National University of Singapore
School of Computing

Semester 1, AY2023-24

CS4246/CS5446 AI Planning and Decision Making

Due: 23 Oct 2023@09:00

Assignment 2

Instructions

- This assignment requires 2 submissions.
  - Submit the PDF file containing your solutions to this assignment on Canvas.
  - You can use this Overleaf project to write your solutions.
  - Submit the ZIP file containing your code to this separate assignment on Canvas.
- You have only one attempt on Canvas.
- You are required to specify your group details in your attempt (group number can be found on Canvas) by updating the `team.tex` file with the relevant details.
- **Total marks: 20; Weightage 10% of final marks**
- On collaboration:
  - The goal of the assignment is to understand and apply the concepts in the class.
  - You may discuss the assignment with other groups via the discussion forum.
  - It is OK for the solution ideas to arise out of such discussions. However, it is considered plagiarism if the solution submitted is highly similar to other submissions or to other sources.
- Citing help and reference
  - At the end of the assignment, clearly cite the sources you referred to when arriving at the answer (Books, External notes, Generative AI tools, etc.,).

Team members

Group number: P35
Member 1 details:
- Name: Niharika Shrivastava
- NUSNet id: E0954756
- Student number: A0254355A

Member 2 details:
- Name: Harshavardhan Abichandani
- NUSNet id: E0945792
- Student number: A0250610X

1 Decision Analysis: EVPI

Singoil refineries, catering to the ASEAN market, like any other petroleum refinery is affected by the demand-supply problem. After analyzing some historical data, the analysts have identified the demand to be three discrete values: 90 million barrels/month, 100 million barrels/month, or 120 million barrels/month. The monthly demand has the following probabilities:

Demand	Demand probability
90 mil barrels	0.2
100 mil barrels	0.5
120 mil barrels	0.3

Table 1: Oil demand probabilities

The cost of producing oil (per 10 million barrels) is \$70 million. Singoil sells oil at \$90 million per 10 million barrels.

1. (4 marks) Based on the above information, how many barrels of oil should Singoil produce monthly to maximize the profit? (Show your working)

2. (4 marks) Sureoil predictors employ Pauline, Paul, the Octopus' cousin, to accurately predict the monthly oil demand. How much should Singoil be paying for Pauline's prediction so that the profit is maximized? (Show your working)

Solution:

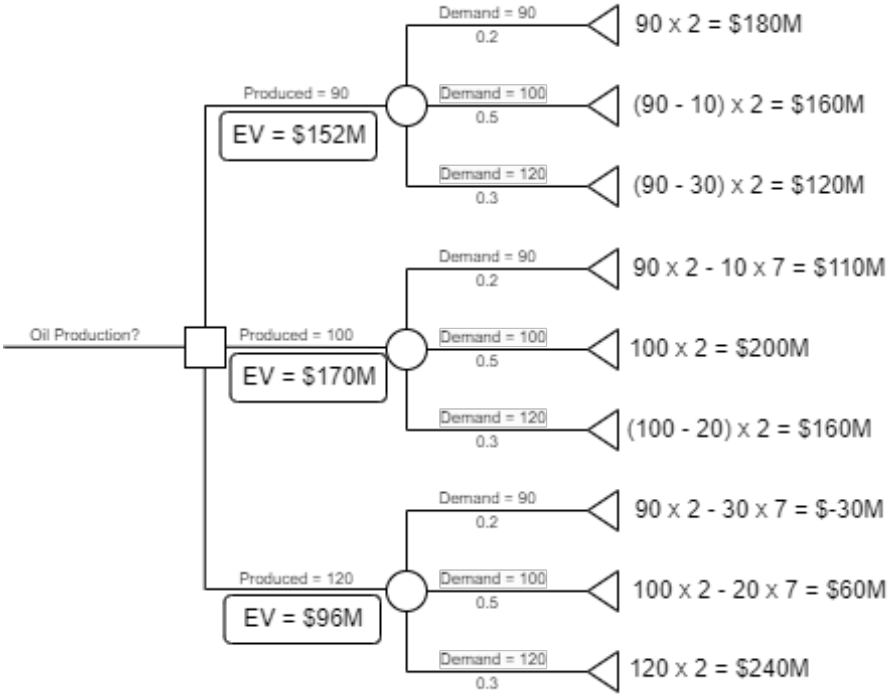
1. Singoil has a decision to make$\{90, 100, 120\}$ million barrels of oil. Based on the demand it incurs a profit/loss. Assuming the following utility function:

