Distributed Intelligent Systems SS 2021-2022

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Course Website: https://disal.epfl.ch/teaching/distributed_intelligent_systems/

1 Credits and Workload

Distributed Intelligent Systems (DIS) 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 DIS will be about 150 h over the whole semester. The approximate breakdown of the workload is 60 h for lecture attendance and exam preparation, 40 h for exercises (including preparation), and 50 h for carrying out and producing requested deliverables for homework.

2 Grade

The final grade for DIS will take into account the performance in the final oral exam as well as that in the two graded homework assignments. Exercises are ungraded but solving them in a thorough and individual way will help the students to be well-prepared for the homework and the final exam. The final oral exam will will involve questions focusing on the different topics covered during the course and the exercises as well on the submitted homework solutions. 40% of the grade will be acquired during the semester, based on the performances in the homework (each homework assignment will count for 20% of the grade). The remaining 60% of the grade will be based on the performance during the final oral exam.

3 Reading

DIS does not follow a specific course book. Weekly reading material will be exclusively made available in electronic format, downloadable from the Moodle server, typically the week before a given lecture and exercise session. Access to this material will be limited to students officially enrolled in the class. Most of this material is copyrighted and therefore it should exclusively be used for course purposes.

The reading material is classified in primary and secondary reading. Primary reading material is covered to large extent during the lecture: it represents therefore a good complement to slides. On average, the primary reading material consists of about 50 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 be discussed in the lecture, although students attending the lecture will get good guidance on the relevance of specific reading material.

4 Lecture Notes

For this edition of the course, lectures will be given either fully on-line through Zoom or fully on-site (i.e. no hybrid mode). By default, the lecture will take place on-site but students will be notified a priori about lectures given exclusively on-line. Recorded lectures of either this or the past edition (depending on the topic and possible changes) will be made available to students in timely fashion. However, due to video rendering timing and the weekly schedule of the course, essentially involving a half day interval between lecture and exercises, it might be difficult for students not attending the lecture to watch its recording before the exercise session. We therefore strongly recommend a regular lecture attendance to cope with the high-gear rhythm of the course. *Preliminary* lecture notes will be available on the course web site *shortly before* a given lecture (typically Monday evening), in PDF format. *Definitive* lecture notes will be available *after a given lecture* in timely fashion, with an e-mail notification through the Moodle forum.

5 Laboratories

The course will involve a total of ten lab exercises, all lasting 3 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 20.4), and will exclusively software tools (Webots robotic simulator, Matlab, and further custom software packages). 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, we will not offer any assistance for the deployment of such tools on private machines.

Assistance for solving the laboratories will be exclusively offered in the two dedicated computer rooms. Because of anticipated on-site unavailability of one of the Help TAs during the initial phase of the course, we recommend students to bring with them a headset (USB-based or with separate microphone/speaker jacks), in order to benefit of additional remote assistance through a Discord channel.

The assignment of labs will be made available at latest the day before a given lab session via the Moodle server. 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 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 the homework and the final exam).

Further discussion on specific points of the exercises can happen during office hours. On-line or on-site office hours will have to be scheduled upon appointment via the TA mailing list; the Moodle discussion forum should be exclusively used for points of general interest (e.g., bug detection in the distributed code, etc.).

6 Homework

DIS will involve a 50h homework effort for each student (this includes reading the distributed material, implementing, and submitting the requested deliverables). Homework assignments will be carried out in three-student (default) or four-student (exception) teams.

Their purpose is to verify the acquisition of the notions transmitted during lab sessions with a series of concrete synthesis exercises.

The course will involve two homework assignments, to be solved in about 17-18 days. The first homework will be distributed at the end of Week 7, will verify the acquisition of selected knowledge transmitted during the first six laboratories, and will be due at the beginning of Week 9, after the Easter break (an exact schedule will be communicated in timely fashion). During Week 8 there will be no dedicated exercise but the lab session will offer assistance for the first homework. The second homework will be distributed in Week 12, will verify the acquisition of selected knowledge transmitted during the last four laboratories (but some notions of the previous laboratories might be still leveraged), and will be due just after the end of the semester (an exact schedule will be discussed communicated in timely fashion). During Week 13 and 14 there will be no dedicated exercises but the lab sessions will offer assistance for the second homework.

No further assistance outside the dedicated lab sessions mentioned above will be dedicated to the homework.

