ROBOTICS (20/07/2016)

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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	08	09	10	11	12	13
14	15	16	17	18	19	20 Goal

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

1) ~~00~~
2) ~~07~~
3) ~~14~~
4) ~~15~~
5) ~~16~~
6) 09, ~~17~~
7) 09, ~~10~~ (Tie)
8) ~~09~~, 03
9) 02, ~~03~~ (Tie)
10) 02, ~~04~~ (Tie)
11) ~~02~~, 05
12) ~~05~~
13) ~~12~~, 06
14) 06, 13, ~~19~~ (Tie)
15) 06, 13, ~~20~~ (Tie)

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

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

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.