$$U(Demand) = (UnitsSold - UnitsDeficient) \times Profit - UnitsSurplus \times CostPrice$$

where
$UnitsSold$: Number of barrels sold,
$UnitsDeficient$: $(Demand$ - $UnitsSold)$ in case oil production was lesser than the demand,
$UnitsSurplus$: $(UnitsSold - Demand)$ in case oil production was more than the demand,
$Profit = (90million - 70million)/10million =$ \$2 million per barrel,
$CostPrice =$ \$7 million per barrel

The above utility function captures the opportunity cost as well as the loss incurred on the unsold goods. Eg., If Singoil decides to produce 90 million barrels and the demand is 100 million barrels, then based on our utility they will make profit on the 90 million barrels sold, but also incur an opportunity cost on the remaining 10 million barrels.

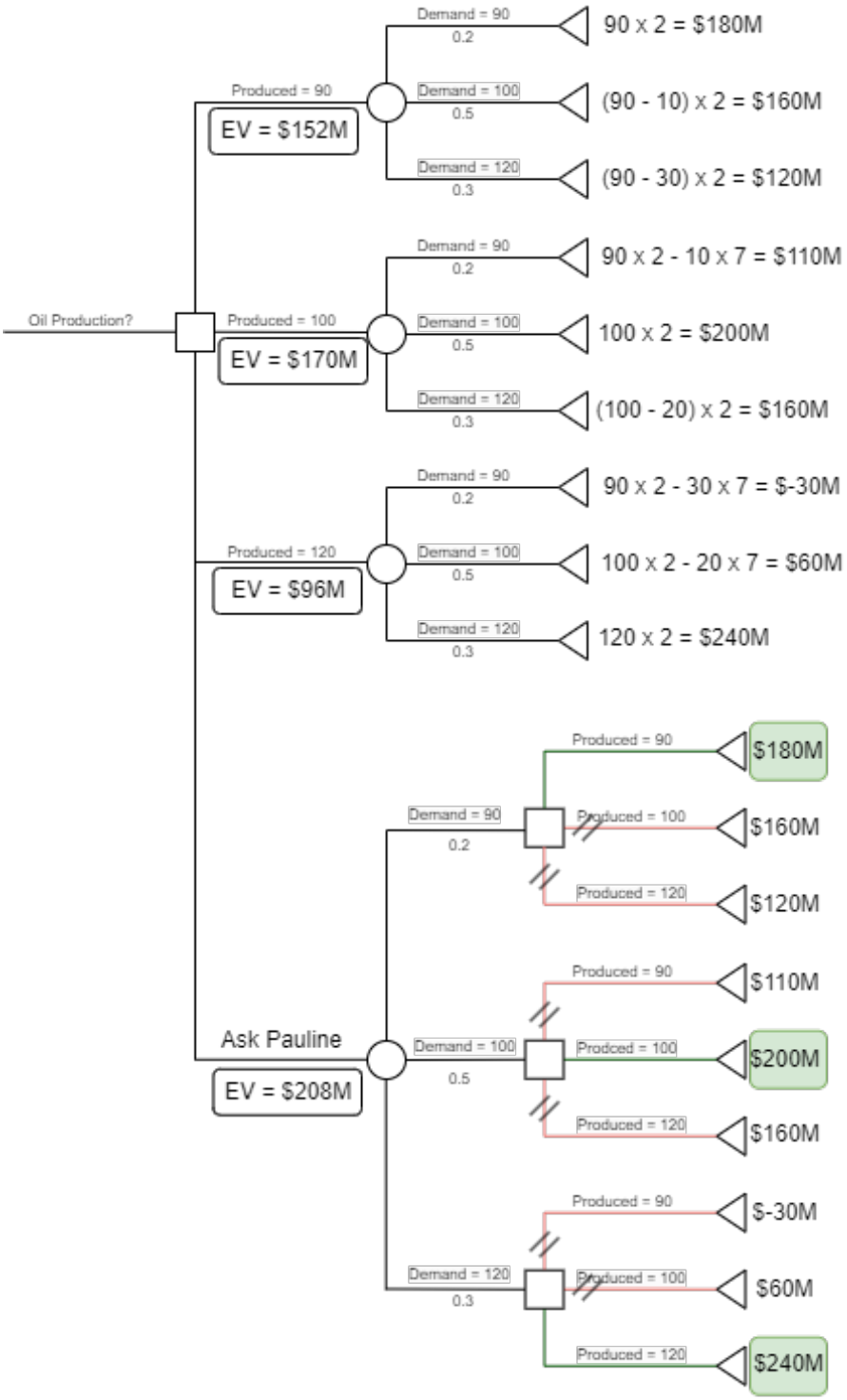
Based on this utility function we have calculated the following values (all numbers for demand and production represent a scale of million).