7 Course Syllabus

WEEK 1 – February 22 and 23

Lecture – 2h on-line of Tue and 2h15 recorded lecture from last edition
Course organization (credits, workload, logistics) and content overview. Introduction to Swarm Intelligence (SI) and key principles, natural and artificial examples. 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 Salesperson 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
- Martinoli A., “Collective Complexity out of Individual Simplicity”. Invited book review on "Swarm Intelligence: From Natural to Artificial Systems", by Bonabeau E., Dorigo M., and Theraulaz G. *Artificial Life*, Vol. 7, No. 3, pp. 315-319, 2001.
- Beni G., “From Swarm Intelligence to Swarm Robotics”. In Şahin E. and Spears W., editors, *Proc. of the SAB 2004 Workshop on Swarm Robotics*, Santa Monica, CA, USA, July, 2004. Lecture Notes in Computer Science (2005), Vol. 3342, pp. 1-9.

Lab
No exercises.

WEEK 2 – March 1 and 2

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

Reading
Primary

- Bonabeau E., Dorigo M., and Theraulaz G., “Swarm Intelligence: From Natural to Artificial Systems", Santa Fe Studies in the Sciences of Complexity, Oxford University Press, 1999, Ch. 2 (pp. 80-107).

Secondary

- Dorigo M. and Stuetzle T., “Ant Colony Optimization”, MIT Press, 2004, Ch. 1 (pp. 1-24) and Ch. 2 (pp. 25-46).

Lab 1

Trail laying and following mechanisms, emphasizing SI concepts; Ant Colony Optimization.

WEEK 3 – March 8 and 9

Lecture – on-site

Introduction to mobile robotics: basic concepts centered around the differential drive vehicle used in the course (e-puck) and the high-fidelity, open-source robotic simulator (Webots). Introduction to control architecture for mobile robots with special focus on reactive control architectures.

Reading

Primary

- Michel O., “Webots: Professional Mobile Robot Simulation”. *Int. J. of Advanced Robotic Systems*, **1**: 39-42, 2004.
- 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.
- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 4 (pp. 89-98).

Secondary

- Brooks R., “A Robust Layered Control System for a Mobile Robot”. *IEEE Trans. on Robotics and Automation*, **2**(1): 14-23, 1986.
- Arkin R. C., “Motor Schema Based Mobile Robot Navigation”. *Int. J. of Robotics Research*, 8(4): 92-112, 1989.

Lab 2

Introduction to Webots, an open-source, high-fidelity robotic simulator.

WEEK 4 – March 15 and 16

Lecture – on-line

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. 102-103).
- Maybeck P. S. “Stochastic Models, Estimation, and Control”, Academic press, 1979, Ch. 1 (pp.1-16).

Secondary

- Siegwart R. and Nourbakhsh I. R., “Introduction to Autonomous Mobile Robots”, MIT Press, 2004, Ch. 4 (pp. 145-154).

Lab 3
Localization methods (odometry and feature-based localization) for single robots.

WEEK 5 – March 22 and 23

Lecture – on-site
Localization methods in mobile robotics: from 1D to 2D. Collective movements in natural societies; focus on flocking phenomena. Collective movements in artificial systems: Reynolds' virtual agents (Boids), experiments with multi-robot systems on flocking and formation (behavior-based); graph-based distributed control for spatial consensus (rendez-vous, formation).

Reading
Primary
- Siegwart R. and Nourbakhsh I. R., "Introduction to Autonomous Mobile Robots", MIT Press, 2004, Ch. 5 (pp. 181-191, pp. 227-233).
- Reynolds C. W. "Flocks, Herds, and Schools: A Distributed Behavioral Model, in Computer Graphics", *Proc. of SIGGRAPH '87*, 21(4), pp. 25-34, 1987.
- Fredslund J. and Matarić M. J., "A General, Local Algorithm for Robot Formations", *IEEE Transactions on Robotics and Automation*, special issue on Advances in Multi-Robot Systems, Vol. 18, p.5, pp. 837-846, 2002.
- 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
- Siegwart R. and Nourbakhsh I. R., "Introduction to Autonomous Mobile Robots", MIT Press, 2004, Ch. 5 (pp. 212-214; 233-244).
- Gowal S., "A Framework for Graph-Based Distributed Rendezvous of Nonholonomic Multi-Robot Systems", EPFL Thesis no. 5845, Ch. 9 and 10 (pp. 69-78), 2013.
- Falconi R., Gowal S., and Martinoli A., "Graph-Based Distributed Control of Non-Holonomic Vehicles Endowed with Local Positioning Information Engaged in Escorting Missions". *Proc. of the 2010 IEEE Int. Conf. on Robotics and Automation*, May 2010, Anchorage, AK, U.S.A., pp. 3207-3214.

