ASSIGNMENT

MULTIAGENT PATH PLANNING

Deadline: 20th of November

GOAL

The goal of the assignment is to explore and compare three multiagent path planning approaches. You will explore two methods in which planning and coordination is done by a coordinating or orchestrating agent: **prioritized planning with A*** and **conflict-based search**. In the third method, planning and coordination will be done by the moving agents themselves using information about their environment and other agents.

At the end of the assignment, students should have correctly implemented and evaluated four multiagent planning and coordination models to improve efficiency and increase capacity of their model, while maintaining safety.

DELIVERABLES

Each student is required to provide an archive containing both the code and the report, which are expected to be the same for the students forming a group (individual submission is needed for grading in Brightspace). The report should contain all the points highlighted in the "In The Report" sections of the different exercises provided below. The modeling and simulation results need to be presented following the modelling and analysis methodology as described in Lectures 2 and 3 of the course. Your model specification could be in the form of a mix of algorithms and semi-formal properties. Note that only the parts of the multiagent system model that you created yourself should be specified in a formal or semi-formal language. You don't need to specify formally or semi-formally the initial model that you are provided for this assignment.

INITIAL EXPLORATION

To familiarize yourself in a stepwise manner with the concepts and algorithmic components of multiagent path finding, perform all the tasks not marked 'optional' from the tutorial developed by researchers from University of Southern California (available in the 'Assignment' folder on Brightspace).

MODELLING AND IMPLEMENTATION OF MULTIAGENT PATH PLANNING

In this assignment, the prioritized planning and conflict-based search algorithms implemented and explored in the tutorial will be scaled up. In addition, a distributed planning method will be elaborated, in which all planning and coordination is done by the moving agents.

In the assignment, you need to implement three layouts shown in Fig. 1, on which you will be testing the path planning algorithms. The layouts have the increasing amount of obstacles.

