Optimization Design of Parking Space of Open Parking Lot

Yanhong Wu[1], Gaixia Wang[2]

[1]Shandong Huayu University of Technology, Shandong, 253500, China

[2]Anhui University of Technology, Anhui, 243002, China

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Abstract: Nonlinear programming model is used to study the optimal design of open parking spaces in this paper. In order to get the optimal design scheme of a given parking space, the formula model is established, and the number of parallel and vertical parking spaces that can be arranged is 84 and 62 respectively. Then the nonlinear programming model is established for the oblique and mixed forms and the maximum number of parking spaces that can be arranged in hybrid arrangement is 88 through programming solution. It can be concluded that the most parking spaces can be arranged by the combination of oblique and parallel arrangement. At last, the width of the passage is solved from the relationship between the width of the passage, the length and the width of the parking space.

1. Channel Design

The minimum turning radius of the car is 5.5 meters (minimum turning radius: the minimum distance between the turning center of the car and the track of the steering wheel outside the car when the car turns). The distance between the steering center and the inside wheel during turning is $R_2 = R_1 - d = 5.5 - 1.7 = 3.8(m)$. As shown in figure 1.

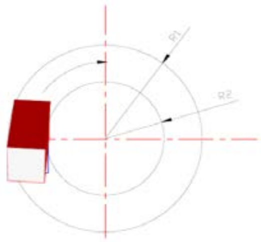

Figure 1

Now the outermost end of the car is driving on a circle with a radius of 5.5m, then enter the parking space through the angle $\theta\,(0 \le \theta \le \pi/2)$. $\theta = \dfrac{\pi}{2}$ is used to enter the parking space vertically from the driveway, while $\theta = 0$ is used to enter the parking space in parallel from the driveway. To reduce the parking area, assume

That all cars are parked at the same angle. As shown in figure 2.

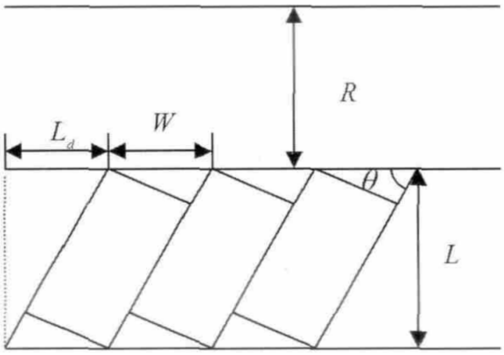

Fig.2

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Now specifically study the situation of cars driving into parking spaces. R_1 is the minimum turning radius, R is the channel width, and the inside radius of the car moves on the R_2 circle, parking in the parking space at the angle θ. The channel width is $R = R_1 - R_2 \cos\theta$.

2. Design Model of Parking Space

2.1. Parallel arrangement

When the vehicles are arranged in parallel rows, the angle between the vehicle and the channel is 0, and the width of the channel is $D = R_1 - R_2 \cos\theta = 5.5\text{-}3.8 = 1.7m$. The length of the parking space is c=5.5�, and the width of the parking space is $A_W = 2.5\text{m}$. So the number of parking spaces that can be arranged in a row is $a = \frac{A}{A_L} = \frac{79}{5.5} \approx 14$, and the number of rows that can be arranged is $b = \frac{B - A_w}{A_w + D} = \frac{26.5 - 2.5}{2.5 + 1.7} \approx 5$.Then the maximum parking number that can be emitted is Smax=a (b+1) =84.

2.2. Vertical arrangement

When the vehicles are arranged in parallel rows, the angle between the vehicle and the channel is $\frac{\pi}{2}$, and the width of the channel is $R = 5.5 - 3.8\cos\theta$,So the number of parking spaces that can be arranged in a row is $a = \frac{A}{A_L} = \frac{79}{2.5} \approx 31$, and the number of rows that can be arranged is $b = \frac{B - A_L}{A_L + D} \approx 1$.Then the maximum parking number that can be emitted is Smax=a (b+1) =62.