Lab 4
Collective movements.

WEEK 6 – March 29 and 30

Lecture – on-site
Division of labor and task-allocation mechanisms: threshold-based and market-based algorithms

Reading
Primary
- Stentz A., Dias M. B., "A free market architecture for coordinating multiple robots". Technical report CMU-RI-TR-99-42, Robotics Institute, Carnegie Mellon University, December 1999.
- 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, pp. 109-139 (Chapter 3).
- Kalra N. and Martinoli A., "A Comparative Study between Threshold-Based and Market-Based Task Allocation". *Proc. of the Eight Int. Symp. on Distributed Autonomous Robotic Systems*, July 2006, Minneapolis/St. Paul, MN, U.S.A. Distributed Autonomous Robotic Systems 7 (2006), pp. 91–102.
- Agassounon W. and Martinoli A., "Efficiency and Robustness of Threshold-Based Distributed Allocation Algorithms in Multi-Agent Systems". *Proc. of the First ACM Int.*

Joint Conf. on Autonomous Agents and Multi-Agent Systems, July 2002, Bologna, Italy, pp. 1090–1097.

Secondary

- Dias M. B., Zlot R., Kalra N., and Stentz A., "Market-Based Multirobot Coordination: A Survey and Analysis". *IEEE Proceedings,* 94(7): 1257-1270, 2006.

Lab 5

Multi-robot systems coordination using market-based and threshold-based algorithms.

Hwk

Consolidation of student teams.

WEEK 7 – April 5 and 6

Lecture – on-site

Distributed environmental sensing using static sensor networks.

Reading

Primary

- 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.
- Prorok A., Cianci C. M., and Martinoli A., "Towards Optimally Efficient Field Estimation with Threshold-Based Pruning in Real Robotic Sensor Networks". *Proc. of the 2010 IEEE Int. Conf. on Robotics and Automation*, May 2010, Anchorage, AK, U.S.A, pp. 5453-5459.
- Evans W. C., Bahr A., and Martinoli A., "Evaluating Efficient Data Collection Algorithms for Environmental Sensor Networks". *Proc. of the Tenth Int. Symp. on Distributed Autonomous Robotic Systems*, November 2010, Lausanne, Switzerland; Springer Tracts in Advanced Robotics (2013), Vol. 83, pp. 77-90.

Secondary

- Culler D., Estrin D., and Srivastava M., "Guest Editors' Introduction: Overview of Sensor Networks". *IEEE Computer*, Vol. 37, No. 8, pp.41-49, 2004.
- Evans W. C., Bahr A., and Martinoli A., "Distributed Spatiotemporal Suppression for Environmental Data Collection in Real-World Sensor Networks". *Proc. of the 2013 IEEE Int. Conf. on Distributed Computing in Sensor Systems*, May 2013, Boston, U.S.A., pp. 70-79.

Lab 6

Distributed environmental sensing with static and mobile sensor networks.

Hwk 1

Assignment distributed by Friday.

WEEK 8 – April 12 and 13

Lecture – on-site

Distributed environmental sensing using mobile sensor networks.

Reading

Primary

- Marjovi A., Arfire A., and Martinoli A., "Extending Urban Air Pollution Maps beyond the Coverage of a Mobile Sensor Network: Data Sources, Methods, and Performance Evaluation," *Proc. of the Int. Conf. on Embedded Wireless Systems and Networks*, February 2017, Uppsala, Sweden, pp. 12-23.

- Arfire A., Marjovi A., and Martinoli A., "Mitigating slow dynamics of low-cost chemical sensors for mobile air quality monitoring sensor networks," *Proc. of the Int. Conf. on Embedded Wireless Systems and Networks*, February 2016, Graz, Austria, pp. 159-167.
- Arfire A., Marjovi A., and Martinoli A., "Enhancing Measurement Quality through Active Sampling in Mobile Air Quality Monitoring Sensor Network," *Proc. of the IEEE Int. Conf. on Advanced Intelligent Mechatronics,* July 2016, Banff, Canada, pp. 1022-1027.

Secondary

- Marjovi A., Arfire A., and Martinoli A., "High Resolution Air Pollution Maps in Urban Environments using Mobile Sensor Networks". *Proc. of the 11th International Conference on Distributed Computing in Sensor Systems*, June 2015, Fortaleza, Brazil, pp. 11-20.

Lab

Assistance for Hwk 1.

