UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE	:	**COMP0182**
ASSESSMENT PATTERN:		**COMP0182F7PF 001**
MODULE NAME	:	**COMP0182 - Real-world Multi-agent Systems**
LEVEL	:	**Postgraduate**
DATE:	:	**14/05/2024**
TIME	:	**14:30**
DURATION	:	**2 Hours**

This paper is suitable for candidates who attended classes for this module in the following academic year(s):

Year
2023/24

EXAMINATION PAPER CANNOT BE REMOVED FROM THE EXAM HALL. PLACE EXAM PAPER AND ALL COMPLETED SCRIPTS INSIDE THE EXAMINATION ENVELOPE

Hall instructions	N/A
Additional materials	Sheets of blank paper, ruler
Standard Calculators	No
Non-Standard Calculators	No

TURN OVER

UCL Computer Science Examination Paper

Paper Details

Academic Year:	2023/24
Module Title:	Real-world Multi-agent Systems
Module Code:	COMP0182
Exam Period:	Central Assessment Period: Main Summer
Duration:	2 hours
Deliveries for which suitable:	A7P (Postgraduate Taught, Level 7)
Cohorts for which suitable:	2023-24

Instructions

Answer ALL questions from SECTION A and SECTION B.

A maximum of 50 marks is available: 25 marks from SECTION A and 25 marks from SECTION B. The marks available for each part of each question are indicated in square brackets [n].

Section A

Answer TWO big questions from this section: questions 1-a to 1-e (5 sub-questions) and 2-a to 2-e (5 sub-questions).

1) This section involves questions regarding multi-agent systems and decision making of agents.

(a) Explain the basic concept of multi-agent systems.

[1 mark]

(b) Propose two applications where multi-agent systems can be integrated and applied within the framework of the Internet of Things.

[2 marks]

(c) Explain the concept of an Intelligent Agent, including its definition and capabilities, and outline at least three characteristics of an agent.

[3 marks]

(d) Explain the differences between agent-oriented programming and object-oriented programming.

[2 marks]

(e) Regarding the decision-making of intelligent agents, propose one technical solution capable of performing deductive reasoning or any form of reasoning, using either traditional or modern approaches.

[2 marks]

[Total for Section A, Question 1: 10 marks]

2) This section involves questions regarding data acquisition, signal processing, and control of robot agents.

(a) Explain why basic signal processing is important for acquiring sensory measurements in physical agent systems, such as filtering and denoising.

[1 mark]

(b) In digital signal processing, what are the key elements or process to consider, while digitizing signals during signal acquisition?

[2 marks]

(c) For a revolutionary encoder capable of measuring resolution finer than 0.1 degree, with a measurement range from 0 to 2π (0 to 360 degrees) for a full revolution, what is the minimum number of bits required to achieve this resolution and accuracy? Write down the formula and steps that can be used to derive the number of bits (you do not need to perform the exact calculation for obtaining the exact number; rather, you need to give equations or formula for doing the calculation).

[4 marks]

(d) For controlling physical robots, such as TurtleBots, whose movements have frequency components less than 5 Hz, propose a solution to design a motion filter to obtain smooth position measurement of the robot. Your solution should include the types of the filter and parameters related to your proposed filter.

[3 marks]

(e) Write pseudocode of a digital PID (Proportional – Integral – Derivative) controller. Note that you need to specify the proportional, derivative, and integral terms, and you can define and use your own notions.

[5 marks]

[Total for Section A, Question 2: 15 marks]

[Total for Section A: 25 marks]

Section B

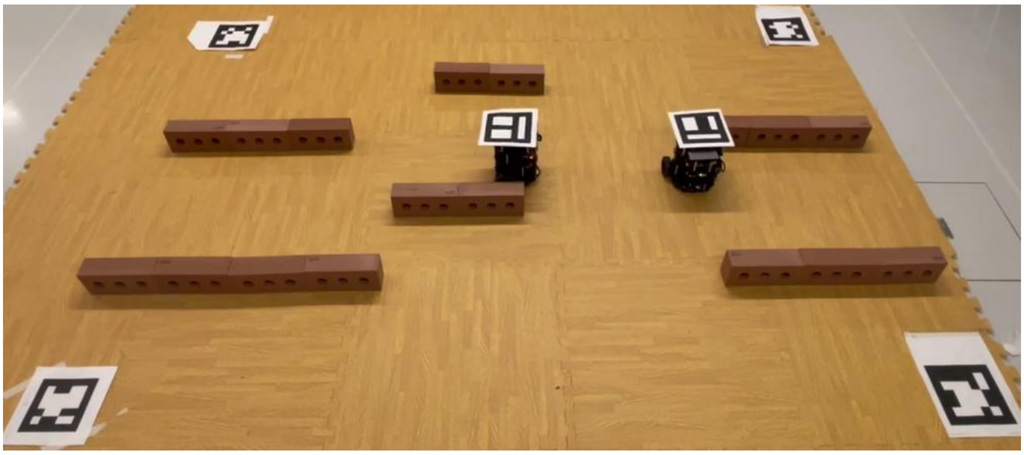

Figure 1 Two TurtleBots in the robot arena, navigating through the maze.

