1 Credits and Workload

Distributed Intelligent Systems 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 Distributed Intelligent Systems will be about 150 h over the whole semester. The approximate breakdown of the workload is 75 h for lecture attendance and exam preparation, 75 h for exercises (lab attendance and verification tests, preparation time included).

2 Grade

The final grade for Distributed Intelligent Systems will take into account the performance in the final written exam as well as in the lab verification tests. The final written exam will last 180 minutes and will involve multiple topics covered during the course (lecture, exercises, and primary handouts). 50% of the grade will be acquired during the semester, based on the performances in the lab verification tests (30% for the first test and 20% for the second test, corresponding to their respective weight in the exercise series); the other 50% of the grade will be based on the performance in the final exam.

3 Reading

Distributed Intelligent Systems does not follow a specific course book. Weekly reading material will be exclusively made available in electronic format, downloadable from the lecture website (student area on the Moodle server), typically the week before a given lecture and exercise session. 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 exclusively be used for course purposes.

For this edition, the reading material has been classified in primary and secondary reading. Primary reading material will be covered to large extent during the lecture: it represents therefore a good complement to slides. On average, the primary reading material will consist of about 45 single-column pages per week (selected book sections and chapters, conference and journal papers, technical reports). Secondary reading material is only briefly mentioned during the lecture, typically because of one specific aspect complementing the information of the core messages. Availability of this material on Moodle can facilitate curious students to look more into such information. Finally, for students interested in a deeper understanding of specific topics, further tertiary reading pointers are suggested at the end of each lecture notes.
Note that in any case the handouts represent a loosely coordinated literature body: some redundancy is possible and their content might not exhaustively discussed in the lecture, although students attending the lecture will get good guidance on the relevance of specific reading material.

4 Lecture Notes

Lecture will be given with the help of a LCD projector and a black board, when appropriate. Preliminary lecture notes will be available on the course web site possibly shortly before a given lecture (Monday evening), in PDF format. No e-mail notification will be send for such posting operation. Definitive lecture notes will be available after a given lecture in a timely fashion, with an e-mail notification through the Moodle forum.

5 Labs and Verification Tests

Each week, with the exception of the first week (lecture instead of exercises) and the last week of the semester (lecture instead of exercises), there will be either a 3 hour lab (see course outline below) or a verification test. The course will involve in total 10 lab assignments and 2 lab verification tests (in the computer room). Solutions for lab assignments will be distributed a few days after a given exercise session. A lab verification test will include material covered in the previous laboratory sessions (first 6 exercises for the first verification test and last 4 for the second one). The submitted solutions of the lab verification tests will be reviewed individually and will be available for download on the Moodle server in timely fashion (up to three weeks after a given lab verification test). Possible discussions of grading and evaluation should take place during office hours of the TAs and not during the lab sessions.

The assignment of labs will be made available at the beginning of the week of a given laboratory 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 lab exercise. The corresponding slides will be made available on the exercise page after the lab session.

No specific office hours of individual TAs will be posted but requests of meeting with a TA (including a meeting in the computer room) can be submitted anytime using the course e-mail list (dis-ta@groupes.epfl.ch).

6 Collaboration Policy

Unless otherwise noted, students can collaborate with their fellow students on the lab assignments and have to work individually during lab verification tests and final written exam.

7 Course Syllabus

WEEK 1 – September 19 and 20

Lecture – 5 h (Tue in CM 4 and Wed in MA B1 11)
Organization meeting, timetable. Overview of the course. Introduction to Swarm Intelligence (SI) and key principles (e.g., self-organization, stigmergy), natural and artificial examples, computational and embedded SI. Foraging, trail laying/following mechanisms. Open-space, multi-source foraging experiments: biological data and microscopic models. From real to virtual ants: Ant System (AS), the first combinatorial
optimization algorithm based on ant trail/following principles. Application to a classical operational research problem: the Traveling Salesman Problem (TSP).

**Reading**

*Primary*
- Bonabeau E., Dorigo M., and Theraulaz G., “Swarm Intelligence: From Natural to Artificial Systems”, SantaFe Studies in the Sciences of Complexity, Oxford University Press, 1999, Ch. 1 (pp.1-23) and Ch. 2 (pp. 25-36 and 39-56).

*Secondary*

**No exercises**

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**WEEK 2 – September 26 and 27**

**Lecture** – 2 h
From AS to Ant Colony Optimization (ACO). Ant-based algorithms (ABC, Ant-Net) applied to routing in telecommunication networks.