2.3. Diagonal row arrangement

When the vehicles are arranged in diagonal rows [1][2], the angle between the vehicle and the channel is $0 < \theta < \frac{\pi}{2}$, and the width of the channel is $D = 5.5 - 3.8\cos\theta$.Then calculate the space S_θ occupied by each car. Considering the limit of the optimal arrangement, Now assume that the parking space is infinitely long and ignore the wasted area $\frac{1}{2}WL_d$ at both ends of the parking space in the row. Because they are small relative to the size of each parking space, they are negligible. From the parking space occupied by vehicles, it occupies an area of $W \cdot L$. In addition, the channel area it occupies is $W \cdot R$. Since the opposite row of cars can borrow from each other, the area should be halved. Therefore, the following optimization model is established [3]

$$S(\theta) = A_w A_l + \frac{1}{2}A_w R = A_w A_l + \frac{A_w^2 \cos\theta}{2\sin\theta} + \frac{R_1 A_w}{2\sin\theta} - \frac{A_w R_2 \cos\theta}{2\sin\theta} \quad (1)$$

Substitute $R_1 = 5.5m$, $R_2 = 3.8m$, $A_L = 5.5m$, $A_W = 2.5m$ into the above equation, and get

$$S(\theta) = 13.75 + \frac{3.125\cos\theta}{\sin\theta} + \frac{6.875}{\sin\theta} - \frac{4.75\cos\theta}{\sin\theta} \quad (2)$$

$$S'(\theta) = \frac{1.625 - 6.875\cos\theta}{(\sin\theta)^2}\left(0 < \theta < \frac{\pi}{2}\right) \quad (3)$$

let $S^{'}(\theta)=0$, then get $\cos\theta=\frac{1.625}{6.875}=\frac{13}{55}$, $\theta=76.33^{0}$. There can be two rows of cars in the parking lot.

2.4. Horizontal and vertical mixing arrangement

The parking lot is divided into $n+2$ parking areas, n horizontal parking areas and 2 vertical parking areas. There are two parking belts in each row of parking areas, and only one parking belt in each row of parking areas. Moreover, vehicles in the row of parking areas are parked vertically. The optimization model [4][5] is established as follows:

$$\max\sum_{i=1}^{n}x_i+2y \quad (4)$$

$$S.T.\begin{cases} nR+mL=B \\ x_i=2(A-L_d-2C-2\times 5.5)/W \\ R=5.5-3.8\cos\theta \\ L=5.5\sin\theta+2.5\cos\theta \\ L_d=5.5\cos\theta+2.5\cot\theta\cos\theta \\ W=\dfrac{2.5}{\sin\theta} \\ y=\dfrac{B}{2.5} \\ m=2n, m,n\in Z^{+} \end{cases} \quad (5)$$

The number of vehicles that can be accommodated is 76.

2.5. Mixed arrangement

If only the inclined arrangement is used, the middle channel is too wide. So use the hybrid arrangement to optimize the model. In order to maximize the utilization of parking space, the parking lot is divided into n parking areas, each of which is composed of a passageway and parking belts on both sides. X_i refers to the number of parking spaces in area i ($i=1,2,\cdots,n$). By analyzing the relationships among various variables, the following nonlinear programming model is established.

$$\max\sum_{i=1}^{4}x_i \quad (6)$$

$$S.T.\begin{cases} W_1=\dfrac{2.5}{\sin\theta_1} \\ W_2=\dfrac{2.5}{\sin\theta_2} \\ \dfrac{26.5-2(L+d)}{2}>R_1=5.5-3.8\cos\theta_1 \\ x_1=(79-L_{d_1})/W_1=(79-5.5\cos\theta_1-2.5\cot\theta_1\cos\theta_1)\sin\theta_1/2.5 \\ x_2=(79-L_{d_2})/W_2=(79-5.5\cos\theta_2-2.5\cot\theta_2\cos\theta_2)\sin\theta_2/2.5 \\ x_3=(79-L_{d_2})/W_2=(79-5.5\cos\theta_2-2.5\cot\theta_2\cos\theta_2)\sin\theta_2/2.5 \\ x_4=(79-L_{d_1})/W_1=(79-5.5\cos\theta_1-2.5\cot\theta_1\cos\theta_1)\sin\theta_1/2.5 \end{cases} \quad (7)$$

The optimal values of the optimization model are $\theta_1=76.33^{0},\theta_2=0^{0}$ which are obtained from the Matlab programming [6], and the number of cars that can be accommodated in the parking lot is

88.

3. Conclusion

In summary, the maximum number of vehicles that can be accommodated by hybrid emission is 88.

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