Design of Structure and Control System of Intelligent Parking Equipment Based on TRIZ and Cloud Platform

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Abstract: With the rapid growth of the number of cars in our country, parking difficulty, especially the phenomenon of parking difficulty and parking annoyance in residential areas has become the focus of people's attention. To solve this problem, an intelligent parking device is designed. The influencing factors of parking time-consuming and laborious are analyzed. The TRIZ theory is used to convert the engineering technical parameters, and the technical contradiction matrix is established. The improvement scheme of parking equipment structure is designed through 40 invention principles, and the architecture of parking equipment management and control system is built by using cloud platform. Through the innovative design of parking equipment, it can reduce the space area of parking space, realize the automatic retrieval of empty parking spaces and the automatic parking and taking of cars, which provides a feasible solution for the industrialization of parking equipment in residential areas.

1. Introduction

In modern society, cars have become an important means of transportation, and the number of family cars has exploded. According to data from the Ministry of Public Security of China News Network, as of the end of 2017, the number of vehicles in the country has reached 217 million, an increase of 23.04 million vehicles for the year compared with 2016, a year-on-year increase of 11.85%[1][2]. The consumer market has entered an unprecedented "golden age", and there will be more room for development.

On the other hand, the explosive growth of car ownership has brought serious challenges to basic transportation facilities, especially urban basic transportation facilities, and the pressure on urban dynamic and static traffic continues to increase. According to the analysis and conclusion of the research results of Wang Yuanqing and others in the "Parking Facilities Planning", every time a registered vehicle is added in the city, 1.2-1.5 parking spaces should be added [3]. However, due to the lack of prediction and understanding of parking problems in urban planning, the current growth rate of parking infrastructure construction in my country is seriously unable to keep up with the growth rate of vehicle ownership. According to the survey, there are about 65% of the parking spaces in the country[3][4]. Many families have bought cars, but there are no parking spaces or can’t afford parking spaces. The car owners park their cars directly on the road. Borders, fire passages, and green belts cause parking difficulties, traffic jams, and even safety problems[5][6].
2. TRIZ theory and cloud platform

TRIZ theory \cite{7}, the theory of the solution of invention problems, was led by the former Soviet Union inventor Archshuller and his team analyzed nearly 2.5 million high-level invention patents in the world. A comprehensive theoretical system is established by formulating the regular patterns that various technological development and evolution follow, as well as the innovative principles and rules for solving various technological contradictions. Its main contents include: the law of technological system evolution, 40 invention principles, 39 engineering parameters, contradiction matrix, matter-field analysis, 76 invention problem standard solution methods, invention problem solving algorithm (ARIZ) and engineering effect knowledge base. Since the TRIZ theory was proposed, it has been widely used all over the world \cite{8}-\cite{10}.

Cloud computing is a cutting-edge technology in the information field. Cloud platforms provide a large number of computing resources and software resources. Users can obtain computing resources and software resources for their own use according to their needs. The first foreign company to advocate cloud computing was Google. Amazon commercialized cloud computing on a large scale. With the development of Amazon’s cloud computing service products, various cloud platform applications have appeared one after another. Different cloud platforms provide different services. The large and low-cost public resources provided by the cloud platform are the biggest competitiveness of cloud platform technology. Users can get a large amount of resources and services in return with a small amount of effort.

Aiming at the problem of domestic car parking in urban communities, the article uses TRIZ theory to analyze the parking conflict problem, establishes a technical contradiction matrix, and finds the original understanding of the invention. Based on the original understanding of the invention, a circular inner and outer double-disc underground parking equipment structure is designed. The cloud platform technology has designed its management and control system. This equipment has a high space utilization rate and can realize automatic storage and retrieval of cars, achieving the effects of smart parking and smart management.

3. Structure design of underground parking equipment

3.1. Problem analysis

Existing family car parking lots are generally located underground in communities or squares. The parking spaces are arranged side by side in a rectangular shape. When parking, car owners find empty parking spaces by themselves. This type of parking space arrangement is within a fixed space area, and the number of parking spaces is limited. It is time-consuming and laborious for car owners to find parking spaces. At this time, the technical contradictions exist: to increase the number of parking spaces, the parking lot area must be increased; To save parking time for vehicle owners and increase the degree of automation of the parking system, the structural complexity of the parking equipment increases.

