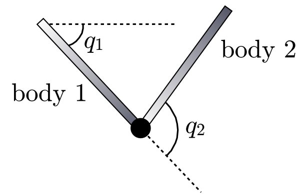
Autonomous and Mobile Robotics
Final Class Test, 2011/2012

Problem 1

Consider the two-body space robot shown in figure. The robot freely floats in the absence of gravity.



This system, whose configuration is described by the vector $(q_1 \;\; q_2)^T$, is subject to the conservation of the angular momentum. This can be expressed as a kinematic constraint:

$$a_1(q_2)\dot{q}_1 + a_2(q_2)\dot{q}_2 = 0$$

where a_1 and a_2 are functions of q_2 and of the dynamic parameters of the robot (masses, lengths, inertias).

1. Is this constraint Pfaffian?
2. Derive the corresponding kinematic model of the system.
3. Is the system controllable or not? Correspondingly, is the constraint holonomic or not?

Problem 2

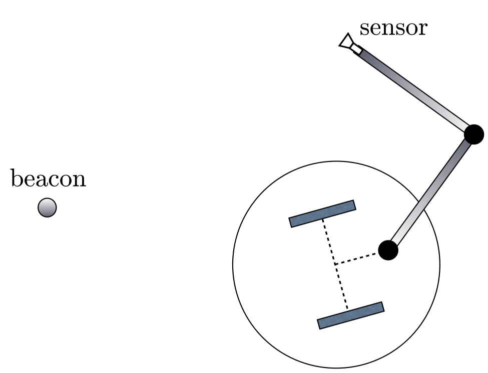
Consider a planar circular robot with differential-drive kinematics. Denote by $v_{\max}$, $\omega_{\max}$ the bounds on the absolute value of the robot velocity inputs, and by R the radius of the robot base. The robot must travel between cartesian points P_S (start) and P_g (goal) in a perfectly known planar environment that contains polygonal obstacles. Build a complete navigation system that integrates the following modules:

- a motion planner that generates a feasible collision-free path;
- a trajectory planner that computes admissible robot velocities along this path;
- a feedback controller that can track the reference trajectory;

Discuss in detail the possible options and the motivation behind your choices. Provide a block scheme of your system with a clear indication of the inputs and the outputs of each block. Points that deserve special attention are: (1) is your motion planner complete, and under which assumptions? (2) does your motion planner generate paths that the robot can follow? (3) will the reference trajectory belong to the class that your feedback controller can track?

Problem 3

Consider the mobile manipulator in figure, consisting of a differential-drive base carrying a 2R planar horizontal arm.



The end-effector of the arm carries an exteroceptive sensor which can measure the distance to a beacon whose position in the environment is exactly known. For simplicity, assume that the sensor can always 'see' the beacon. The proprioceptive sensors are the wheel encoders for the base and the joint encoders for the arm. Derive the equations of an Extended Kalman Filter for estimating the configuration of the mobile manipulator, providing also a detailed block scheme of its structure. [*Hint: a kinematic model for the arm consists of simple integrators*]

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