ASSIGNMENT REPORT FOR AI6125: MULTI-AGENT SYSTEM

Assignment 2

ZENG ZHENG

G211941J

zzeng006@e.ntu.edu.sg

School of Computer Science and Engineering

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Question 1

(a) Describe what an expert system is. List TWO main differences between agents and expert systems.

Expert systems are typically disembodied 'expertise' about some (abstract) domain of discourse(e.g.,blood diseases). Two main differences are:

1. Agents are situated in an envirnment while expert systems obtain imformation by user input.
2. Agents take actions while expert systems do not operate on patiens.

(b) Explain with an example what *intelligence* means.

It means that the complexity of the tasks we have the ability to automate and delegate to computers has steadily grown.

(c) Give two types of utility functions and discuss the challenges faced when designing such functions.

Utility functions could calculate:

1. the sum of utilities of states on a run
2. maximum utility of state on run

Both functions above have difficulty to specify a long term view when assigning utilities to individual states because there could be infinite state sequences.

(d) Two most common types of tasks are *achievement tasks* and *maintenance tasks*. Explain what these two types of tasks are.

For the achievement tasks, the agent succeeds if it is guaranteed to bring about at least one of "good" states (we do not care which one they are all considered equally good).

For the maintenance tasks, the agent succeeds in a particular environment if it manages to avoid all "bad" states -— if it never performs actions that causes any "bad" state to occur.

Question 2

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

The three types of nodes are:

1. Decision nodes, that the agent chooses the value for. Domain is the set of possible actions. Drawn as a rectangle.
2. Chance nodes, the node represent probabilistic dependence. Drawn as an ellips.
3. Utility nodes, whose parents are the variables on which the utility depends. Drawn as a diamond.

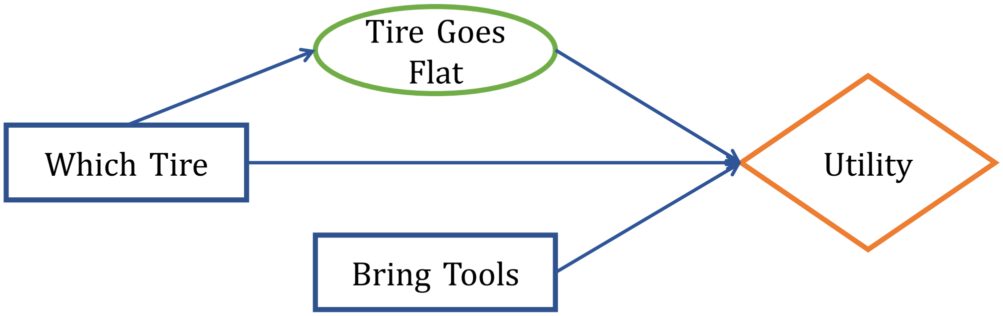

Figure 1: The decison network

The decision network is as Figure 1. In this diagram, there are two decision nodes for which tire to use(road tires or thicker tires), and whether to bring toolss(bring or not). In addition, there is a chance node here that represents the possibility of the tire blowning up during the trip.(tire goes flat or not). Also, there is a utility node.

(b) What is the optimal decision? What is the expected utility of the optimal decision?

We can obtain a table of probabilities of flat tire accidents as Table1, which depends on the use of different tires.

Table 1: The probabilities of flat tire accidents

Which tire to use	Whether tire goes flat	Probability
Road tire	Yes	0.4
Road tire	No	0.6
Thicker tire	Yes	0.1
Thicker tire	Yes	0.9

Now, we have four decisions to consider, which are:

1. to use road tire and bring tools, we use $E(road, tools)$ to represent its expected utility.
2. to use road tire and not bring tools, we use $E(road, \neg tools)$ to represent its expected utility.
3. to use thicker tire and bring tools, we use $E(thicker, tools)$ to represent its expected utility.
4. to use thicker tire and not bring tools, we use $E(thicker, \neg tools)$ to represent its expected utility.

