applied sciences

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Evaluation Model of Parking Equipment Planning and Design Based on Object-Oriented Technology

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Abstract: Stereo parking equipment has become an important means to solve the problem of parking difficulties, so it is necessary to study the planning of stereo parking equipment. This paper proposes an evaluation model for parking equipment planning and design, and verifies the feasibility of the model through an example. First, obtain the surface information of the planned area through object-oriented technology, and then complete the design layout of the area that can accommodate the most parking spaces according to the plan information map of the study area. Next, calculate the number of parking spaces required for each building in the area, and the number of available parking spaces within the maximum acceptable time for each building. Finally, compare the two to design the number and location of parking equipment. This method can quickly and accurately obtain the ground plane information map of the study area, while ensuring the capacity of parking spaces to meet the needs of users, it also improves the rationality and suitability of the planning and layout of stereo parking equipment, which can effectively guide the planning and construction of urban parking equipment.

Keywords: parking equipment; parking space planning; object-oriented; evaluation model

Citation: Ni, M.; Sun, Z.; Luo, Y.; Yi, Q.; Zhang, Y.; Wang, Z. Evaluation Model of Parking Equipment Planning and Design Based on Object-Oriented Technology. *Appl. Sci.* **2021**, *11*, 4263. https://doi.org/10.3390/app11094263

Academic Editor: Antonio Fernández-Caballero

Received: 2 April 2021
Accepted: 27 April 2021
Published: 8 May 2021

1. Introduction

With the rapid growth of the number of motor vehicles in China, the problem of parking difficulties has become increasingly prominent. The increase in parking spaces can ease the tension of urban parking to a certain extent, but at the same time it will also induce new traffic congestion on urban roads. In order to solve the problem of the contradiction between urban parking spaces and parking demand, stereo parking equipment has become an important means of solving parking problems in major cities, so reasonable stereo parking equipment planning is particularly important. At present, the related research on parking space planning is mainly carried out from two aspects: improving the parking space capacity and the rationality of parking space planning.

1.1. Research on Increasing Parking Capacity

In order to make full use of the parking space to build parking facilities. Abdelfatah et al. applied the optimization algorithm to the layout design of underground parking spaces, and studied the parking space layout problem that can accommodate the maximum number of parking spaces from the perspective of parking lot shape and parking space [1]. Azevedo et al. uses electrification and low-level driving automation to make parking density more than twice as high as traditional parking lots [2]. Dianawati and Kristianto studied the use of integer linear programming (ILP) to build a parking lot layout model to determine the best parking angle and number of parking [3]. Banzhaf et al. proposed a new method to integrate high-density parking lots into existing parking lots [4]. Zou et al. used genetic algorithms to optimize the parking space allocation of the Paternoster-type automatic parking system to increase parking density [5]. Based on the space utilization of different parking methods, Sawangchote et al. developed a heuristic algorithm for the layout of small-scale garage parking spaces [6]. According to the concept of parking space unit, Ramli et al. used a mathematical model to determine the optimal parking space angle [7]. Syahrini et al. discussed the mathematical model of vehicle parking spaces in the triangle area, and established an optimization model of the triangle parking lot [8].

1.2. Research on the Rationality of Parking Space Planning

Aiming at the rationality and applicability of the parking space layout design, Guo et al. established a campus bicycle sharing parking spot plan based on the user's total travel time and total construction cost as optimization goals [9]. Han et al. proposed an automatic parking lot allocation mechanism under the premise of considering the personalized needs of parking users and avoiding traffic conflicts [10]. Qin et al. established two nested logit models to analyze the correlation between travelers' parking behavior and their travel characteristics [11]. Shi et al. proposed a collaborative planning scheme for an unmanned parking system in a large underground parking lot [12]. Feret et al. designed a new camera-based parking space detection method to detect and track on-site in a coherent manner to maintain the consistency of the structure and time of the overall parking lot layout [13]. Hsu and Chen proposed a parking space detection method and parking space analysis algorithm based on the surrounding perspective [14]. Mettupally and others used novel big data analysis and deep learning technology to propose a smart parking solution [15]. Shan et al. proposed an automatic parking lot allocation mechanism under the premise of considering the personal needs of parking users and avoiding traffic conflicts [10]. Nourinejad et al. proposed a mixed-integer nonlinear programming to alleviate lane congestion in parking lots [16]. In order to solve the scheduling problem of multiple automatic guided vehicles (agv), Sun and Zhao et al. built an intelligent parking system [17]. It can be seen from the above research that only considering the space layout design of the parking space that can accommodate the maximum number of parking spaces may result in the waste of the parking area, and starting from the rationality of the parking position, it may not be able to deal with complex contours or obstacles to the parking space. The impact of the layout needs to fully meet the actual physical environment and user needs in the planning and design of the parking equipment space. Therefore, this paper uses object-oriented technology in the planning and design of parking equipment, and first extracts the planned parking area through this technology, and improves the rationality of parking equipment planning on the basis of ensuring that the parking space meets the needs of users.

1.3. Research on Object-Oriented Technology

Object-oriented technology refers to the remote sensing image and other related geospatial data of the surface area obtained through satellites, etc., combined with corresponding features and remote sensing imaging mechanism, using spectrum, shape, texture and other characteristics through image segmentation technology, using the object as the image processing unit classification, so as to quickly obtain the high-precision feature distribution [18–21]. At present, object-oriented technology has been widely used in various spatial planning fields. Li et al. proposed an object-oriented recognition method for monitoring ion-type rare earth mining using high spatial resolution remote sensing images [22]. Yang and Wan used GF-1 WFV sea surface oil spill images as data sources, and used four classic supervised classification algorithms to extract sea surface oil spill information [23]. Sun and Liu et al. used high spatial resolution GF (high score)-1 remote sensing images to finely classify the construction land in the planned restricted area of nuclear power plants [24]. The object-oriented landslide individual separation method proposed by Lin et al. can well solve the problem of rapid risk assessment of landslide hazards [25]. Fathizad et al. used remote sensing technology and object-oriented classification algorithms to evaluate the desertification of the desert in central Iran [26]. Merchant et al. used optical satellite images and object-oriented convolutional neural networks to classify open water features [27]. Perea-Moreno et al. applied digital photogrammetry and object-oriented imaging technology to evaluate the soil erosion risk of olive groves [28]. Tuno et al. evaluated the accuracy of forest area boundary location based on object-oriented classification of multispectral images [29]. Yang and Wang et al. extracted seismic road blockade information based on convolutional neural networks and high-resolution satellite images [30].

