwk.

WEEK 13 – December 13 and 15**Lecture – AM**

Robotic sensor systems for environmental monitoring. Course take home messages. Re-discussion of the course evaluation submitted by the students during Week 5.

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 hwk.

WEEK 14 – December 20 and 22**Lecture**

Hwk demonstrations (moved on Wed December 21).

Reading

None.

Lab

Hwk demonstrations.

Hwk

Submission of homework deliverables by the beginning of the week (Monday).