Distributed Intelligent Systems
Course Projects

1 General information

Distributed Intelligent Systems will involve a 45h course project (this should include reading, implementation, reporting, oral defense of the project, and reviewing the report of another student team). Students will choose a project from a list of approved topics to be distributed during the sixth week. Projects will be carried out in groups of three (default) and two (if needed) students belonging as much as possible to different teaching sections or program (a minimal amount of two different sections/programs per team will be enforced). Each of the team members will have to defend part of the project in front of the audience and will also be asked to serve as a reviewer for another student project (i.e., ask questions during the defense session). Every project will be supervised by a Teaching Assistant or a Support Staff member. Definitive assignment of course projects will be communicated during the seventh week, based on the preferences expressed by the students. Students will be expected to contact their project supervisor by the end of the same week to begin planning their work schedule.

During the eight week, a common kick-off session for the implementation of the course project will be organized during the Wednesday morning exercise hours, after the lab verification test. On the following Monday, students will be required to submit a project work plan describing their understanding of the project topic and its related literature, as well as a concrete implementation plan (1 page total). This will allow their project supervisor to give them feedback in terms of implementation feasibility, problem understanding, and time planning. The project defense will be organized in the last week of the semester.

2 Topic list

The acronyms used for the different sections below are defined as follows:

- CSE – Computational Science and Engineering
- EL – Electrical Engineering
- GM – Mechanical Engineering
- IN – Computer Science
- MT – Microengineering
- SIE – Environmental Science and Engineering
- SV – Life Sciences and Technologies
- SC – Communication Systems
- ED – Doctoral School
Graph-based formation with real e-pucks

This project is based on two papers:

The goal of this project is to make three e-pucks escort a leader in defined formation. To perform the escorting formation control with four e-pucks graph theory will be used [1]. The target formation is a square with one leader being on one of the corners. To achieve this, the students will first implement the algorithm in Webots. The sensing modality will be relative range and bearing measurements based on infrared emitters and receivers [2]. The e-pucks can share their IDs but the leader cannot share its motion. For the real robots the range and bearing measurement will be provided with the proximity sensors and the use of the libIrcom library. Filtering may be required to enhance the range and bearing performance. As final step the students will compare the simulations with real experiments using suitable metrics (e.g., time of convergence) and explain the differences. The robots in the Webots simulation and the real e-pucks will need to use the same parameters for the formation control to allow for comparison.

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Distributed sensing using market-based task allocation

This project is based on two papers:

Consider a team of N cooperative e-pucks performing a distributed sensing mission. The e-puck robots must gather data from specific sites of interest while consuming the least amount of energy. One important aspect of completing the mission is to determine which robot should visit each site. This project will solve this problem using a market-based approach in which robots compete in auctions for each task of visiting a site (similar to [1,2]). After estimating their resource usage for an offered task and submitting bids based on those expected costs, the robot with the best bid is awarded a contract for that site. For each e-puck the cost of picking up a particular site will depend on the time taken to reach the site.

The scenario will be designed in Webots using simulated e-pucks; they will be able to localize using a combination of odometry and an emulated GPS system characterized by realistic errors. The sampling sites are given by a random generating function in a supervisor.

The project will have a focus on modeling and will study the impact of model simplification on performance estimation. Apart from the high-level task allocation, at the sub-microscopic modeling level, some basic navigation/obstacle avoidance behaviors will be implemented. Possible simplifying choices for the higher level modeling would be: dropping the non-
holonomicity of the robots, not considering their volume anymore (no more obstacle avoidance), simplifying the assumption on the energy consumption (from a possibly quite sophisticated one for the sub-microscopic level to considering only distance traveled...), etc.

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Swarm compactness maintenance using only local communication

This project is based on two papers:

In this project, you will explore several levels of a multi-level modeling methodology applied to a distributed robotic system. You will consider a case study concerned with the spatial coordination of a swarm of simple robots that has to maintain wireless connectivity and a certain degree of spatial compactness using only local communication.

In a first stage, you will implement a basic algorithm [1] to achieve this task at a submicroscopic level implemented as a realistic simulation (Webots). In a second stage, you will then develop a macroscopic model of the task using the robots’ controller as a starting point, following the methodology of [2], and quantitatively compare results between levels. Additionally you will have to implement a more complex algorithm also described in [1] and compare the performance of both algorithms, or you will have to implement also a microscopic level of the multi-level modeling methodology and compare its results with those of the submicroscopic and macroscopic levels.

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Optimized navigation behavior of multiple robots based on motor-schema

This project is based on two papers:
This project targets the navigation of multiple robots using a motor-schema architecture. Robots should navigate ultimately in an environment populated with obstacles. The goal is for the group of robots to move towards a target position while keeping a formation. The focus of this project would be on optimizing the behavior of the robots. The goal is to create a controller that is able to perform the formation and navigation as effectively as possible. For this purpose an appropriate fitness function should be designed along using an optimization method. There are a number of parameters which shape the navigation behavior that need to be considered by the optimization methods. We are interested to see the resulting behavior of the optimized controllers using Particle Swarm Optimization.

Evaluation of the projects would be based on the final performance of the navigation with and without optimization, effectiveness of the designed fitness function, and the discussion that the students make on the comparison of the two steps.

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**Event handling with real e-pucks using threshold-based task allocation**

This project is based on the two papers:


This project deals with threshold-based task allocation. The robots will handle events that appear throughout the environment, as long as their stimulus is above a certain threshold they keep moving in search for events, otherwise they stop. Events (black and white striped cylinders) are identified with the onboard camera. When a robot encounters an obstacle it stops to take a picture and evaluate if it is another robot (avoids obstacle), or an event (handles event). We propose two different ways the robots perceive the stimulus; either the robots do a random walk and updates the stimulus as a function of time between the last two detected events; or the robot continuously takes pictures and updates the stimulus as a function of the distance to the nearest detected event (the stripe width is proportional to the robot-event-distance). Furthermore, by adding peer-to-peer radio communication, the robots could share their stimulus estimation with others nearby. Moreover, the robots’ thresholds can be a fixed value or be a variable one (ruled-based). The quality of the algorithm is measured as the total number of events handled over a fixed time window, and the cost is measured as the total distance travelled by the team (and possibly communication/computation complexity). The scenario should first be implemented in Webots in order to investigate and evaluate the different variations of the threshold-based algorithms (not necessarily limited to the ones presented above). Finally, one algorithm is selected and implemented on real e-pucks. The performance of the simulated versus the real world scenario should also be evaluated.

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