1.4. Research Process and Goals

1.4.1. Research Process

In this paper, object-oriented technology is used to extract the surface information of the study area, and the classification accuracy of the image is improved by multi-scale segmentation of the satellite remote sensing image of the study area. Then high-resolution image extraction is carried out to classify various objects. Finally, each area is classified Regularize it into a rectangular image, and obtain the plane map required by the parking equipment planning and design evaluation model. Next, the parking space was planned from two aspects: the rationality and suitability of the parking space layout, and the parking equipment planning design evaluation model was established, and the layout plan of the parking equipment was designed in combination with specific cases, which verified the rationality and feasibility of the model. To provide a reference for alleviating the difficulty of urban parking. This model can provide a reference for alleviating the difficulty of urban parking.

1.4.2. Research Goals

(1) In order to quickly and accurately obtain the effective information of the target parking area, comprehensively use multi-scale segmentation processing and high-resolution image analysis technology to classify environmental features;
(2) Based on the research on the classification of environmental features, obtain the plane map required by the parking equipment planning and design evaluation model;
(3) Carry out the planning and design of the parking space from the rationality and suitability design of the parking space, and establish the parking equipment planning and design evaluation model to meet the product experience and actual needs of the target users;
(4) Carry out feasibility study based on specific cases to provide reference for improving the reasonable space planning and design of parking equipment.

2. Model Map Extraction

The evaluation model of parking equipment planning and design proposed in this paper is mainly aimed at the above-ground parking space around the building. Firstly, the high-resolution remote sensing image of the study area is obtained by satellite, and then the model plane map is obtained by multi-scale segmentation, high-resolution image extraction and information geometric processing.

2.1. Multi-Scale Segmentation of Image

Image segmentation refers to a process of classifying and merging "homogeneous" objects in an image. Single-scale segmentation will result in incomplete information extraction of object image, so it is necessary to segment image from multiple scales. Image multi-scale segmentation is a key step based on object-oriented remote sensing information extraction based on e-cognition [31]. The multi-scale segmentation result of the image is affected by different parameters, which is the criterion for judging whether the pixels in the study area are merged with the adjacent image objects. Different segmentation algorithms will get different segmentation results. Therefore, the segmentation parameters should be analyzed synthetically, and the parameters should be set according to the characteristics of different original images to improve the validity of multi-scale segmentation.

In this paper, the degree of homogeneity factor heterogeneity is taken as the condition of merging two adjacent objects. If the heterogeneity of each pixel and the surrounding pixel is less than the threshold value, the two pixels are merged to achieve the goal of image segmentation. The heterogeneity of homogeneity factor includes spectral heterogeneity and shape heterogeneity. The method of combination and the formula of heterogeneity in this paper are from literature [32].

2.1.1. Spectral Heterogeneity

Spectral heterogeneity Δh_{color} refers to comparing the variance of two images before and after merging:

$$\Delta h_{color} = \sum_{c} \omega_c [n_{merge} \times \delta_c^{merge} - (n_{object1} \times \delta_c^{object1} + n_{object2} \times \delta_c^{object2})] \quad (1)$$

In the above formula, c represents the number of bands, δ_c represents the spectral standard value of the band, and ω_c represents the weight of the layer.

2.1.2. Shape Heterogeneity

Shape heterogeneity can be divided into smoothness heterogeneity and compactness heterogeneity [33], Image shape heterogeneity something Δh_{shape}:

$$\Delta h_{shape} = \omega_{compt} \times \Delta h_{compt} + \omega_{smooth} \times \Delta h_{smooth} \quad (2)$$

where, ω_{compt} and ω_{smooth} are the proportions of compactness and smoothness, respectively, $0 \leq \omega \leq 1$, so we have $\omega_{compt} + \omega_{smooth} = 1$.

2.1.3. Total Heterogeneity

Spectral heterogeneity and shape heterogeneity can be combined to obtain the total heterogeneity of the two objects to be merged f:

$$f = \omega_{color} \times \Delta h_{color} + \omega_{shape} \times \Delta h_{shape} \quad (3)$$

After the multi-scale segmentation of the above parameters, the image is divided into several smaller single-pixel image objects, and then the image objects are merged according to the threshold of the set heterogeneity f to form a larger image object. The heterogeneity of the merged image will be within the threshold range of the set segmentation scale, that is, the heterogeneity f, and the segmentation result will increase with the increase of the f threshold.

2.2. High Resolution Image Extraction

After performing multi-scale segmentation, the image is segmented into several "homogeneous" image objects, which need to be extracted and integrated with the same kind of surface information. According to the characteristics of image and terrain, classification rules are made from spectral, shape and texture features to select and extract houses, roads and vegetation.

2.2.1. Spectral Characteristic

Spectral features refer to spectral information such as mean, standard deviation and luminance of the image object. Different types of ground objects have different reflectivity to electromagnetic radiation, so different types of surface information are classified.

2.2.2. Shape Characteristic

The shape feature refers to the geometric features that reflect the shape information such as the extracted area, aspect ratio, shape index, compactness, density, and asymmetry of the image object. The surface information is calculated and classified based on the above shape features.

2.2.3. Texture Characteristic

The texture feature refers to the 8 texture parameters of the image object's average value, variance, information entropy, angle second-order distance, correlation, heterogeneity, contrast and homogeneity, which are mainly extracted by gray-level co-occurrence matrix [32,34].

2.3. Geometrical Extraction of Model Plane Map

After the high-resolution image is extracted, the image is classified according to the established rules to obtain the corresponding feature information classification image. However, the irregular edges of the contours of various features in the image are not conducive to the calculation and establishment of the model. Therefore, the average value of the coordinate points on the edge lines of various ground feature image objects is taken as the reference point, and each area is regularized into geometric images such as rectangles, and finally the plane map required by the parking equipment planning design evaluation model is obtained.

