Due: **by 11:59pm on the due date**.

Total marks: **10**.

Weighting: This assignment counts toward 10% of your final mark.

Question 1 [4 marks]

For this question, you are asked to solve a classical planning problem using PDDL. Read the problem description carefully.

Polynesian navigators trained in schools (wānanga) to learn a body of wayfinding techniques that provided the skills necessary to travel to other locations throughout the Pacific, including over vast distances.

Jeff Evans describes the general process as follows:

> A voyage is divided into three main stages. First there is the departure and the setting of the primary course. This primary course takes into account any local sea or wind conditions likely to push the waka off course as it departs land. The second challenge for the navigator is to maintain the appropriate course en route, while the third objective is to reach the destination successfully. (*Polynesian navigation and the discovery of New Zealand* pp. 58-59).

Wayfinding required the ability to interpret reliable environmental signs. For our purposes, we are going to divide this into three *actions* representing groups of signs to look out for at different degrees of proximity to the destination:

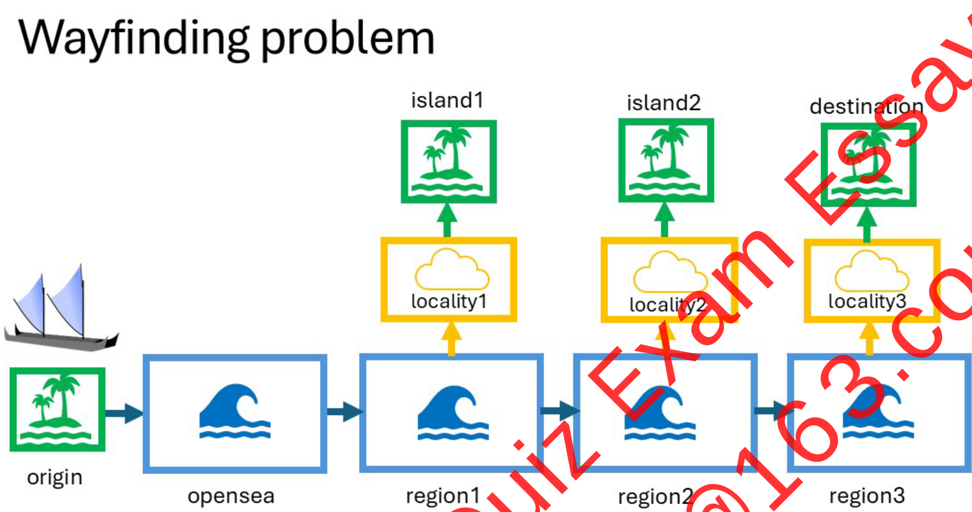
1) Navigators would memorise a star path—a number of stars that can be seen rising from the same point on the horizon each night—to guide them in their direction of sail. They would also have an understanding of familiar currents and techniques to detect ocean swells that allows them to know more about the general **`region`** they are travelling toward. We will call this action schema: **`check_currents_star_map`**.

2) When navigators were nearing the **`locality`** of their destination, they would check for signs including cloud formations that typically indicate a land mass is near. It has also been recorded that certain signs of phosphorescence under the water could provide direction toward the nearest land mass. We will call this action schema: **`check_clouds_phosphoresence`**.

3) As navigators were nearing the **`island`**, other signs would indicate where the land mass was. Certain birds that returned to land at night could provide direction based on their flight

path. Skilled navigators could identify colours reflecting on the horizon that are indicative of land. Weeds and logs in the water would also indicate that land was close. These signs would result in landfall at their destination. We will call this action schema: **`check_birds_horizon_detritus`**.

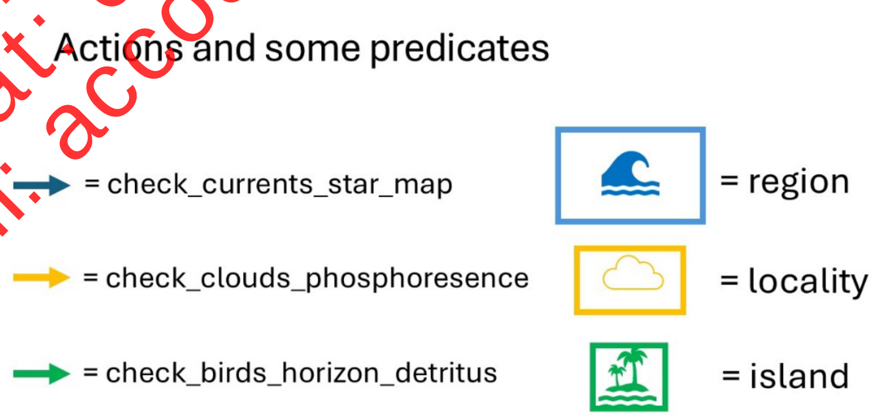
Our planning problem is represented by the diagram below. We are considering a wayfinder-in-training who is attempting to sail from the **`origin`** to the **`destination`**.



