AI 2002 – Artificial Intelligence (Spring 2024)
Assignment 1

Topics Covered: Rational agents, environments & architectures, PEAS, search problem & state space	**Submission Deadline:** *Monday – February 19, 2024 by 16.00 sharp*
Submission Guidelines: • **Group assignment: 2 members (at max.)** • You may use internet for help but **do not submit "copy-paste" answers**. • Submit a PDF file containing your responses on the Google Classroom (of your respective section). • Plagiarism across different groups will not be accepted.	

Question 1

Examine the AI literature to discover whether the following tasks can currently be solved by computers. If yes, then list the name of a successful application or otherwise, state a reason that why a specific task is not possible yet.

i. Drive safely on a highway.

As of the most recent information, the utilization of computer systems for safe highway driving, commonly referred to as autonomous driving, has made strides but achieving full autonomy across all scenarios remains an ongoing development.

Applications:

Autonomous Vehicles

Advanced Driver Assistance Systems (ADAS)

ii. Drive safely in a busy city with other traffic and pedestrians.

As per the most recent information, the endeavor to attain safe autonomous driving in bustling city environments is a multifaceted and continuous initiative.

While advancements are noticeable, overcoming challenges for achieving complete autonomy necessitates ongoing refinement.

Applications:

Urban Autonomous Vehicles.

Smart City Integration.

Challenges and Limitations:

Complex Traffic Scenarios.

Pedestrian Interaction.

Regulatory and Ethical Considerations.

iii. Buying a week’s worth of groceries online.

As of the latest information, the task of purchasing a week's worth of groceries online is not only achievable but has become a widespread and convenient practice.

Applications:

Online Grocery Platforms

Automated Inventory Management

iv. Buying a week’s worth of groceries at a superstore.

As of the latest information, the traditional task of purchasing a week's worth of groceries at a superstore does not currently involve extensive AI applications. While superstores may implement basic technologies like self-checkout systems, the overall shopping experience is primarily driven by human decision-making.

Applications:

Self-Checkout Systems

Challenges and Limitations:

In big stores, people are the main helpers, and they make most decisions. Even though there are machines for self-checkout, fancy computer stuff doesn't control the whole shopping experience yet.

People still walk around the store, pick out what they want, and decide what they need.

v. Booking a doctor’s appointment online. vi. Win a soccer game against human(s).

As of the latest information, booking a doctor's appointment online has become a streamlined and commonplace task, benefiting from the integration of technology and AI-driven systems.

Applications:

Online Appointment Scheduling Platforms

AI-Assisted Booking Systems

vi. Win a soccer game against human(s).

As of the latest information, achieving victory in a soccer game against human players remains a task that relies on human skill, strategy, and teamwork. While AI technologies have made notable progress in various domains, conquering the dynamic and complex nature of a soccer match, especially against skilled human opponents, is a challenge that extends beyond the current capabilities of artificial intelligence.

Challenges and Limitations:
Dynamic and Unpredictable Nature
Human Intuition and Teamwork
Real-time Decision-Making:

vii. Win an art competition.

Based on the most recent information, triumphing in an art competition mainly depends on human creativity, skill, and subjective expression. Even though technology, including AI, has made progress in creating art, winning an art competition showcases the distinctive qualities of human artistic talent.

Challenges and Limitations:

Subjectivity in Art Appreciation
Originality and Innovation
Intuitive Decision-Making

viii. Win a chess game against human(s).

As of the latest information, winning a chess game against human opponents is a task where both human intelligence and artificial intelligence (AI) have demonstrated remarkable capabilities.

Applications:

AI Chess Engines
Training and Analysis Tools

ix. Discovering and proving new mathematical theorems.

As of the latest information, the process of discovering and proving new mathematical theorems is a complex and intellectually demanding task that predominantly relies on human mathematicians. While technology and computational methods assist in exploration and verification, the creative and intuitive aspects of mathematical discovery remain firmly rooted in human expertise.

Applications:

Computational Assistance
Automated Theorem Proving

Challenges and Limitations:

Creative Insight
Problem Formulation

x. Giving competent legal advice in a specialized area of law.

