Open book exam. Duration: 2h30m. Exame da Época Normal

Note: Answer each question (1, 2, 3 and 4) in separate exam sheets.

1. **[4 points]** A mobile robot has the goal of transporting objects from their current position to specific destinations. The grid in the figure shows the robot's initial position (R), the current positions of each object (X, Y and Z), their destinations (X_f, Y_f and Z_f) and the battery charger. The robot has autonomy of 20 cells, and is able to charge its battery **a single time**. The robot may move to orthogonal adjacent positions, and may **transport a maximum of 2 objects** at the same time, one on top of the other. When doing so, the object on the top (the second that was picked up) has to be dumped first. **Objects may only be dumped at their destination spots**. Given their different sizes, **a larger object can never be transported on top of a smaller one**, and we know that X>Y>Z. For instance, it is not possible to transport Y on top of Z.

	a	b	c	d	e	f	g	h
1	R							Z_f
2		X_f						
3								
4							Z	
5				Y				
6								±
7								
8		X		Y_f				

We want to find the solution with the smallest travelled distance. In the following exercises, represent each state in the form `a1[]20`: the robot is in position a1, is not carrying any object (empty list) and has a 20 cell autonomy. Another example: `g4[X,Z]3`, where the robot is in cell g4, transports Z on top of X and has a 3 cell autonomy. Note that we only care about representing states in which the robot is in a point of interest, that is, b2, b8, d5, d8, g4, h1 or h6.

a) Starting in state `a1[]20`, determine the first 5 expanded states by the **uniform cost** search strategy, showing their associated costs. Show the construction of the search tree with the 5 expanded states.

b) Let Θ be the set of existing objects, Ni the number of objects in their initial positions and Nf the number of objects in their final positions. For each of the following heuristic functions, show, in the general case, whether it is admissible (prove with examples if it is not):

- $h_1 = Ni$
- $h_2 = |\Theta| - Nf$, where $|\Theta|$ represents the number of existing objects
- $h_3 = \sum_{o \in \Theta} dist(o)$, where $dist(o)$ represents the Manhattan distance between the current and final positions of object o
- $h_4 = \max dist(o), o \in \Theta$

c) From the admissible heuristics identified in the previous question, which is the best one? Why?

2. **[4 points]** We want to optimize a production plan in a factory with 3 machines: M1, M2, M3. Production includes manufacturing products A, B, C, D and E, which require the usage of different machines and have a specific time to produce (as shown in the table). We need to allocate the products to machines, with the goal of minimizing the total production time, by applying **Genetic Algorithms**. The initial population should include the following 4 individuals:

Prod	Machine	Duration
A	M1 or M2	10
B	M1 or M3	7
C	M2 or M3	11
D	M2 or M3	12
E	M1 or M2 or M3	8

i) A-M1, B-M1, C-M2, D-M2, E-M1;
ii) A-M1, B-M3, C-M2, D-M3, E-M3;
iii) A-M1, B-M1, C-M2, D-M2, E-M2;
iv) A-M2, B-M1, C-M2, D-M2, E-M2.

a) Propose a codification to represent an individual. Explain. Exemplify by representing individual ii) of the initial population.

b) Propose a fitness function (textual description). Calculate the fitness values for each of the individuals in the initial population.

c) In the process of selecting of the individuals that will form the next generation, we use elitisms (1 individual). Consider that the following random numbers have been generated (between 0 and 1): 0.22 / 0.4 / 0.88. Show the outcome of this selection process. Explain.

d) Calculate the 2nd generation (which includes the individual obtained through elitism). Explain your choices. Propose a crossover strategy. The crossover probability is 70% and the following random numbers have been generated: 0.35 / 0.75 / 0.5. Mutation probability is 3% and only in the 22nd random number a value below 0.03 has been found.

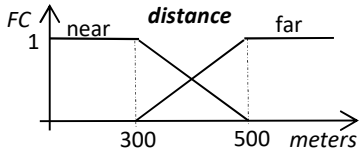
3. [**4 points**] To aid in calculating the renting price of a house in greater Porto, an Expert System has been implemented. Its rules comprise the following:

R1: IF metro nearby OR in city center THEN location ok (CF=0,8)

R2: IF metro far AND next to beach THEN location ok (CF=0,9)

R3: IF location ok AND typology>=T3 THEN high rental (CF=0,9)

R4: IF location ok AND no tv THEN low rental (CF=0,8)



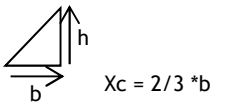
The house in question is a T3 apartment, is not in the city center (CF=0,7) and is close to the beach (CF=0.9). The nearest metro station is at a 340m distance. The house does not include a tv (CF=0.5).

The concept of ***distance*** (close/far) is described by the fuzzy sets represented in the figure above.

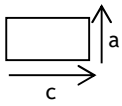
a) What does the Expert System conclude, and with what Certainty Factor? Show all your calculations.

b) Consider the membership function for the fuzzy set ***renting value*** (low / high) shown in the figure below. Which is the renting value for the apartment?

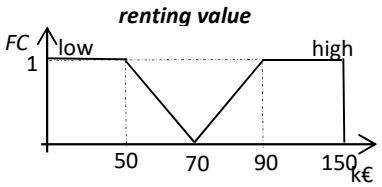
Note: centroid calculation (Xc,Yc) for a geometric figure:



Xc = 2/3 *b



Xc = c/2



4. [**8 points**] Answer **six (6)** of the following seven (7) questions (each in 5-10 lines).

a) When using informed search strategies, distinguish the concepts of admissible heuristic and consistent heuristic. Can an admissible heuristic not be consistent?

b) A computer technician has decided to restore old PCs to create a cloud. The usage of a recent software computation infrastructure offers some assurance that the cloud will work fine (Belief=0.8); the same conclusion is supported (Belief=0.7) by the fact that the PCs seem to work fine. On the other hand, the physical infrastructure and the old network cables being used point to the direction that the cloud may not work (Belief=0.3). According to the **Dempster-Shafer** model, which is the confidence interval in the fact that the cloud will work fine?

c) When applying simulated annealing, at a certain stage you have that the current state has a value of 15. A next state has been generated, with the value of 12. The current temperature is 0.8. Calculate the probability that the generated state is accepted.

d) Explain the advantages and disadvantages of Monte Carlo Tree Search (MCTS) as compared to Minimax with alpha-beta cuts.

e) Let S be a collection of examples distributed in 3 classes. There are twice as many examples of class A when compared to class B, and the same number of examples in classes B and C. Calculate the average amount of information (entropy) related with the classification of the examples in S.

f) An agent moving in a space perceives the environment through its sensors, based on which it infers about the safety of its position. Is this kind of inference based on causal rules or diagnostic rules? Explain.

g) Draw a simple neural network that is able to implement function NXOR (Not eXclusive OR).