

Techniker Autonomer System

-- A strategy of autonomous parallel parking

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Presentation

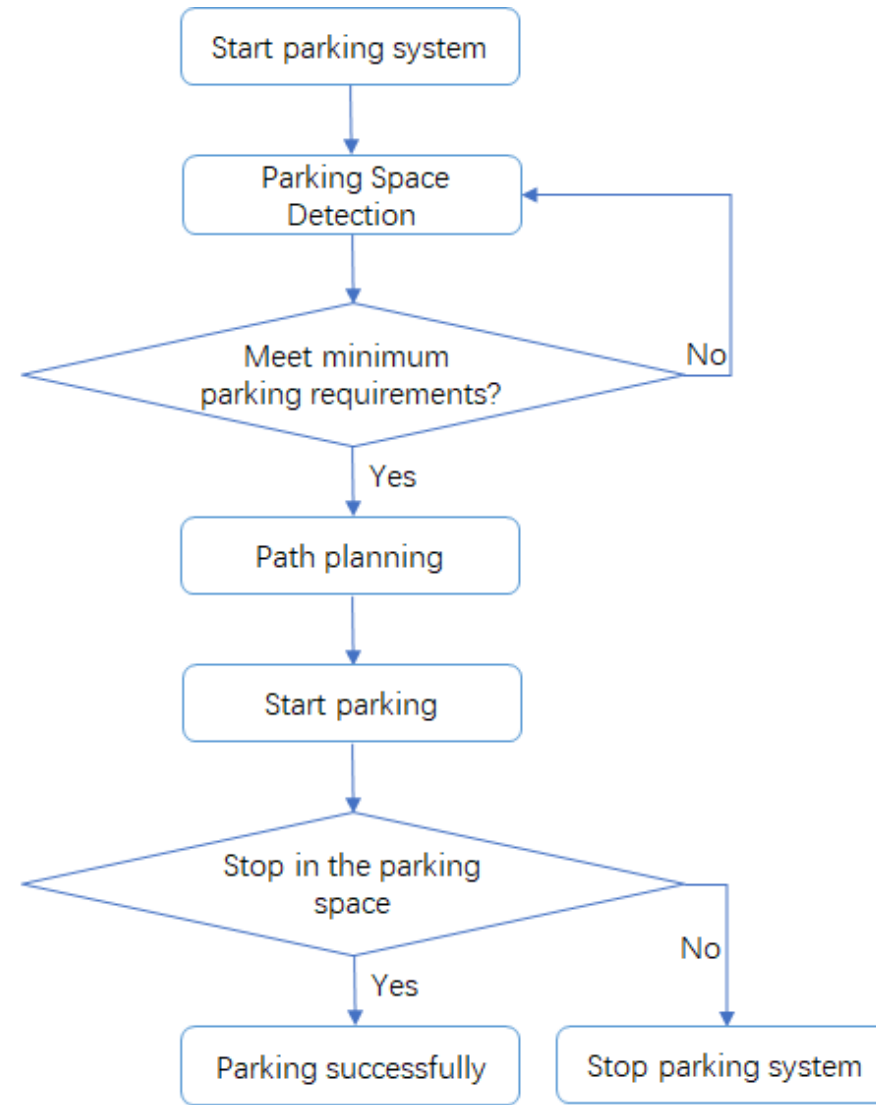
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Motivation