As of the latest information, providing competent legal advice in a specialized area of law is a task that requires the expertise of human legal professionals. While technology can assist in legal research and document review, the nuanced interpretation of laws, understanding of complex legal contexts, and the application of legal principles to specific cases remain within the purview of trained legal professionals.

Applications:

Legal Research Tools

Document Review Software

Challenges and Limitations:

Nuanced Interpretation of Laws

Legal Ethics and Professional Judgment

Client Interaction and Communication

xi. Translating spoken Urdu into spoken English in real time.

As of the latest information, real-time translation of spoken Urdu into spoken English has seen advancements with the integration of technology, particularly in the field of machine translation and speech recognition.

Applications:

Speech-to-Text Technology

Machine Translation Systems

Speech Synthesis

xii. Writing an intentionally funny story.

The AI can certainly write an intentionally funny story. Here is an example that we copied from an AI source.

Title: The Great Coffee Caper

In the bustling city of Brew burgh, known for its love affair with coffee, an unprecedented crisis unfolded when the city's beloved coffee beans vanished mysteriously. The mayor, a jittery espresso shot named Mayor Macchiato, called upon the Caffeine Chronicles, a duo of coffee enthusiasts renowned for solving brew-related mysteries.

Meet Detective Java Jolt, a charismatic cup of black coffee with a nose for intrigue, and his witty partner, Latte Larry, a frothy and suave latte.

Determined to restore the city's caffeinated calm, they embarked on a quest to find the missing coffee beans.

The duo interrogated a line-up of suspects, including Mocha Mike, a chocolatey barista with a penchant for whipped cream, and Espresso Eddie, a short and intense shot of coffee with a steamy temper. However, their investigations brewed into a frothy mess until they encountered the elusive Barista Bandit, a stealthy figure with a penchant for decaf mischief.

Through a series of coffee-stained clues, Detective Java Jolt and Latte Larry followed the aromatic trail to Brew burgh's central coffee roastery. There, they confronted the mastermind behind the coffee caper, Roast master Regina,

who had hoarded the beans for a secret blend.
As the beans were returned to their rightful place, Brewburgh erupted in cheers, celebrating the return of its precious coffee. Detective Java Jolt, raising his coffee cup in triumph, declared, "Another case brewed to perfection! Let's espresso our gratitude for a caffeinated city!"

xiii. Writing a publishable research article.

As of the latest information, the task of writing a complete and publishable research article is primarily a human-driven process. While there are AI tools that can assist in various aspects of the writing process, the creation of a comprehensive and coherent research article involves a level of creativity, critical thinking, and nuanced understanding that is currently beyond the capabilities of AI systems.

AI Applications in Writing Assistance:
Grammar and Style Checking Tools
Automated Abstract Generation:

Question 2

For each of the following assertions, say whether it is true or false and support your answer with examples or counter-examples where appropriate.

i. An agent that senses only partial information about the state cannot be perfectly rational.

The assertion that "an agent that senses only partial information about the state cannot be perfectly rational" is generally true. A perfectly rational agent is expected to make decisions that lead to optimal outcomes given its knowledge and goals. However, when an agent has only partial information about the state, its decisions may not always align with the true underlying state of the environment.

Example:

Consider a self-driving car equipped with sensors that can detect nearby objects but not the entire environment. If the car is unable to sense a pedestrian approaching from a blind spot, it might make decisions based on incomplete information, leading to suboptimal or even unsafe actions.

Counter-Example:

In some cases, an agent with partial information can still exhibit rational behavior if the partial information is sufficient to make accurate decisions. For instance, a chess-playing agent might not see the entire board but can make rational moves based on the visible pieces and known game rules.

ii. There exist task environments in which no pure reflex agent can behave rationally.

The assertion that "there exist task environments in which no pure reflex agent can behave rationally" is true. Pure reflex agents make decisions based solely on the current percept, without considering the history of events or the future consequences of their actions. In certain environments, this approach may lead to irrational behavior due to the lack of sufficient information.