3. Parking Space Planning Model

3.1. Factors Affecting Parking Space Layout

Liu pointed out in his book *Science of Human Affairs* [35] that in design 'things' refers to the process of behavioral relationship or information exchange between people and things in a certain time and space, 'things' are composed of people, behavioral objects, environment, time, space and other elements. Its 'reasons' means the rule, which refers to the structural relationship between the elements that make up the 'things'. From the science of human affair, the influencing factors of parking space layout can be divided into rationality and suitability. Rationality refers to physical objective aspects, including the actual environment, the flow of people and vehicles, and the width of the road, etc. The suitability includes the convenience of getting a car, whether it meets the actual demand of parking space, frequency of use and distance, etc.

The evaluation model of parking equipment planning and design proposed in this paper is based on the plane map of the model obtained above, and carries out parking space planning in this area from the aspects of rationality and suitability.

3.2. Maximum Capacity Layout of Parking Spaces

The maximum capacity layout of parking spaces is to study and plan from the rationality of the parking space layout, comprehensively consider the environmental conditions in the study area, and calculate the maximum planable ground in the study area on the basis of satisfying the width of the road and the smooth driving of people and vehicles. Parking capacity. The Chinese national standard for parking space size is 2.5 m wide and 5.0 m long to 5.5 m long [36]. This study selected a length of 5.0 m for planning and design. (This article mainly proposes a design method for parking equipment planning, which can be modified according to the size standards of specific countries and regions).

Firstly, the maximum planable ground parking capacity N_O in any orientation of a building in the study area is defined:

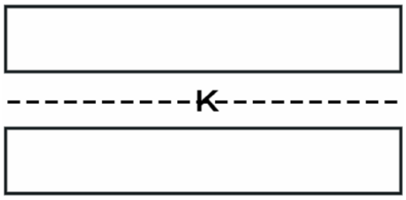
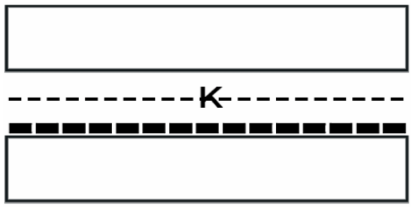
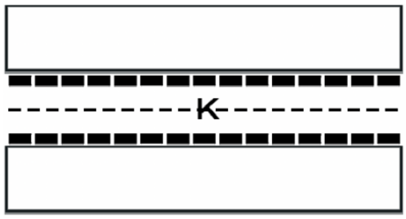
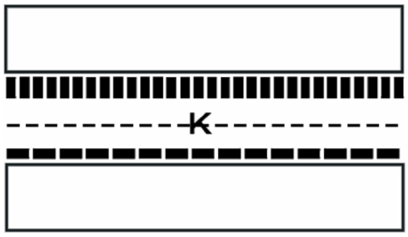
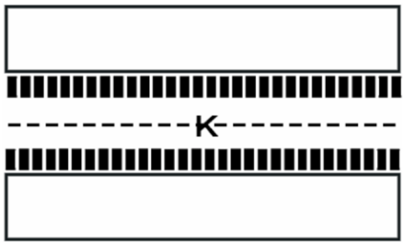
$$N_{\mathrm{O}} = \begin{cases} 0, & K < K0 + 2.5 \\ \frac{R}{10}, & K0 + 2.5 \leq K < K0 + 5 \\ \frac{R}{5}, & K0 + 5 \leq K < K0 + 7.5 \\ \frac{R}{5} or \frac{2R}{5}, & K0 + 7.5 \leq K < K0 + 10 \\ \frac{2R}{5}, & K0 + 10 \leq K \end{cases} \quad (O = S, N, E, W) \tag{4}$$

S, N, E and W represent south, north, east and west orientation respectively. K represents the width of the adjacent road corresponding to this orientation, $K0$ represents the minimum width specified for the road, R is the length of one building surface in this direction, and N_O rounds down. On the basis of suitability and rationality, the purpose of this research is to study the layout design of the maximum capacity of parking spaces in the planable space, and provide the maximum number of reference values for parking planning and design. If there are parking requirements for vehicles of larger sizes and wider road size, the number can be reduced based on this reference value. The $K0$ value is the minimum value of the road width. and it's based on the road specifications of Chinese residential communities as an example. Other countries and regions can modify it according to the regulations of different regions and parking requirements:

(1) When $K \leq K0 + 2.5$, the width K corresponding to a certain direction of the research road is less than the sum of the minimum width $K0$ specified by the direction road and the national standard width 2.5 m for the size of parking spaces, the two sides of the road cannot be installed parking space.
(2) When $K0 + 2.5 < K \leq K0 + 5$, the width K corresponding to a certain direction of the research road is greater than or equal to the sum of the minimum width $K0$ stipulated by the direction road and the standard width 2.5 m of the national parking space size, but less than the minimum width $K0$ stipulated by the direction road and the national parking space size when the total standard length is 5.0 m, the road can choose to set parking spaces on both sides of the road but on one side of the road, and the parking spaces are oriented parallel to the road. The number of parking spaces that can be set is $R/5$, so the number of parking spaces allocated to one side of the research road is $R/10$.
(3) When $K0 + 5 \leq K < K0 + 7.5$, the width K corresponding to a certain direction of the research road is greater than or equal to the sum of the minimum width $K0$ specified by the direction road and the standard length of 5.0 m specified by the national parking space size, but less than the minimum width $K0$ specified by the direction road and the national parking space size when the sum of the standard length and width is 7.5 m, the road can be equipped with parking spaces on both sides of the road, and the orientation of the parking spaces on both sides is parallel to the road. The number of parking spaces that can be set is $2R/5$, so the number of parking spaces allocated to one side of the research road is $R/5$.
(4) When $K0 + 7.5 \leq K < K0 + 10$, he width K corresponding to the direction of the research road is greater than or equal to the minimum width $K0$ specified by the direction road and the sum of the standard length and width of the national parking space size is 7.5 m, but it is less than the minimum width $K0$ specified by the direction road and the national when the size of the parking space is twice the standard length and 10.0 m, the road can have parking spaces on both sides of the road. One side of the parking space is oriented parallel to the road, and the number of parking spaces on this side is $R/5$. The other side of the parking space is oriented perpendicular to the road, and the number of parking spaces on this side is $2R/5$.
(5) When $K0 + 10 \leq K < K0 + 12.5$, the width K of a certain direction of the research road is greater than or equal to the minimum width $K0$ specified by the direction of the road and the standard length of the national parking space size is twice and 10.0 m, the road can be equipped with parking spaces on both sides of the road. The side parking spaces are all perpendicular to the road. The number of parking spaces that can be set is $4R/5$, so the number of parking spaces allocated to one side of the research road is $2R/5$.

