Techniker Autonomer System

-- A strategy of autonomous parallel parking

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Presentation

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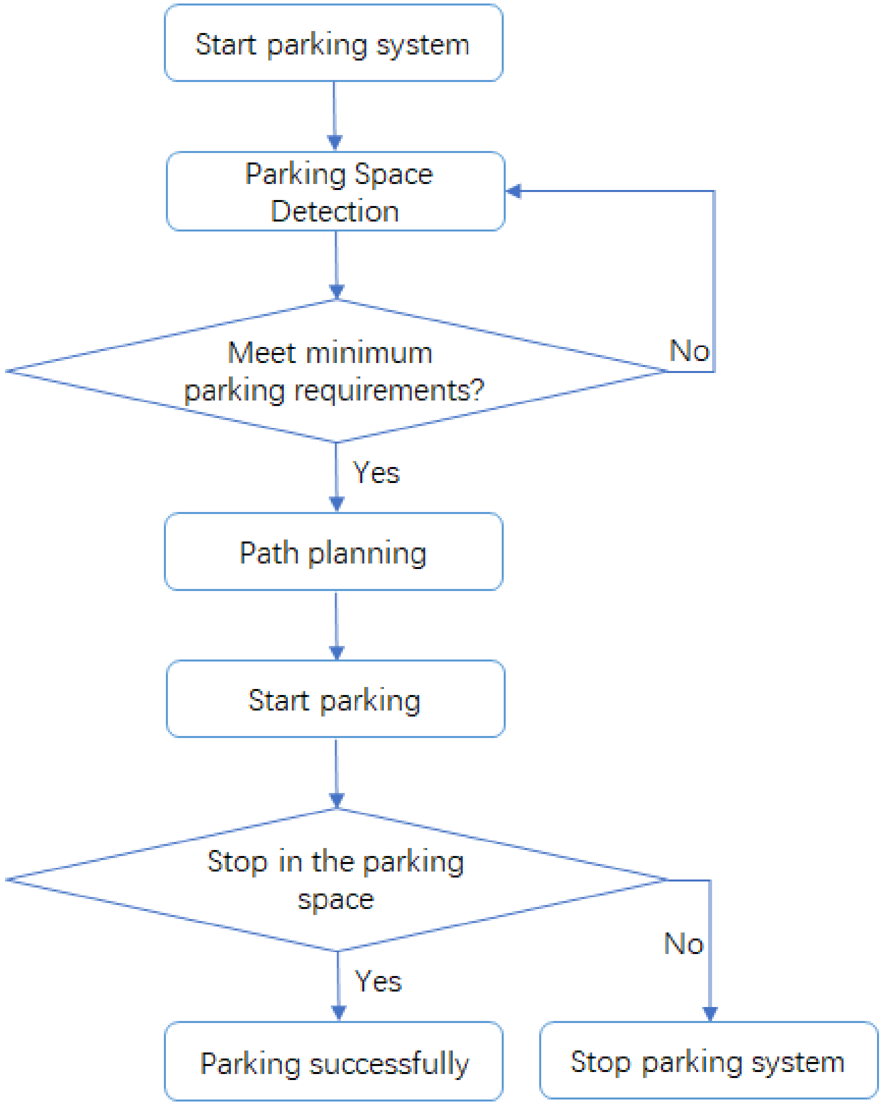
Motivation

- To detect the parking place precisely
- To solve the problem that the car are far away from the parking space when autonomous parallel parking
- To avoid the collision with the obstacles

