Agent

Based on the material in Chapter 2 of the course book, define succinctly in your own words, the following terms:

- **(a) Agent, Agent Function, Agent Program**
- **(b) Performance Measure, Rationality, Autonomy**
- (c) Reflex Agent. Also provide a schematic diagram of such an agent.
- (d) Model-based Agent. Also provide a schematic diagram of such an agent.
- (e) Goal-based Agent. Also provide a schematic diagram of such an agent.

Logic

- CNF

Answer Set Programming

(a) Given the program Π1, consisting of the following rules (where a1 is a constant):
r1: apple(a1). r2: tasty(a1) ← apple(a1), not ab(a1). r3: rotten(a1). r4: ab(a1) ← rotten(a1). 1 what is the reduct ΠS 1 for Π1 given that S = {apple(a1), ab(a1)}? [1p] 2 what is the reduct ΠS 1 for Π1 given that S = {apple(a1), rotten(a1)}?

(b) Given the program Π2 consisting of the following two rules (where short, tall are constants): r1: height(tall) ← not height(short) r2: height(short) ← not height(tall). What are the possible answer sets for Π2?

(c) Given the possible answer sets for Π2 above, which of those possible answer sets are in fact answer sets for program Π2? [2p] When answering this question be sure to show why, by using the reducts, ΠSi 2 , where Si is instantiated to each possible answer set, and the consequence operator TΠ described in appendix 3.

(d) Why is Answer Set Programming considered to be a nonmonotonic reasoning formalism?

Bayesian Networks

Alan Turing

- **(a) Describe the Turing Test using your own diagram and explanations.**
- (b) Do you believe this is an adequate test for machine intelligence? Justify your answer.

Simon

- **(a) What is a physical symbol system (PSS) and what does it consist of?**
- **(b) What is the Physical Symbol System Hypothesis?**
- (c) Do you think the Physical Symbol System Hypothesis is true or false or somewhere in between? Provide reasonable justifications for your opinion.

Automated Planning

Recall that partial-order planning generates plans where actions are not necessarily constrained to be ordered in a sequence but can (at least during search) be placed “in parallel”. This requires a completely different search space than the one used for forward-chaining state space search. The standard partial-order causal-link search space gives rise to the concept of a flaw.

(a) Name two distinct types of flaw that can arise when a partial-order causal-link planner searches for a plan and explain each type of flaw clearly. [2p] The explanations should be sufficiently clear that someone who has not seen the definitions in the book or lecture notes can take a partial plan, analyze it, and identify the flaws it contains (if any). Feel free to include examples of partial plans that illustrate each flaw type, but be aware that examples in themselves are not sufficient to define the exact boundaries between flaws and non-flaws.

(b) For each type of flaw, describe at least one way that one may be able to resolve it.

(a) Explain the main ideas underlying landmark heuristics.

   a. For example, what is a fact landmark for a state s in a planning problem P? That is, what type of entity is it that may or may not qualify as a fact landmark, and what are the requirements for this entity to actually be a fact landmark for s given the problem P?
   b. Also, explain at least one way in which landmarks can be used to define a heuristic function h(s) in a planning problem P. Make sure to clearly specify how the value of the heuristic function would be calculated given the state and problem.

(a) State three distinct and important reasons why planning should be automated. In other words, why do we want computers to create plans, rather than simply creating the plans ourselves?

(b) What is satisficing planning?

(c) Recall that the two heuristic functions $h_1(n)$ and $h_{add}(n)$ are very similar, but that their definitions have one crucial difference that results in significant differences in their behavior. What is this crucial difference? Which of the functions is inadmissible, and why? Which function provides more information, and why?

(d) Plan-space search begins with an initial plan and iteratively modifies this plan in order to repair flaws. Name the two distinct types of flaw that exist. Explain clearly how these flaw types can be identified in a plan. For the explanation to be sufficiently clear, you may need to provide an example plan drawn in the same way as during the lectures.

Search (A*)

(a) Explain what an admissible heuristic function is using the notation and descriptions in (d).

(b) Can a consistent heuristic function be inadmissible? Explain why or why not.

(c) Suppose a robot is searching for a path from one location to another in a rectangular grid of locations in which there are arcs between adjacent pairs of locations and the arcs only go in north-south (south-north) and east-west (west-east) directions. Furthermore, assume that the robot can only travel on these arcs and that some of these arcs have obstructions which prevent passage across such arcs. Provide an admissible heuristic for this problem. Explain why it is an admissible heuristic and justify your answer explicitly.

