Introduction to Robotics Institut für Informatik, Freie Universität Berlin
WiSe 2021/22 Prof. Daniel Goehring, Stephan Sundermann, Khaled Alomari

Exercise 12 (v1.0.1) February 1, 2022

Submission online until **Tuesday, 08.02.2022, 11:55 a.m.**

Assignment 12-1: Obstacle avoidance (5 Points)

Avoid obstacles using the laser scanner. The scan is published at `/sensors/rplidar/scan`. Take a look at the definition of the LaserScan message and transform the points into cartesian coordinates. Then transform the points into the map frame using the localization information from `/simulation/odom_ground_truth`.

Now check if there are points near to the drive spline and if so, change the lane or if both lanes are occupied stop. Use boxes as obstacles. You can use the `Map` class from the previous assignment and use the `closest_point` function.

Take a video (max. 5 MB, mp4 format) of how your vehicle changes the lane in front of an obstacle and how it stops, whenever both lanes are occupied.

Assignment 12-2: Vector field (2 Points)

Your goal position is $q_{Goal} = (5,5)$. Calculate the vector for point $q = (2,4)$, with $U_g(q) = d^2(q, q_{Goal})$. d represents the L_2-norm.

Now, assume a point obstacle with position $q_{Obst} = (7,7)$. $U_o(q) = \frac{1}{d^2(q, q_{Obst})}$. Calculate the vector, resulting from the obstacle, for point $q = (2,4)$, again.

Assignment 12-3: RRTs (1 Point)

Add the following 2D-points to your RRT, with an (x,y) starting position of (1,1) and a maximum step length ($\triangle q = 2$): (2,1),(5,1),(4,4). Distance norm is L_2. Draw the resulting RRT-graph.

Assignment 12-4: Dubins Car (2 Points)

The starting position of your car is $(1,1)$ with orientation $\pi/2$. The goal position is $(2,1)$ with orientation $\pi/2$. The turning radius is 4. Calculate the distance for a RSR-Dubins-curve (right-straight-right), which the car needs to travel from the starting to the goal position. What are the distances traveled on each of the three segments? Please solve this problem graphically.

Assignment 12-2: Vector field (2 Points)

a) Your goal position is $q_{Goal} = (5,5)$. Calculate the vector for point $q = (2,4)$, with $U_g(q) = d^2(q, q_{Goal})$. d represents the L_2-norm.

b) Now, assume a point obstacle with position $q_{Obst} = (7,7)$. $U_o(q) = \frac{1}{d^2(q, q_{Obst})}$. Calculate the vector, resulting from the obstacle, for point $q = (2,4)$, again.

$$U_q = dist^2(q, q_{Goal}) = (x-5)^2 + (y-5)^2$$

a) Ableiten

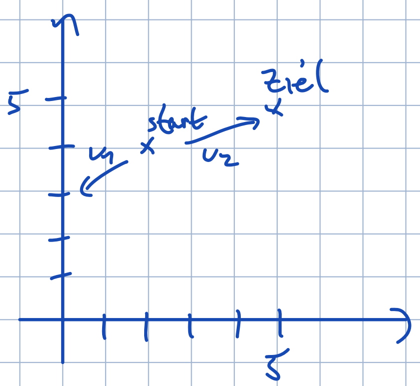
$$\frac{\partial}{\partial x} = 2(x-5)$$

$$\frac{\partial}{\partial y} = 2(y-5)$$

q (start) einsetzen

$$\frac{\partial}{\partial x}(\overset{2,4}{q}) = -6 \quad \Rightarrow \quad v_1 = (-6, -2)$$

$$\frac{\partial}{\partial y}(\overset{2,4}{q}) = -2$$



$\Rightarrow$ v_1 falsche Richtung (immer negieren)

$\Rightarrow$ $v_2 = -v_1 = (6, 2)$

b)

$$U_o(q) = \frac{1}{(x-7)^2(y-7)^2} \overset{\text{ableiten}}{=}$$

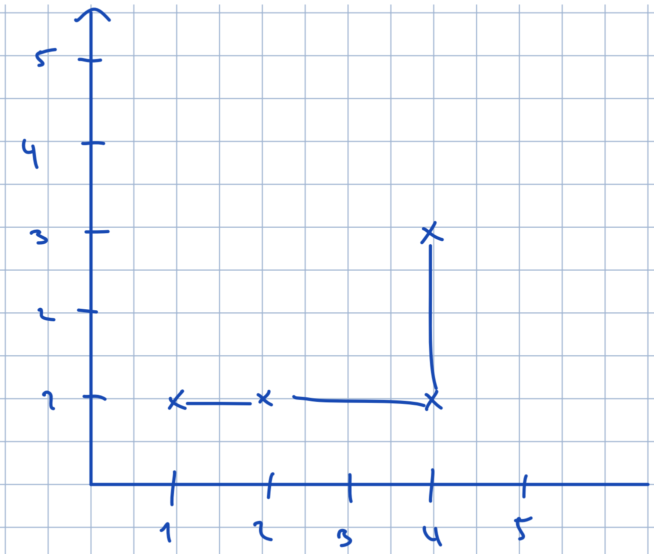
$$\frac{\partial}{\partial x} = -\frac{2(x-7)}{((x-7)^2+(y-7)^2)^2} \qquad \frac{\partial}{\partial x}(q) = \frac{10}{1{,}156} = 1$$