WEEK 9 – April 26 and 27

Lecture – on-line

Introduction to multi-level modeling techniques (underlying theoretical framework, levels, assumptions, principles). Linear case studies and calibration of model parameters.

Reading

Primary

- Lerman K., Martinoli A., and Galstyan A., "A Review of Probabilistic Macroscopic Models for Swarm Robotic Systems". In Sahin E. and Spears W., editors*, Proc. of the SAB 2004 Workshop on Swarm Robotics*, July 2004, Santa Monica, CA, USA. Lecture Notes in Computer Science (2005), Vol. 3342, pp. 143-152.
- Martinoli A., Easton K., and Agassounon W., "Modeling of Swarm Robotic Systems: A Case Study in Collaborative Distributed Manipulation". Special Issue on Experimental Robotics, Siciliano B., editor, *Int. Journal of Robotics Research*, Vol. 23, No. 4, pp. 415-436, 2004.

Secondary

- Correll N. and Martinoli A., "Collective Inspection of Regular Structures using a Swarm of Miniature Robots". In Ang Jr., M.H. and Khatib, O., editors, *Proc. of the Ninth Int. Symp. Experimental Robotics,* June 2004*,* Singapore*.* Springer Tracts in Advanced Robotics (2006), Vol. 21, pp. 375–385.

Lab 7

Multi-level modeling of swarm robotic systems – Introduction

Hwk 1

Submission by Monday.

WEEK 10 – May 3 and 4

Lecture – on-site

Multi-level modeling: nonlinear case studies. Combined modeling and machine-learning methods for control optimization; diversity and specialization metrics.

Reading

Primary

- Agassounon W., Martinoli A., and Easton K., "Macroscopic Modeling of Aggregation Experiments using Embodied Agents in Teams of Constant and Time-Varying Sizes". *Autonomous Robots*, special issue on Swarm Robotics, Dorigo M. and Sahin E., editors, 17(2-3): 163-192, 2004.
- Li L., Martinoli A., and Abu-Mostafa Y., "Learning and Measuring Specialization in Collaborative Swarm Systems". Special issue on Mathematics and Algorithms of Social Insects*,* Balch T. and Anderson C., editors, *Adaptive Behavior,* Vol.12, No. 3-4, pp. 199-212, 2004.

Secondary
- Martinoli A., Ijspeert A. J., and Gambardella L. M., “A Probabilistic Model for Understanding and Comparing Collective Aggregation Mechanisms”. In Floreano D., Mondada F., and Nicoud J.-D., editors, *Proc. of the Fifth Europ. Conf. on Artificial Life*, September 1999, Lausanne, Switzerland. Lectures Notes in Artificial Intelligence (1999), Vol. 1674, pp. 575–584.

Lab 8
Multi-level modeling of swarm robotic systems – Advanced

WEEK 11 – May 10 and 11

Lecture – on-site
Introduction to evaluative multi-agent machine-learning techniques for automatic design and optimization: terminology and classification. Particle Swarm Optimization (PSO): algorithm and performance evaluation. Application of machine-learning techniques to automatic control design and optimization of single-robot systems.

Reading
Primary
- Eberhart R. C. and Kennedy J., “A New Optimizer using Particle Swarm Theory”. *Proc. of the Sixth IEEE Int. Symp. Micro Machine and Human Science*, Nagoya, Japan, 1995, pp. 39–43.
- Shi, Y. H., Eberhart, R. C. “A Modified Particle Swarm Optimizer” *Proc. of the IEEE International Conference on Evolutionary Computation,* Anchorage, Alaska, May 1998, pp. 69-73.
- Pugh J., Zhang Y., and Martinoli A., “Particle Swarm Optimization for Unsupervised Robotic Learning”. *Proc. of the Second IEEE Symp. on Swarm Intelligence,* Pasadena, CA, USA, June 2005, pp. 92-99.
- Engelbrecht A. P., “Particle Swarm Optimization: Where Does it Belong?” *Proc. of the Third IEEE Symp. on Swarm Intelligence,* Indianapolis, IN, USA, May 2006, pp. 48-54.

Secondary
- Poli R., Kennedy J., and Blackwell T., “Particle Swarm Optimization: An Overview”. *Swarm Intelligence Journal,* **1**(1): 33-57, 2007.
- Floreano D. and Mondada F., "Evolution of Homing Navigation in a Real Mobile Robot", *IEEE Trans. on System, Man, and Cybernetics: Part B*, **26**(3): 396-407, 1996.
- Lipson, H., Pollack J. B., "Automatic Design and Manufacture of Artificial Lifeforms", *Nature*, **406**: 974-978, 2000.
- Bongard J., Zykov V., Lipson H. (2006), “Resilient Machines Through Continuous Self-Modeling", *Science* Vol. 314. no. 5802, pp. 1118 – 1121.

