Robotik - exercise 3

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Assignment 3-1: Simple Parking Maneuver

The goal of this task is to park the model car between two virtual boxes.

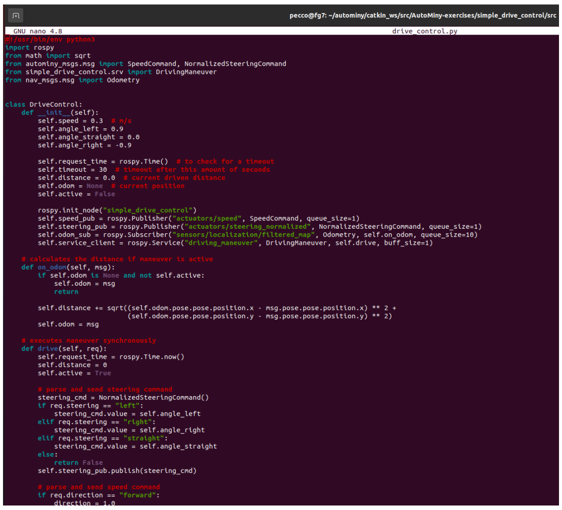
Please look at the source code of the `simple_drive_control` *and* `simple_parking_maneuver` *packages:*

https://github.com/AutoMiny/AutoMiny-exercises

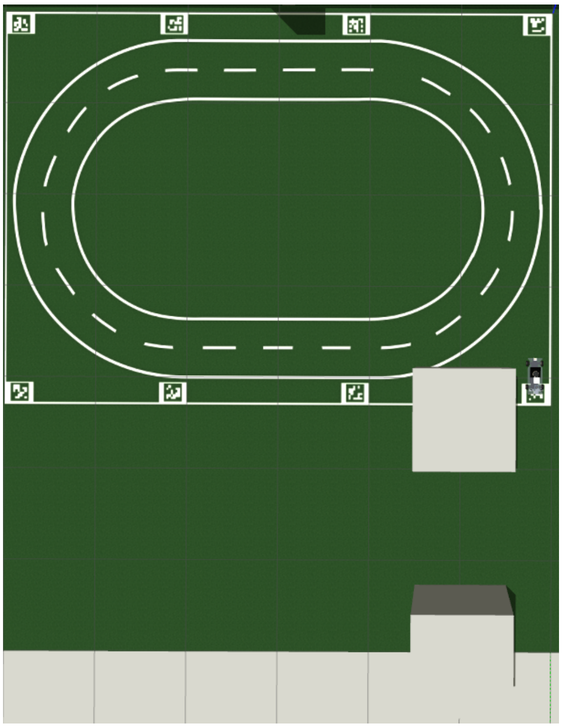
You should have a copy of these two packages in your repository. We provide empty.world with the assignment which needs to replace the existing file in `autominy/catkin_ws/src/autominy_simulato` *This places two boxes in your world which you should park the car in between.*

```
 cd autominy/catkin_ws/src
git clone https://github.com/AutoMiny/AutoMiny-exercises
catkin build simple_parking_maneuver
source devel/setup.bash # for bash
source devel/setup.zsh # for zsh
```

here is the sourcecode of the maneuver opened in my repository:

and here the new emty world can be seen:



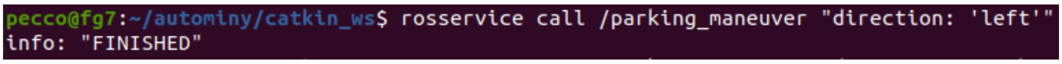
This task is based on a given ***`driving_maneuver`*** *service which can execute simple driving maneuvers. We provide a launch file to start the driving maneuver service and your service conveniently:*

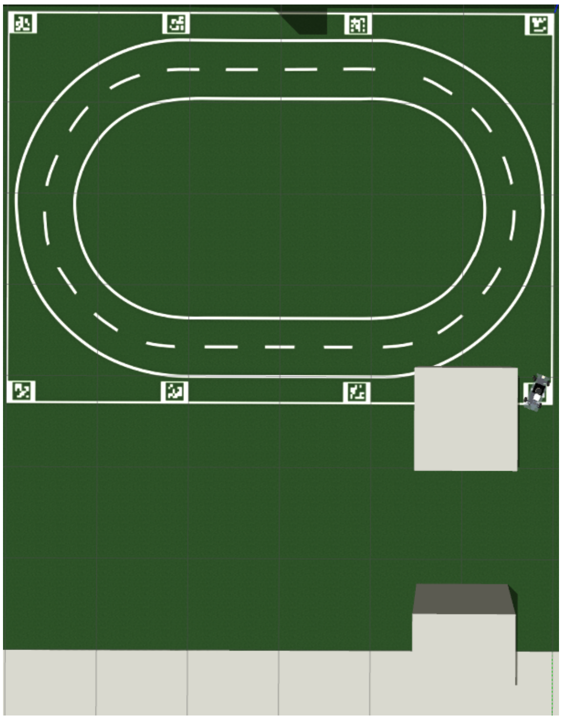
```
roslaunch simple_parking_maneuver simple_parking_maneuver.launch
```

