SC4003 Exam 2018-2019 Semester 2

1. (a) The question 'Isn't a multi-agent system just a distributed/concurrent system?' is an objection to the multi-agent system filed. Provide TWO arguments against this objection.

(6 marks)

Answer

- Argument 1: Autonomous
  - In a multi-agent system (MAS), each agent operates autonomously, making independent decisions based on its own goals and knowledge.
  - In contrast, distributed/concurrent system components typically follow a centralized or pre-defined control logic and do not make decisions independently.
- Argument 2: Proactive Behaviour
  - Agents in a MAS exhibit goal-directed behaviour and can take initiative (proactiveness).
  - In contrast, distributed/concurrent system usually lack this level of intentionality and goal-driven behaviour.

1. (b) One of the properties that an intelligent agent needs to have is "social". What does this property mean? Which of the five trends in the history of computing has made this property possible?

(6 marks)

Answer

- Social
  - An intelligent agent must be social to interact and collaborate with other agents or humans.
  - This enables coordination, negotiation, and information sharing, leading to better problem-solving.
- The trend that has made the "social" property possible is interconnection. *Computer systems today no longer stand alone, but are networked into large distributed systems*

1. (c) Agents are different from objects. List FOUR main differences between agents and objects.

(8 marks)

Answer

- Four main differences:
  1. Autonomy
     - Agents: Operate autonomously, making independent decisions based on their goals and environment.
     - Objects: Do not have autonomy, they do not act on their own.
  2. Social Ability
     - Agents: Can interact, communicate, and negotiate with other agents and humans.
     - Objects: Interact through method calls but lack the ability to engage in complex social interactions.
  3. Proactiveness
     - Agents: Can initiate actions on their own to achieve their goals.
     - Objects: React to method calls and do not initiate actions independently.
  4. Goal-Oriented Behaviour
     - Agents: Have specific goals and can adapt their behaviour to achieve these goals.
     - Objects: Perform predefined functions and do not have goals or intentions.

1. (d) What is the main difference between a purely reactive agent and a state-based agent? Describe a scenario where a state-based agent is beneficial.

(5 marks)

Answer

- Purely reactive agent acts solely based on the current percepts from the environment without considering any history or internal state.

- State-based agent keeps track of the internal state that summarizes past percepts to make more informed decisions.

- Scenario
  - Consider a vacuum cleaning robot.

  - A state-based agent would be beneficial because it can remember which rooms it has already cleaned, avoid revisiting the same places, and track where obstacles were encountered.

  - A purely reactive agent, in contrast, might repeatedly go over the same areas or get stuck in loops because it does not remember past actions or locations.

2. A robot can decide whether or not to go to get coffee for its owner. The robot is clumsy, and there is a probability of 0.4 that it will drop the coffee. The robot has sensors to know when it has dropped the coffee. It also has the option to clean up the floor. The utilities of different cases are given in Table Q2 below.

Table Q2

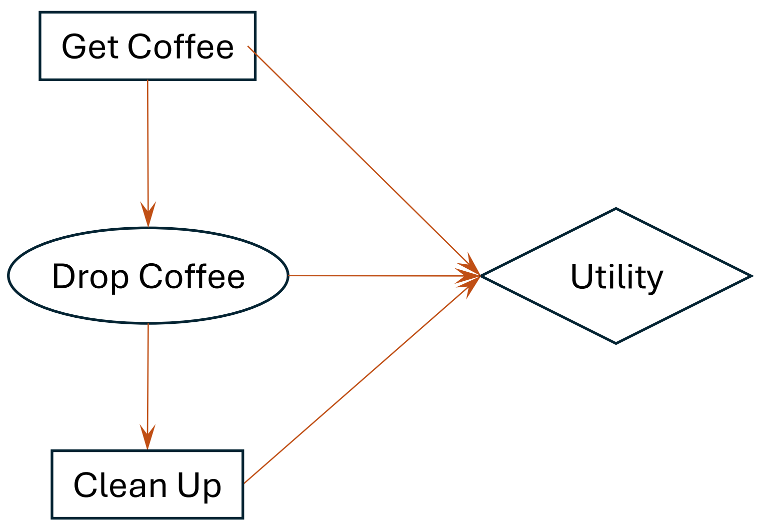
Whether to get coffee	Whether to drop coffee	Whether to clean up	Utility
No	No	No	0
No	No	Yes	20
Yes	No	No	100
Yes	No	Yes	-50
Yes	Yes	No	-100
Yes	Yes	Yes	-50

2. (a) What are the three types of nodes in a decision network for this problem? Draw the decision network.