- 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

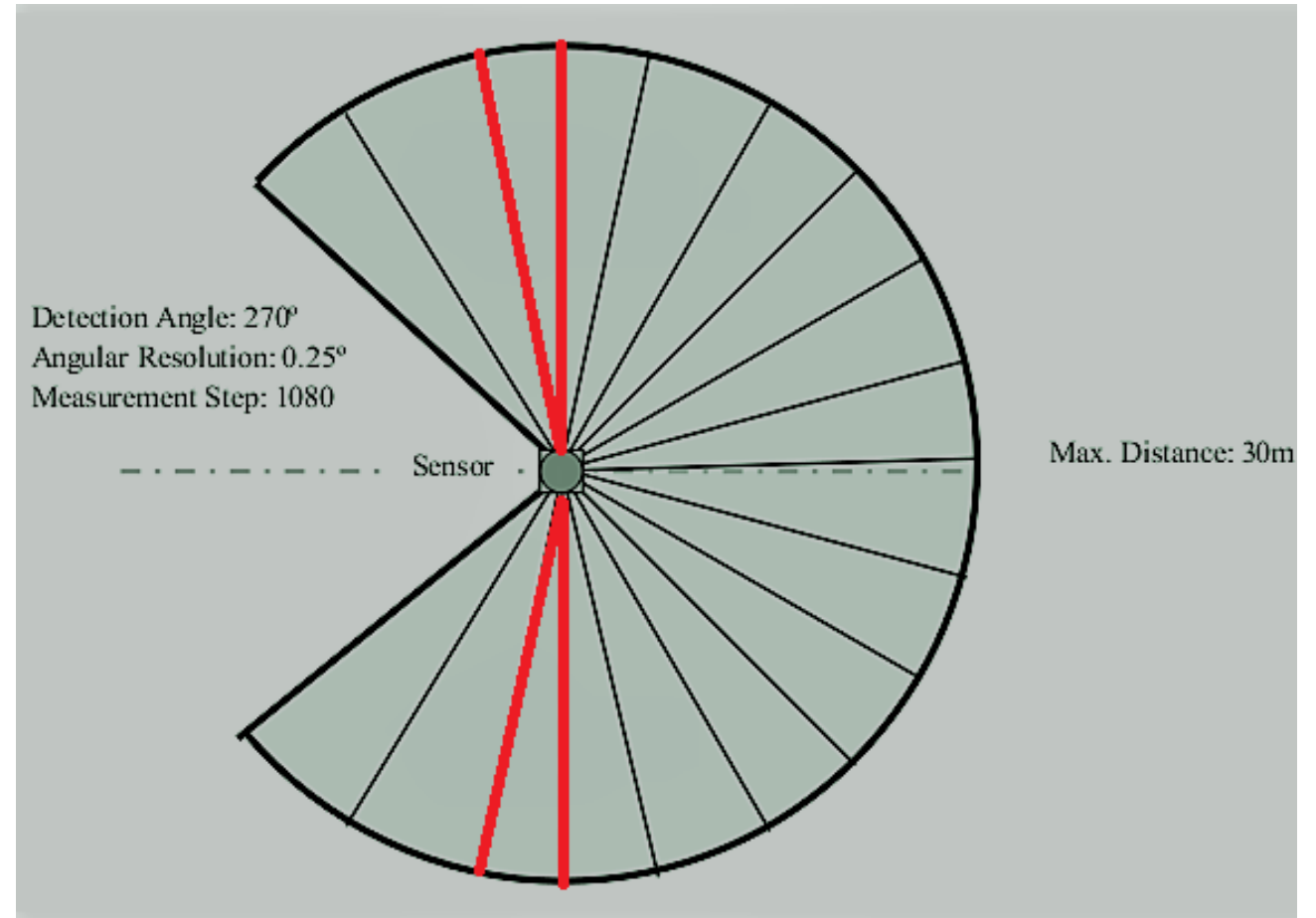
Flow chart of parallel parking



Parking space detection

Detection tool:

- Hokuyo lidar
 - detection angle: 15°



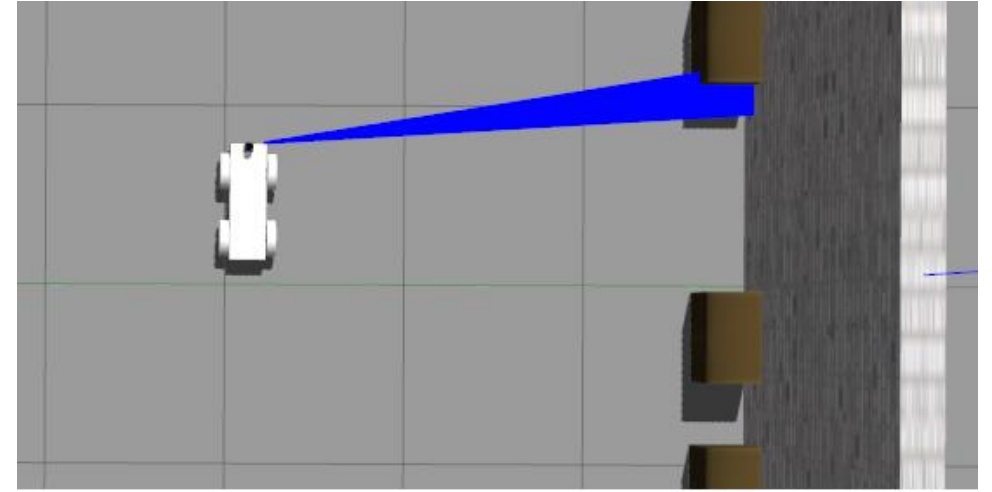
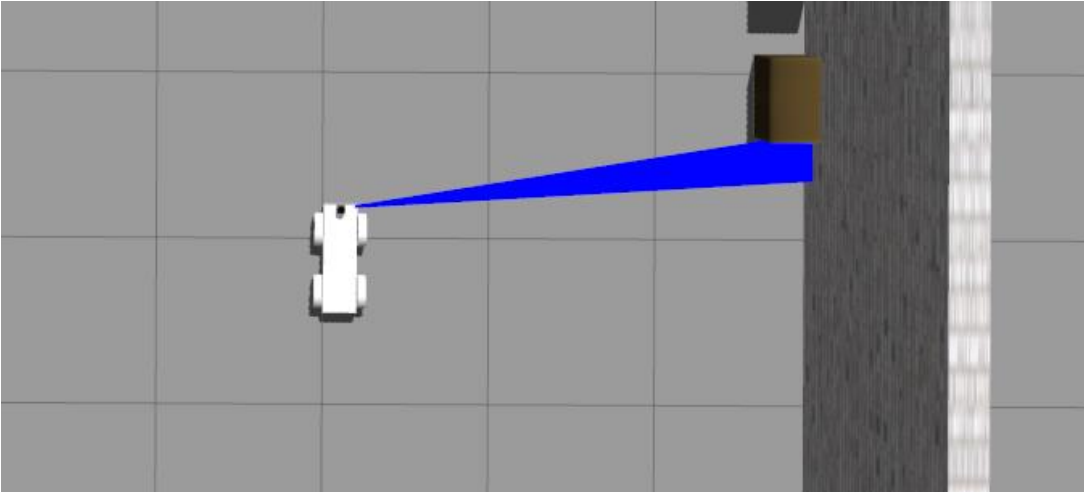
Parking space detection

Hokuyo placement:

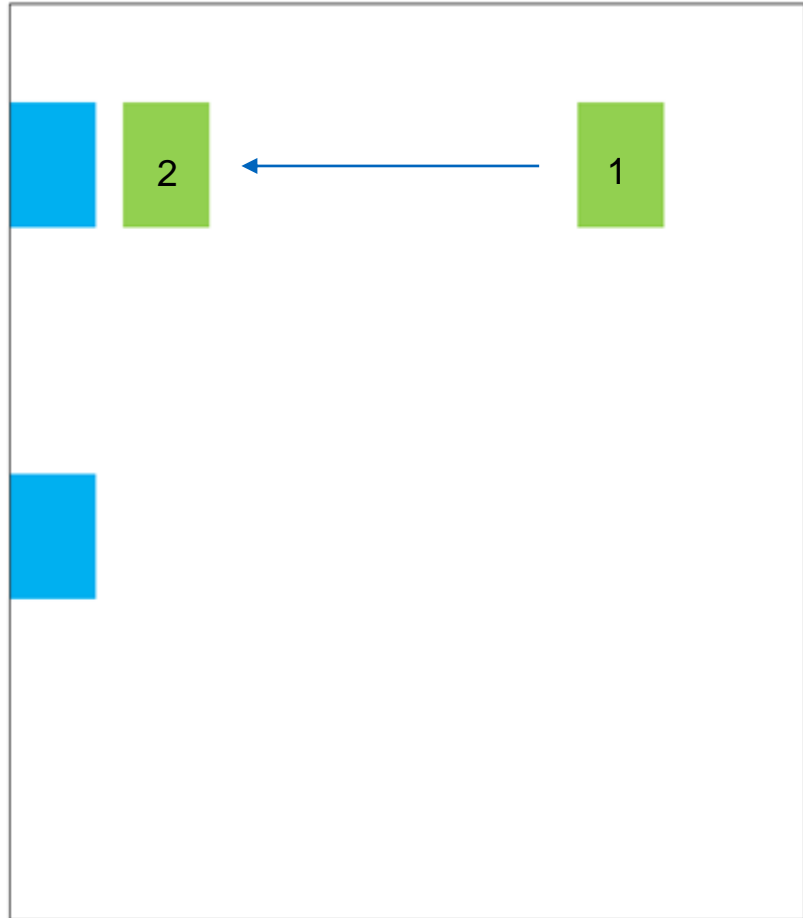
- Hokuyo is laid flat in front
- A vertical detection range
small obstacle will also be detected
final detected 3-dimensional free space

