ROBOTICS (17/07/2017)

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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

<u>Exercise 1 (Theory/Numerical Exercise) [2+1+2+2 points]</u>

Consider a graph-based trajectory planner based on the A* algorithm using as heuristic function the Manhattan distance $MD = abs(\Delta x) + abs(\Delta y)$ (ignoring obstacles)

a) Describe the role of the heuristics in the A* algorithm, i.e., what it is and how it is used, and discuss if and why the suggested heuristic is a proper one?
b) Provide a map of the environment reporting, for each cell the value of the corresponding heuristics
c) 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
d) 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
21	22	23	24	25	26	27

<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), and the value of the g function for each state. 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
21	22	23	24	25	26	27

1) ~~00(0)~~
2) ~~07(1)~~
3) 14(2)
4) …

Exercise 2 (Theory/Algorithm) [2+1+1+2]

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) the aim of local path planning and what should be its frequency with respect to global path planning (explain the reason for that!)
b) The functioning of the Vector Field Histogram approach (VFH) for obstacle avoidance, and its improvement Vector Field Histogram+ (VFH+)
c) The Dynamic Window Approach (DWA)
d) All these 3 algorithms use a navigation function, i.e., a function evaluating the value/cost of possible actions. Describe such navigation function and the parameters involved in it. Discuss briefly how it could be possible to set up such parameters in practice.

Exercise 3 (Theory) [3 + 3 points]

In the figures below you can appreciate the same vehicle but with two different kinematics. For each picture of the two picture describe: the **type of kinematic** of the vehicle (we have seen both during classes!), their ***direct kinematic*** equations (in terms of the control variables), the ***advantages/disadvantages*** of each.

Exercise 4 (ROS and Gazebo) [1 + 3 points]

In ROS you have ***topics***, ***services*** and ***actions***, (a) what are they used for, (b) what are the characteristics of each of them in terms of usage, blocking/asynchronous behavior?

Exercise 5 (Other) [2 + 2 points]

Describe the Beam Sensor Model in terms of (a) its components and the rationale behind each of them, (b) its use in a particle filter used for Monte Carlo localization (to answer properly this point you need to first briefly describe particle filtering and Monte Carlo localization).