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Autonomous robotics: Action, Perception, and Cognition

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Exercise 4 Attractor Dynamics for vehicle motion planning: Why the sub-symbolic approach works

The paper referenced in Exercise 3 is still relevant to support this new exercise: Bicho, Mallet, Schöner (2008): Using Attractor Dynamics to Control Autonomous Vehicle Motion. In: *Proceedings of the 24th Annual Conference of the IEEE Industrial Electronics Society* (IECON98), p. 1176-1182, Aachen, Germany (available on the web page). We will be using notation from this paper. Note that in Eq. 1 of that paper, the exponential term is missing a minus sign.

Invariance

In last week's excercise you examined a single and a pair of forcelets of the obstacle dynamics (Eqs 1, 2, and 3 of the paper). This week we'll have a look at why the sum of two obstacle forcelets is approximately invariant when the robot vehicle rotates on the spot. To do this, we have to consider a specific environmental situation.

Assume the robot is faced with a single obstacle at distance $d = 5R$ (where R is short for the robot's radius denoted as R_{robot} in the paper). Assume further that the obstacle's size is such that is covers exactly the angular range, $\Delta\theta = 60\,\text{deg}$, of the distance sensors at the given distance. Finally, assume that the sensors return the true distance to that obstacle, irresprective of how much of the sensor's angular range is covered by the obstacle. The sensors are mounted at distances of $\Delta\theta$, so that the sensor sectors are all exactly continguous to each other. To simplify the illustrations and computations, consider the sensor range to be measured relative to a sector centered in the robot's center, not in the sensor itself.

To analyze the invariance of the obstacle terms, we will imagine the obstacle to be at different positions on a circle around the center of the robot with Radius $d = 5R$. Because of the chosen size of the obstacle this implies that at some positions, the obstacle will fall into the sector of a single sensor, while at all other positions it will fall into the sectors of two adjacent sensors.

1. Make a sketch of a birds eye view of the situation and introduce notation as in the paper, so that you can mathematically characterize the heading directions in which sensors are pointing when the obstacle falls into a sensor's cone of detection. Plot the more typical case in which the obstacle falls into the sectors of two adjacent sensors.

2. Simplifying the repulsion force-let by only taking its linear part, compute the heading direction from which the sum of these two neighboring force-lets repel.

3. Make a plot of that direction of repulsion as a function of the angle at which the obstacle is located on its circle around the robot. This plot will be glued together by the contributions of different pairs of sensors. Compare that direction of repulsion to the true direction in which the obstacle lies.

4. In the same setting, keep the obstacle in place but instead rotate the robot on the spot. Make a plot of the direction of repulsion as a function of the robot's heading direction. Interpret this plot in light of the issue of "invariance" of the dynamics under rotation of the vehicle.