$$\frac{\partial}{\partial y} = \frac{2(y-7)}{((x-7)^2+(y-7)^2)^2} \qquad \frac{\partial}{\partial y}(q) = \frac{6}{1156}$$

negieren $-v_3 = \left(-\frac{10}{1156}, -\frac{6}{1156}\right)$

Assignment 12-3: RRTs (1 Point)

Add the following 2D-points to your RRT, with an (x,y) starting position of (1,1) and a maximum step length ($\triangle q = 2$): (2,1),(5,1),(4,4). Distance norm is L_2. Draw the resulting RRT-graph.



1. add $q_{start} = (1,1)$
2. add $(2,1)$

$d((2,1)\ (1,1)) = 1$

$\Rightarrow$ add edge $\{(2,1)\ (1,1)\}$

3. add $(5,1)$

$d((5,1)\ (1,1)) = 4$

$d((5,1)\ (2,1)) = 3$

$\rightarrow 3 < \Delta q$

$\rightarrow$ Berechne näheren Punkt

$$\begin{pmatrix}2\\1\end{pmatrix} + \frac{\begin{pmatrix}5\\1\end{pmatrix} - \begin{pmatrix}2\\1\end{pmatrix}}{\left\|\begin{pmatrix}5\\1\end{pmatrix} - \begin{pmatrix}2\\1\end{pmatrix}\right\|} \Delta q$$

$$= \begin{pmatrix}2\\1\end{pmatrix} + \frac{\begin{pmatrix}3\\0\end{pmatrix}}{3} \cdot 2 = \begin{pmatrix}2\\1\end{pmatrix} + \begin{pmatrix}2\\0\end{pmatrix} = \begin{pmatrix}4\\1\end{pmatrix}$$

$\Rightarrow$ add edge $\{(4,1)\ (2,1)\}$

4. add $(4,4)$

$d((4,4)\ (1,1)) = 6$

$d((4,4)\ (2,1)) = 5$

$d((4,4)\ (4,1)) = 3$

$\rightarrow 3 < \Delta q$

$\rightarrow$ Berechne näheren Punkt

$$\begin{pmatrix}4\\1\end{pmatrix} + \frac{\begin{pmatrix}4\\4\end{pmatrix} - \begin{pmatrix}4\\1\end{pmatrix}}{\left\|\begin{pmatrix}4\\4\end{pmatrix} - \begin{pmatrix}4\\1\end{pmatrix}\right\|} \Delta q$$

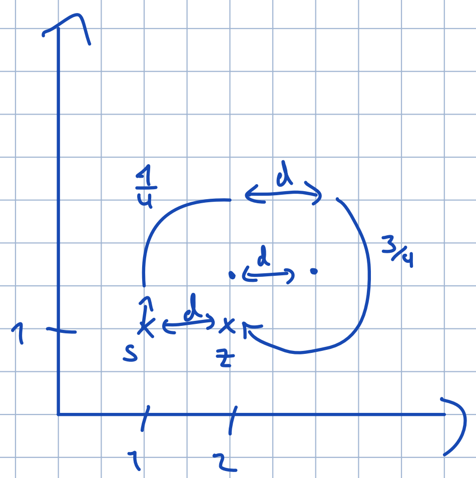
$$= \begin{pmatrix}4\\1\end{pmatrix} + \frac{\begin{pmatrix}0\\3\end{pmatrix}}{3} \cdot 2 = \begin{pmatrix}4\\1\end{pmatrix} + \begin{pmatrix}0\\2\end{pmatrix} = \begin{pmatrix}4\\3\end{pmatrix}$$

$\Rightarrow$ add edge $\{(4,3)\ (4,1)\}$

Assignment 12-4: Dubins Car (2 Points)

The starting position of your car is $(1, 1)$ with orientation $\pi/2$. The goal position is $(2, 1)$ with orientation $\pi/2$. The turning radius is 4. Calculate the distance for a RSR-Dubins-curve (right-straight-right), which the car needs to travel from the starting to the goal position. What are the distances traveled on each of the three segments? Please solve this problem graphically.

Um Kreis fahren $r \cdot 2pi \cdot$ amount



$\Rightarrow$

1. R dist $= \frac{1}{4} \cdot 2pi \cdot 4 = 2pi$
2. S dist $= 1$
3. R dist $= \frac{3}{4} \cdot 2pi \cdot 4 = 6pi$