Based on the above figure EMV $= \max(152M, 170M, 96M) = \$170M$. This corresponds to a production of 100 million barrels. Therefore Singoil should produce **100 million barrels**.

2.

Expected Value of Perfect Information (EVPI) = EMV(with perfect info) − EMV(original)
Based on the figure below,
EVPI $= (\$208M - \$170M) = \$38M$
Therefore, Singoil should pay **up to $ 38 million** to Pauline.


Oil Production?
Produced = 90
EV = $152M
Demand = 90
0.2
90 x 2 = $180M
Demand = 100
0.5
(90 - 10) x 2 = $160M
Demand = 120
0.3
(90 - 30) x 2 = $120M
Produced = 100
EV = $170M
Demand = 90
0.2
90 x 2 - 10 x 7 = $110M
Demand = 100
0.5
100 x 2 = $200M
Demand = 120
0.3
(100 - 20) x 2 = $160M
Produced = 120
EV = $96M
Demand = 90
0.2
90 x 2 - 30 x 7 = $-30M
Demand = 100
0.5
100 x 2 - 20 x 7 = $60M
Demand = 120
0.3
120 x 2 = $240M
Ask Pauline
EV = $208M
Demand = 90
0.2
Produced = 90
$180M
Produced = 100
$160M
Produced = 120
$120M
Demand = 100
0.5
Produced = 90
$110M
Produced = 100
$200M
Produced = 120
$160M
Demand = 120
0.3
Produced = 90
$-30M
Produced = 100
$60M
Produced = 120
$240M

2 MDP

Moonwalker, the moon rover, is embarking on a mission to the moon to collect "interesting" rock samples in five regions on the moon: (regions $R1, R2, R3, R4, R5$). Moonwalker's two actions are to drill for rock samples (D) or stop to charge the onboard batteries using sunlight (C).

1. (4 marks) Formulate Moonwalker's decision problem as a discrete MDP with the following conditions:
   (a) Moonwalker starts from $R1$ and progressively goes to regions with higher index (i.e., $R1 \rightarrow R2 \cdots \rightarrow R5$). When it reaches $R5$ it will stay there forever, irrespective of the action.
   (b) For the other regions if action D is taken, it will always transition to the next region at the next time step; if action C is taken, it will always remain in the same region at the next time step.
   (c) Assume that "interesting" rocks are found only in region $R3$, and will give a reward of 256, if action D is carried out; all other rewards are zero.

   Specify the state space and action space using proper set notations; transition function, and reward function as tables for convenience.

2. (2 marks) If the utility of state $R1, U^*(R1) = 4$, what is the discount factor γ based on the considerations given in the above question?

Solution:

1.