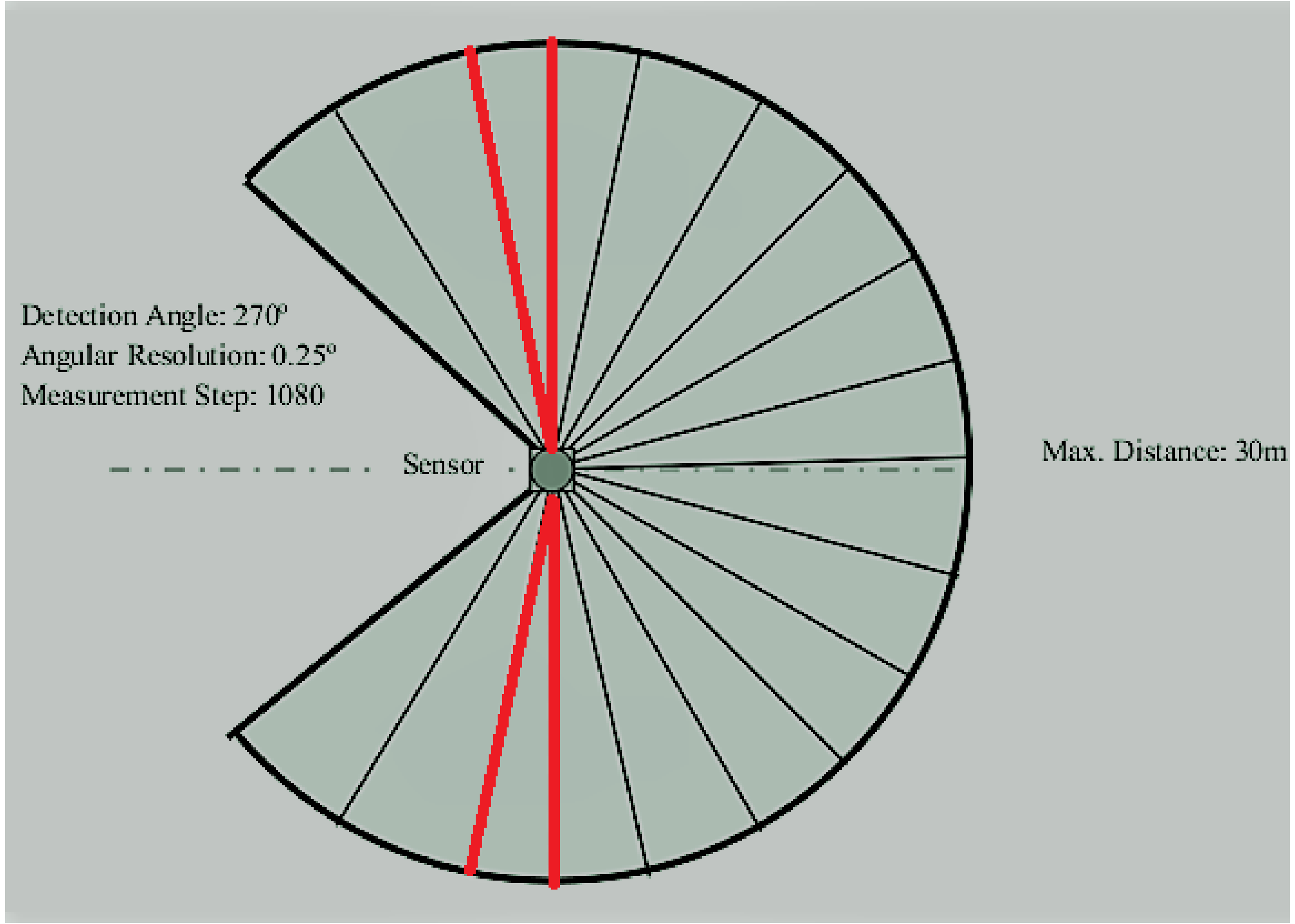
Flow chart of parallel parking



Parking space detection

Detection tool:

- Hokuyo lidar
  - detection angle: 15°



Parking space detection

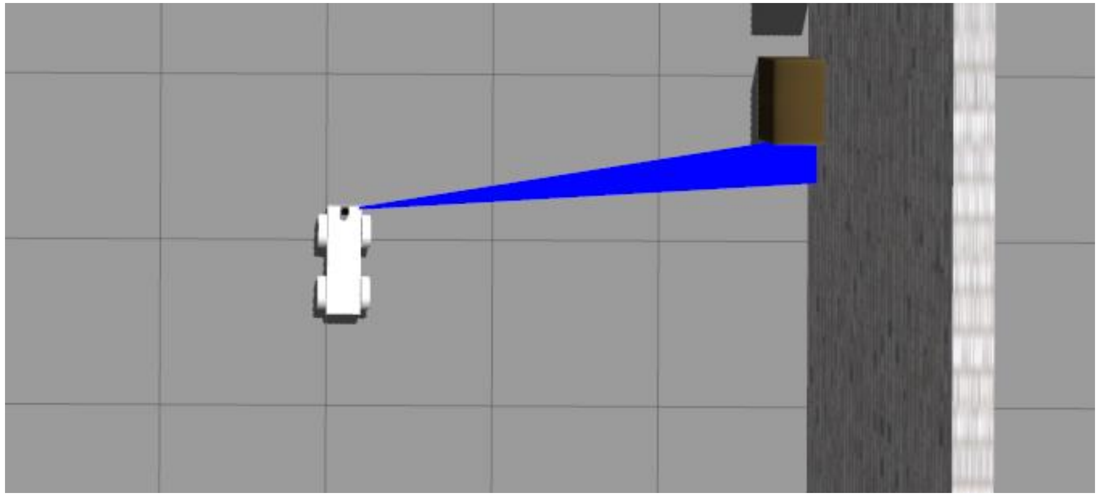
Hokuyo placement:

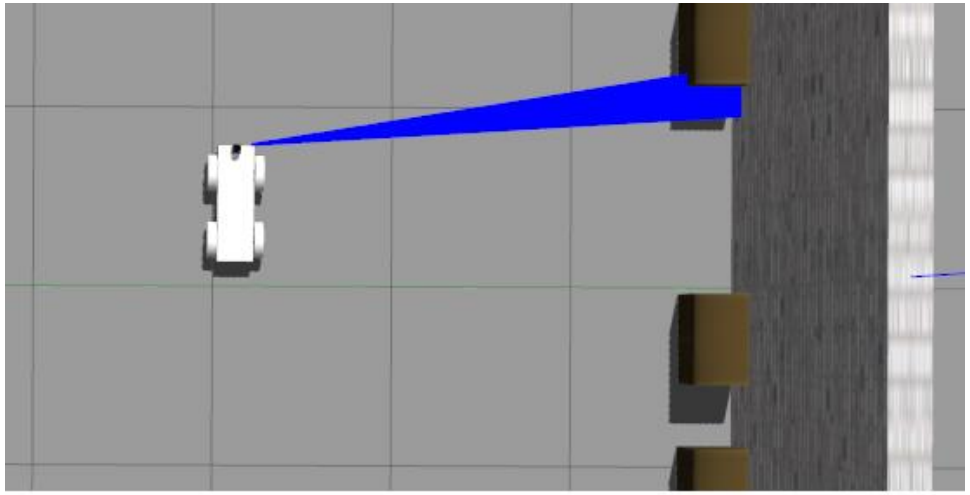
- Hokuyo is laid flat in front

- A vertical detection range
  small obstacle will also be detected
  final detected 3-dimensional free space

