ROBOTICS (20/07/2016)

Matteo Matteucci, Gianluca Bardaro

The exam will be graded IFF the following recommendations have been taken into account:

- Write clearly so that the teacher can easily understand your answers
- Write your name, surname, and student id on each sheet you deliver for evaluation
- For each exercise/question report clearly the number and sub-number (if present)
- You are not allowed to use any programmable device (e.g., smartphone, calculator, etc.)
- You can use pen or pencil, paper will be provided, you cannot use notes or books

Exercise 1 (Algorithm)

Let's consider the Online SLAM problem, in particular:

- a) Provide the derivation of the recursive Bayes Filter for Online SLAM
- b) Describe the Bayes filter algorithm for Online SLAM
- c) Describe the assumption in terms of uncertainty representation, motion model and measurement model behind the EKF-SLAM algorithm
- d) Describe the EKF-SLAM algorithm for Online SLAM

Exercise 2 (Numerical Exercise)

Consider a graph-based trajectory planner based on the A* algorithm using as heuristic $max(\Delta x, \Delta y)$

- a) Describe the role of the heuristics in the A* algorithm, i.e., what it is and how it is used. Is the suggested heuristic a proper one?
- b) Apply the A* algorithm assuming a 4 cells connectivity for the graph, i.e., the robot can move in the cells above, below, on the right, and on the left with the cost of 1
- c) Apply the A* algorithm assuming a 8 cells connectivity for the graph, i.e., the robot can move in all the cells around with the cost of 1

00 Start	01	02	03	04	05	06
07	80	09	10	11	12	13
14	15	16	17	18	19	20 Goal

<u>Note:</u> for the solution of the exercise provide the status of the list of OPEN states of A^* at each iteration (one per line), you can strike out at each step the state you decide to expand and move into the CLOSED list. Keep track of the g value for each state in the grid. For instance:

00 Start	01	02	03	04	05	06
07 <u>1</u>	80	09	10	11	12	13
14 2	15	16	17	18	19	20 Goal

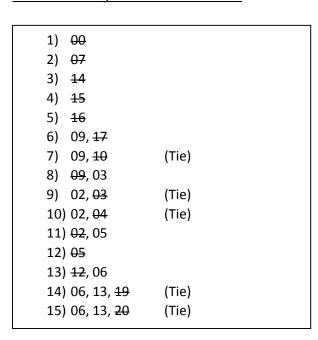
1)	00				
2)	07				
3)	14				
4)					

For the solution of point a), please refer to course slides (in particular to the properties the heuristics needs to let the A* algorithm to find the optimal solution – consistency and admissibility).

The proposed heuristics has the required properties for being a proper heuristics for the problem. It can be represented as

00	01	02	03	04	05	06
Start		4	3	2	2	2
07	08	09	10	11	12	13
6		4	3		1	1
14	15	16	17	18	19	20
6	5	4	3		1	Goal

For the solution of point b) the open list is the following with the final solution for the g function, ties are broken selecting the last node inserted



00	01	02	03	04	05	06
Start		6	7	8	9	10
07	08	09	10	11	12	13
1		5	6		10	11
14	15	16	17	18	19	20
2	3	4	5		11	વેન્ટ્રા

For the solution of point c) the open list is the following with the final solution for the g function, ties are broken selecting the last node inserted

1)	00	
2)	07	
3)	14, 15	
4)	14, 16 , 09	(Tie)
5)	14, 09, 17 , 10	(Tie)
6)	14, 09, 10	(Tie)
7)	14, 09, 02, 03, 04	
8)	14, 09, 02, 03, 05, 12	

9) 14, 09, 02, 03, 05, 06, 13, 19, 20

00	01	02	03	04	05	06
Start		4	4	5	6	7
07	80	09	10	11	12	13
1		3	4		6	7
14	15	16	17	18	19	20
2	2	3	4		7	G <mark>7</mark> al

Exercise 3 (Theory/Algorithm)

Let's consider the problem of obstacle avoidance, a.k.a., local path planning, and the algorithms to implement it. Provide a description of

- a) What is the aim of local path planning
- b) The Vector Field Histogram approach (VFH) and its improvement Vector Field Histogram+ (VFH+)
- c) The Dynamic Window Approach (DWA)
- d) All these three algorithm use a navigation function, i.e., a function evaluating the value/cost of possible actions. Discuss briefly how it could be possible to set up the parameters involved in these functions

Exercise 4 (ROS)

Describe the differences between messages, services, and actions in ROS.

Exercise 5 (Other)

What are direct and inverse kinematics of a robot? Provide an example of their use.