Parking space detection

Hokuyo on the car



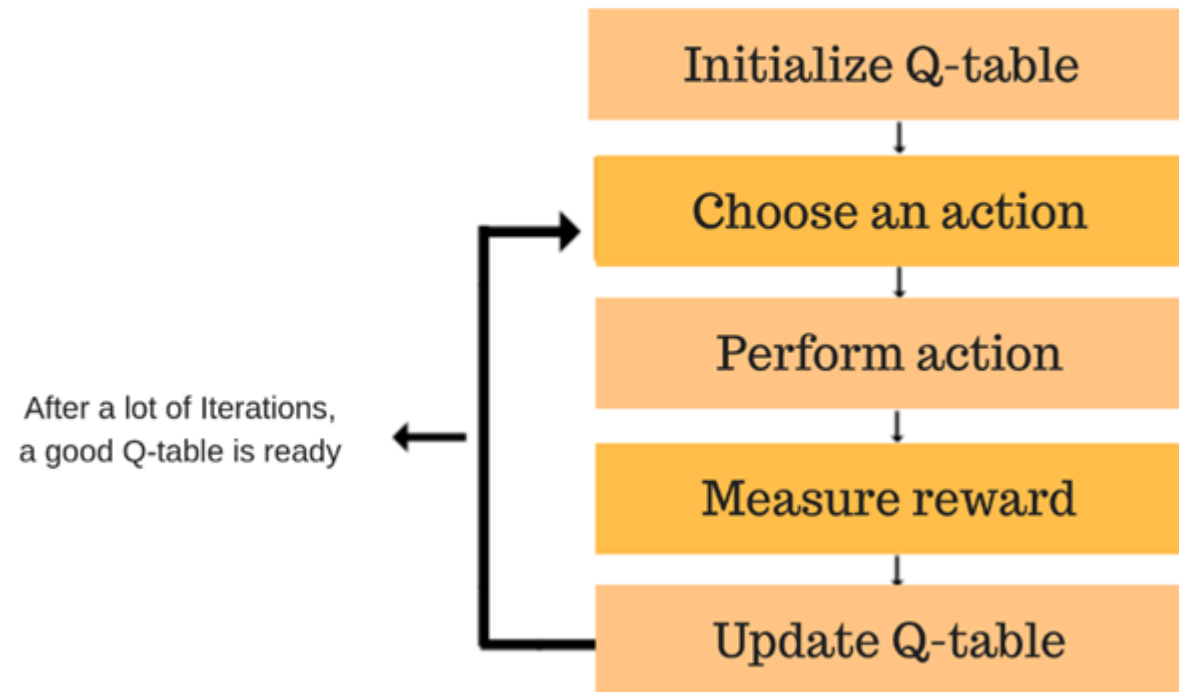
Problem Statement



- 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

Introducing the Q-learning algorithm process



Q-Learning Algorithm



Algorithm 1 Q-Learning

```
1:  $Q(s, a) \leftarrow 0 \ \forall (s, a)$ 
2: for each epoch  $k \leftarrow 0$  to  $K$  do
3:    $s \leftarrow \text{pick\_up\_state}()$ 
4:   while a terminal state is not reached do
5:      $\pi \leftarrow \text{SelectPolicy}(Q)$  {e.g. via  $\pi(s) = \arg \max_{a \in \mathcal{A}} Q(s, a)$ , or  $\epsilon$ -greedy}
6:      $a \leftarrow \text{SelectAction}(\pi, s)$ 
7:      $r \leftarrow \text{ObserveReward}(s)$ 
8:      $s' \leftarrow \text{ObserveNextState}(s, a)$ 
9:      $Q(s, a) \leftarrow Q(s, a) + \alpha[r + \gamma \max_{a' \in \mathcal{A}} Q(s', a') - Q(s, a)]$ 
10:     $s \leftarrow s'$ 
11:   end while
12: end for
13: return  $Q$ 
```



