

## COS30019 – Final Assessment

### Answering Instructions:

Please do not use a red pen/type in red.

**There are 5 problems.**

Total marks on paper: 90 + 8 bonus marks

The maximum mark you can get for the final assessment is 90 (100%). However, if you lose marks in some questions and you get the bonus marks, the bonus marks will be added to your total of the final assessment.

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## Problem 1 – Propositional Logic (18 marks)

About the insurance policy the intelligent agent is reviewing, the agent knows the following:

- *IF the policy holder has made no insurance claims AND (the policy holder is a new customer OR the policy holder holds multiple policies with the company), THEN the policy holder is eligible for a discount.*
- *The policy holder is NOT eligible for a discount.*
- *The policy holder has made no insurance claims.*

Represent the above knowledge base in propositional logic using the following vocabulary:

(5 marks)

**NC** for *The policy holder has made no insurance claims*,

**NEW** for *The policy holder is a new customer*,

**MP** for *The policy holder holds multiple policies with the company*,

**DC** for *The policy holder is eligible for a discount*.

Using a **truth table**, please answer the following questions:

- a. How many models does the knowledge base have? (5 marks)
- b. Is the policy holder a new customer? (4 marks)
- c. Does policy holder hold multiple policies with the company? (4 marks)

For questions (b) and (c), your answer has to be **Yes** or **No** or **Don't know**. For instance, if you answer **Yes** to question **1.b.**, you'll have to demonstrate that the knowledge base entails '*The policy holder is a new customer*'; if you answer **No** to question **1.b.**, you'll have to demonstrate that the knowledge base entails '*The policy holder is NOT a new customer.*' Clearly indicate which **rows** of the truth table support your answer.

**Answer:**

Truth Table for Insurance Policy Statement:

NC	NEW	MP	DC	$(NC \wedge (NEW \vee MP))$	$(NC \wedge (NEW \vee MP)) \Rightarrow DC$	$\neg DC$
T	T	T	T	T	T	F
T	T	T	F	T	F	T
T	T	F	T	T	T	F
T	T	F	F	T	F	T
T	F	T	T	T	T	F
T	F	T	F	T	F	T
T	F	F	T	F	F	F
T	F	F	F	F	T	T
F	T	T	T	F	T	F
F	T	T	F	F	T	T
F	T	F	T	F	T	F
F	T	F	F	F	T	T
F	F	T	T	F	T	F
F	F	T	F	F	T	T
F	F	F	T	F	T	F
F	F	F	F	F	T	T

Knowledge Base (KB):

1.  $NC \wedge (NEW \vee MP) \Rightarrow DC$
2.  $\neg DC$
3.  $NC$

a) How many models does the knowledge base have?

- Based on the insurance policy, if the policy holder has made insurance claims, then he/she is NOT eligible for a discount. Therefore, we can focus on the first 8 rows of truth table, where  $NC = \text{True}$ .

- Based on the first 8 rows, there are 4 models that the knowledge base has.

⇒ **4 models**

b) Is the policy holder a new customer?

- Based on the 2<sup>nd</sup> column of the truth table, we can see the value of NEW is True or False depending on different cases of KB.

⇒ **Don't know if the policy holder is a new customer.**

c) Does policy holder hold multiple policies with the company?

- Based on the 3<sup>rd</sup> column of the truth table, we can see the value of MP is True or False depending on different cases of KB.

⇒ **Don't know if the policy holder holds multiple policies with the company.**

## Problem 2 – Propositional Logic (16 marks)

Decide whether each of the following sentences is **valid**, **unsatisfiable**, or **neither**. Verify your decisions using truth table. Clearly indicate which **rows** of the table support your answer.

- $(\neg A \vee B) \wedge (A \wedge \neg B)$
- $(A \wedge \neg B) \Rightarrow A$
- $A \vee (B \Rightarrow B)$
- $(A \Rightarrow \neg A) \wedge B$

*Hint:* You can use just one truth table for all four sentences.