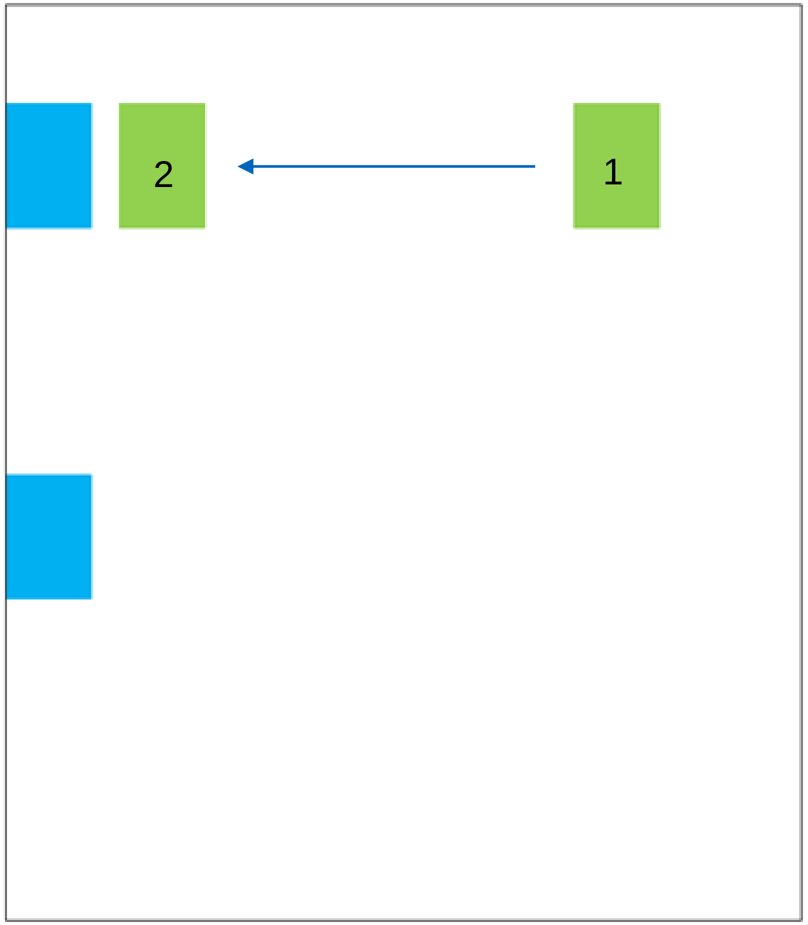
Parking space detection

Hokuyo on the car





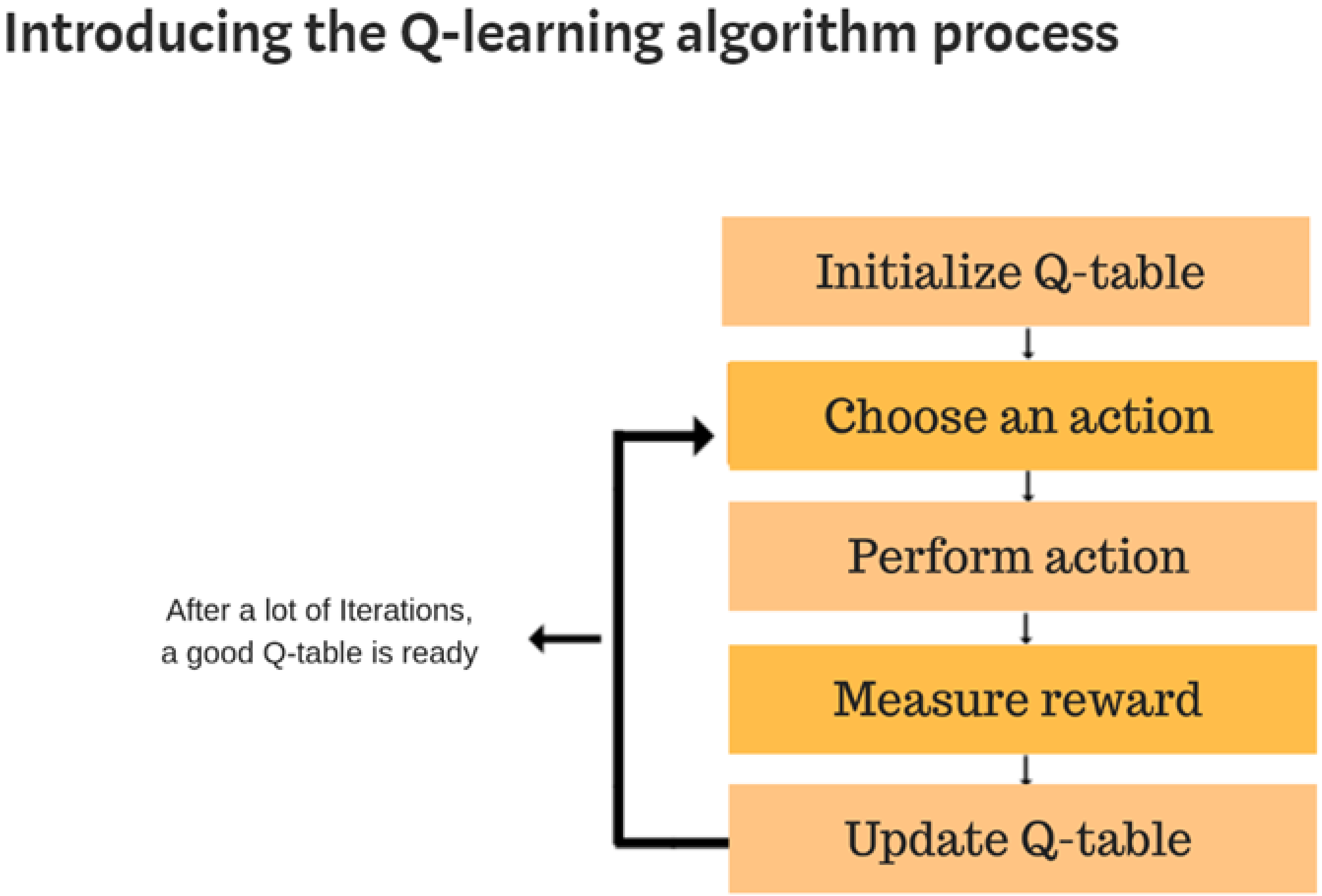
Problem Statement



- After detection, the car is at place 1
- To ensure to park successfully, we have to arrive at place 2
- How to achieve the goal with the least effort?