States, Actions & Rewards

3080	3081	3082	3083	3084	3085	3086	3087	3088	3089	3090	3091	3092	3093	3094	3095	3096	3097	3098	3099	3100	3101	3102	3103	3104	3105	3106	3107	3108	3109	3110	3111	3112	3113	3114	3115	3116	3117	3118	3119	3120	
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Q Table Update

Left-up right-up up down left-down right-down

states

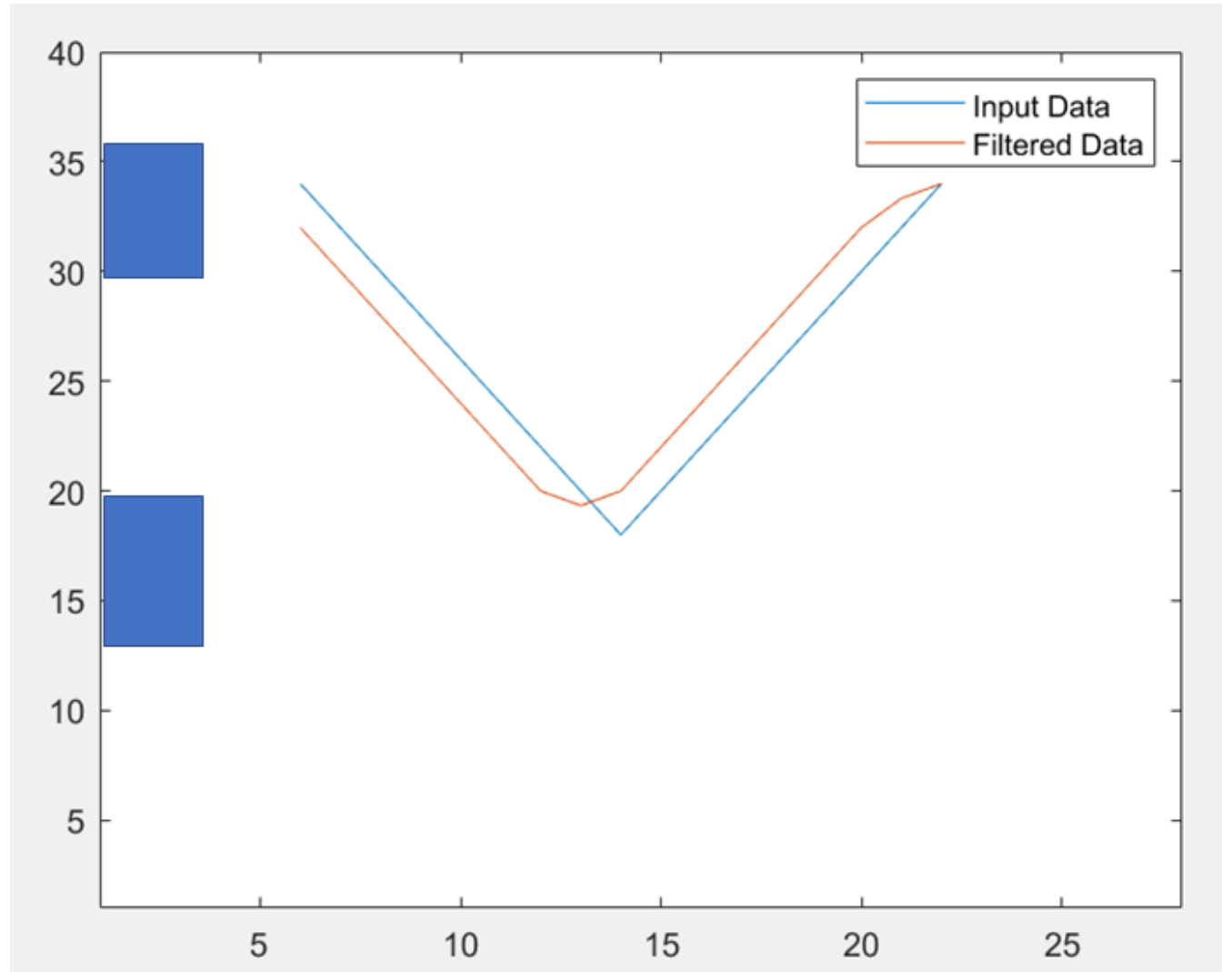
Q_table x

1120x6 double

	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



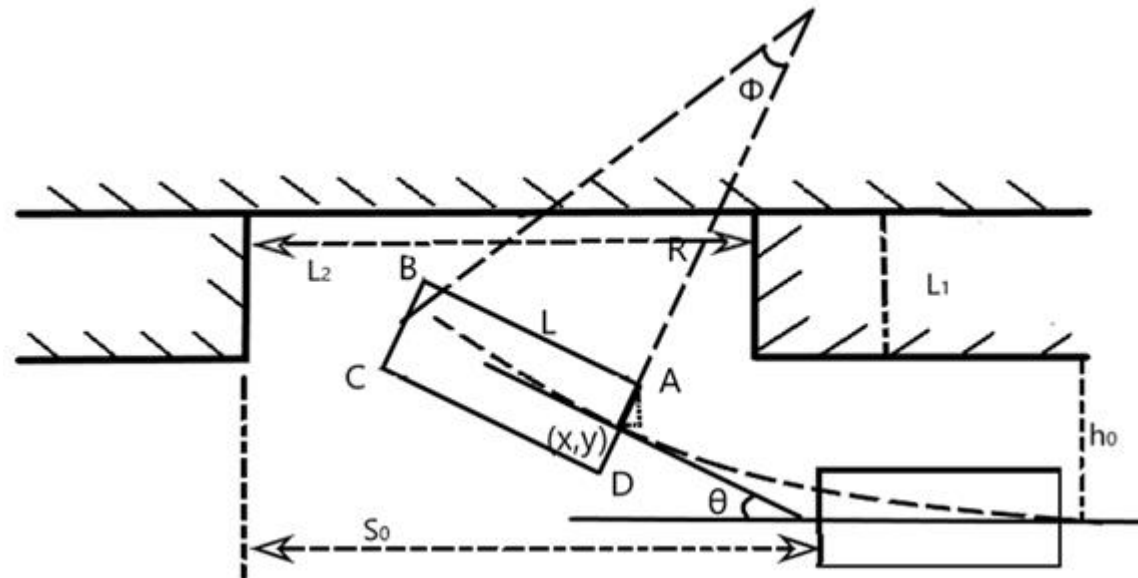
The restriction of parking path