Table 1 shows the layout plan of ground parking spaces.

Table 1. Schematic diagram of ground parking space layout planning.

K	**Diagram of Layout Planning**
$K < K0 + 2.5$	
$K0 + 2.5 \leq K < K0 + 5$	
$K0 + 5 \leq K < K0 + 7.5$	
$K0 + 7.5 \leq K < K0 + 10$	
$K0 + 10 \leq K$	

N_i refers to the maximum ground parking capacity around a building in the study area, which is defined as:

$$N_i = N_S + N_N + N_E + N_W \tag{5}$$

where, N_S, N_N, N_E and N_W respectively represent the maximum floor parking capacity that can be planned in the south, north, east and west directions, and i is the number of each building.

The maximum planable ground parking capacity N in the study area is defined:

$$N = \sum_{i=1}^{M} N_i \tag{6}$$

M is the total number of buildings in the study area.

3.3. Planning of Accessible Parking Spaces

The planning of accessible parking spaces is based on the suitability of parking space layout. On the basis of the layout of the maximum capacity of parking spaces, the research is carried out from three aspects: the demand for parking spaces, the distance of taking cars and the frequency of using parking spaces.

Q_i refers to the parking space demand of users in each building in the research area, which is defined as:

$$Q_i = 0.18 \times S \tag{7}$$

where, taking China as an example, the current per capita car ownership in China is 0.18 [37]. The coefficient can be adjusted according to the standards of different countries and regions. i is the number of each building, S is the number of residents in the building, and Q_i rounds up.

Define the accessible parking spaces of each building in the study area: take the research building as the center and the maximum distance L within the acceptable maximum pick-up time T as the radius of the covered parking spaces. The calculation formula of L is:

$$L = 90 \times T \tag{8}$$

T is the maximum acceptable time for people to pick up the car, and the unit is per minute. Since the normal walking speed of a normal adult is 1–2 m/s, which is 60–120 m/min [38], this paper chooses 90 m/min as Research standards. The value of T will directly affect the size of the radius L to determine the number of parking spaces in the coverage area.

When a parking space is covered by multiple buildings, it means that the parking space is shared by these buildings. Define the actual representative number of parking spaces S_h:

$$S_h = \frac{1}{n} \tag{9}$$

where, n is the number of times the parking space is covered by the reach of all buildings in the study area, and h is the number of each parking space.

If D_i is the sum of the actual number of parking spaces represented by all parking spaces within the reach of a building, we define it as:

$$D_i = \sum_{h=1}^{P} S_h \tag{10}$$

where, i is the number of each building, and the value of P is the total number of parking spaces within the reach of the building.

3.4. Layout of Multi-Storey Parking Equipment

Define the adaptation degree P_i of the parking space layout around a building in the study area:

$$P_i = \frac{D_i}{Q_i} \tag{11}$$

where, D_i is the total number of actual parking spaces represented by all parking spaces within the reach of the building, Q_i is the number of parking spaces required by users of the building, and i is the number of each building. The closer the P_i is to 1, the higher the adaptability of the parking spaces around the building. When $P_i > 1$, it means that all parking spaces within the reach of the building meet the needs of the user building. When $P_i < 1$, it is not. As a result, a building that does not meet the needs of users is obtained, and the layout of multi-storey parking equipment is planned within its reach according to the needs, and finally $P_i \geq 1$.

P refers to the fitness of the overall parking layout in the study area, which is defined as:

$$P = \frac{\sum_{i=1}^{M} P_i}{M} \tag{12}$$

where, i is the number of each building, and M is the total number of buildings in the study area. The closer P is to 1, the higher the overall adaptation of the parking spaces in this area.

4. Practical Application

4.1. Characteristics of the Study Area

This paper selects a study area, which is a part of residential buildings in Songjiang District, Shanghai, China. The image data is derived from high-definition remote sensing image of Google, with a ground resolution of about 0.5 m, as illustrated in Figure 1. Eleven adjacent residential buildings are chosen as research objects, and their actual geographical range is 121°11′04″–121°11′11″ E, and 31°03′00″–31°02′55″ N. The land-use of urban blocks of it mainly include dwelling, roads, and green plants. This paper focuses on the optimization design of layout planning for the parking equipment around the housing estate. The final study area is shown in Figure 2, which is the non-red area.

Figure 1. High-definition remote sensing images of the study area.

The information of residential buildings is processed and extracted through E-Cognition, an image processing software, which includes multi-scale image segmentation, object feature extraction and model plane map.

4.2. Plane Map Extraction of the Study Area

4.2.1. Multi-Scale Image Segmentation

By setting the threshold f of Formulation 3 to 80 and merging the adjacent pixels whose heterogeneity is less than the threshold, the image segmentation results of the study area are obtained, as shown in Figure 3.

Figure 2. Schematic diagram of the study area.