- Reinforcement Learning
- Reward

Path Planning using Q-Learning



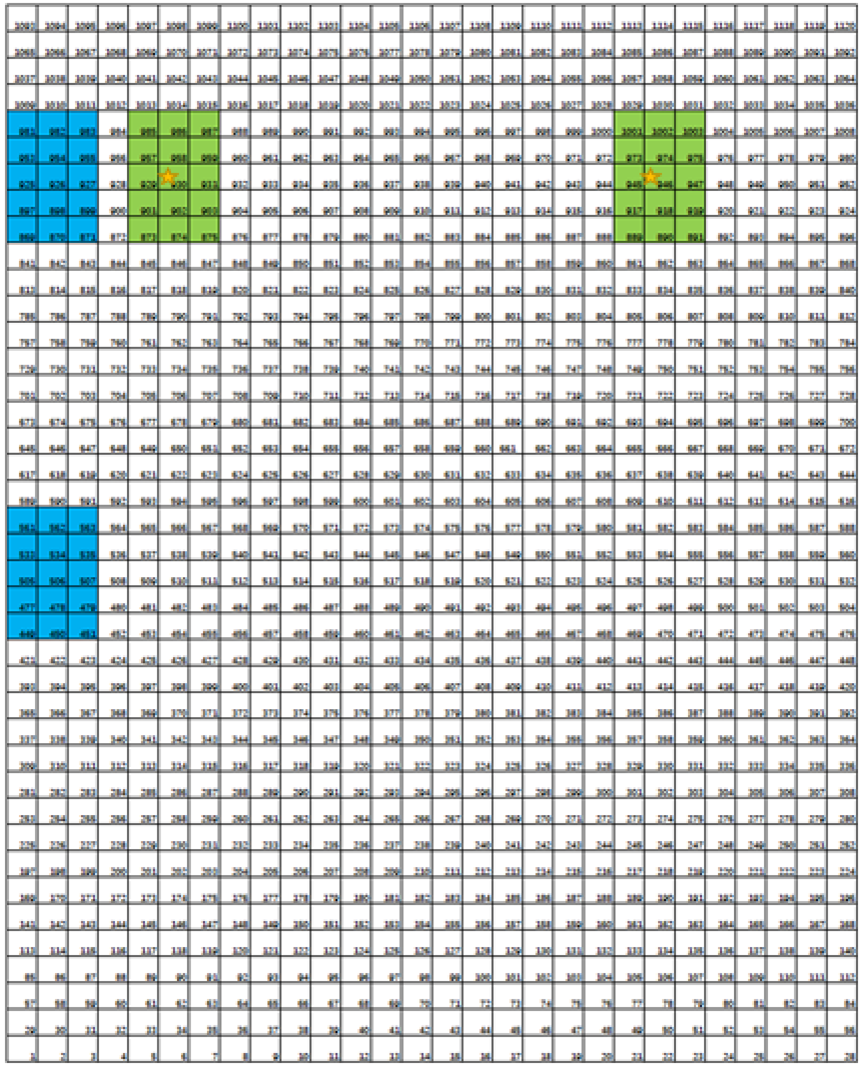
Q-Learning Algorithm

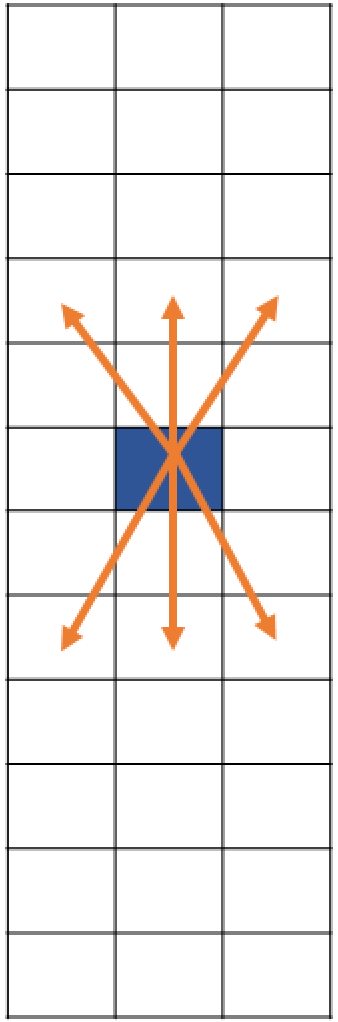
Q-Learning

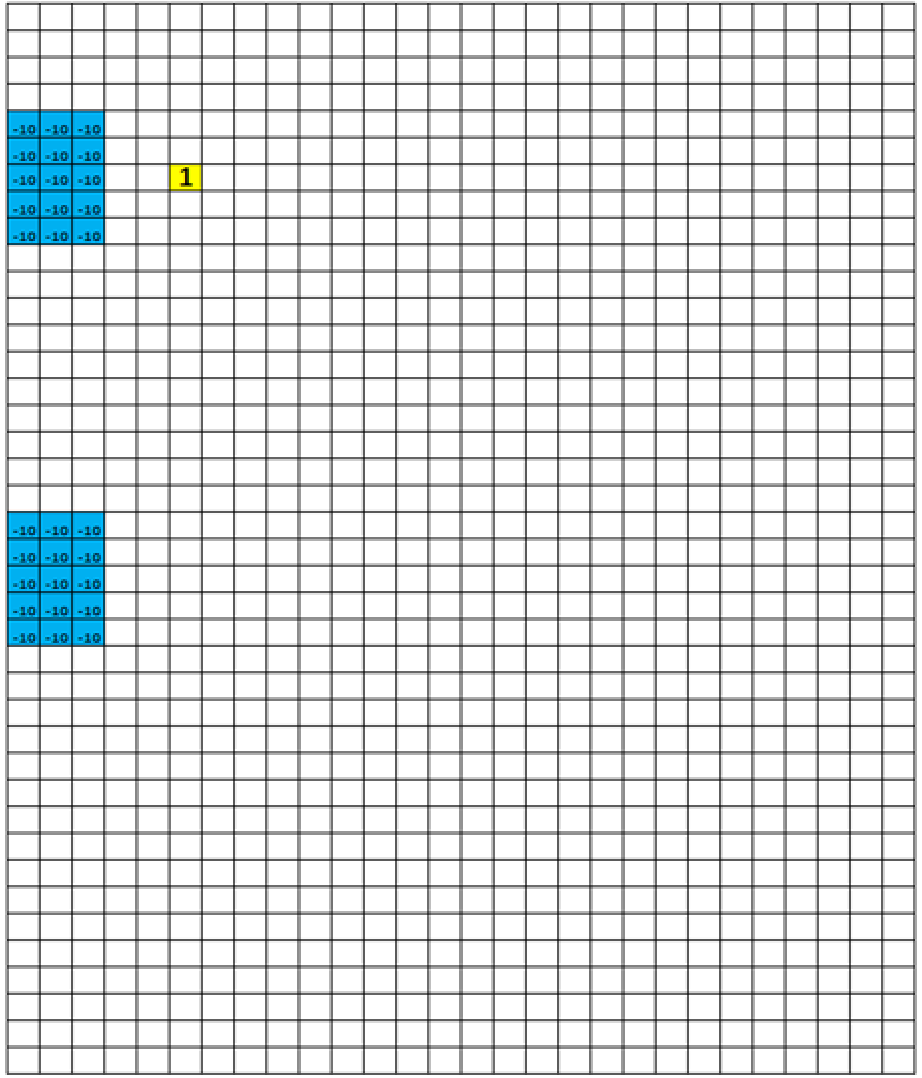
Algorithm 1 Q-Learning

$Q(s,a) \leftarrow 0 \ \forall (s,a)$
for each epoch $k \leftarrow 0$ to K **do**
  $s \leftarrow$ pick_up_state()
  while a terminal state is not reached **do**
    $\pi \leftarrow \mathrm{SelectPolicy}(Q)$ {e.g. via $\pi(s) = \arg\max_{a \in \mathcal{A}} Q(s,a)$, or ϵ-greedy}
    $a \leftarrow \mathrm{SelectAction}(\pi, s)$
    $r \leftarrow \mathrm{ObserveReward(s)}$
    $s' \leftarrow \mathrm{ObserveNextState}(s,a)$
    $Q(s,a) \leftarrow Q(s,a) + \alpha[r + \gamma \max_{a' \in \mathcal{A}} Q(s',a') - Q(s,a)]$
    $s \leftarrow s'$
  end while
end for
return Q

States, Actions & Rewards







Other places are all -0.01.