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

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

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

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



The restriction of parking path

Restrictions:

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

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

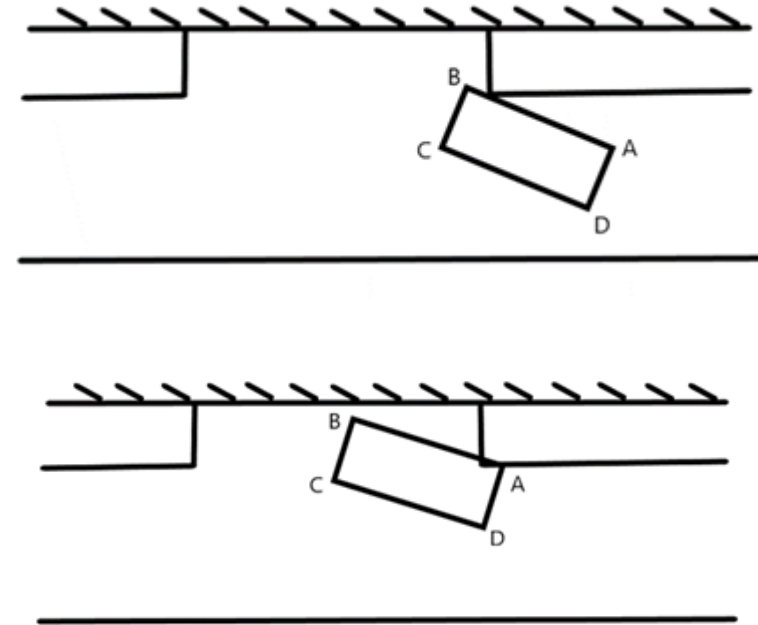
$$\tan \phi = \frac{L}{R} \rightarrow \phi = \tan^{-1} \left(\frac{L \cdot y''}{(1+y'^2)^{3/2}} \right)$$