(10 marks)

Answer

- Decision network nodes
  - Decision nodes : rectangle shape
  - Chance nodes : oval shape
  - Utility nodes : diamond shape



2. (b) If the robot gets coffee and drops it, should it clean up? If the robot gets coffee but does not drop it, should it clean up? If the robot does not get coffee, should it clean up?

(6 marks)

Answer

Whether to get coffee	**Whether to drop coffee**	**Whether to clean up**	**Utility**
No	No	No	0
No	No	Yes	20
Yes	No	No	100
Yes	No	Yes	-50
Yes	Yes	No	-100
Yes	Yes	Yes	-50

i) If robot gets coffee and drops it:
- Not clean up: Utility $U(\neg clean, get, drop) = -100$
- Clean up: Utility $U(clean, get, drop) = -50$

Decision: Since utility -50 > -100, robot should clean up

ii) If robot gets coffee but does not drop it:
- Not clean up: Utility $U(\neg clean, get, \neg drop) = 100$
- Clean up: Utility $U(clean, get, \neg drop) = -50$

Decision: Since utility 100 > -50, robot should not clean up

iii) If robot does not get coffee:
- Not clean up: Utility $U(\neg clean, \neg get) = 0$
- Clean up: Utility $U(clean, \neg get) = 20$

Decision: Since utility 20 > 0, robot should clean up

<u>Decisions</u>
- If robot gets coffee and drops it, it should clean up
- If robot gets coffee but does not drop it, it should not clean up
- If robot does not get coffee it, it should clean up

2. (c) Should the robot go to get coffee for its owner? Show clearly all the steps of calculation.

(9 marks)

Answer

Whether to get coffee	Whether to drop coffee	Whether to clean up	Utility
No	No	No	0
No	No	Yes	20
Yes	No	No	100
Yes	No	Yes	-50
Yes	Yes	No	-100
Yes	Yes	Yes	-50

P(drop | get) = 0.4
P(¬drop | get) = 0.6

From 2(b),

If John gets coffee and drops it: U(get, drop) = max (-100, -120) = -100
If John gets coffee but does not drop it: U(get, ¬drop) = max (80, -30) = 80
If John does not get coffee: U(¬get) = max (0, -20) = 0

EU(get) = P(drop | get) * U(get, drop) + P(¬drop | get) * U(get, ¬drop)
= [0.4 * (-50)] + (0.6 * 100)
= -20 + 60
= 40

EU(¬get) = U(¬get) = 20

<u>Summary of EU</u>

- EU(get) = 40
- EU(¬get) = 20

- Since EU(get) = 40 > EU(¬get) = 20, robot should get coffee for its owner

3. (a) The popular online strategy game StarCraft has emerged as an important benchmark for AI. StarCraft is a complicated strategy game that requires players to consider hundreds of options at any given moment, to make strategic choices with payoffs a long way down the road, and to operate in a fast-changing environment with imperfect information. Each player starts with a number of worker units, which gather basic resources to build more units and structures and create new technologies. List and briefly explain a few key ideas in multi-agent systems which can be used to build a successful agent to play StarCraft.

(6 marks)

Answer

i. Coordination
   - Multiple units need to work together to achieve strategic objectives.

ii. Communication
   - Agents must share information (e.g., enemy location, resource status) and coordinate actions (e.g., attack together) to achieve team objectives efficiently.

iii. Task Allocation
   - Assigning roles to agents (e.g., gathering resources, defending base) and enabling cooperation (e.g., one agent builds while others protect) helps optimize resource usage and strategy.

iv. Decentralized Control
   - Each unit (e.g., workers, soldiers) can act as an agent with its own decision-making ability. This allows for scalable and responsive behaviour without relying on a central controller.

v. Opponent Modelling
   - Agents must predict the behaviour or strategies of opposing team, develop counter-strategies.

vi. Learning and Adaptation
   - Agents can use reinforcement learning or other learning methods to adapt to opponents' tactics over time and improve performance through experience.

3. (b) In the classic Contract Net protocol, contracts have traditionally been binding. In the leveled commitment Contract Net protocol, the level of commitment is set by decommitting penalties. To be freed from the contract, an agent simply pays its penalty to the other contract party(ies). Explain the potential benefit of using such leveled commitment Contract Net protocol.

(5 marks)

Answer

3. (c) Explain why the first price auction is not truthful.

(5 marks)

Answer

- In a first-price auction, each bidder submits a sealed bid, and the highest bidder wins, paying the amount they bid.

- Reasons why first-price auction is not truthful:
  - Underbidding maximises profit
    - If a bidder bids their true valuation, their profit is zero (since they pay exactly what the item is worth to them).
    - They strategically lower their bids to balance the risk of losing the auction with the desire to pay less if they win.