Q Table Update

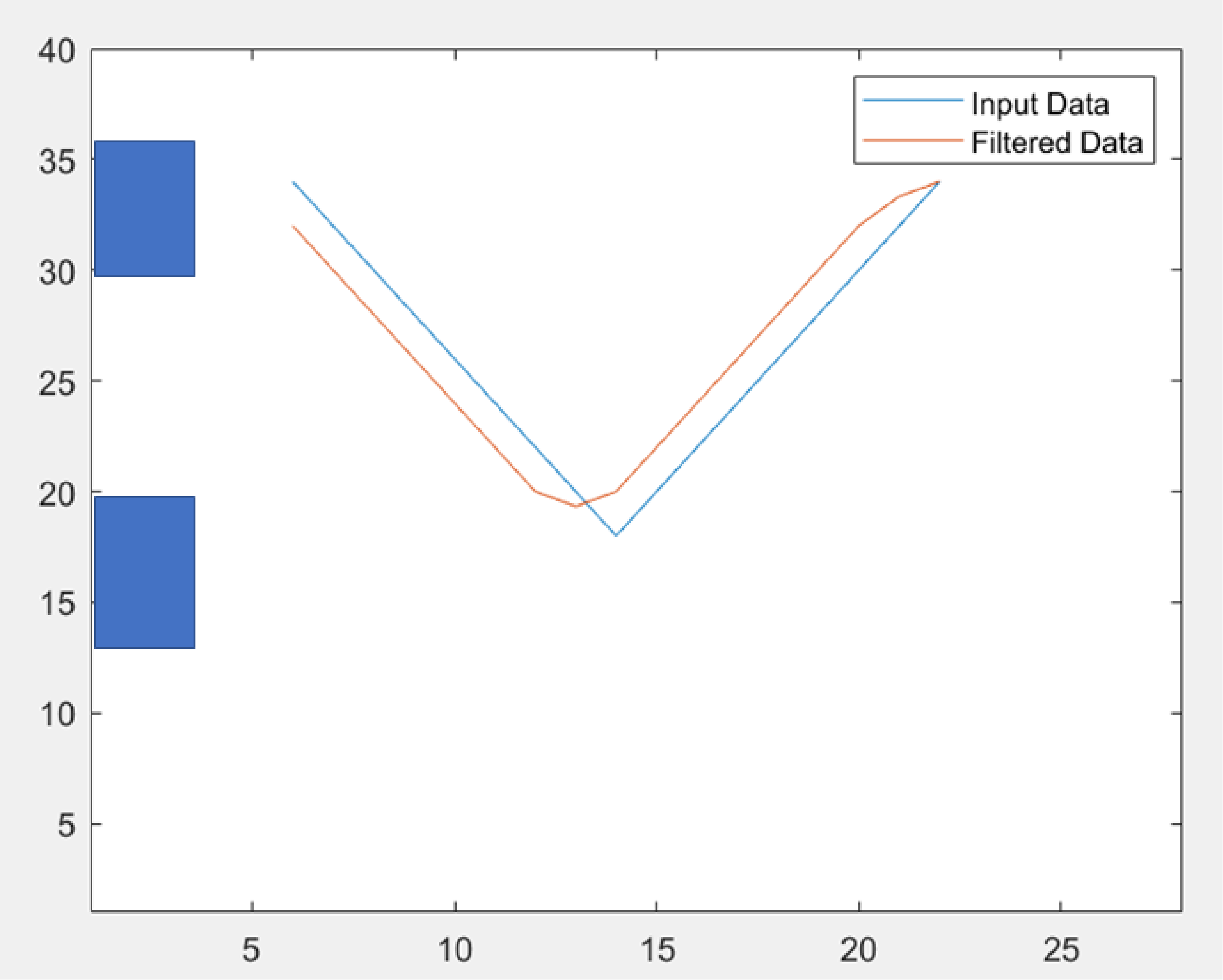
Q_table

1120x6 double

states	Left-up	right-up	up	down	left-down	right-down
	1	2	3	4	5	6
873	0.6220	1	0.6220	0.6220	0.6220	0.6220
874	0.6220	0.6220	1	0.6220	0.6220	0.6220
875	1	0.6220	0.6220	0.6220	0.6220	0.6220
876	0.6220	0.3801	0.6220	0.6220	0.6220	0.3801
877	0.6220	0.3801	0.3801	0.3801	0.6220	0.3801
878	0.3801	0.2253	0.3801	0.3801	0.3801	0.2253
879	0.3801	0.2253	0.2253	0.2253	0.3801	0.2253
880	0.2253	0.1262	0.2253	0.2253	0.2253	0.1262
881	0.2253	0.1262	0.1262	0.1262	0.2253	0.1262
882	0.1262	0.0627	0.1262	0.1262	0.1262	0.0627
883	0.1262	0.0627	0.0627	0.0627	0.1262	0.0627
884	0.0627	0.0222	0.0627	0.0222	0.0627	0.0222
885	0.0627	-0.0038	0.0222	0.0222	0.0222	0.0222
886	0.0222	-0.0038	0.0222	0.0222	0.0222	-0.0038
887	0.0222	-0.0038	-0.0038	-0.0038	-0.0038	-0.0038
888	-0.0038	-0.0204	-0.0038	-0.0038	-0.0038	-0.0204