(d) Let h(n) be the estimated cost of the cheapest path from a node n to the goal. Let g(n) be the path cost from the start node n0 to n. Let f(n) = g(n) + h(n) be the estimated cost of the cheapest solution through n. Provide a sufficiently rigid proof that A∗ is optimal if h(n) is admissible. You need only provide a proof for either tree-search (seminar slides) or graph-search (in course book). If possible, use a diagram to structure the contents of the proof to make it more readable.

(a) In the course book, we considered the 8-puzzle. This consists of a 3x3 game board with 8 tiles (and one empty space) in the 9 slots. Each tile is numbered from 1 to 8. The start state of the game places the 8 numbered tiles arbitrarily on the board. The goal state is for the tiles to be numbered in numerical order from top to bottom, left to right. There is one action in the game. A tile can be moved from slot A to slot B if slot B is empty.
    a. The Hamming distance measures the number of misplaced tiles in a board configuration. Is this an admissible heuristic? Explain why this is the case.
    b. Provide an additional admissible heuristic for this problem and explain why it is an admissible heuristic.
    c. Compare your heuristic with the Hamming distance heuristic and state what heuristic dominates the other. Why is the more dominant heuristic better?

Constraint Satisfaction Problem

(a) What is the Forward Checking technique?
(b) What is arc consistency? Provide a definition.
(c) Provide a constraint graph that is arc consistent but globally inconsistent.
(d) Make the constraint graph in figure 2 arc consistent using the AC3 algorithm in Appendix 4. For the answer, only the resulting consistent bindings for each variable in the constraint graph output by the AC3 algorithm are required although you may show more of the process. As stated above, the value domain for each of the variables, A, B and C is {1, 2, 3, 4}.

(a) Suppose there are 5 territories T1, T2, T3, T4, and T5, each with a sensor that monitors the area associated with that territory. Each sensor has three possible radio frequencies, F1,F2, F3. Sensors overlap if they are in adjacent areas. The adjacency relation between two territories is symmetric. Let Adj(x, y) represent the adjacency relation where Adj(T1, T2), Adj(T1, T3),Adj(T2, T3), Adj(T3, T4). If two sensors overlap, they can not use the same frequency.
    a. Define a constraint satisfaction problem for this scenario.
    b. Provide a constraint graph for the CS problem.
    c. Provide one solution for the CS problem.

Constraint satisfaction problems consist of a set of variables, a value domain for each variable and a set of constraints. A solution to a CS problem is a consistent set of bindings to the variables that satisfy the constraints. A standard backtracking search algorithm can be used to find solutions to CS problems. In the simplest case, the algorithm would choose variables to bind and values in the variable's domain to be bound to a variable in an arbitrary manner as the search tree is generated. This is inefficient and there are a number of strategies which can improve the search. Describe the following three strategies:

(a) Minimum remaining value heuristic (MRV).
(b) Degree heuristic.
(c) Least constraining value heuristic.

Machine Learning

(a) Assume you want to learn a climate model to predict temperature (degrees) from examples.

  a. What would a suitable loss function be to use for such output examples?

  b. Assume you chose a neural network model with p parameters (weights, biases), and you want to train it using gradient descent on n examples. What would the computational complexity be of computing the parameter gradients?

(b) Consider a Q-learning agent with the update equation shown below. Explain how decreasing γ will change agent behavior.

$$Q(st, at) \leftarrow Q(st, at) + \alpha(R(st) + \gamma \max at{+}1 \in A\ Q(st{+}1, at{+}1) - Q(st, at))$$

(c) This question pertains to deep learning.

  a. How can deep representations be more effective than shallow ones?

  b. Assume you want to classify images with neural networks, using the pixels as inputs to the network. What type of network layers would be suitable to include to make learning more effective than just using fully-connected multi-layer networks?

(d) Explain how a loss function is used during training in supervised learning.

(e) Describe an exploration strategy in the context of reinforcement learning.

(f) Consider a Q-learning agent with the update equation shown below.

$$Q(st, at) \leftarrow Q(st, at) + \alpha(R(st) + \gamma \max at{+}1 \in A\ Q(st{+}1, at{+}1) - Q(st, at))$$

  a. How would the overall behavior of the agent change if the value of γ was reduced?

  b. What is the purpose of α?

(a) Explain supervised and reinforcement learning in terms of the input and output of the respective types of algorithms, highlighting their differences.

(b) Explain the concept of overfitting and a princpled way to detect it.

(c) Explain when and why exploration is needed and outline an example algorithm.