Example:

Consider a navigation task where an agent has to move through a maze to reach a goal. If the agent relies only on its immediate percept (e.g., the current position in the maze), it might make decisions solely based on the immediate surroundings without considering the overall structure of the maze or potential dead ends. This can lead to suboptimal or irrational choices.

Counter-Example:

In environments with simple, predictable rules and where actions have immediate and clear consequences, a pure reflex agent may behave rationally. For instance, in a tic-tac-toe game, a reflex agent can make rational moves based on the current state of the board, as the consequences of each move are straightforward and easily perceivable.

iii. There exists a task environment in which every agent is rational.

The assertion that "there exists a task environment in which every agent is rational" is not necessarily true. Rationality in the context of agents refers to making decisions that lead to optimal outcomes given the available information and the agent's goals. In some task environments, achieving perfect rationality for every possible agent may be challenging or impossible.

Example:

Consider a hypothetical task environment where agents are required to predict the exact future stock prices in a highly volatile and unpredictable market. Due to the inherent uncertainty and complexity of financial markets, achieving perfect rationality for every agent might be unattainable. The unpredictable nature of market fluctuations makes it difficult for agents to consistently make optimal decisions.

Counter-Example:

In relatively simple and deterministic task environments, such as a chess game with complete information and clear rules, every agent could potentially exhibit rational behavior. Each agent can analyze the current state of the board, consider possible moves, and choose the one that maximizes its chances of winning.

iv. Every agent function is implementable by some program/machine combination.

The assertion that "every agent function is implementable by some program/machine combination" aligns with the ChurchTuring thesis, a foundational concept in computer science and theoretical computation. According to the Church-Turing thesis, any algorithmic process that can be computed by an agent is, in theory, implementable by a Turing machine or equivalent computational model.

Explanation:

The Church-Turing thesis posits that any effectively calculable function can be computed by a Turing machine. Since modern computers are considered Turing machines, this implies that any algorithmic process or agent function that is computable can be implemented by some program/machine combination.

Example:

Consider an agent function that involves sorting a list of numbers in ascending order. This function is algorithmic and can be implemented by a variety of programs running on different machines, ranging from simple algorithms on a basic computer to more complex sorting algorithms on high-performance servers.

v. Suppose an agent selects its action uniformly at random from the set of possible actions. There exists a deterministic task environment in which this agent is rational.

The assertion that "there exists a deterministic task environment in which an agent, selecting its action uniformly at random from the set of possible actions, is rational" is not accurate. Rationality, in the context of agents, typically refers to making decisions that lead to optimal outcomes given the available information and the agent's goals.

Explanation:

In a deterministic environment, where the outcomes are completely predictable based on the current state and the agent's actions, selecting actions uniformly at random is unlikely to result in rational behavior. Rationality involves making choices that maximize expected utility or achieve the agent's goals effectively.

Example:

Consider a deterministic task environment where an agent needs to navigate through a maze to reach a goal. In such an environment, the optimal action can be determined based on the current state (agent's position in the maze). If the agent randomly selects actions without considering the optimal path, it is unlikely to reach the goal efficiently, and its behavior would not be considered rational.

Counter-Example:

In certain scenarios, where the goal is not influenced by the agent's actions, and the outcomes are inconsequential, randomness in action selection might be rational. For instance, in a deterministic environment where the agent's goal is simply to explore without a specific destination or objective, randomly selecting actions might be considered rational behavior.

vi. It is possible for a given agent to be perfectly rational in two distinct task environments.

The assertion that "it is possible for a given agent to be perfectly rational in two distinct task environments" is generally true, with some qualifications. Perfect rationality, in the context of agents, implies making decisions that lead to optimal outcomes given the available information and the agent's goals. An agent can exhibit perfect rationality in different task environments as long as it adapts its decision-making processes to the specific characteristics of each environment.