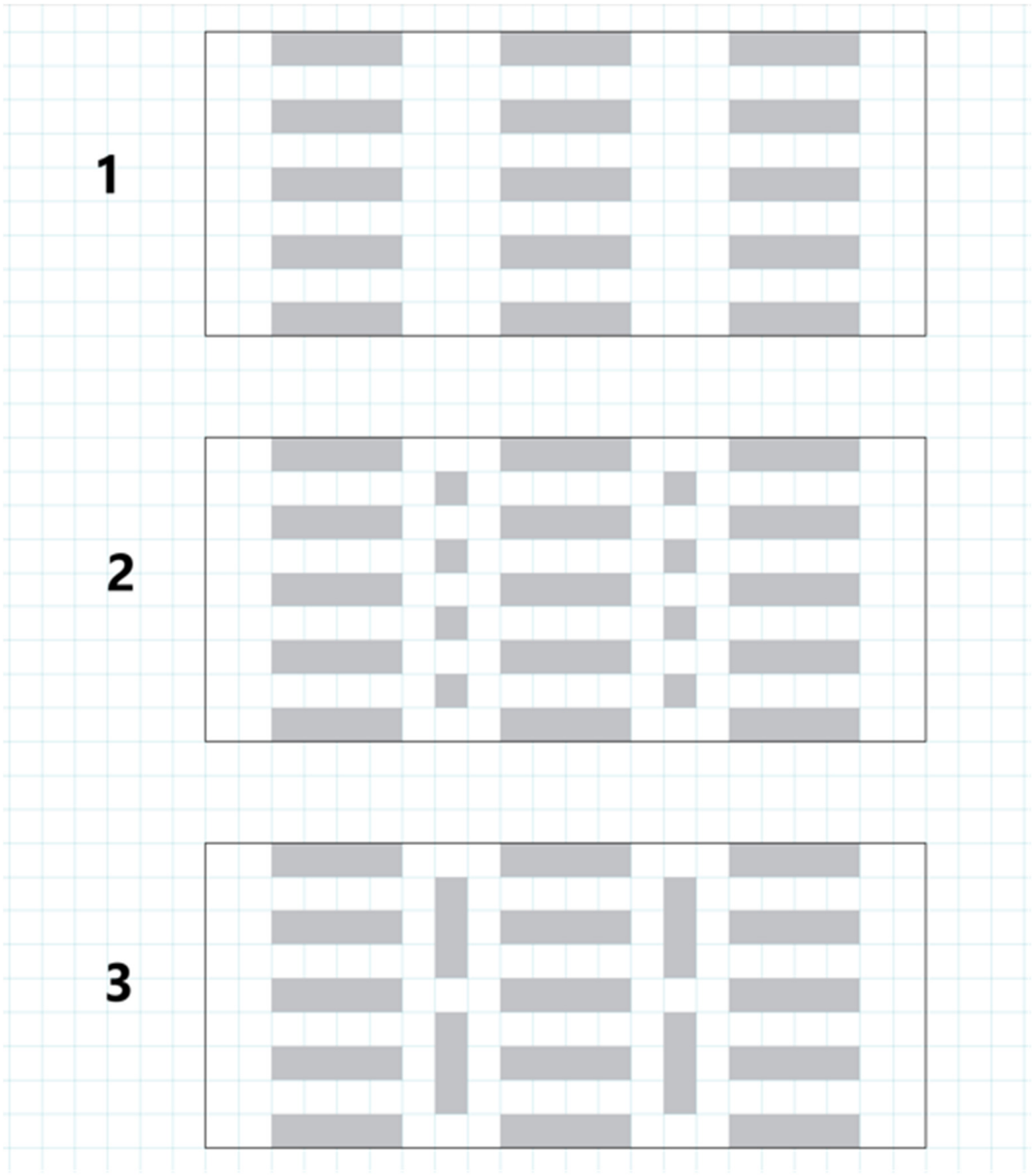

Fig. 1: The layouts of the environment considered in the assignment. The agents can move on white cells, the grey cells represent obstacles.

EXERCISE 1 – IDENTIFYING PERFORMANCE INDICATORS

Identify performance indicators that will be used to assess the performance of your models, and to compare the models with each other.

IN THE REPORT:

- Identify relevant system-wide and agent-specific performance indicators reflecting both efficiency/capacity and safety dimensions, and possibly other dimensions.

EXERCISE 2 – IMPLEMENT AND EVALUATE PRIORITIZED PLANNING WITH A* AND CONFLICT-BASED SEARCH

Implement prioritized planning with A* and conflict-based search for the layouts in Fig 1.

Verify your implementation.

For the evaluation of the models you could use the following experimental setups:

a) place agents on the left side of the environment (in the left two columns) and define their goals on the opposite right side of the environment (in the right two columns), i.e. the agent at the top of the environment will have its goal at the bottom; in this and the following exercises the agents stay at their goal locations after reaching them.
b) place agents on the left side of the environment (in the left two columns) and define their goals on the opposite right side of the environment (in the right two columns), i.e. the agent at the top of the environment will have its goal at the bottom; in this and the following exercises the agents stay at their goal locations after reaching them.

Experiment with different numbers of agents as well as their initial and goal locations. For better analysis of the model, you could implement a randomized spawning mechanism for the agents' initial locations and goals. Ensure that the available capacity does not become overloaded ('frozen') by the demand (generated traffic).

IN THE REPORT:

- If any modifications were made to the standard CBS and prioritized planning algorithms, describe them in the report.
- Describe how you varied the number of agents and their initial and goal locations. How these variations impacted the performance of the models?
- Report the evaluation results of the models, including the statistical significance analysis.

In the third multiagent planning and coordination method, planning and conflict resolution is done by moving agents themselves, without support of the orchestrating agent. Modelling and implementation of this method will be done in a stepwise manner, by executing the exercises below. Please read all three exercises 3, 4 and 5, as your choices in one exercise may have an effect on your choices in other exercises.

Moreover, you may also introduce infrastructure agents to help coordinating the aircraft agents (e.g., to resolve conflicts between them). It's possible, but not strictly required.

EXERCISE 3 - INDIVIDUAL PLANNING OF MOVING AGENTS

The moving agents use the shortest path algorithm for path planning, based on their environment representation. In this representation, the agents may assign different weights to the cells of the environment depending on the current (or future) status of these cells (e.g., whether or not they are occupied by other agents; whether these agents wait or move).

It is assumed that the environment provides up-to-date information about the status of its cells to all agents. The agent's scope of observation may be *local*, meaning that only a limited number of cells around the agent is observed. However, the scope of observation may also cover larger areas reflecting a bigger picture of the environment.

IN THE REPORT:

- Describe individual planning of moving agents; you may decide yourself how large and which shape the observation areas around the moving agents will have, however, a motivation for your choice needs to be provided.

Suggestions for implementation:

- Implement a global radar and get locations of each agent on the map
- Think about what part of the radar is visible for individual agents
- Provide agents with new information with a certain frequency
- What factors do you consider to determine the planning for a single agent?

EXERCISE 4 – COORDINATION BETWEEN AGENTS

In addition to individual planning, moving agents need also to coordinate with each other to resolve conflicts, in particular to keep separation between each other. One of the following forms of coordination could be implemented:

- Implicit coordination by rules
- Coordination by (simple) negotiation

IN THE REPORT:

- Describe and implement the coordination mechanism. Discuss which factors need to be considered either in coordination rules or in negotiation and why.

Suggestions for implementation:

- If necessary, create a structure in the layouts by manually adding constraints reflecting the coordination rules

EXERCISE 5 – EVALUATION OF THE DISTRIBUTED PLANNING METHOD

Evaluate the developed distributed planning method in the same way as you did in exercise 2.

IN THE REPORT:

Report the evaluation results of the model, including the statistical significance analysis.

EXERCISE 6 – COMPARISON OF THE PLANNING METHODS

IN THE REPORT:

Compare four developed planning models using relevant performance metrics.

Draw conclusions about the strengths and weaknesses of different methods, in particular with respect to different types of environment (with different amount of obstacles) and the number of agents.