**Reading**

*Primary*

*Secondary*

**Lab 1** – 3 h
Trail laying and following mechanisms, emphasizing SI concepts; Ant Colony Optimization.

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**WEEK 3 – October 3 and 4**

**Lecture** – 2 h
Introduction to mobile robotics: basic hardware and software concepts centered around the differential drive vehicle used in the course (e-puck) and the high-fidelity robotic simulator (Webots). Introduction to control architecture for mobile robots with special focus on reactive control architectures.

**Reading**

*Primary*

*Secondary*

**Lab 2 – 3 h**
Introduction to Webots, a high-fidelity robotic simulator. E-copies of the Webots user manual will be available.

**WEEK 4 – October 10 and 11**

**Lecture – 2 h**
Localization methods in mobile robotics: positioning systems, odometry-based and feature-based localization. Sources of localization uncertainties and corresponding handling methods for mobile robots.

**Reading**

*Primary*
- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 3 (pp. 47-53), Ch. 4 (pp. 145-154), Ch. 5 (pp. 181-200).

*Secondary*

**Lab 3 – 3 h**
Introduction to the e-puck robot. Illustrate key concepts of the course for basic behavior using different reactive control architectures (Artificial Neural Network, linear Braitenberg, behavior-based, rule-based). Simple localization algorithms based on odometry. An e-copy of a simple e-puck manual will be made available to the students.

**WEEK 5 – October 17 and 18**

**Lecture – 2 h; guest lecturer: Ali Marjovi**
Collective movements in natural societies; focus on flocking phenomena. Collective movements in artificial systems: Reynolds' virtual agents (Boids) and experiments with multi-robot systems (flocking, formation). Graph-based distributed control for continuous consensus algorithms (spatial rendez-vous, formation).

**Reading**

*Primary*
- Gowal S., “A Framework for Graph-Based Distributed Rendezvous of Nonholonomic Multi-Robot Systems”, EPFL Thesis no. 5845, Ch. 6 and 7 (pp. 49-60), 2013.

*Secondary*

Lab 4 – 3 h
Multi-robot localization, coordinated and collective movements in a point-simulator (Matlab) and Webots.

WEEK 6 – October 24 and 25

Lecture – 2h
Division of labor and task-allocation mechanisms: threshold-based algorithms, market-based algorithms and comparisons between the two algorithmic classes.

Reading
Primary

Secondary

Lab 5 – 3 h
Multi-robot systems coordination using market-based and threshold-based algorithms using Webots/point-simulator.

WEEK 7 – October 31 and November 1

Lecture – 2h
An introduction to wireless sensor networks; discrete consensus algorithms (collective decisions).

Reading
Primary

Secondary

Lab 6 – 3h
Introduction to Mica-z sensor nodes. Simulated (Webots with NS-3 plugin) and real (e-puck and Mica-z) sensor and actuator networks: networking static sensor nodes with mobile robots for performing collective decisions.

WEEK 8 – November 7 and 8

Lecture – 2 h
Introduction to multi-level modeling techniques (underlying theoretical framework, levels, assumptions, principles). Linear and nonlinear modeling case studies.

Reading
Primary

Lab verification test 1 – 3 h
In the computer room; subject: lab 1 to 6.

WEEK 9 – November 14 and 15

Lecture – 2 h

Reading
Primary

Secondary

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Lab 7 – 3 h
Multi-level modeling of distributed robotic systems.

WEEK 10 – November 21 and 22

Lecture – 2 h

Reading
Primary

Secondary

Lab 8 – 3 h
Particle Swarm Optimization: application to benchmark functions and control shaping for single robot (in simulation).

WEEK 11 – November 28 and 29

Lecture – 2 h
Application of machine-learning techniques to automatic control design and optimization of multi-robot systems. Specific issues for automatic control design and optimization in distributed systems (e.g., credit assignment problem). Advanced techniques for expensive and noisy optimization problems.

Reading
Primary

**Secondary**

**Lab 9 – 3 h**
Particle Swarm Optimization application to noisy problems: benchmark functions and multi-robot problems.

**WEEK 12 - December 5 and 6**

**Lecture – 2 h**
Distributed sensing using sensor networks: energy efficiency and mobility.

**Reading**

**Primary**

**Secondary**

**Lab 10 – 3 h**  
Distributed sensing with static, mobile, and robotic nodes (implementation in Webots).

**WEEK 13 – December 12 and 13**

**Lecture – 2 h**  
Distributed sensing using robotic sensor networks.

**Reading**

*Primary*


*Secondary*


**Lab verification test 2 – 3 h**  
In the computer room; subject: lab 7 to 10.

**WEEK 14 – December 19 and 20**

**Lecture – 5h (Tue in CM 4 and Wed in MA B1 11)**  
Self-aggregation and self-assembling in natural and artificial systems. Discussion based on student feedback. General take home messages.

**Reading**

*Primary*


Secondary

*No exercises.*