Example:

Consider an intelligent agent designed for chess playing. In one task environment, the agent may be operating under standard chess rules and board configurations. In another task environment, the rules might be slightly modified, or the board size might differ. If the agent is designed to adapt its decisionmaking process based on the specific rules and configurations of each environment, it can exhibit perfect rationality in both, optimizing its moves to achieve the best possible outcomes given the rules in each setting.

Qualifications:

Task Relevance:

The agent must be designed to recognize and appropriately respond to the relevant features of each task environment. It should adapt its decision-making strategy based on the specific requirements and objectives of the environment.

Information Availability:

Perfect rationality requires making decisions based on all available information. If the information available in one environment is significantly different from another, the agent must adjust its decision-making processes accordingly.

Adaptability:

The agent needs to be inherently adaptable or programmatically designed to adjust its decision-making algorithms, strategies, or heuristics to accommodate variations in different task environments.

vii. Every agent is rational in an unobservable environment.

The assertion that "every agent is rational in an unobservable environment" requires examination, given the complexity of decision-making in environments where direct observation is limited. Rationality, defined by optimal decision-making based on available information, becomes nuanced in unobservable settings.

Example:

Consider an intelligent agent navigating a maze with hidden obstacles. In the absence of direct observation, the agent relies on inferred knowledge, past experiences, and predictive models to navigate effectively. Rational behavior, in this context, involves making decisions that maximize the chances of reaching the goal while avoiding potential hazards.

Counter-Example:

However, achieving perfect rationality in unobservable environments is challenging. The inherent uncertainty makes optimal decision-making elusive. An agent may lack complete information, leading to suboptimal decisions despite employing inference mechanisms and adaptive strategies. The unpredictability of unobservable environments introduces a level of uncertainty that may hinder the attainment of perfect rationality.

viii. A perfectly rational poker-playing agent never loses.

The assertion that "a perfectly rational poker-playing agent never loses" is not accurate. Rationality, in the context of agents, refers to making decisions that lead to optimal outcomes given the available information and the agent's goals. In poker, perfect rationality does not guarantee a win in every situation due to the inherent uncertainty and incomplete information.

Explanation:

Incomplete Information:

Poker involves hidden information, as players' cards are not fully revealed. A rational agent makes decisions based on probabilities, opponent behavior, and its own cards, but it cannot guarantee victory due to the uncertainty associated with hidden information.

Risk and Uncertainty:

Rational decision-making in poker considers risk and uncertainty. Even with optimal decisions, the outcome is influenced by factors beyond the agent's control, such as card distribution, opponents' strategies, and luck.

Example:

A perfectly rational poker-playing agent may consistently make optimal decisions based on the available information, adjusting its strategy according to the game's dynamics. However, factors like unpredictable opponent moves or an unfavorable distribution of cards can still lead to losses.

Counter-Example:

In a simplified poker variant with complete information and fixed rules, a perfectly rational agent might secure a win. But in traditional poker with hidden information, no agent, no matter how rational, can guarantee victory in every hand due to the uncertainties involved.

Question 3

For each of the following activities, give a PEAS description of the task environment in a tubular form.

i. Playing soccer ii. Exploring the subsurface oceans of Titan iii. Playing a tennis match
iv. Practicing tennis against a wall
v. Performing a high jump vi. Knitting a sweater
vii. Bidding on an item at an auction

Activity	Performance Measure	Environment	Actuators	Sensors
Playing soccer	Score, Team Position	Soccer field, weather conditions	Legs, Feet, Eyes, Arms	Eyes (for vision), Ears (for communication)
Exploring subsurface oceans of Titan	Scientific discoveries, Depth reached	Titan's subsurface ocean	Robotic Submersible, Sensors	Cameras, Sonar, Temperature sensors
Playing a tennis match	Winning points, Game statistics	Tennis court, weather conditions	Racket, Feet, Eyes	Eyes (for vision), Ears (for communication)
Practicing tennis against a wall	Racket control, Stamina	Tennis court, wall	Racket, Feet	Eyes (for vision), Ears (for communication)
Performing a high jump	Jump height, Technique perfection	High jump mat, weather conditions	Legs, Arms	Eyes (for alignment), Ears (for cues)