You can start the parking maneuver by calling the ***`parking_maneuver`*** *service:*

```
rosservice call /parking_maneuver "direction: 'left'"
```

here you can see the default parking maneuver:





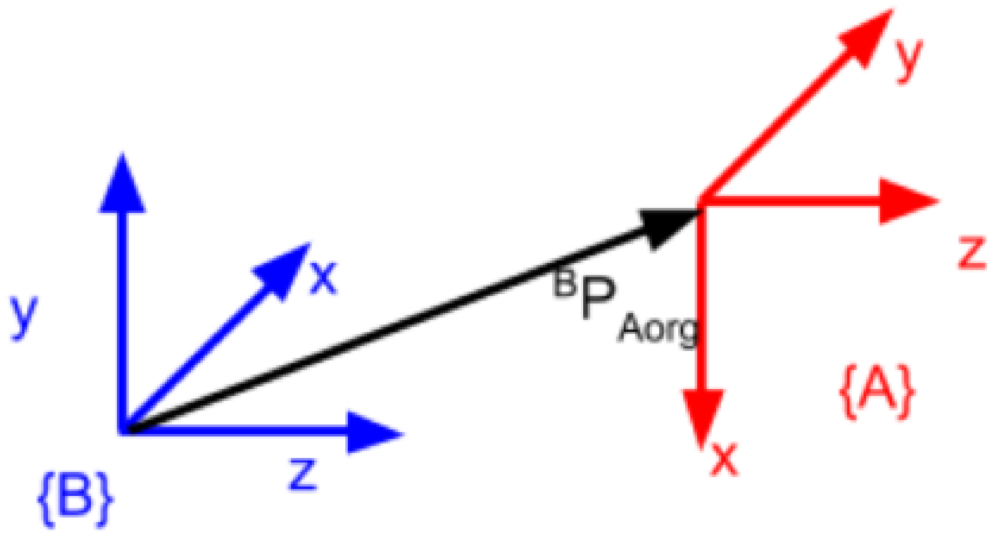
The default maneuver will not park the car properly between the boxes. Your task is to tune the parameters and the driving maneuver sequence in the `parking_maneuver.py` *file.*

https://github.com/AutoMiny/AutoMiny-exercises/blob/master/simple_parking_maneuver/src/parking_maneuver.py

The adjusted parking maneuver can be found here:

https://github.com/evakoumartzi/catkin_ws_GIR

Assignment 3-2: Coordinate System Transformation



Please provide the homogenious transformation matrix ^B_AT, which maps a vector represented in coordiante frame {A} into the coordinate frame { B}. The translation vector between both coordinate frames is $^BP_{A_{org}} = (-1, 4, 5)$.

The homogeneous transformation matrix ^B_AT is composed of a rotational Part ^B_AR and a translational part $^BP_{A_{org}}$.

$$^B_AT = \begin{bmatrix} ^B_AR & ^BP_{A_{org}} \end{bmatrix} \tag{1}$$

$$^B_AR = (^BX_A, ^BY_A, ^BZ_A) \tag{2}$$

$$= \begin{bmatrix} X_B \cdot X_A & X_B \cdot Y_A & X_B \cdot Z_A \\ Y_B \cdot X_A & Y_B \cdot Y_A & Y_B \cdot Z_A \\ Z_B \cdot X_A & Z_B \cdot Y_A & Z_B \cdot Z_A \end{bmatrix} \tag{3}$$

The scalar product is given with $\vec{a} \cdot \vec{b} = cos(\gamma)|a||b|$. The in a Cartesian coordinate system the unity vectors (X, Z, Y) are of length 1 the scalar product will just be the cosine of the angle between the axes of the original system {B} and the new system {A}. Since in the exercise no more information is given in the exercise we believe that the angles between the axes of the different systems are supposed to be exactly $\angle(Y_B, X_A) = 180°$,$\angle(X_B, Y_A) = \angle(Z_B, Z_A) = 0°$ and $\angle(X_B, X_A) = \angle(X_B, Z_A) =$

$\angle(Y_B, Y_A) = \angle(Y_B, Z_A) = \angle(Z_B, X_A) = \angle(Z_B, Y_A) = 90°$. Now we can set up the Rotation Matrix as:

$$^A_BR = \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{4}$$

So the homogeneous transformation matrix ^B_AT is given as:

$$^B_AT = \begin{bmatrix} 0 & 1 & 0 & -1 \\ -1 & 0 & 0 & 4 \\ 0 & 0 & 1 & 5 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{5}$$