The above problem is transformed into the conflict between the volume of No. 8 static problem and the shape of No. 12 and the conflict between the degree of automation of No. 37 and the complexity of No. 35 device described by 39 engineering parameters \cite{12}. As shown in Table 1 is the contradiction matrix table. The corresponding original understanding of the invention is found according to Table 1, which is shown in Table 2.

| Improve parameters          | Deterioration parameter | NO.12 shape | NO.35 Device complexity |
|-----------------------------|-------------------------|-------------|-------------------------|
| NO.8 Volume of stationary object | 1, 3, 5, 17             | 26, 1       |
| NO.37 degree of automation  | 1, 13, 15               | 15, 29      |
Table 2 The Solution of Invention

| Number | Name of Principle of Invention | method |
|--------|--------------------------------|--------|
| 1      | separation                     | (1) Divide an object into independent parts.  
|        |                                | (2) Divide the object into parts that are easy to assemble and disassemble.  
|        |                                | (3) Improve the separability of objects.  |
| 3      | Local quality improvement      | Improve the characteristics of specific areas of the object to obtain the necessary characteristics.  |
| 5      | combination                    | (1) Combine the same or similar objects or operations in space.  
|        |                                | (2) Combine the same or similar operations in time.  |
| 13     | Reverse effect                 | (2) Make the movable part of the object or environment immobile, and the immobile part movable.  
|        |                                | (3) Turn the object upside down or upside down.  |
| 15     | Dynamic characteristics         | (1) Adjust the performance of the object or environment to make it reach the optimal state in all stages of work.  
|        |                                | (2) Split the object so that its parts can change the relative position.  
|        |                                | (3) Make stationary objects movable.  |
| 17     | Multidimensional method         | (1) Innovate through the dimensional changes of the system, so that the motion or distribution of objects changes from one dimension to multiple dimensions.  
|        |                                | (2) Using multi-layer structure instead of single-layer structure.  
|        |                                | (3) Use the opposite or the other side of the prescribed side.  |
| 26     | copy                           | (1) The object serves itself by performing auxiliary or maintenance functions.  
|        |                                | (2) The ability and material to utilize waste.  |
| 29     | Pneumatic or hydraulic structure | The fixed parts of the object can be replaced by pneumatic or hydraulic parts.  |

According to the description of the principle of invention, select the principle of invention 1 division, principle of invention 3 partial quality improvement, principle of invention 5 combination, principle of invention 15 dynamic characteristics, principle of invention 17 multidimensional method, principle of invention 29 pneumatic or hydraulic structure for underground parking device design, design underground. The structure improvement design plan of the parking device is shown in Table 3.

Table 3 The Improvement Design

| Improve parameters | Deterioration parameter | Principles of Invention | Engineering solution |
|--------------------|-------------------------|-------------------------|----------------------|
| Parking lot volume | Number of parking spaces| 1 segmentation          | Divide the entire parking device into several separate parking spaces |
|                    |                         | 3 Local quality improvement | Change the shape of the parking space from rectangle to fan |
|                    |                         | 5 combination            | Combine the separate fan-shaped parking spaces into a circle |
|                    |                         | 17 Multidimensional      | Use inner and outer circle 2D instead of rectangle 1D |
| degree of automation | Device complexity      | 29 Pneumatic and hydraulic structure | Use hydraulic system to drive the lifting mechanism |
|                    |                         | 15 Dynamic characteristics | Turn a stationary parking space into a sporty |

3.2. Structure design of parking device
The underground parking device is composed of a parking disc, a vehicle lifting and transporting platform mechanism, a trailer carrying mechanism and other parts, which can realize the functions of
automatic parking and automatic pickup. The overall structure of the design is shown in Figure 1. Among them, the parking disc is a circular structure and is set in an underground parking lot. It is divided into an outer parking disc and an inner parking disc along its radial direction. The outer parking disc and the inner parking disc operate separately. And the outer parking disc and the inner parking disc are evenly divided into multiple parking spaces; the vehicle lifting and transporting platform mechanism is arranged beside the parking disc and docking with any parking spot of the outer parking disc, and is used to carry vehicles between the ground and underground parking discs, and then the storage and retrieval of vehicles are come true; the trailer carrier mechanism is used in conjunction with the vehicle lifting and transporting platform mechanism and the parking disk, through the multiple wheels set on both sides of the trailer carrier, the parking space of the vehicle lifting and transporting platform mechanism and the underground parking disk Transport vehicles between.