Knitting a sweater	Quality of knitting, Time taken	Knitting workspace, materials	Hands, Needles	Eyes (for precision), Touch (to sense tension)
Bidding on an item at an auction	Winning bids, Budget management	Auction platform, bidding interface	Mouse/Keyboard, Voice (if applicable)	Eyes (for reading information), Ears (for auctioneer announcements)

Question 4

For each of the activities listed in the previous question, describe the environment type as:

i. Fully or partially observable
ii. Deterministic or stochastic
iii. Episodic or sequential
iv. Static or dynamic
v. Discrete or continuous
vi. Single or multi-agent

Provide your answers in a tubular form.

Activity	Observability	Determinism	Episodic/Sequential	Static/Dynamic	Discrete/Continuous	Single/Multi-Agent
Playing soccer	Partially observable	Stochastic	Sequential	Dynamic	Continuous	Multi-agent
Exploring subsurface oceans of Titan	Partially observable	Stochastic	Sequential	Dynamic	Continuous	Multi-agent

Playing a tennis match	Fully observable	Deterministic	Sequential	Dynamic	Discrete	Multi-agent
Practicing tennis against a wall	Fully observable	Deterministic	Sequential	Static	Discrete	Single-agent
Performing a high jump	Partially observable	Deterministic	Episodic	Static	Continuous	Single-agent
Knitting a sweater	Fully observable	Deterministic	Sequential	Static	Discrete	Single-agent
Bidding on an item at an auction	Partially observable	Stochastic	Sequential	Dynamic	Discrete	Multi-agent

Question 5

Pick a real-world example of your choice (a robot or software agent/bot, except for the examples discussed in detail in the class e.g., taxi & vacuum-cleaner agents) and describe different scenarios in the context of the following agent types that solve the problem.

i. Reflex agent
ii. Model-based
iii. Goal-based
iv. Utility-based
v. Learning agent

1. Reflex Agent:

Scenario: The reflex agent drone operates reactively to its immediate environment. When it encounters an obstacle during its delivery route, it changes its direction or altitude to avoid the obstacle without a comprehensive understanding of the entire delivery path.

Operation: The drone's reflex actions are triggered by real-time inputs from its sensors, such as proximity sensors, obstacle detection, and GPS coordinates.

2. Model-Based Agent:

Scenario: The model-based delivery drone maintains a detailed map of its delivery area, including landmarks, buildings, and no-fly zones. It uses this model to plan the most efficient delivery routes and avoid restricted areas.

Operation: By constantly updating its internal model, the drone can adapt to changes in the environment, plan optimal routes, and ensure timely and safe deliveries.

3. Goal-Based Agent:

Scenario: The goal-based drone aims to maximize the number of successful deliveries within a given time frame. It assesses the urgency of each delivery, prioritizes packages based on delivery times, and plans its routes accordingly.

Operation: The drone dynamically adjusts its goals, taking into account factors like delivery deadlines, package sizes, and delivery locations to optimize its overall delivery performance.

4. Utility-Based Agent:

Scenario: The utility-based drone considers multiple factors, such as battery life, weather conditions, and package importance. It seeks to maximize the overall utility by balancing efficient deliveries with factors like battery conservation and adverse weather conditions.

Operation: The drone makes decisions that maximize the overall utility, ensuring it completes deliveries efficiently while considering external factors that might impact its performance and resource usage.

5. Learning Agent:

Scenario: The learning agent drone continually improves its delivery performance based on past experiences. It learns from successful and unsuccessful deliveries, adapting its navigation strategies, obstacle avoidance techniques, and delivery prioritization over time.

Operation: By leveraging machine learning algorithms, the drone refines its decision-making processes, becoming more adept at navigating complex environments, optimizing delivery routes, and improving overall delivery success rates.

Question 6

A problem can be described as a "search problem" by specifying the following components: (a) initial state, (b) actions, (c) transition model/successor function, (d) goal state, (e) path cost (assume a path cost of 1 per action, if not specified explicitly). For each of the following problems, identify the above components.

i. There are six glass boxes in a row, each with a lock. Each of the first five boxes holds a key unlocking the next box in line, the last holds a banana. You have the key to the first box, and you want the banana.