Answer TWO big questions from this section: questions 1-a to 1-d (4 sub-questions) and 2-a to 2-c (3 sub-questions).

As shown in Figure 1, a real robot arena is set up with brick walls and marked by QR code markers at its four corners, and each TurtleBot has its own marker on the top. Right above the robot arena, there is a camera that takes continuous video feeds for the visual perception system. The robot itself also has local onboard sensors, such as Lidar, to measure its distance and proximity to its surroundings.

1) Given the external visual perception of the environment and the robot's onboard sensing system, considering the actual robot arena:

   (a) Propose a type of visual perception algorithm that can recognize the robot and its environment, such as bricks and obstacles.

   [1 mark]

   (b) Given pre-planned trajectories allowing two robots to navigate without collision, as shown in Figure 1, propose a solution to enable two robots to follow these paths without colliding with the environment or each other.

   [2 marks]

   (c) Given the measurements of the robot position over time (see TurtleBots in Figure 1), i.e., *p*(i), p(*i*-1), *p*(*i*-2), where *p* represents "position" and *i* represents discrete time, write down the pseudocode for calculating the velocity of the robot's movement.

[2 marks]

(d) Regarding Rapidly-exploring Random Trees (RRT) as a sampling-based planning method, explain the basic concept of RRT and whether or not RRT method is suitable for real robot navigation and motion planning, as shown by the setup in Figure 1.

[3 marks]

[Total for Section B, Question 1: 8 marks]

2) Consider a simpler case of a 4x4 grid world with rows labelled A, B, C, D and columns labelled 1, 2, 3, 4. Figure 1 illustrates the grid world with initial locations, goal locations, and obstacles.

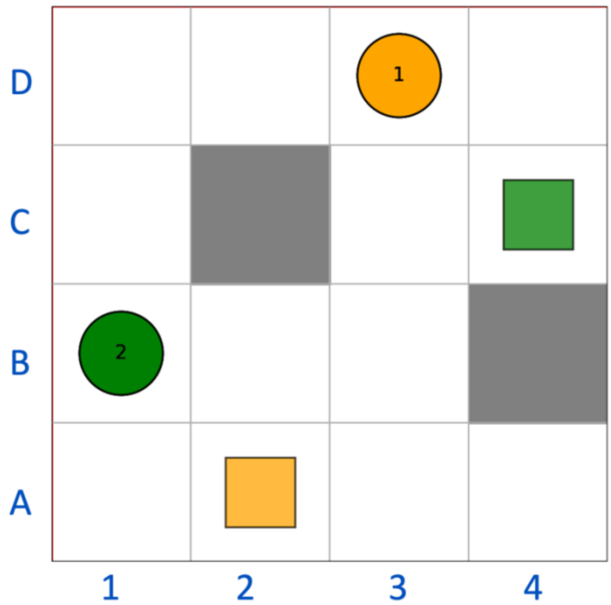

Figure 2: Grid World with initial locations, goal locations, and obstacles.

The grid world contains two obstacles, and the initial locations of two agents, Agent 1 and Agent 2, are specified. Agent 1 start at location D3, and Agent 2 starts at location B1. The goal is for Agent1 to reach A2 and for Agent 2 to reach C4. The obstacles are at C2 and B4.

Your task is to find shortest paths for both agents while avoiding collisions. Assume that each agent can move up, down, left, right or stop, but cannot pass through obstacles or occupy the same cell simultaneously.

Use the Conflict-Based Search algorithm to find paths for both Agent 1 and Agent 2. Consider Flowtime (the sum of travel times) as cost of this optimisation problem. If you find alternative solutions with equal cost to each other, assign Agent 1 as the highest priority.

(a) Use the low-level search to find all the optimal routes for each agent. Explain which low level search algorithm you used.

[5 marks]

(b) Construct the Conflict Tree (CT). Please label each node in the CT and describe how you resolve conflicts.

[8 marks]

(c) Clearly indicate the steps taken by each agent to reach their respective goals.

[4 marks]

[Total for Section B, Question 2: 17 marks]

[Total for Section B: 25 marks]

END OF PAPER