National University of Singapore
School of Computing

Semester 1, AY2023-24

CS5446 AI Planning and Decision Making

Due: 9 Oct 2023@09:00

Assignment 1

Instructions

- Submit the PDF file containing your solutions on the Canvas.
  - You can use this Overleaf project to write your solutions.
- You have only one attempt on Canvas.
- You are required to specify your group number in your attempt (group number can be found from Canvas).
  - Update 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: A35

Member 1 details:
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Member 2 details:
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1 Classical planning: Elevator

You are developing a planner to operate an elevator in a building with just two floors ($Level0$ and $Level1$). You have three actions available for the elevator $Move$, $OpenDoor$, and $CloseDoor$. $Move$ automatically moves the elevator up if it is in $Level0$ and down if it is in $Level1$, you don't have to check for the direction. However, the elevator cannot move if the door is open. The elevator door can be opened only if it is closed, and it can be closed only if it is open.

1. (6 marks) Write the action schemas for $Move$, $CloseDoor$, and $OpenDoor$ actions following PDDL notations. You can use negative preconditions. State/define all the predicates and fluents you use in your action schema.

   Solution:

Action:	$Move(Elevator, from, to)$
Precondition:	$At(Elevator, from) \wedge Floor(from) \wedge Floor(to) \wedge \neg Open(ElevatorDoor)$
Effect:	$\neg At(Elevator, from) \wedge At(Elevator, to)$
Action:	$CloseDoor(ElevatorDoor)$
Precondition:	$Open(ElevatorDoor)$
Effect:	$\neg Open(ElevatorDoor)$
Action:	$OpenDoor(ElevatorDoor)$
Precondition:	$\neg Open(ElevatorDoor)$
Effect:	$Open(ElevatorDoor)$

2. (4 marks) If negative preconditions are not allowed, how would your schema change? Write the updated schema for $Move$ and highlight the differences from your above answer.

   Solution:

Action:	$Move(Elevator, from, to)$
Precondition:	$At(Elevator, from) \wedge Floor(from) \wedge Floor(to) \wedge$ Close(ElevatorDoor)
Effect:	$\neg At(Elevator, from) \wedge At(Elevator, to)$

   Since negative preconditions are not allowed in the action schema, we will introduce a new fluent "$Close(ElevatorDoor)$" that will replace the negative fluent "$\neg Open(ElevatorDoor)$."

2 Planning and Satisfiability

1. (2 marks) The fluents in a planning problem end up in the following form

$$(A \wedge B) \vee (P \wedge Q) \vee Z$$

after being simplified by Mr. Bean, who plans to use a SAT solver to determine the problem's satisfiability. Help Mr. Bean by writing the form of the expression that can be fed into a SAT solver. (Show the steps in arriving at the appropriate form).

Solution:
In order to convert the expression into a form that can be fed into a SAT solver, we need to convert it to its corresponding Conjunctive Normal form (CNF).

$(A \wedge B) \vee (P \wedge Q) \vee Z$
= $(A \vee (P \wedge Q)) \wedge (B \vee (P \wedge Q)) \vee Z$ (Distributive law)
= $(A \vee P) \wedge (A \vee Q) \wedge (B \vee P) \wedge (B \vee Q) \vee Z$ (Distributive law)
= $(A \vee P \vee Z) \wedge (A \vee Q \vee Z) \wedge (B \vee P \vee Z) \wedge (B \vee Q \vee Z)$ (Distributive law)

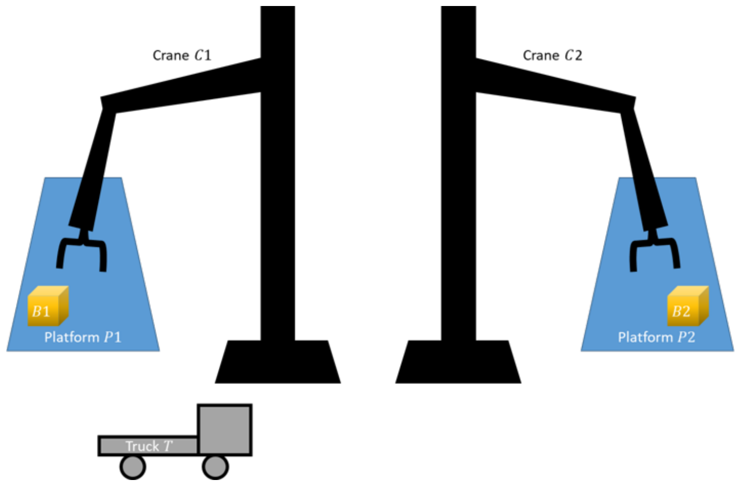


Figure 1: Swapping problem

3 Hierarchical planning: Transportation

Consider the following problem of swapping containers, $(B1, B2)$ on the two platforms, $(P1, P2)$. The cranes $(C1, C2)$ help to load and unload the containers onto the truck (T). Figure 1 shows the schematic representation of the problem.

1. (4 marks) Draw the HTN hierarchy (similar to the "Going to Changi Airport" example on Slide 4 of the Hierarchical Planning lecture notes) for this swapping problem. Clearly indicate the refinements and implementations in your answer.
   Note: You are **not required to** include the precondition, effects, or the action schemas. Just writing which are the refinements and what are the implementations clearly is sufficient.