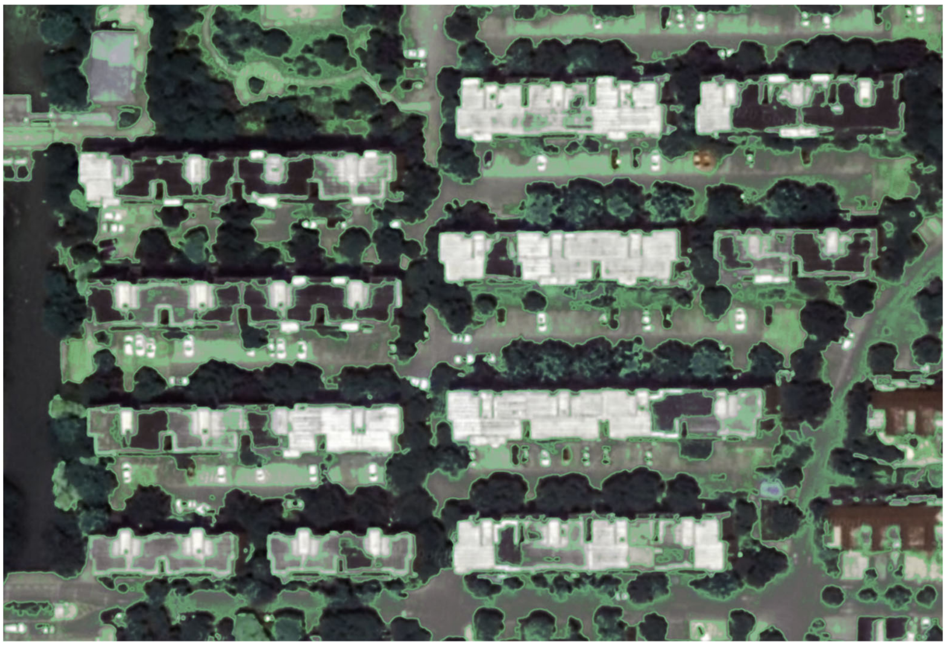


Figure 3. The results of image segmentation in the study area.

4.2.2. Image Extraction

This research mainly focuses on the planning of parking spaces for parking equipment on the available land around the building. The research object is selected as the residential area. Therefore, the house feature information in the study area is extracted, and then the image extraction results of the red study area are obtained. The extracted image is shown in Figure 4, which is a three-channel figure. The red area has a unique RGB pixel color, the RGB value is (255, 0, 0), and the other areas are all noise.

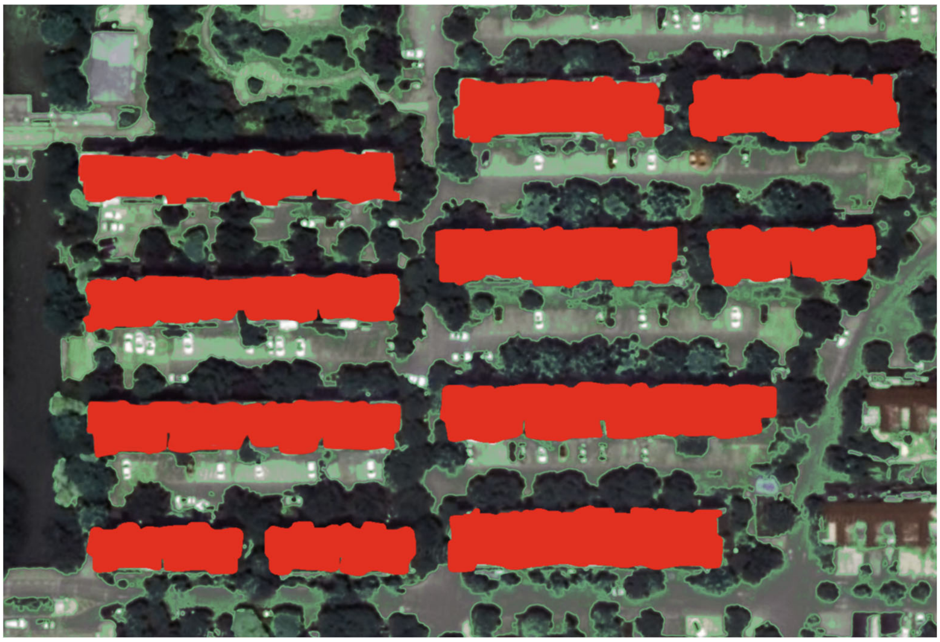


Figure 4. The results of image extraction in the study area.

On the basis of Figure 4, use the OpenCV image processing algorithm library to perform image segmentation and extract the target, convert the three-channel image to the binary image of the single-channel image. The grayscale value of the target pixel is 255, and the grayscale value of the other pixels that belong to the background is 0. On this basis, the contour and circumscribed rectangle are further extracted, and the extracted house information contour is geometricized. The extraction process is shown in Figure 5.

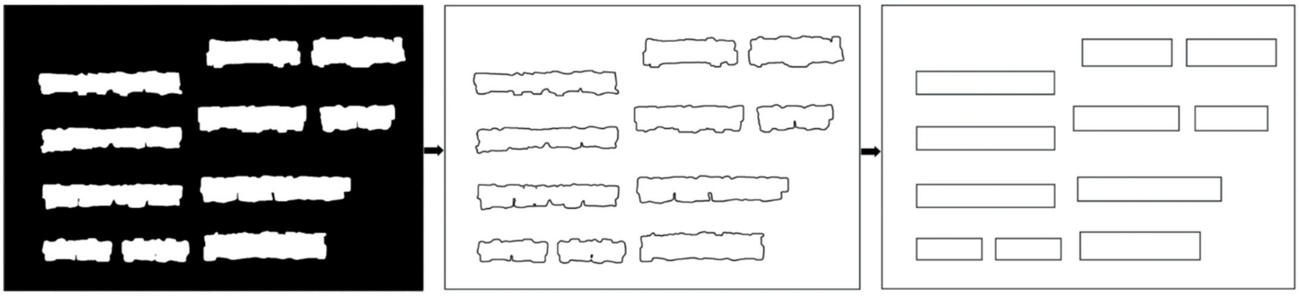


Figure 5. The geometrical extraction process of housing information contours in the study area.

4.2.3. Plane Map

Considering the features of the study area comprehensively, corresponding numbers are added to the model plane map to distinguish between buildings and roads, as shown in Figure 6. The study area contains a total of 11 residential buildings, which are numbered randomly from 1 to 11. In addition, there are 13 two-lane roads, which are numbered randomly by $K1$~$K13$. The basic information of the eleven residential buildings in the study area was obtained by integrating object-oriented technology and field survey, as shown in Tables 2 and 3. The object-oriented technology is used to extract the building spacing and length and width values. The field survey is to obtain the number of residents, and use the method of sampling survey to average the data to provide a reference for the follow-up demand for parking spaces. In order to facilitate the model establishment, the value is rounded.