(4x4=16 marks)

### Answer:

A	B	$\neg A$	$\neg B$	$(\neg A \vee B)$	$(A \wedge \neg B)$	$(\neg A \vee B) \wedge (A \wedge \neg B)$	$(A \wedge \neg B) \Rightarrow A$	$A \vee (B \Rightarrow B)$	$(A \Rightarrow \neg A)$	$(A \Rightarrow \neg A) \wedge B$
T	T	F	F	T	F	F	T	T	F	F
T	F	F	T	F	T	F	T	T	F	F
F	T	T	F	T	F	F	T	T	T	T
F	F	T	T	T	F	F	T	T	T	F

- a)  $(\neg A \vee B) \wedge (A \wedge \neg B)$

The column 7 of the truth table represents the value of  $(\neg A \vee B) \wedge (A \wedge \neg B)$ , which equals False every rows  
 $\Rightarrow$  **Unsatisfiable**

- b)  $(A \wedge \neg B) \Rightarrow A$

The 8<sup>th</sup> column of the truth table represents the value of  $(A \wedge \neg B) \Rightarrow A$ , which equals True every rows  
 $\Rightarrow$  **Valid**

- c)  $A \vee (B \Rightarrow B)$

The 8<sup>th</sup> column of the truth table represents the value of  $A \vee (B \Rightarrow B)$ , which equals True every rows  
 $\Rightarrow$  **Valid**

- d)  $(A \Rightarrow \neg A) \wedge B$

The 11<sup>th</sup> column of the truth table represents the value of  $(A \Rightarrow \neg A) \wedge B$ , which might equal True or False in different cases, so there is no fixed value for this sentence.  
 $\Rightarrow$  **Neither**

### Problem 3 – First-Order Logic (16 marks)

Represent the following statements in first-order logic, using the following vocabulary:

<b>Student(x):</b>	<b>x is a student</b>
<b>Phone(y):</b>	<b>y is a phone</b>
<b>Game(z):</b>	<b>z is a game</b>
<b>Has(u,v):</b>	<b>u has v</b>
<b>Plays(u,v):</b>	<b>u plays v</b>

1. Every student has some phones.
2. There is a student who has all games or plays some games.
3. Every student has all games but does not play some games.
4. There is a student who has exactly one phone.

(4+4+4+4 = 16 marks)

#### Answer:

1. Every student has some phones:

$$\forall x (\text{Student}(x) \Rightarrow \exists y (\text{Phone}(y) \wedge \text{Has}(x, y)))$$

Statement 1 indicates that for every student, there exists at least one phone they have.

2. There is a student who has all games or plays some games:

$$\exists x (\text{Student}(x) \wedge ((\forall z (\text{Game}(z) \Rightarrow \text{Has}(x, z))) \vee (\exists z (\text{Game}(z) \wedge \text{Plays}(x, z))))$$

Statement 2 indicates that there exists a student who either has all games or plays some games (or both).

3. Every student has all games but does not play some games:

$$\forall x (\text{Student}(x) \Rightarrow ((\forall z (\text{Game}(z) \Rightarrow \text{Has}(x, z))) \wedge (\exists z (\text{Game}(z) \wedge \neg \text{Plays}(x, z))))$$

Statement 3 indicates that every student has all games but avoids playing some games.

4. There is a student who has exactly one phone:

$$\exists x (\text{Student}(x) \wedge (\exists y (\text{Phone}(y) \wedge \text{Has}(x, y)) \wedge \neg \exists y' (\text{Phone}(y') \wedge \text{Has}(x, y') \wedge y' \neq y)))$$

Statement 4 indicates the existence of a student with exactly one phone.

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## Problem 4 – AI Planning (25 marks)

Our agent is a robot with two hands: *Hand1* and *Hand2*. The robot's task is to tidy up the room by putting rubbish into the *Bin* and putting things at their right places. Initially, the robot is at the *Door*, the *Rubbish* and the *Toy* are at the *Table* and both hands of the robot are free. The right place for the *Toy* is at the *Shelf*. The actions available to the robot include *Go* from one place to another, and *Grasp* or *Ungrasp* an object. Grasping results in holding the object using a free hand if the robot and object are at the same place. One effect of grasping is that the free hand that the robot uses to grasp the object will no longer be free after grasping the object.