  - Risk of Overpayment
    - If a bidder bids their true valuation and wins, they pay the full amount of their bid.
    - This can result in overpayment, especially if the second-highest bid is significantly lower.

  - No dominant strategy for truthful
    - In a first-price auction, there is no dominant strategy for honesty, bidders gain by lying.

3. (d) Explain the difference between core and Shapley value.

(5 marks)

Answer

- The Core and the Shapley Value are both solution concepts in cooperative game theory but they differ in their approach and the type of solution they provide.

- There is no direct relationship between them.

- Differences:
  - Stability vs. Fairness:
    - The core focuses on stability, ensuring no coalition has an incentive to deviate.
    - The Shapley value focuses on fairness, distributing payoffs based on contributions.

  - Multiplicity vs. Uniqueness:
    - The core can contain multiple allocations or be empty.
    - The Shapley value provides a unique allocation for each player.

3. (e) Explain manipulation in voting.

(4 marks)

Answer

- Manipulation in voting refers to strategic behaviour where voters do not vote for their true preferences in order to influence the outcome in their favour.

- Voters may believe that voting truthfully will not lead to their most preferred outcome, so they vote strategically to prevent a less desirable result.

- For example, in a 3-candidate election (A, B, C), a voter who prefers A > B > C might vote for B if they believe A has no chance to win, just to prevent C from winning.

- The Gibbard-Satterthwaite theorem shows that, under certain conditions, all non-dictatorial voting systems are susceptible to manipulation.

- Manipulation undermines fairness and trust in the election process, voters can benefit by strategically misrepresenting their preferences.

4. Consider the two payoff matrices 1 and 2 in Table Q4a and Table Q4b, respectively. The first number in each entry is the payoff received by the row player **A;** while the second number is the payoff received by the column player **B**.

Payoff matrix 1:

Table Q4a

	B: left	**B: right**
A: up	**(-1, 0)**	**(2, 1)**
A: down	**(0, 2)**	**(1, -1)**

Payoff matrix 2:

Table Q4b

	B: left	**B: right**
A: up	**(2, -2)**	**(-1, -1)**
A: down	**(1, 1)**	**(-1, 0)**

4. (a) Identify the dominant strategies (if any) of each player in these two payoff matrices. Briefly explain your answer.

(5 marks)

Answer

Table Q4a

	B: left	B: right
A: up	(-1, 0)	(2, 1)
A: down	(0, 2)	(1, -1)

Table Q4b

	B: left	B: right
A: up	(2, -2)	(-1, -1)
A: down	(1, 1)	(-1, 0)

Payoff matrix 1 (Table Q4a)

- Player A (row player):
  - If B plays left, A: up = -1, down = 0 → down is best
  - If B plays right, A: up = 2, down = 1 → up is best
  - Player A has no dominant strategy

- Player B (column player):
  - If A plays up, B: left = 0, right = 1 → right is better
  - If A plays down, B: left = 2, right = -1 → left is better
  - Player B has no dominant strategy

Payoff matrix 2 (Table Q4b)

- Player A (row player):
  - If B plays left, A: up = 2, down = 1 → up is best
  - If B plays right, A: up = -1, down = -1 → up or down same
  - Dominant strategy for Player A is up

- Player B (column player):
  - If A plays up, B: left = -1, right = -1 → right is best
  - If A plays down, B: left = 1, right = 0 → left is best
  - Player B has no dominant strategy

Summary

Matrix 1: Neither player has a dominant strategy

Matrix 2: Player A has a dominant strategy → up
Player B has no dominant strategy

- Dominant strategy is when there is a single action yields a better or equal payoff in all situations compared to the other actions.

4. (b) Identify which strategy pairs (if any) in these two payoff matrices are in Nash equilibrium. Briefly explain your answer.

(8 marks)

Answer

- To identify Nash equilibrim, we need to find strategy pairs where neither player has an incentive to change their strategy.

Payoff matrix 1 (Table Q4a)

Table Q4a

	B: left	**B: right**
A: up	**(-1, 0)**	**(2, 1)**
A: down	**(0, 2)**	**(1, -1)**

• (A: up, B: left) • A: up = -1, down = 0 → A prefers down • B: left = 0, right = 1 → B prefers right • Not Nash equilibrium	• (A: up, B: right) • A: up = 2, down = 1 → A prefers up • B: left = 0, right = 1 → B prefers right • Nash equilibrium
• (A: down, B: left) • A: up = -1, down = 0 → A prefers down • B: left = 2, right = -1 → B prefers left • Nash equilibrium	• (A: down, B: right) • A: up = 2, down = 1 → A prefers up • B: left = 2, right = -1 → B prefers left • Not Nash equilibrium

