Signals, Instruments, and Systems

Summer Semester 2019-2020

Instructor:	Alcherio Martinoli (AM)
Guest lecturers:	Chiara Ercolani (CE), I. Kagan Erünsal (IKE), Faëzeh Rahbar (FR)
Teaching assistants:	Chiara Ercolani (Head TA), I. Kagan Erünsal (TA), Anwar Quraishi (TA), Faëzeh Rahbar (TA), Aurélien Brun (Help TA)
Support staff:	Cyrill Baumann
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 30 h of workload. Therefore, the total workload for SIS will be about 150 h over the whole semester. The approximate breakdown of the workload is 60 h for lecture attendance and exam preparation, 30 h 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 thourough 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 white board, when appropriate. The same scheme will be adopted for on-line lecturing. *Preliminary* lecture notes will be available on the course web site *possibly shortly before* a given lecture (Wednesday evening usually), in PDF format. *Definitive* lecture notes will be available *after a given lecture* in timely fashion.

5 Laboratories

Most of the weeks, there will be a 3-hour lab session. The course will involve a total of eight lab exercises. All the lab exercises will be ungraded and no points are therefore mentioned on their assignments.

The assignment of labs will be made available at latest the Monday 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 exercise Moodle server after the lab session. Official solutions will be distributed for each laboratory exercise after a given laboratory session. For the lab 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 lab 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 can also be leveraged for exercise discussion.

6 Course Project

SIS will involve a 60 h 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 7 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 8, based on the preferences expressed by the students in terms of project topic and team mate. During Week 9, 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 either during the very same time window of the lab sessions or upon appointment, via the TA mailing list.

7 Course Syllabus

WEEK 1 – February 20

Lecture – CE

Refresh of C programming background: UNIX environment, compilation tools, variable types, execution flow management, operators (e.g., binary, logical).

Reading
Lecture notes.

Lab
None.

WEEK 2 – February 25 and 27

Lecture – AM and FR
Overview of the course: fundamentals of signal processing; fundamentals of computer science and C programming; embedded systems and real-time control. Selected pointers of current research projects involving embedded system deployment in civil and environmental applications.

Consolidation of C programming background: functions, and static structures (e.g., array, matrices); similarities and differences between compiled (e.g., C) and interpreted (e.g., Matlab) languages.

Reading
Lecture notes.

Lab 1
Refresh of C concepts learned at the first year of BS; Linux environment, compilation and editing tools, simple programs.

WEEK 3 – March 3 and 5

Lecture – FR
Consolidation of C programming background: pointers, memory management, good practices in C programming (e.g., multi-file project organization, syntax indentation and commenting, use of debugging tools).

Reading
Lecture notes.

Lab 2
C/Matlab exercise showing differences between an interpreted and compiled languages; structure, matrix, and vector manipulations.

WEEK 4 – March 10 and 12

Lecture – AM
Introduction to signal processing – Signals, series, transforms.

Reading
Lecture notes.

Lab 3

C exercise on pointers and memory management (e.g., dynamic allocation, pointer passing in functions); use of a debugger as support tool for memory management and proper coding.

WEEK 5 – March 17 and 19

Lecture - AM
Introduction to signal processing – Convolution, sampling, reconstruction.

Reading
Lecture notes.

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

WEEK 6 – March 24 and 26

Lecture – AM
Introduction to signal processing – Filter analysis and synthesis.

Reading
Lecture notes.

Lab 5
Exercise in Matlab on signal processing concepts explained in the lecture.

WEEK 7 – March 31 and April 2

Lecture – AM
(Tue, 1h) Introduction to signal processing (block wrap-up).
(Thu, 2h) Introduction to embedded systems hardware and sensor nodes (focus on microcontrollers, sensors and communication channels). Concrete examples based on educational and field tools for simple sensing modalities (e.g., temperature, light).

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

Lab 6
Exercise in Matlab on signal processing concepts explained in the lecture.

Course project
Distribution of course project list and request preferences.

WEEK 8 – April 7 and 9

Lecture – IKE/all TAs

(1h) Introduction to realistic simulation (Webots), C programming in this environment, basic concept of perception-to-action loop, controller, sensor & actuator, communication channel modeling.
(1h) 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 7
Exercise in Matlab on signal processing concepts explained in the lecture.

Course project
Assign projects.

WEEK 9 – April 21 and 23

Lecture – AM
(1h) Introduction to mobile robotics, the e-puck robot, and simple control architectures. Concrete example of memory and computation limitations in embedded system based on the e-puck platform.

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

Course project
(1h) Compulsory course project guided kick-off session.

WEEK 10 – April 28 and May 30

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).

Lab
Assistance for course project.

WEEK 11 – May 5 and 7

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 (literature read, concrete implementation plan, tool familiarization, preliminary implementation results).

WEEK 12 – May 12 and 14

Lecture – AM
Advanced field instruments for environmental engineering: mobile and robotic sensor nodes. Introduction to Distributed Intelligent Systems (follow-up master course) and course take home messages.

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 – May 19

Lecture
None (Ascension)

Reading
None

Lab
Course project assistance.

Course project
Reports will be due on Sun May 24.

WEEK 14 – May 26 and 28

Lecture
Course project defenses

Reading
None.

Lab
Course project defenses.