The vessel will always be **`at`** one of the locations on this map.

You should note in this diagram that *only* the moves indicated by arrows are possible (e.g., you can move from **`region1`** directly to **`region2`** but you cannot move directly from **`locality1`** to **`locality2`**). Each of the arrows in the diagram represents a **`possiblemove`**. The colours of the arrows also indicate which specific actions need to be performed to move into a new **`region`** or to move to a new **`locality`** or to land at an **`island`**.

For your reference, here is a key to the objects in this diagram:



Note that for the action **check_currents_star_map**, the position that the vessel will end up at must be a **region**. For the action **check_clouds_phosphoresence**, the position that the vessel will end up at must be a **locality**. For the action **check_birds_horizon_detritus**, the position that the vessel will end up at must be an **island**.

For this assignment, you will write PDDL code to represent this problem and successfully generate a plan to travel from the **origin** to the **destination**. All of the terms that have appeared in these instructions so far in **bold courier new** font and also in the diagrams should also appear in your code as predicates, objects, and actions.

(a) Write a PDDL domain file **wayfinding_domain.pddl** that specifies predicates and the three action schemas: *check_currents_star_map*, *check_clouds_phosphoresence* and *check_birds_horizon_detritus*. (2 marks)

(b) Write a PDDL problem file **wayfinding_task.pddl** that defines all components of the task, including specifying the objects, initial state and the goal state. (2 marks)

Submit the two files **wayfinding_domain.pddl** and **wayfinding_task.pddl**.

You may use the PDDL Editor to test your code: http://editor.planning.domains/

Question 2 [3 marks total]

Lots of people training for marathons have a goal, for example, to run a sub-four-hour marathon. When runners talk about running a sub-four-hour marathon, this implies that they will achieve a time 3 hours or over but below four hours. Below are the probabilities associated with the finishing times for runners in marathons.

subhour	Description	Probability
1	Sub-one-hour range (Less than 1 hour)	0
2	Sub-two-hour range (1 hour or over but less than 2 hours)	0
3	Sub-three-hour range (2 hours or over but less than 3 hours)	0.1
4	Sub-four-hour range (3 hours or over but less than 4 hours)	0.4
5	Sub-five-hour range (4 hours or over but less than 5 hours)	0.35
6	Sub-six-hour range (5 hours or over but less than 6 hours)	0.15

It was found that people who run their first marathon will either get the same time or faster in their second marathon.

Write ProbLog code for this scenario to generate answers for the questions below.

(a) Based on the output of your ProbLog program, what is the probability that a runner will run in the *sub-four-hour range* in both their first and second marathon? (2 marks)

(b) Based on the output of your ProbLog program, what is the probability that a runner will improve their run time so that they fall in the *next-shortest* sub-hour range in their second marathon. (E.g., if their time is in the sub-hour 6 range in the first marathon, their time will be in the sub-hour 5 range in the second marathon; if their time is in the sub-hour 5 range in the first marathon, their time will be in the sub-hour 4 range in the second marathon; and so on.) (1 mark)

You may use the ProbLog editor: https://dtai.cs.kuleuven.be/problog/editor.html. Please save your code as **marathon.txt** and submit this file.

Question 3 [3 marks total]

We are analysing the expression of various genes and their relationships to one another.
The following facts are found: The expression of **GeneA** and/or **GeneB** regulates the expression of **GeneC**. The expression of **GeneC** regulates the expression of **GeneD**.

(a) Consider the following facts:

$P(GeneA) = 0.2$

$P(GeneB) = 0.5$

$P(GeneC \mid GeneA, GeneB) = 0.8$
$P(GeneC \mid GeneA, \neg GeneB) = 0.1$
$P(GeneC \mid \neg GeneA, GeneB) = 0.25$
$P(GeneC \mid \neg GeneA, \neg GeneB) = 0$

$P(GeneD \mid \neg GeneC) = 0.85$
$P(GeneD \mid GeneC) = 0.1$

A gene may be in a state of "on" (=1) or "off (=0). Given this information, draw the full conditional probability tables for the following probability distributions: **P**(*GeneA*), **P**(*GeneB*), **P**(*GeneC*), and **P**(*GeneD*). (1 mark)

(b) Use the variable elimination algorithm to calculate the probability that gene B is "on" given that we have found that gene D is "on". I.e., What is $P(GeneB \mid GeneD)$? Show all working. (2 marks)