States = {R1, R2, R3, R4 R5}
Actions = {Drill (D), Charge (C)}

State(s)	Action(a)	Next State(s')	T(s, a, s')	R(s, a)
R1	C	R1	1	0
R1	D	R2	1	0
R2	C	R2	1	0
R2	D	R3	1	0
R3	C	R3	1	0
R3	D	R4	1	256
R4	C	R4	1	0
R4	D	R5	1	0
R5	C	R5	1	0
R5	D	R5	1	0

2.

Utility of state is the value of optimal policy. Given by:

$$U(s) = U^{\pi^*}(s) = \max_{a \in A(s)} \sum_{s'} P(s'|s,a)[R(s,a,s') + \gamma U(s')]$$

Note:

1. In our case $P(s'|s,a) = 1$ because there is no uncertainty in the environment.
2. The rewards in our environment are a function of current state and action (Independent of next state) $R(s,a)$.
3. $U^*(R_1) = 4$ Therefore, the utility at R_1 after **convergence** is 4.
4. Assuming $\gamma \in [0,1]$.

Hence, the utility of a state at the current horizon h is given by:

$$U_h(s) = \max_a \left[R(s,a) + \gamma \sum_{s'} U_{h-1}(s') \right]$$

In order to derive the value of γ, we solve the MDP till convergence in the below table.

Horizon(h)	$U(R_1)$	$U(R_2)$	$U(R_3)$	$U(R_4)$	$U(R_5)$
0	0	0	0	0	0
1	0	0	$\max_a[256, 0] = 256$	0	0
2	0	$\max_a[0, \gamma 256] = \gamma 256$	$\max_a[\gamma 256, 256] = 256$	0	0
3	$\max_a[0, \gamma^2 256] = \gamma^2 256$	$\max_a[\gamma 256, \gamma^2 256] = \gamma 256$	256	0	0
4	$\max_a[\gamma^3 256, \gamma^2 256 = \gamma^2 256$	$\gamma 256$	256	0	0

The MDP converges at $h = 4$. Hence,

$$U^*(R_1) = \gamma^2 \cdot 256 = 4$$

$$\implies \gamma = \sqrt{\frac{4}{256}} = 0.125$$

3 Programming component

(6 marks)

In this programming assignment, we will use a modified form of the elevator domain from the International Planning Competition, 2023.

The Elevator domain models evening rush hours when people from different floors in a building want to go down to the ground floor using elevators. Potential passengers arrive at a floor according to the Poisson process, with specific rates that can be different across different floors. An elevator can move upwards to pick up passengers; once it opens its door to let people in, it can only move down towards the ground floor, though the elevator can stop at intermediate floors to pick up more passengers.

Per each person in an elevator, there is a small penalty in rewards. Additionally, there is a penalty for each person waiting for an elevator. When an elevator delivers a passenger to their destination, a large positive reward is given per person. So, a good policy should be able to minimize the penalties while maximizing the positive rewards by delivering many people so that they can go back home!

Handout and task

- Use the `assignment2_handout.zip` file on Canvas to attempt the programming assignment.
- The `README.md` file has additional details about the environment.
- Your task is to complete the `solve_value_iteration` function that implements the Value Iteration algorithm in the `agent/agent.py` file. (It is marked with `FILL_ME`)

Submission

- Please write both the team member names and student numbers (Axxxxxxx) at the top of the agent file (as comments) to help us identify your submissions.
- **Zip the `agent.py` file alone and submit this zip file.**
- Submissions for the programming part will happen on the AiRENA portal for grading.
- You are **also required** to submit the zip file on Canvas for record-keeping/backup purposes.
- Please refer to the user guide (`AiRENA Guide for CSxx46.pdf` file on Canvas) for submission instructions.
  - Please ensure you follow the instructions provided to create your account.
  - If the account details don't match your information on Canvas, such submissions will not be graded.
- You need to use the following token to join the course:
  b68f4d45-a95f-449d-93f7-2e1f0edf154e

Grading

- We will evaluate your implementation using three private test cases, and take the average of the score obtained.
- To obtain full 6 marks for this part, you need to attain an average score of -300 and above.

Support

- We have prepared a Google collab file for you to play around and understand the elevator domain.
- If you have questions about the assignment, please ask on the discussion forums.