Lab 9
Particle Swarm Optimization: application to benchmark functions and control shaping for single robot.

WEEK 12 - May 17 and 18

Lecture – on-site
Noisy and expensive optimization problems. Application of evaluative 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).

Reading
Primary

- Pugh J. and Martinoli A., “Distributed Scalable Multi-Robot Learning using Particle Swarm Optimization”. *Swarm Intelligence Journal*, **3**(3): 203-222, 2009.
- Di Mario E. and Martinoli A., “Distributed Particle Swarm Optimization for Limited Time Adaptation with Real Robots”. Chirikjian G. and Hsieh A., editors, Special issue on Distributed Robotics, *Robotica*, 32(2): 193-208**,** 2014.
- Di Mario E., Navarro I., and Martinoli A., “Analysis of Fitness Noise in Particle Swarm Optimization: From Robotic Learning to Benchmark Functions”. *Proc. of the 2014 IEEE Congress on Evolutionary Computation*, July 2014, Beijing, China, pp. 2785-2792.
- Di Mario E., Navarro I., and Martinoli A., “A Distributed Noise-Resistant Particle Swarm Optimization Algorithm for High-Dimensional Multi-Robot Learning”, *Proc. of the 2015 IEEE International Conference on Robotics and Automation*, May 2015, pp. 5970–5976.

Secondary

- C. Chen, J. Lin, E. Yücesan, and S. E. Chick, “Simulation Budget Allocation for Further Enhancing the Efficiency of Ordinal Optimization,” *Discrete Event Dynamic Systems: Theory and Applications*, pp. 251–270, 2000.
- Di Mario E., Navarro I., and Martinoli A., “Distributed Particle Swarm Optimization using Optimal Computing Budget Allocation for Multi-Robot Learning,” in *IEEE Congress on Evolutionary Computation*, 2015, pp. 566–572.

Lab 10

Particle Swarm Optimization application to noisy problems: benchmark functions and multi-robot problems.

Hwk 2

Assignment distributed by Friday.

WEEK 13 – May 24 and 25

Lecture – on-site

Distributed environmental sensing using robotic sensor networks.

Reading

Primary

- Lochmatter T. and Martinoli A., “Tracking an Odor Plume in a Laminar Wind Field with Bio-Inspired Algorithms”. *Proc. of the Eleventh Int. Symp. Experimental Robotics,* July 2008*,* Athens, Greece, Springer Tracts in Advanced Robotics (2008), Vol. 54, pp. 473-482, 2008.
- Soares J. M., Aguiar A. P., Pascoal A. M., and Martinoli A., “A Distributed Formation-based Odor Source Localization Algorithm - Design, Implementation, and Wind Tunnel Evaluation,” *Proc. of the IEEE Int. Conf. on Robotics and Automation*, 2015, pp. 1830–1836.

Secondary

- Lochmatter T., Aydın Göl E., Navarro I., and Martinoli A., “A Plume Tracking Algorithm based on Crosswind Formations”. *Proc. of the Tenth Int. Symp. on Distributed Autonomous Robotic Systems*, November 2010, Lausanne, Switzerland; Springer Tracts in Advanced Robotics (2013), Vol. 83, pp. 91-102.

Lab

Assistance for Hwk 2.

WEEK 14 – June 1 and 3

Lecture – on-site

Distributed environmental sensing using robotic sensor networks. General take home messages of the course. Discussion about student feedback for the course.

Reading

Primary

- Rahbar F., Marjovi A., Kibleur P., and Martinoli A., "A 3-D Bio-inspired Odor Source Localization and its Validation in Realistic Environmental Conditions," *Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, September 2017, Vancouver, Canada, pp. 3983-3989.
- 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.
- Soares J. M., Marjovi A., Giezendanner J., Kodiyan A., Aguiar A. P., Pascoal A. M., and Martinoli A., "Towards 3-D Distributed Odor Source Localization: An Extended Graph-Based Formation Control Algorithm for Plume Tracking," *Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems,* October 2016, Daejeon, Korea, pp. 1729-1736.

Lab
Assistance for Hwk 2.

Hwk 2
Hwk 2 submitted by Tuesday June 7.