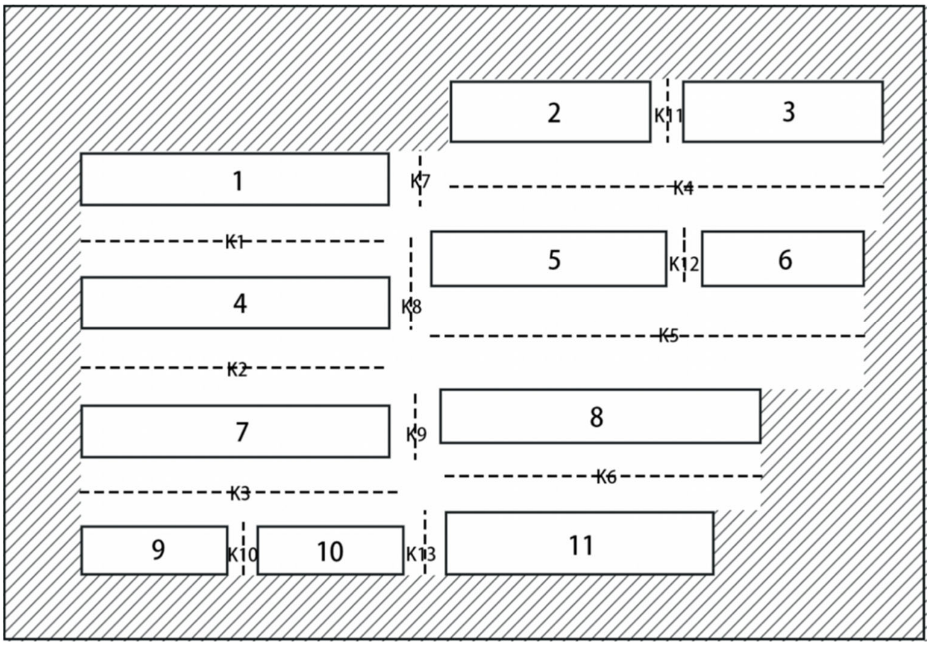


Figure 6. The results of plane map in the study area.

Table 2. The basic situation of residential buildings in the study area.

Building	1	2	3	4	5	6	7	8	9	10	11
Length/m	75	48	48	75	58	39	75	78	35	35	65
Width/m	15	18	18	15	17	17	15	15	13	13	16
Number of residents	193	137	134	204	172	122	177	221	99	115	151

Table 3. Basic information of the study area.

Building Spacing	$K1$	$K2$	$K3$	$K4$	$K5$	$K6$	$K7$	$K8$	$K9$	$K10$	$K11$	$K12$	$K13$
Width/m	18	18	18	21	24	18	13	9	10	8	8	9	10

4.3. The Layout of the Maximum Parking Space in the Study Area

The limit width of the road in China at the dwelling level is generally 10–14 m, the roadway is around 7–9 m, and the width of the sidewalk is about 1.5–2.5 m [39]. Therefore, the value of $K0$ in Formulation 4 is set to 10 m in this paper.

Taking $K2$ as an example, the road width of $K2$ is 18 m, which is in line with $K0 + 7.5 \leq K < K0 + 10$, that is, $10 + 7.5 \leq 18 < 10 + 10$. Hence, parking spaces can be set on both sides of the road. One side of it is parallel to the road, and the other side is perpendicular to the road, as shown in Figure 7.

Taking $K3$ as an example, the road width of $K3$ is 18 m, which is in line with $K0 + 7.5 \leq K < K0 + 10$, that is, $10 + 7.5 \leq 18 < 10 + 10$. Hence, parking spaces can be set on both sides of the road. One side of it is parallel to the road, and the other side is perpendicular to the road. To increase the planned number of parking spaces, the short side of the building is selected to set parking spaces parallel to the road, as shown in Figure 8. On this basis, the overall plan of parking spaces in the study area is set, as shown in Figure 9.

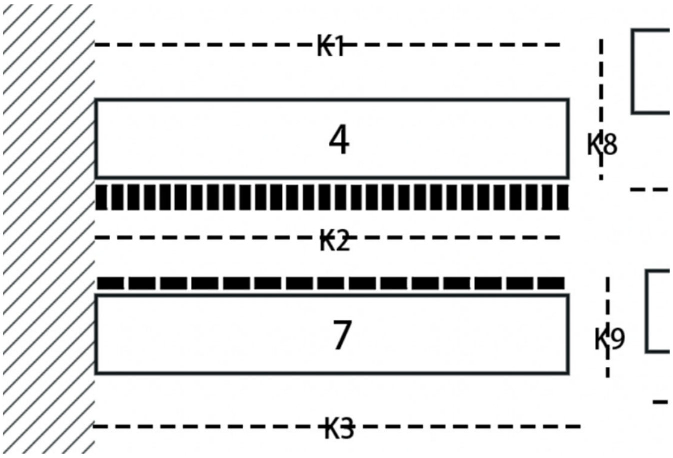


Figure 7. Parking Planning Map of *K*2.

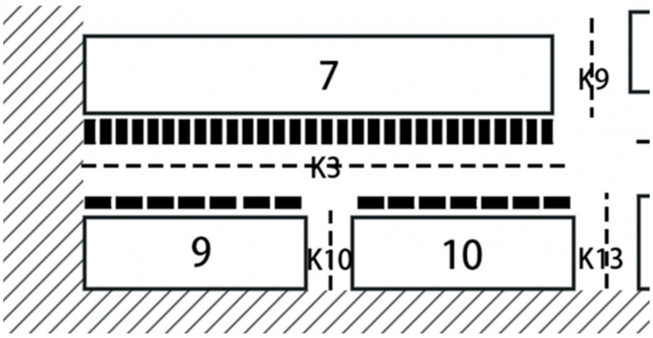


Figure 8. Parking Planning Map of *K*3.

