Signals, Instruments, and Systems

Summer Semester 2018-2019

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Guest lecturers:	Ali Marjovi (AMj), Alicja Wasik (AW)
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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 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, 45 h for exercises (labs and lab verification test, preparation time included), and 45 h for carrying out, documenting, and defending a course project.

2 Grade

The final grade for SIS will take into account performance in the final written exam as well as exercises and course project. 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 lab verification test (20%) as well as in the course project (30%, 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. *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

Each week, with the exception of Week 1, 13 and 14 as well the week having the lab verification test (Week 8), there will be a 3-hour lab session. The course will involve a total of ten lab exercises. All the lab exercises will be ungraded and no points are therefore mentioned on their assignments. The verification of the assimilation of laboratory content will happen only during the lab verification test, taking place in the computer room (during the exercise hours). Additional details for the preparation of this test will be distributed in timely fashion.

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 laboratory verification test, course project, and final exam).

Assisted completion of laboratory work and further discussion on specific points of the lab exercises can happen during the office hours. 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 45 h course project (this includes reading, implementation, reporting, oral defense, and review of the report of another student team). Students will choose a project from a list of approved topics to be distributed during Week 5 of the semester. Projects will be carried out in groups of three students (an ad hoc arrangement will be found in case of a total number of students non-divisible by three). Each member of the student team will have to defend part of the project in front of the audience (during the week following the semester end). 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 members. During Week 8, a compulsory kick-off session for the implementation of the course project will be organized by each individual supervisor with his or her student teams.

Students will be required to submit a brief progress report (not graded) on their project by the end of Week 10, 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 their project supervisor to give them feedback 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. Each student will also be asked to serve as a reviewer for another student project and invited to ask questions during the defense session.

There will be dedicated office hours for the course project but they will organized differently than for exercises. In addition to the kick-off session mentioned above, every week from Week 9 to 12 each project supervisor will be available during one hour for responding to questions. Time of the week and location of these office hours will take maximally into account student and supervisor preferences and communicated in timely fashion. During Week 13 and 14, as there will be no exercises, the lab sessions will serve as common office hours for all project topics and take place in the computer room. it is worth noticing that TAs will not be available for further additional office hours (even upon appointment) for course projects outside the pre-established weekly slots. Any non-respect of such assistance mode will result in penalties in the grading of the course project, as fostering autonomy is one of the key learning outcomes pursued in such exercise.

7 Course Syllabus

WEEK 1 – February 21

Lecture – AM and AMj
Organization meeting, timetable. 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.
Refresh of C programming background: UNIX environment, compilation tools, variable types, execution flow management.

Reading
Lecture notes.

Lab
None.

WEEK 2 – February 26 and 28

Lecture – **AMj**
Consolidation of C programming background: operators (e.g., binary, logical), 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 5 and 7

Lecture – AMj
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 12 and 14

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 19 and 21

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

Reading
Lecture notes.

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

Course project
Distribution of course project list.

WEEK 6 – March 26 and 28

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

Reading
Lecture notes.

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

Course project
Collect preferences for the course projects (topic ranked list + team composition).

WEEK 7 – April 2 and 4

Lecture – AM
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/C on signal processing concepts explained in the lecture.

Course project
Assign projects.

WEEK 8 – April 9 and 11

Lecture – AW (1h)
Introduction to realistic simulation (Webots), C programming in this environment, basic concept of perception-to-action loop, controller, sensor & actuator, communication channel modeling.

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

Lab
Lab Verification Test – Lab 1 to 6, mixed practical and theoretical questions, computer facility leveraged as appropriate.

Course project (1h)
Compulsory course project guided kick-off session (during the 2nd hour of the lecture time window).

WEEK 9 – April 16 and 18

Lecture - AM
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 7
Webots lab; programming in C but use of Matlab when appropriate.

WEEK 10 – April 30 and May 2

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 8
E-puck lab, communicate data from and to the base station; reading sensor values and visualize with Matlab when appropriate, simple closed-loop control (Braitenberg, behavior-based).

WEEK 11 – May 7 and 9

Lecture
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 9
Advanced e-puck lab, use the e-puck as a robot/robotic sensor node; local (in-network processing) and on the base station; recall initial signal processing; use Matlab when appropriate.

Course project
Compulsory progress verification milestone (literature read, concrete implementation plan, tool familiarization, preliminary implementation results).

WEEK 12 – May 14 and 16

Lecture – AM
Real-time programming in embedded systems and field instruments; advanced field instruments for environmental engineering: mobile sensor nodes and networks.

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 10
DISAL Arduino Xbee lab, communicate data to the base station from a single node; process data using simple data processing and visualization techniques

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WEEK 13 – May 21 and 23

Lecture – AM
Advanced field instruments for environmental engineering: field robots and robotic sensor networks. 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 in the computer room

WEEK 14 – May 28

Lecture
None (Ascension)

Reading
None.

Lab
Course project – assistance in the computer room and last hints before submission report.

Course project
Reports will be due on Sunday June 2. The project presentations will take place on Wednesday June 5. Exact time slots will communicated in timely fashion as much as possible based on preferences expressed by students. Student teams having the same project topic will have to be present in the same session and the total amount of time to be invested by a team during the period above is therefore about one hour and an half (the estimated length of the session).