1. Write down the initial state description and the agent's goals. (7 marks)
2. Write down STRIPS-style definitions of the three actions. (9 marks)
3. Write down a consistent partial-order plan (POP) with no open preconditions for this problem. (9 marks)

(Hint: You may consider using the following template for question 3 of this problem:

**Actions** = {Start, Go (Door, Table), ...}

**Orderings** = {Start < Go (Door, Table), ...}

**Links** = {Start - RobotAt (Door) -> Go (Door, Table), ...}

**Open preconditions** = {...}

And complete it with your answer.

You may also want to include a hand-drawn diagram showing the partial-order plan POP if you wish.)

### Answer:

- 1) Write down the initial state description and the agent's goals:
  - Initial state
    - Robot: RobotAt (Door)
    - Object: RubbishAt (Table); ToyAt (Table)
    - Hands: Free (Hand1); Free (Hand2)
  - Agent's goals
    - RubbishAt (Bin)
    - ToyAt (Shelf)
- 2) Write down STRIPS-style definitions of the three actions:
  - Go (x, y)
    - Precondition: RobotAt (x)
    - Effect:  $\neg$ RobotAt (x), RobotAt (y)
  - Grasp (Obj, Hand)
    - Precondition: Free (Hand), At (Obj, x), RobotAt (x)
    - Effect: Holding (Obj, Hand),  $\neg$ Free (Hand)
  - Ungrasp (Obj, Hand)
    - Precondition: Holding (Obj, Hand)
    - Effect:  $\neg$ Holding (Obj, Hand), Free (Hand), At (Obj, x), RobotAt (x)

3) Write down a consistent partial-order plan (POP) with no open preconditions for this problem:

- **Actions** = {Start; Go (Door, Table); Grasp (Rubbish, Hand1); Go (Table, Bin); Ungrasp (Rubbish, Hand1); Go (Bin, Table); Grasp (Toy, Hand2); Go (Table, Shelf); Ungrasp (Toy, Hand2); End}
- **Orderings** = {Start < Go (Door, Table); Go(Door, Table) < Grasp (Rubbish, Hand1); Grasp (Rubbish) < Go (Table, Bin); Go (Table, Bin) < Ungrasp (Rubbish, Hand1); Ungrasp (Rubbish, Hand1) < Go (Bin, Table); Go (Bin, Table) < Grasp (Toy, Hand2), Grasp (Toy, Hand2) < Go (Table, Shelf), Go (Table, Shelf) < Ungrasp (Toy, Hand2), Ungrasp (Toy, Hand2) < End}
- **Links** = {Start - RobotAt(Door) -> Go (Door, Table); Go (Door, Table) - RobotAt(Table) -> Grasp (Rubbish, Hand1); Grasp (Rubbish, Hand1) – Holding (Rubbish, Hand1) -> Go (Table, Bin); Go(Table, Bin) – RobotAt (Bin) -> Ungrasp (Rubbish, Hand1), Ungrasp (Rubbish, Hand1) – RubbishAt (Bin) -> Go (Bin, Table), Go (Bin, Table) – RobotAt (Table) -> Grasp (Toy, Hand2); Grasp (Toy, Hand2) – Holding (Toy, Hand2) -> Go (Table, Shelf), Go (Table, Shelf) – RobotAt (Shelf) -> Ungrasp (Toy, Hand2), Ungrasp (Toy, Hand2) – ToyAt (Shelf) -> End}
- **Open Preconditions** = { }

## Problem 5 – Uncertain reasoning (15 marks + 8 bonus marks)

Mr James Bond takes his car to the mechanic for regular servicing. The mechanic runs a test on the car transmission. The test would return one of two values: **TF** or **NF**. If the test returns **TF**, it indicates that the transmission has a major issue and needs to be replaced. If the test returns **NF**, it indicates that the tests finds no issues and the transmission does not need to be replaced. The accuracy of the test is as follows: The probability of the test returning **TF** when the car transmission is actually faulty is 0.99, and the probability of the test returning **NF** when the car transmission is NOT faulty is 0.97. After running the test on Mr James Bond's car, the mechanic told him that the test returns **TF**. According to the manufacturer of Mr James Bond's car, at the age of his car, only 1 in 500 cars would have a faulty transmission that needs replacement.