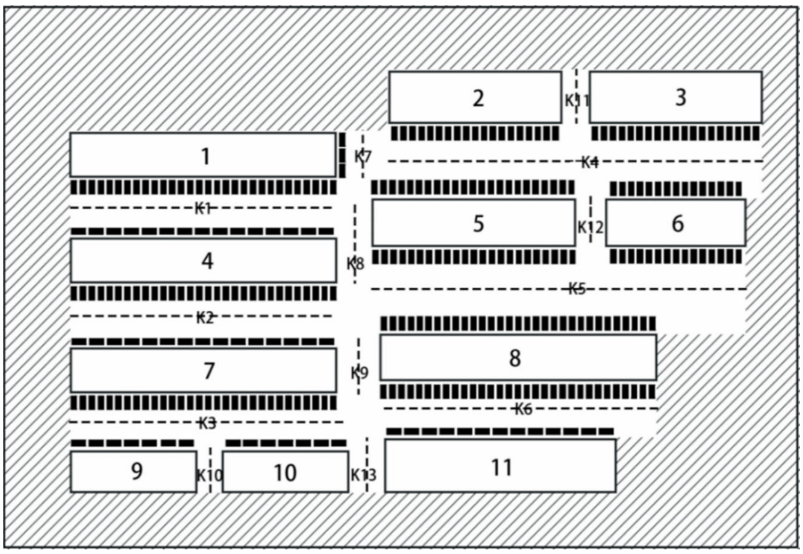


Figure 9. Parking Planning Map of the study area.

4.4. The Layout of the Accessible Parking Space in the Study Area

According to the data in Equation (7) and Table 2, the parking space demand Q_i of users in each building in the study area can be obtained, as shown in Table 4.

Table 4. The demand of residential building parking space in the study area.

Building	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Parking Demand	35	25	25	37	31	22	32	40	18	21	27

The acceptable walking time for travelers is generally around 5 min [40]. The shorter the walking time to pick up the car, the higher the convenience of picking up the car. In this paper, the T value is selected as 1 min for research. Figure 10 is the diagram of accessible parking spaces of Building 4, Building 5 and Building 8 in the study area when the T value is 1 min, with a radius of 90 m. If only the accessible parking spaces of Building 4, Building 5 and Building 8 are considered, as defined by Formulation 9, it can be seen that the gray shaded part in Figure 10 is within the reach of three residential buildings at the same time, so the actual number of parking spaces in this area is 1/3. In the same way, the actual number of parking spaces covered by the shaded part of the white background in Figure 10 is 1/2.

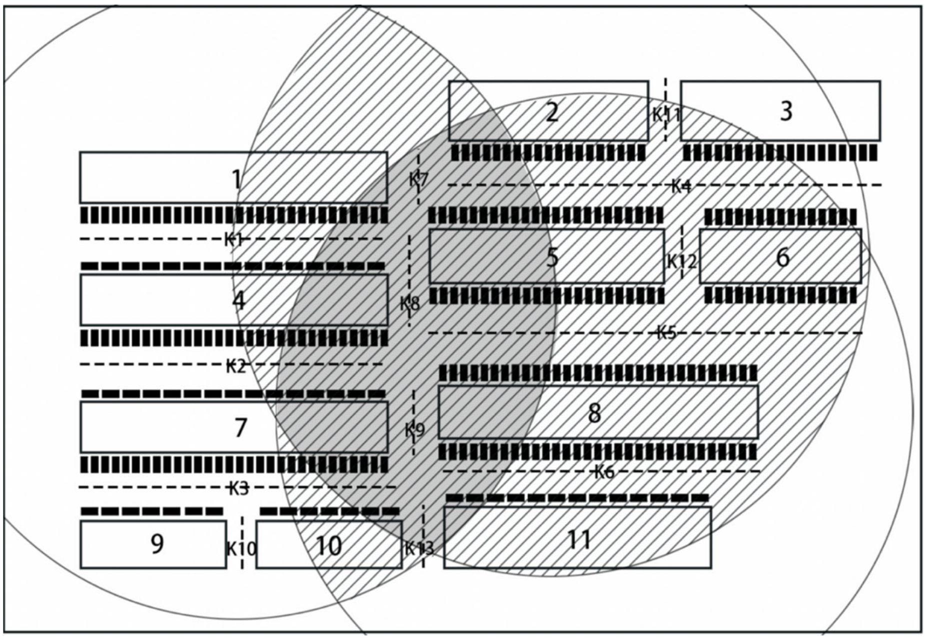


Figure 10. Parking space diagram of some buildings in the study area.

Figure 11 is the diagram of the accessible parking spaces of all buildings in the study area when the T value is 1 min, with a radius of 90 m. The parking spaces with different gray levels in Figure 11 represent the actual number corresponding to each parking space in the area.

Table 5 shows the number of available parking spaces for each residential building in the study area.

Table 5. The number of accessible parking spaces to residential buildings in the study area.

Building	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Available Parking Space	29	28	21	34	31	30	33	38	19	26	24

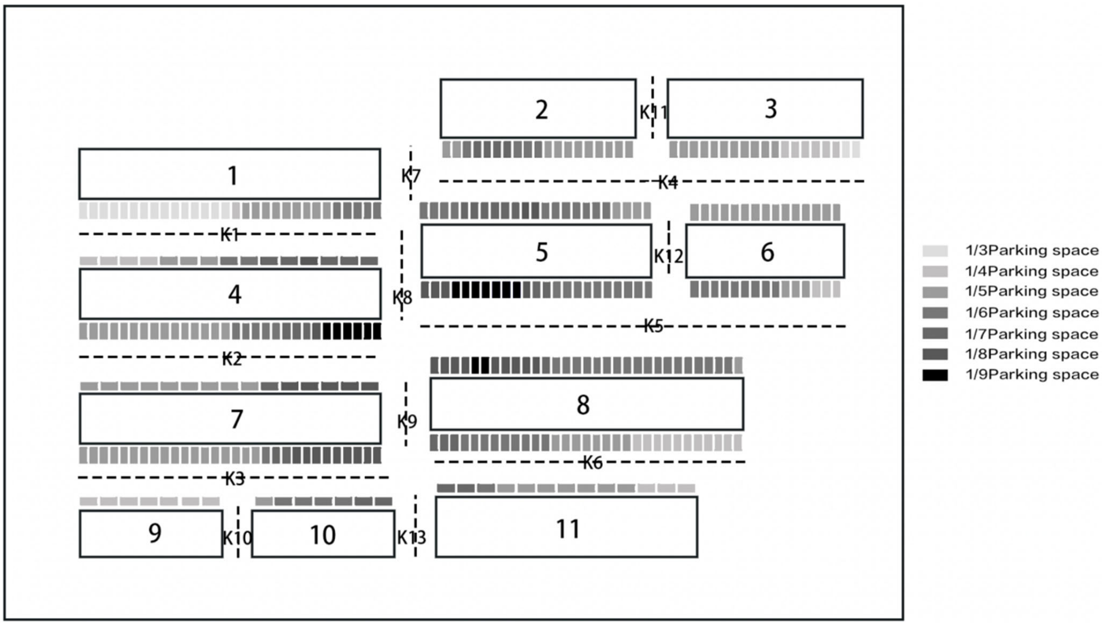


Figure 11. Diagram of the actual number of accessible parking spaces in the study area.