The expected utility of four decisions above can be calculated using Table 1 and Table Q2:

$$\begin{aligned}
E(road, tools) &= P(flat|road, tools) \times U(flat|road, tools) + P(\neg flat|road, tools) \times U(\neg flat|road, tools) \\
&= P(flat|road) \times U(flat|road, tools) + P(\neg flat|road) \times U(\neg flat|road, tools) \\
&= 0.4 \times 50 + 0.6 \times 75 \\
&= 65
\end{aligned}$$

$$
\begin{aligned}
E(thicker, tools) =& P(flat|thicker, tools) \times U(flat|thicker, tools) \\
& + P(\neg flat|thicker, tools) \times U(\neg flat|thicker, tools) \\
=& P(flat|thicker) \times U(flat|thicker, tools) + P(\neg flat|thicker) \times U(\neg flat|thicker, tools) \\
=& 0.1 \times 40 + 0.9 \times 65 \\
=& 62.5
\end{aligned}
$$

$$
\begin{aligned}
E(road, \neg tools) &= P(flat|road, \neg tools) \times U(flat|road, \neg tools) + P(\neg flat|road, \neg tools) \times U(\neg flat|road, \neg tools) \\
&= P(flat|road) \times U(flat|road, \neg tools) + P(\neg flat|road) \times U(\neg flat|road, \neg tools) \\
&= 0.4 \times 0 + 0.6 \times 100 \\
&= 60
\end{aligned}
$$

$$
\begin{aligned}
E(thicker, \neg tools) =& P(flat|thicker, \neg tools) \times U(flat|thicker, \neg tools) \\
& + P(\neg flat|thicker, \neg tools) \times U(\neg flat|thicker, \neg tools) \\
=& P(flat|thicker) \times U(flat|thicker, \neg tools) + P(\neg flat|thicker) \times U(\neg flat|thicker, \neg tools) \\
=& 0.1 \times 0 + 0.9 \times 75 \\
=& 67.5
\end{aligned}
$$

Comparing four expected utility of the above four decisions, we can conclude that the optimal decision is to use thicker tires and not bring tools, and the expected utility of this decision is 67.5.

Question 3

(a) When building a team of fighter jet agents for fighting with another team of fighter jet agents, what are the additional issues we have to consider compared with designing a single fighter jet agent? Comparing with designing a single fighter jet agent, the system design task of building a team of fighter jet agents for fighting can be viewes as a cooperative distributed problem solving (CDPS) between benevolent agents. In this way, communication and cooperation between agents are the additional issues we have to consider.

There are three stages included in CDPS: problem decomposition which divides the overall problem into smaller sub-problems, sub-problem solution which typically involving information sharing between agents, and answer synthesis which integrates solutions to sub-problems.

In order to evaluating how well robots cooperate with each other, we normally use two criteria: coherence and coordination. To be more specific, coherence is how well the flighter jet team system behaves as a unit along some dimension of evaluation. For example, we can measure the quality of the solution (whether it can beat another team), the efficiency of the use of resources, the clarity of the concept, etc. In addition, the degree of "coordination" usually refers to the extent to which agents can avoid "disjoint" activities among themselves, synchronizing and aligning their activities. If the system is perfectly coordinated, agents will not impede each other's activities in a physical or metaphorical sense. For instance, a fighter jet should not cause an accident by blocking the planned route of a companion or the expected trajectory of a projectile.

(b) Briefly describe the five stages included in the CONTRACT NET protocol.

The contract net includes five stages: recognition, announcement, bidding, awarding, and expediting. In the recognition stage, an agent recognises it has a problem it wants help with. If the agent has a goal, then it realizes that it cannot achieve it alone (does not have the capacity), or realizes that it does not want to achieve it alone (usually because of the quality of the solution, deadlines, etc.). As a result, it needs to involve other agents.

Besides, in announcement stage, the agent with the task sends out an announcement of the task which includes a specification of the task to be achieved. As for bidding, agents in this progress receive the announcement, and decide for themselves whether they wish to bid for the task.