What is the inverse of your transformation matrix? To determine the inverse form of a matrix there are several different ways, we use cramer's rule:

$$A^{-1} = \frac{1}{det(A)} * adj(A) \tag{6}$$

$$det(^B_AT) = -0 \cdot \begin{bmatrix} 1 & 0 & -1 \\ 0 & 0 & 4 \\ 0 & 1 & 5 \end{bmatrix} + 0 \cdot \begin{bmatrix} 0 & 0 & -1 \\ -1 & 0 & 4 \\ 0 & 1 & 5 \end{bmatrix} - 0 \cdot \begin{bmatrix} 0 & 1 & -1 \\ -1 & 0 & 4 \\ 0 & 0 & 5 \end{bmatrix} + 1 \cdot \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{7}$$

$$= 1 * \left(+0 \cdot \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix} - (-1) \cdot \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} + 0 \cdot \begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \right) \tag{8}$$

$$= 1 \cdot 1 \cdot (1 \cdot 1 - 0 \cdot 1) \tag{9}$$

$$= 1 \tag{10}$$

So it follows that ^B_AT has an inverse form (since $det(^B_AT) \neq 0$) wich is given by $^B_AT^{-1} =$

$adj(^B_AT)$.

$$^B_AT^{-1} = adj(^B_AT) \tag{11}$$

$$= \begin{bmatrix} det\begin{bmatrix}0&0&4\\0&1&5\\0&0&1\end{bmatrix} & -det\begin{bmatrix}1&0&-1\\0&1&5\\0&0&1\end{bmatrix} & det\begin{bmatrix}1&0&-1\\0&0&4\\0&0&1\end{bmatrix} & -det\begin{bmatrix}1&0&-1\\0&0&4\\0&1&5\end{bmatrix} \\ -det\begin{bmatrix}-1&0&4\\0&1&5\\0&0&1\end{bmatrix} & det\begin{bmatrix}0&0&-1\\0&1&5\\0&0&1\end{bmatrix} & -det\begin{bmatrix}0&0&-1\\-1&0&4\\0&0&1\end{bmatrix} & det\begin{bmatrix}0&0&-1\\-1&0&4\\0&1&5\end{bmatrix} \\ det\begin{bmatrix}-1&0&4\\0&0&5\\0&0&1\end{bmatrix} & -det\begin{bmatrix}0&1&-1\\0&0&5\\0&0&1\end{bmatrix} & det\begin{bmatrix}0&1&-1\\-1&0&4\\0&0&1\end{bmatrix} & -det\begin{bmatrix}0&1&-1\\-1&0&4\\0&0&5\end{bmatrix} \\ -det\begin{bmatrix}-1&0&0\\0&0&1\\0&0&0\end{bmatrix} & det\begin{bmatrix}0&1&0\\0&0&1\\0&0&0\end{bmatrix} & -det\begin{bmatrix}0&1&0\\-1&0&0\\0&0&0\end{bmatrix} & det\begin{bmatrix}0&1&0\\-1&0&0\\0&0&1\end{bmatrix} \end{bmatrix} \tag{12}$$

$$= \begin{bmatrix}0&-1&0&4\\1&0&0&1\\0&0&1&-5\\0&0&0&1\end{bmatrix} \tag{13}$$

Assignment 3-3: Coordinate Frames

Assume, you have the following vectors for coordinate axes of frame (or coordinate system):

$\{A\}: x = (-\sqrt{0.5}, \sqrt{0.5}, 0);\ y = (\sqrt{0.5}, \sqrt{0.5}, 0)$

Calculate the vector for the z-axis of this frame $\{A\}$

In a cartesian koordinate systhem the unit vectors along the axes have to ber perpendicular (90°) to each other and of the length 1. This can easily be determined by the skalar product:

$$x_i \cdot x_j = \begin{cases} 1 & \text{,if } i = j \\ 0 & \text{,if } i \neq j \end{cases} \tag{14}$$

this is given for x and y. Since x and y are both set in the x-y-plane of a naive Cartesian coordinate system the 3rd axes will be along the z-axes of the neive systherm, so we can set the 3rd unit vector to be eighter:

$\{A\}: z = (0, 0, 1)$; or

$\{A\}: z = (0, 0, -1)$;

to choose which of these possible vectors is the right one, lastly comes into play that that conventionally the 3rd axes is chosen so that the 90°angle from x to y is counter-clockwise (right hand rule). We can calculate the correct z- unit vector by using the vector product:

$$\begin{aligned} z &= x \times y && (15) \\ &= (0, 0, -1) && (16) \end{aligned}$$

.

The length of a vector product can be determinedd by $|a \times b| = |a||b| \cdot sin(\theta)$. Since the angel between the unit vectors is 90°and x and y have unit length, we already know that also z has unit length, so we are done.