889	-0.0038	-0.0204	-0.0204	-0.0204	-0.0038	-0.0204

Result & Analysis

- The fastest way is a V-path
- Realization in the real car



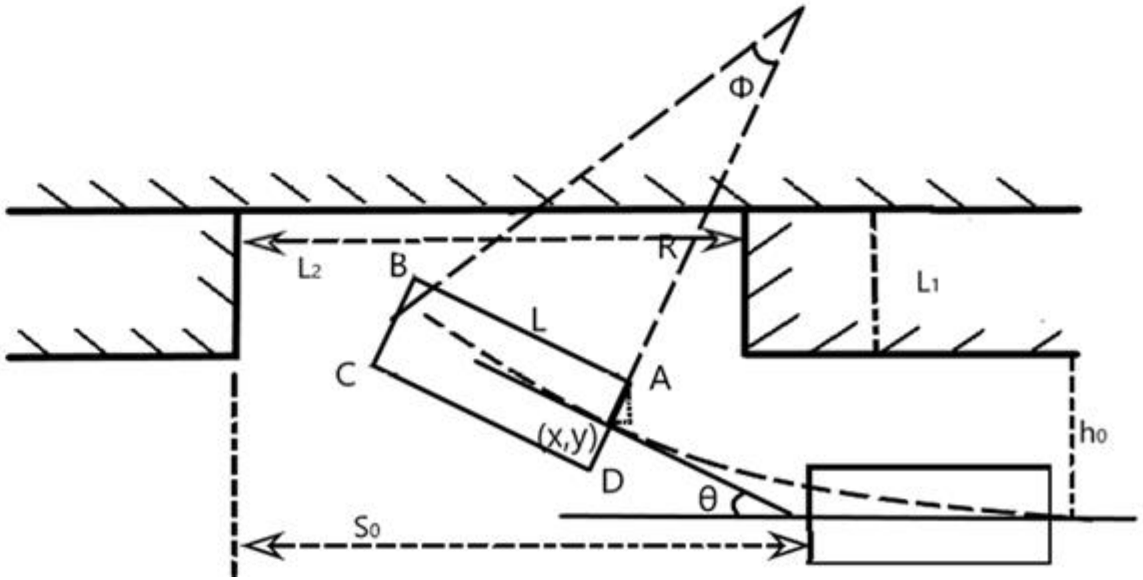
The restriction of parking path

$$\theta = \tan^{-1}(\frac{dy}{dx})$$

$$\rho = \frac{y''}{[1+(y')^2]^{3/2}} \rightarrow R = \frac{1}{\rho}$$

$$\begin{cases} x_A = x + \frac{W}{2} \cdot \sin\theta \\ y_A = y + \frac{W}{2} \cdot \cos\theta \end{cases}$$

$$\begin{cases} x_B = x - L \cdot \cos\theta + \frac{W}{2} \cdot \sin\theta \\ y_B = y + L \cdot \sin\theta + \frac{W}{2} \cdot \cos\theta \end{cases}$$



The restriction of parking path

Restrictions:

1、 restriction $of\ the\ steering\ radius: \rho\ \geq 1/R_{min}$

2、restriction of the directional angular velocity: $|\Psi| \leq \Psi_{\max}$

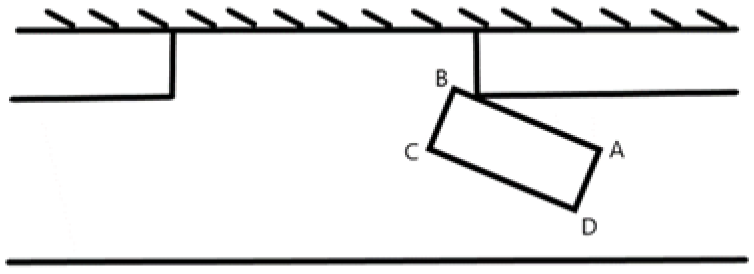
$$\tan\emptyset = \frac{L}{R} \rightarrow \emptyset = \tan^{-1}\left(\frac{L \cdot y''}{(1+y'^2)^{3/2}}\right)$$