In the awarding and expediting stages, the agent that sent task announcement must choose between bids and decide who to "award the contract" to. The result of this process is communicated to agents that submitted a bid. The successful contractor then expedites the task. The successful contractor may also involve generating further manager-contractor relationships: sub-contracting.

(c) Anyone who wishes to register a new vehicle in Singapore must first obtain a Certificate of Entitlement (COE). COEs are bid through the COE Open Bidding System. The number of successful bidders is limited by the COEs available for each particular COE category. Each successful bidder pays the price of the highest unsuccessful bid. Assume that each bidder wants only one COE. Is the biding mechanism truthful? Explain why.

The COE bidding system is truthful since it is a open bidding system.

We get five stages of the bidding process of this policy:

1. Bidders submit their reserve price to the open bidding system. This price is the maximum amount that the bidder is ready to pay for their COE.
2. Then, the bidding system automatically raises the current COE price by 1$. The COE price is raised depending of the bidder's reserve price.
3. When a bidder's reserve price is outmatched by the current COE price (CCP), that bidder is out of the bid, and his deposit is given back.
4. When the number of bidders that had their reserve price over the CCP and the number of available COE equals, then the CCP stops.
5. The bidding then stops, and the bidders that are left in the bid win their COE.

The above steps conform to the 5 stages of CONTRACT NET and are therefore trustworthy.

Question 4

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

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

For matrix A, cooperation is a dominant strategy for agent i. This is because, when j cooperates, i can choose to cooperate to get a greater payoff, that is 7, and when agent j defects, the choice of agent i has no effect on its payoff. Thus, we can say that cooperation is a dominant strategy for agent i. Similarly, cooperation is a weakly dominant strategy for agent j because when i cooperates, j can choose to cooperate for a larger payoff, that is 8, but when i does not cooperate, agent j's choice has no effect on its payoff.

As for matrix B, cooperation is the dominant strategy for agent j. When agent i cooperates, j can choose to cooperate in order to receive a payoff of 5, which is higher than 2 when it chooses to defect. And when i does not cooperate, j's choice makes no difference to its payoff, which is 3.

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

For matrix A, both agent i and j cooperating is a Nash equilibrium.

If j cooperates, i can do no better than cooperating because the agent i receives a payoff of 7 and 6 if it cooperates and defects, respectively.

If i cooperate, j can do no better than cooperating, because the agent j receives a payoff of 8 and 7 if it cooperates and defects, respectively.

There is no strategy pairs in Nash equilibrium in matrix B.

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

In matrix A, pair (C, C), both i and j cooperating is Pareto optimal since there is no other better outcome that makes one agent better off without making another agnte worse off. The outcome is (7, 8) and total payoff is 15.

As for both i and j defecting (7, 7), it is not Pareto optimal payoff for j can get higher if i cooperates. The pair of i cooperating and j defecting (7, 7) is also not Pareto optimal. Lastly agent i defecting and j cooperating is not Pareto optimal because both of them can choose to other strategy to get a better payoff.

In matrix B, all pairs except pair (D, D) are Pareto optimal. For (D, D) pair, that is both i and j defecting, j can choose to cooperate to improve total payoff of i (from 2 to 3) without losing payoff of other agents. Therefore, it is not Pareto optimal.

As for the pair (D, C) , i.e., i defecting and j cooperating, there is no other outcome that makes one agent's situation better without making the other agent's situation worse. For example, i can choose to cooperate to get more payoffs (from 3 to 4), but it will reduce agent j's payoff to 2.

Similarly, the pair (C, D) is also Pareto optimal, any changes of strategy to increase payoff of agent i decreases that of agent j. So is the pair (C, C), any changes to increase payoff of agent j decreases that of agent i.

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

Social welfare is the total amount of utility that each agent receives from an outcome. Threfore, for matrix A, social welfare peaks when both agent i and agent j cooperate, with a total payoff of 15. As for matrix B, all outcomes except $(D; D)$ maximise social welfare, and the highest pay off is 6.