$$\psi = \frac{d\phi}{dt}$$

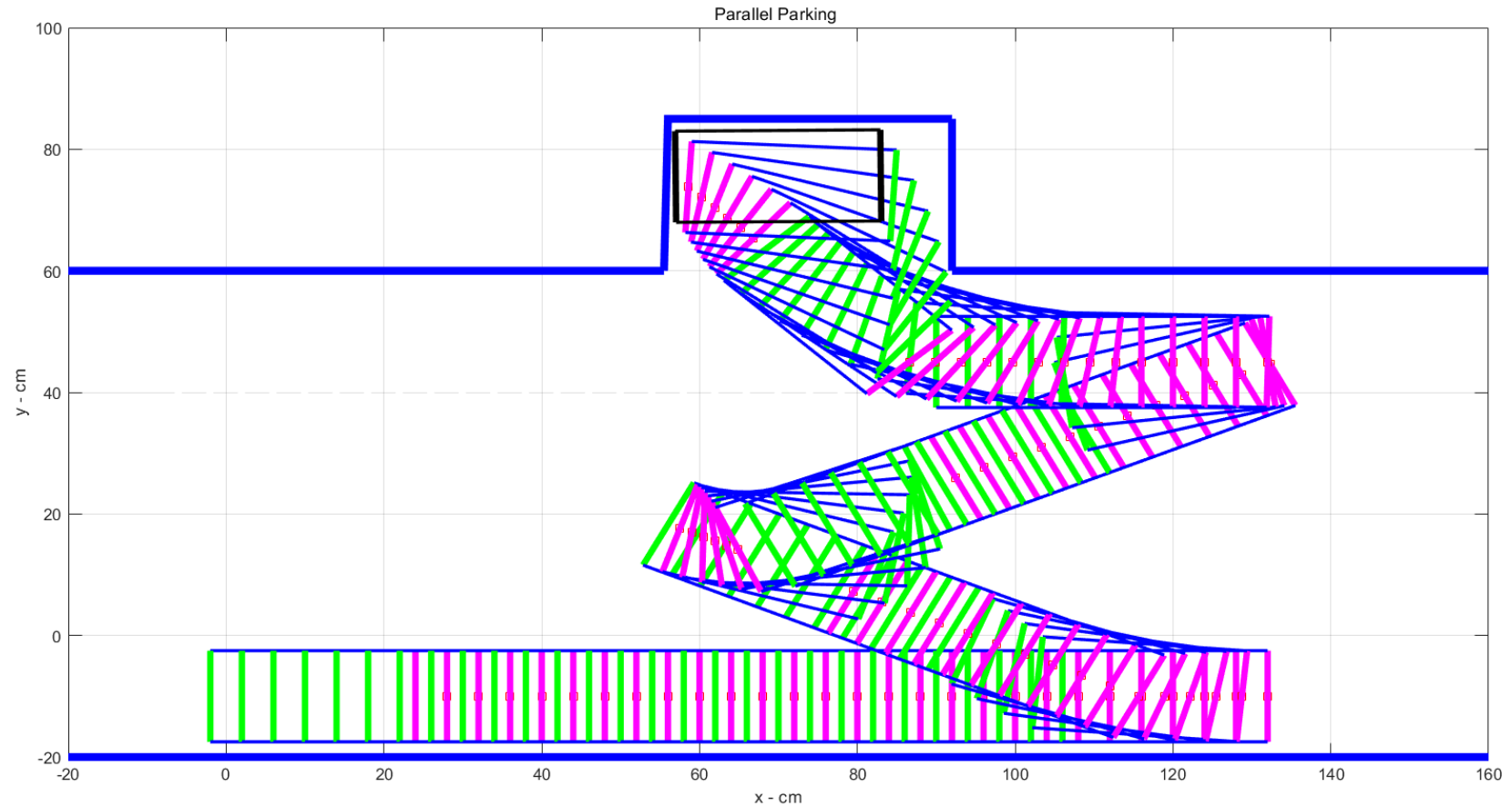
3、 restriction of the points y_A and y_B

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

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



Video



References



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Trajectory planning of automatic parallel parking with multi-constraints based on Matlab[J].

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