Distributed Intelligent Systems
Course Project

General Information

Distributed Intelligent Systems involves a 50-hour (per student) course project (this includes reading, implementation, reporting, and oral presentation of the project). This edition includes four project topics, which will be elaborated on later. Projects will be carried out in groups of three students belonging as much as possible to different teaching sections or programs. The teams and the topic choice will be organized based on the preferences expressed by the students during Week 6.

In the lab session of Week 7 (October 30), there will be a kickoff session of 1-hour, during which the details of the project topic and organization will be presented while the material will be made previously available on Moodle. This session serves as the official start of the project period until the end of the semester, when the project presentations, the report, and further implementation material will have to be submitted. Additional details about the project presentations will be communicated in a timely fashion. The students will be asked to submit their preferences on groups and project topics via Moodle. During the course project period, the last hour of each lab session will be dedicated also to project assistance. In the lab session of Week 13 (December 11), we will provide assistance to the course project for three hours. No further office hours will be made available.

Each group must submit a report. The report is at most four pages long including bibliography and annex. The report should be based on the provided latex template. The final project presentations will be carried out as a team and will take place during the last week of the semester. The presentations should last at most 6 minutes with equal speaking time among team members. The follow-up Q&A session, which is 6 minutes, will cover the whole project. We expect equal contributions from students in this session. Presentation slides and material will be due ahead of time, namely by **Sunday, December 14, 23:59.**

Deliverables

Your deliverables include three components:

1. Submit a .pdf file named `DIS_project_report_group_X.ppt` where X is the group number, including:
    a. Clear division of labor and contributions of individuals
    b. Problem statement, formulation, and motivation
    c. Quantitative and qualitative results outlined for each project
    d. Citation of the most relevant methods related to your approach
2. Submit a .ppt file named `DIS_project_presentation_group_X.ppt`, where X is the group number, including:
    a. Problem statement, formulation, and motivation
    b. Quantitative and qualitative results outlined for each project
    c. An informative video showcasing your solution in action within the simulation environment
3. Submit a .zip file named `DIS_project_material_group_X.zip`, where X is the group number, including:
    a. Webots environments and controllers
    b. Any additional code or resources used

Grading

As previously mentioned in the syllabus, the course project performance will weigh 50% of the total grade of the course, 30% based on the team's overall performance, and 20% based on the part of the individual performance focusing on the presentation and discussion of your contribution to the course project. Therefore, the project grade (scaled to 100%) will be evaluated using the following criteria:

Quality of the proposed solution	40 %	Team
Quality of the report	20 %	Team
Quality of the presentation	20 %	Ind.
Quality of the answers delivered during the oral discussion	20%	Ind.

Topic 4: *Market-based task allocation with heterogeneous team of robots*

Introduction

In a post-disaster scenario, several victims are located in certain areas: some victims are badly injured and need medical treatment (task A), and others are in shock and only need psychological support (task B). A fleet of robots should reach the victims as quickly as possible and provide the necessary assistance in a limited amount of time. Although autonomous robots can provide both medical and psychological treatment (task A or B), they are specialized in one or the other task, which means they can perform specific tasks faster. As in any search and rescue scenario, the robots have a limited battery life. Therefore, the multi-robot system is assumed to be heterogeneous and energy-constrained. In this project you will tackle a market-based task allocation problem in a multi-robot system. First, you will be asked to implement a centralized strategy. Then, you will implement a distributed strategy. Finally, you will extend the task allocation to a multi-step horizon optimization.

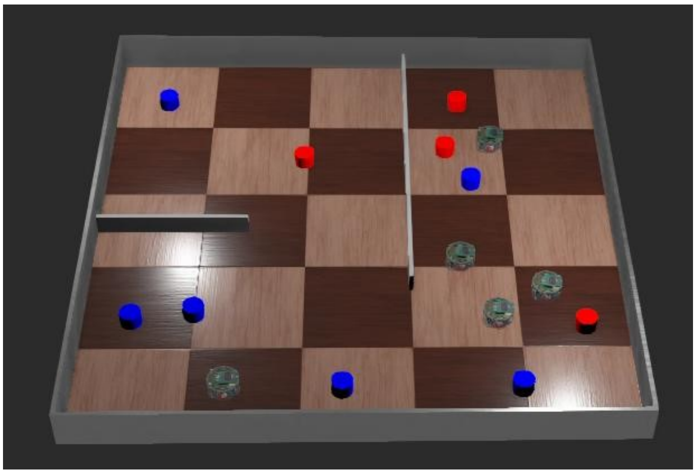

Figure 4. The provided Webots world with 5 robots and 10 tasks of type A and B.