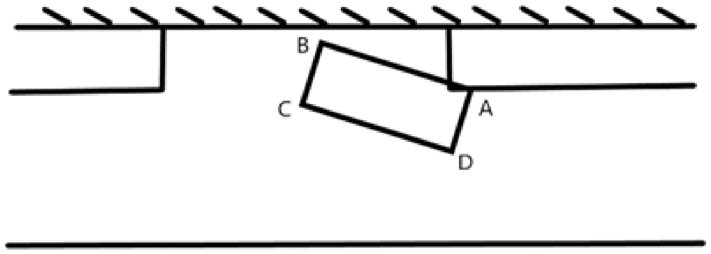
$$\Psi = \frac{d\Phi}{dt}$$

3、restriction of the points y_A and y_B

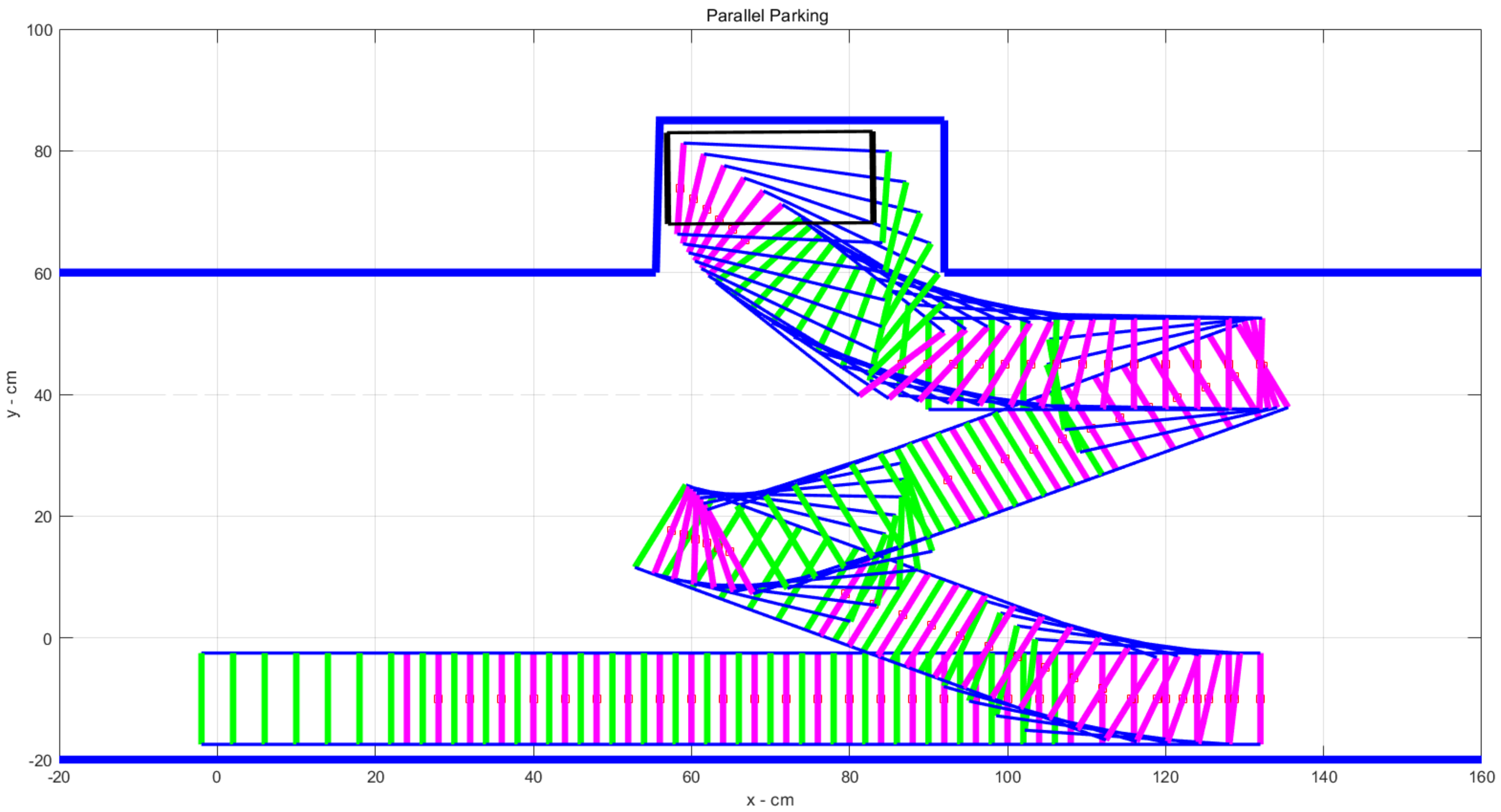
$$y_A < h_0, x_A \in [0, s_0 - L_1]$$

$$y_B < h_0, x_B \in [0, s_0 - L_1]$$





Video



Parallel Parking
100
80
60
40
20
0
-20
y - cm
-20
0
20
40
60
80
100
120
140
160
x - cm

References

Li H, Guo K, Song X, et al.
Trajectory planning of automatic parallel parking with multi-constraints based on Matlab[J].
Journal of Central South University (Science and Technology), 2013, 44(1): 2013-01.

Watkins C J C H, Dayan P.
Q-learning[J].
Machine learning, 1992, 8(3-4): 279-292.