Please use the following vocabulary when answering the following questions **using Bayes' rules**:

**F** – The car transmission is faulty

**TF** – The test returns the value **TF** indicating that the transmission has major issues

1. What is the probability that Mr James Bond's car transmission is faulty?  
(15 marks)
2. **(Bonus question)** After further investigation, we also know that Mr James Bond has a very aggressive driving style that is really damaging to the car transmission and the car manufacturer informs that with Mr James Bond's driving style, 1 in 10 cars would have a faulty transmission that needs replacement. The mechanic then informs that the cost of replacing the transmission is \$4,000. If the car transmission does have a major issue and it is not replaced, then it will break during driving causing the entire engine to be broken which will cost \$12,000. If Mr James Bond does not replace the transmission of his car now, what is the *expected cost* for him? If Mr James Bond is rational, would he replace the car transmission now?  
(8 bonus marks)

### Answer:

1. What is the probability that Mr James Bond's car transmission is faulty?
  - The probability of the test returning TF when the car transmission is actually faulty is 0.99  
 $\Rightarrow P(\text{TF}|\text{F}) = 0.99$
  - The probability of the test returning NF when the car transmission is NOT faulty is 0.97, so the test returning TF when the car transmission is NOT faulty equals  $(1 - 0.97)$   
 $\Rightarrow P(\text{TF}|\sim\text{F}) = 1 - 0.97 = 0.03$
  - At the age of Mr James Bond's car, only 1 in 500 cars would have a faulty transmission that needs replacement  
 $\Rightarrow P(\text{F}) = 1/500 = 0.002$   
 $\Rightarrow P(\sim\text{F}) = 1 - P(\text{F}) = 1 - 0.002 = 0.998$
  - According to the Bayes Rules, the value of  $P(\text{F}|\text{TF})$  can be calculated like this:  
$$P(\text{F}|\text{TF}) = (P(\text{TF}|\text{F}) * P(\text{F})) / (P(\text{TF}|\text{F}) * P(\text{F}) + P(\text{TF}|\sim\text{F}) * P(\sim\text{F}))$$
$$= (0.99 * 0.002) / ((0.99 * 0.002) + (0.03 * 0.998))$$
$$= 0.062$$

$\Rightarrow$  So, with the value **TF** returned, the probability that James Bond's car transmission is faulty is **6.2%**.



2. **(Bonus question)** After further investigation, we also know that Mr James Bond has a very aggressive driving style that is really damaging to the car transmission and the car manufacturer informs that with Mr James Bond's driving style, 1 in 10 cars would have a faulty transmission that needs replacement. The mechanic then informs that the **cost of replacing the transmission is \$4,000. If the car transmission does have a major issue and it is not replaced, then it will break during driving causing the entire engine to be broken which will cost \$12,000.** If Mr James Bond does not replace the transmission of his car now, what is the *expected cost* for him? If Mr James Bond is rational, would he replace the car transmission now?

- With Mr James Bond's driving style, 1 in 10 cars would have a faulty transmission that needs replacement

⇒ New  $P(F) = 1/10 = 0.1$

⇒ New  $P(\sim F) = 1 - P(F) = 1 - 0.1 = 0.9$

- According to the Bayes Rules, the value of  $P(F|TF)$  can be calculated like this:

$$\begin{aligned} P(F|TF) &= (P(TF|F) * \text{New } P(F)) / (P(TF|F) * \text{New } P(F) + P(TF|\sim F) * \text{New } P(\sim F)) \\ &= (0.99 * 0.1) / ((0.99 * 0.1) + (0.03 * 0.9)) \\ &\approx 0.786 \end{aligned}$$

- If the car transmission does have a major issue and it is not replaced, then it will break during driving causing the entire engine to be broken which will cost \$12,000.

⇒ On this condition, the expected cost for him will be:  $12000 * P(F|TF) + (1 - P(F|TF)) * 0 = \mathbf{9432}$

- If Mr. Bond is rational, **he would replace the transmission now**, since if the transmission break, he will have to spend \$9,432 to fix his car, while replacing the transmission only cost him \$4,000.