Initial State

The initial state is having a key to the box.

Actions

Actions involve unlocking each box with the keys you find. You start with the key to the first box, and then use each new key you discover to unlock the next box.

Transition Model

After using a key to unlock a box, you move to the next state, revealing a new key inside

Goal State

The aim is to get to the box with the banana.

Path Cost

Each action is assumed to have a cost of 1.

ii. Consider a 3-coins problem, C1-C2-C3 where each coin has two sides: a head (or H) and a tail (or T). Only one coin can be flipped at a time which will change an H to T or a T to H.

Since, we have three coins, the coin position would tell the coin to be flipped, that is, C1 will flip coin 1 and so on. The initial state is H-H-H and the goal is to get at least two tails.

Initial State

The starting state is H-H-H, meaning all three coins initially show heads.

Actions

Actions involve flipping one coin at a time. The coin position determines which coin to flip. For instance, C1 indicates flipping the first coin, C2 for the second, and C3 for the third.

Transition Model

The transition model describes the result of an action in a given state. In this case, flipping a coin changes its side from heads (H) to tails (T) or vice versa.

Goal State

The goal is to achieve at least two tails. The specific arrangement of heads and tails is not explicitly stated, so any configuration with at least two tails is considered a goal state.

Path Cost

Each action is assumed to have a cost of 1.

iii. In the "missionaries and cannibals" problem, three missionaries and three cannibals must cross a river using a boat which can carry at most two people, under the constraint that, for both banks, if there are missionaries present on the bank, they cannot be outnumbered by cannibals (if they were, the cannibals would eat the missionaries). The boat cannot cross the river by itself with no people on board.

Initial State

Start with three missionaries, three cannibals, and the boat on one side of the river. The other side is empty.

Actions

Move either one or two people (missionaries or cannibals) from one side to the other using the boat. The boat can carry a maximum of two people.

Transition Model

After using the boat, update the state by moving individuals across the river. Be careful to follow the rule that missionaries can't be outnumbered by cannibals on either side.

Goal State

The goal is to move all three missionaries and three cannibals from one side to the other without breaking the rule. Achieve this when everyone is on the opposite bank.

Path Cost

Each action is assumed to have a cost of 1.

Question 7

For each of the problem in the previous question:

i. Construct a state space and clearly show the initial state(s), possible actions, and goal state(s).

Six Glass Boxes Problem:

State Space:

- States: Each state represents a configuration of unlocked boxes.
- Initial State: (Box1 unlocked, Box2 locked, Box3 locked, Box4 locked, Box5 locked, Box6 locked).
- Possible Actions: Unlocking the next available box.
- Goal State(s): (Box1 unlocked, Box2 unlocked, Box3 unlocked, Box4 unlocked, Box5 unlocked, Box6 unlocked) - reaching the box with the banana.

3-Coins Problem:

State Space:

- States: Each state represents a configuration of coin positions (H or T).
- Initial State: (H, H, H).
- Possible Actions: Flipping one coin at a time (C1, C2, C3).
- Goal State(s): Any state with at least two tails.

Missionaries and Cannibals Problem:

State Space:

- States: Each state represents the number of missionaries and cannibals on each side of the river, along with the boat position.
- Initial State: (3M, 3C, B) on one side; (0M, 0C) on the other side.
- Possible Actions: Moving missionaries and cannibals across the river.
- Goal State(s): (0M, 0C, B) on one side; (3M, 3C) on the other side.

ii. Is the state space a graph or a tree?

Six Glass Boxes Problem:
The state space is a graph, as unlocking one box can lead to multiple possible states.

3-Coins Problem:
The state space is a tree, as each state (coin configuration) can lead to multiple possible next states.

Missionaries and Cannibals Problem:
The state space is a graph, as there can be multiple ways to reach the same state. The actions depend on the current state, and different paths can lead to the same state.