Payoff matrix 2 (Table Q4b)

Table Q4b

	B: left	**B: right**
A: up	**(2, -2)**	**(-1, -1)**
A: down	**(1, 1)**	**(-1, 0)**

• (A: up, B: left) • A: up = 2, down = 1 → A prefers up • B: left = -2, right = -1 → B prefers right • Not Nash equilibrium	• (A: up, B: right) • A: up = -1, down = -1 → up or down same • B: left = -2, right = -1 → B prefers right • Nash equilibrium
• (A: down, B: left) • A: up = 2, down = 1 → A prefers up • B: left = 1, right = 0 → B prefers left • Not Nash equilibrium	• (A: down, B: right) • A: up = -1, down = -1 → up or down same • B: left = 1, right = 0 → B prefers left • NotNash equilibrium

Summary of Nash Equilibrium

Payoff matrix 1: (A: up, B: right) → (2, 1),
(A: down, B: left) → (0, 2)

Payoff matrix 2: (A: up, B: right) → (-1, -1)

Neither player has an incentive to change their strategy

4. (c) Identify which outcomes in these two payoff matrices are Pareto optimal. Briefly explain your answer.

(7 marks)

Answer

- An outcome is said to be Pareto optimal if there is no other outcome that makes one agent better off without making another agent worse off. (win-win)

- If an outcome is Pareto optimal, then at least one agent will be reluctant to move away from it (because this agent will be worse off).

- If an outcome ω is not Pareto optimal, then there is another outcome ω' that makes everyone as happy, if not happier, than ω.

Table Q4a

	B: left	**B: right**
A: up	**(-1, 0)**	**(2, 1)**
A: down	**(0, 2)**	**(1, -1)**

Payoff matrix 1 (Table Q4a)

- (A: up, B:left) → (-1, 0)
  - Dominated by (2, 1) & others
  - Not Pareto optimal

- (A: up, B:right) → (2, 1)
  - No other better domination
  - Pareto optimal

- (A: down, B:left) → (0, 2)
  - No other better domination
  - Pareto optimal

- (A: down, B:right) → (1, -1)
  - Dominated by (2, 1)
  - Not Pareto optimal

4. (c) cont.

Table Q4b

	B: left	B: right
A: up	(2, -2)	(-1, -1)
A: down	(1, 1)	(-1, 0)

Payoff matrix 2 (Table Q4b)

- (A: up, B:left) → (2, -2)
  - No other better domination
  - Pareto optimal
- (A: up, B:right) → (-1, -1)
  - Dominated by (1, 1) & others
  - Not Pareto optimal

- (A: down, B:left) → (1, 1)
  - No other better domination
  - Pareto optimal

- (A: down, B:right) → (-1, 0)
  - Dominated by (1, 1)
  - Not Pareto optimal

Summary of Pareto optimal

Payoff matrix 1: (A: up, B:right) → (2, 1)
(A: down, B:left) → (0, 2)

Payoff matrix 2: (A: up, B:left) → (2, -2)
(A: down, B:left) → (1, 1)

No other outcome makes one player better off without making the other worse off

4. (d) Identify which outcomes in these two payoff matrices maximize social welfare. Briefly explain your answer.

(5 marks)

Answer

- Social welfare is measured as the sum of all players' payoffs. The outcome with the highest total payoff maximizes social welfare.

Table Q4a

	B: left	B: right
A: up	(-1, 0)	(2, 1)
A: down	(0, 2)	(1, -1)

Table Q4b

	B: left	B: right
A: up	(2, -2)	(-1, -1)
A: down	(1, 1)	(-1, 0)

Payoff matrix 1 (Table Q4a)

- (A: up, B: left): Total payoff = -1 + 0 = -1
- (A: up, B: right): Total payoff = 2 + 1 = 3
- (A: down, B: left): Total payoff = 0 + 2 = 2
- (A: down, B: right): Total payoff = 1 + (-1) = 0

- Maximize social welfare = 3
- Outcome: (A: up, B: right) → (2, 1)

Payoff matrix 2 (Table Q4b)

- (A: up, B: left): Total payoff = 2 + (-2) = 0
- (A: up, B: right): Total payoff = -1 + (-1) = -2
- (A: down, B: left): Total payoff = 1 + 1 = 2
- (A: down, B: right): Total payoff = -1 + 0 = -1

- Maximize social welfare = 2
- Outcome: (A: down, B: left) → (1, 1)

Summary of maximize social welfare

Payoff matrix 1: (A: up, B: right) → (2, 1)

Payoff matrix 2: (A: down, B: left) → (1, 1)

Their outcomes achieve the highest total payoff maximizes social welfare.