4.5. Layout Planning of Multi-Layer Parking Equipment in the Study Area

According to the calculation results, $P_i < 1$ exists in Building 1, Building 3, Building 4, Building 8 and Building 11, so the parking spaces can be planned fail to meet the needs of residents in these buildings, and parking spaces should be added in the accessible parking spaces range of buildings that fail to meet the needs of residents.

Referring to the existing industry specifications, considering the shading, noise and other practical problems, the three-dimensional parking equipment of more than 3 m should not be installed near the wall of residential buildings as far as possible, that is, double-layer parking equipment should be added. Finally, Figure 12 of double-layer stereo parking spaces planning is obtained according to the requirements. Based on the above analysis results, the amount of red parking spaces is the lowest value that can be set for double-layer stereo parking equipment, which is 66. The remaining gray parking spaces can be equipped with single-layer parking equipment.

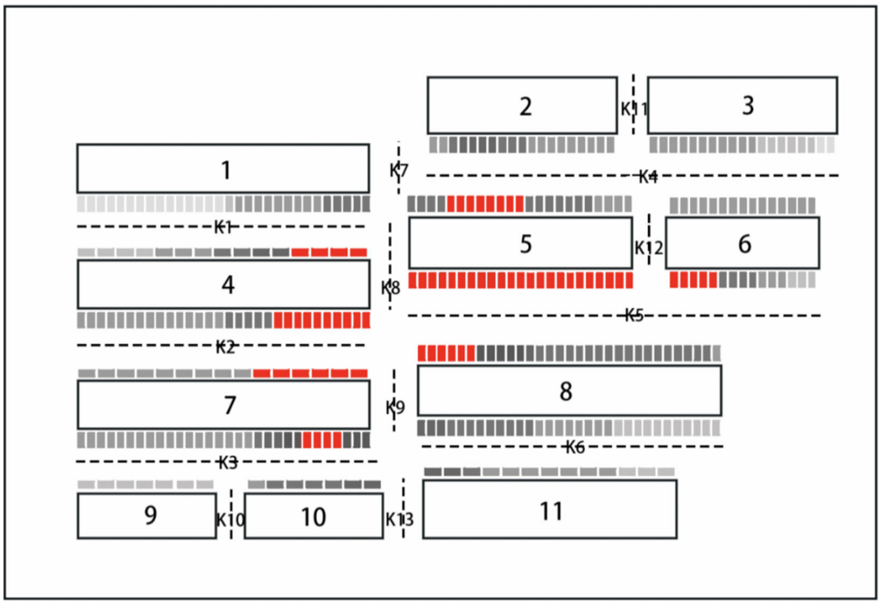


Figure 12. Schematic diagram of double-layer stereo parking spaces in the study area.

Table 6 is the comparison of the number of available parking spaces before and after the planning of the double-layer stereo parking equipment for residential buildings in the study area. It can be obtained that $P_i \geq 1$ for the buildings in the area, so the number of parking spaces in the study area after planning meets the needs of users.

Table 6. Comparison before and after planning of double-layer stereo parking equipment.

Building	1	2	3	4	5	6	7	8	9	10	11
Plan the number of double-layer stereo parking equipment	49	53	26	51	66	35	43	66	21	41	52
Available double-layer stereo parking equipment	6	6	4	6	8	4	5	8	2	5	6
Parking Demand	35	25	25	37	31	22	32	40	18	21	27
Available parking spaces before planning	29	28	21	34	31	30	33	38	19	26	24
Available parking spaces after planning	35	34	25	40	39	34	38	46	21	31	33

5. Conclusions

(1) Multi-scale segmentation and image extraction of satellite images in the study area are carried out through object-oriented technology, combined with the characteristics of the image and feature types in the study area, so that the similar surface information in the image can be classified and merged;

(2) Based on the results of classification and extraction of feature information in the study area, the edge of the image contour is regularized to obtain a planar map of the area. This information graph is the basis of this article's parking equipment planning and design evaluation model;

(3) From the perspective of science, the influencing factors of parking space layout are divided into two aspects: rationality and suitability, and an evaluation model for parking equipment planning and design is proposed. The rationality is to carry out the research from the physical and objective aspects, comprehensively consider the environmental conditions in the research area, and plan the layout of the maximum capacity of parking spaces in the research area. The suitability is based on the study of parking demand. On the basis of the maximum capacity layout planning of parking spaces, the accessibility parking space planning and the layout design of multi-storey parking equipment are carried out.

(4) The feasibility of the evaluation model for the planning and design of parking equipment is verified by an actual case. Based on the acceptable pick-up distance and time, and considering the surface information of parking area and the rationality and suitability of parking layout, the specific planning and design is carried out including of the type, quantity and location of parking equipment.

(5) The object image technology is used in the map extraction of the evaluation model of parking equipment planning and design proposed in this paper. This technology has fast recognition speed and low cost. It is a valuable planning map extraction method, which can provide a powerful reference for parking planning and design. However, due to the influence of sampling image accuracy and classification objects, the accuracy of object-oriented technology still needs to be further improved.

Author Contributions: Conceptualization, M.N. and Z.S.; methodology, Y.L.; software, Y.L.; validation, M.N., Z.S. and Y.L.; formal analysis, Y.L.; investigation, Y.Z.; resources, Q.Y.; data curation, Z.W.; writing—original draft preparation, M.N.; writing—review and editing, Q.Y.; visualization, Y.L.; supervision, Z.S.; project administration, M.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

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