   Solution:

   Definitions for clarification:

   (a) Swap(container, container)
   (b) Deliver(container, to)
   (c) Load(container, on, from, using)
   (d) Drive(vehicle, from, to)
   (e) Unload(container, on, from, using)

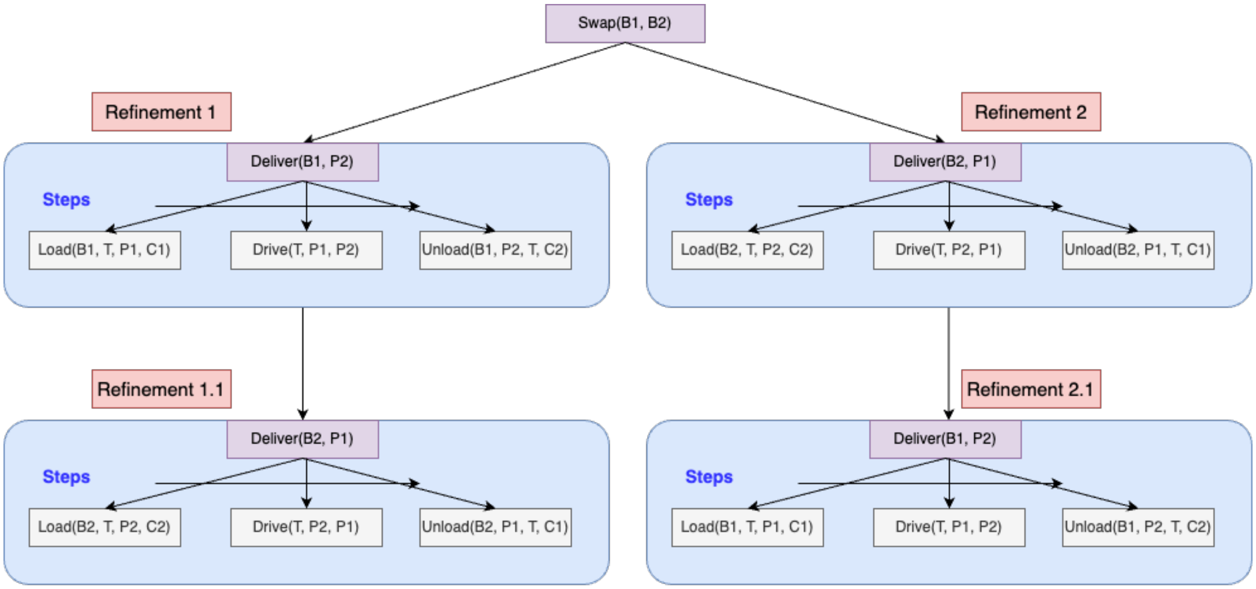


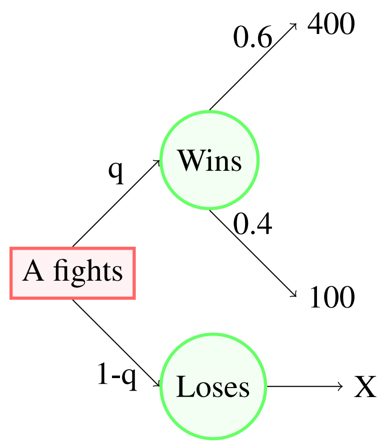
Figure 2: Hierarchical Task Network

4 Decision theory

Company A (A) and Company B (B) are suing each other over patent infringements. If A wins, there is a 60% chance that it will dominate the market with a total valuation of \$400 billion, and a 40% chance that it will have a valuation of \$100 billion (after paying for the lawsuit).

1. (2 marks) Let q be the probability that A will win the patent lawsuit. Let X be the valuation if it loses the patent lawsuit. What is the expected monetary value for A's situation? Express your answer in the simplest form in terms of q and X.

Solution:



Assuming that both Company A and B are rational agents and prefer more money, we define a utility function as:

$$U(x) = x$$

i.e., the utility of each outcome is its corresponding monetary value.
We know, that the expected utility of this situation is the average utility value of the outcomes, weighted by the probability that the outcome occur. (We assume the notation that "a" represents Company A's overall situation of needing to fight the lawsuit).

$$EV[a] = \sum_{s'} \sum_{s} P(s)P(s'|s,a)U(s')$$

Therefore,

$EV[a] = q[0.6 \cdot 400 + 0.4 \cdot 100] + (1-q)(\mathbf{X})$

$EV[a] = 280q + (1-q) \cdot X$

$EV[a] = \$(280q + X - qX)$ billion

2. (2 marks) If B decides to negotiate a settlement with A, what is the minimum value (in terms of X and q) that the CEO of A must demand?

Solution:

Assuming that A is a rational agent, the minimum value the CEO of A must demand is equal to the Certainty Equivalent (CE) of this situation. We know that the expected monetary value equals the utility of its certainty equivalent.

$$EV[a] = U(CE) = CE$$

Therefore, the CEO of A must demand $\$(280q + X - qX)$ billion in order to negotiate a settlement.