Description

The main task of the project is to reach the victims as quickly as possible, i.e., to provide help to as many victims as possible. For this use the provided world `topic4.wbt,` where the environment is separated in three regions with walls whose coordinates are known a priori. The environment contains custom e-puck robots with a receiver and an emitter having a limited communication range of 0.3m. At the beginning of the simulation, all robots are placed randomly and equally distributed in the environment.

There are 5 agents who have the following specializations:

- 2 robots specialized in task A,
- 3 robots specialized in task B.

During the task completion, the robot is not allowed to move for a given amount of time:

- Robot specialized in task A, completing task A: 3s
- Robot specialized in task B, completing task B: 1s
- Robot specialized in task A, completing task B: 5s
- Robot specialized in task B, completing task A: 9s

The tasks should be distributed randomly and uniformly in the environment, such that at each moment there are 10 tasks present. After a robot completes a task it should disappear from the environment, and a new one should be created. The probability of a new task being of kind A is 1/3, and of kind B is 2/3. These probabilities are unknown to the robots a priori. For visualization, color task A in red and the task B in blue. The rescue mission lasts for 3 minutes.

The robots may use GNSS for absolute localization and are assumed to know the position of all tasks at any given moment. The task is considered as reached if a robot is closer than 0.1 m to the task center location. Note that each robot may move at a maximum speed of 0.5 m/s and has a limited energy budget:

it can move or complete a task only for 2 minutes. After a robot runs out of time, it has to shut down and remain static in the world. The robots must avoid collisions at any time. A collision is defined as a robot being closer than 0.05 m to a wall or another robot.

Tasks

The project consists of three main tasks:

1. *Implementation of a centralized algorithm*
   Use a centralized market-based strategy to maximize the total number of completed tasks. The centralized unit can be implemented as part of a supervisor controller. You may use Lab 5 as a template.
   a. Implement a single-step planning, where each agent should be assigned a single task at a time.
   b. Implement a multiple-step planning, where each agent plans up to 3 tasks in the future.
2. *Implementation of a distributed algorithm*
   Use a market-based strategy in a distributed fashion, i.e., without a centralized unit to organize the task allocation. The robots are allowed to broadcast information to their neighbor robots using the emitter and receiver, which have a limited range of 0.3m. Note that the centralized and distributed algorithms should be comparable.
   a. Implement a single-step planning, where each agent should be assigned a single task at a time.
   b. Implement a multiple-step planning, where each agent plans up to 3 tasks in the future.
3. *Multi-level modelling*
   Model the number of robots being active (time moving or completing a task) for a centralized market-based strategy with a macroscopic and a microscopic model. You may assume that there is only one type of task and two types of robots that require different times to complete the task.

Metrics & Results

Report always the average metric over 5 runs.

- Tasks 1 and 2:
  - Total number of completed tasks.
  - Average time of the robots doing collision avoidance as a percentage (average time closer than 0.05 m to an obstacle or another robot over average active time).
- Tasks 1, 2 and 3:
  - Average number of active robots (robots either moving to a task or completing it).

You are expected to present the following results:

- Give an overview of how you solve the task allocation problem for the four methods (centralized/distributed & one-step/multi-step). Cite the most relevant publications related to your approach.
- Compare the four methods quantitatively (metrics) and qualitatively (videos, illustrations, …).
- Present the multi-level modeling and what assumptions you are making. Compare the macroscopic and microscopic models to the sub-microscopic model.

Provided Material

- worlds/
  - topic4.wbt
- protos/
  - epuck_range.proto
- controllers/
  - supervisor/
    - supervisor.c
  - e-puck/
    - e-puck.c