![Figure 1. Overall Structure](image)

3.2.1. Design of Lifting Platform Mechanism for Vehicle Transportation.

The vehicle transportation lifting platform mechanism includes: a carrying plane, a scissor arm, a hydraulic system, and a vehicle lifting platform bottom plate. The structure is that the scissor arm 2 is connected under the carrying plane 1, and the scissor arm is connected with the hydraulic system 3, which is installed on the bottom plate 4 of the vehicle lifting platform. The most important hydraulic system is the driving and control part of the vehicle transportation lifting platform. The hydraulic cylinder drives the scissor arm to change the amplitude to complete the lifting task. Through the control function of the balance valve, speed control valve and overflow valve, the speed control, The functions of holding pressure, braking and balancing. The vehicle transportation lifting platform designed in this paper has the characteristics of compact structure, large carrying capacity, strong pass ability and good controllability, and it is a relatively simple structure, large lifting force, stable lifting, low noise, convenient operation, and simple maintenance. It is a widely used lifting platform that can stay at any position within the lifting range. Its design structure is shown in Figure 2.
3.2.2. Design of trailer carrying mechanism.

The trailer carrying mechanism is used in conjunction with the vehicle lifting and transporting platform mechanism and the parking disc, and the vehicle is transported between the vehicle lifting and transporting platform mechanism and the parking space of the underground parking disc through multiple wheels arranged on both sides of the trailer carrying mechanism. The trailer carrying mechanism includes: carrying lifting plane, hydraulic lifting system, trailer floor, and wheels. The structure is that the carrying lifting plane 1 is connected to the hydraulic lifting system 2, which is fixedly connected to the trailer floor 3, and the wheels 4 are installed on the trailer floor. The function of this mechanism is to move the trailer as a whole to the bottom of the car by wheels, and then lift the carrying lifting plane by the hydraulic lifting system of the trailer, thereby lifting the whole car from the vehicle transportation lifting platform. The design structure is shown in Figure 3.

3.2.3. Design of parking disc.

The parking disc has a circular structure and is set in an underground parking lot. It is divided into an outer parking disc 1 and an inner parking disc 2 along its radial direction. The outer parking disc and the inner parking disc operate separately, and the outer parking disc and the inner parking disc are evenly divided into multiple parking spaces. The parking disc is made of steel and hollowed out as a whole, which can reduce the overall quality of the parking disc without reducing its hardness. The bottom of the parking disc is designed to be gear-shaped, which is for the overall structure to be simple, easy to drive and easy to maintain. The design structure is shown in Figure 4.

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Figure 2. Lifting platform mechanism for vehicle transportation

Figure 3. Trailer Carrier

Figure 4. Parking Lot

Figure 5. Parking Wheel Drive Mechanism
3.2.4. Design of Drive Mechanism of Parking Disk.
The design of the parking disc drive mechanism includes: motor, gear, gear belt. Its structure is that
the motor 1 drives the gear 2, and then the gear drives the gear belt 3, and finally the gear drives the
inner and outer disks for transmission. The design structure is shown in Figure 5.

4. Design of management and control system for underground parking equipment

4.1. Overall scheme design of control system
The underground parking device management and control system is mainly composed of three parts:
the upper computer cloud platform, the mid-range control system, and the end effector;

Host computer cloud platform: With Delta cloud platform and industrial cloud router as nodes,
APP and SCADA monitoring software are connected to the PLC host through the cloud platform and
industrial router to realize vehicle data management and remote monitoring functions;

Mid-end control system: PLC programmable logic controllers, sensors, and code scanning guns are
mainly used to realize real-time data processing and exchange of intelligent parking lots, and realize
parking space selection and control functions;

End effector: The QR code parking data generated by the car owner through the APP, scanned and
processed by the code scanner, is driven by the servo motor in the first and second directions of the
axis, the expansion of the hydraulic cylinder, and the coordination of the sensors Realize the
integration of parking and fetching of vehicles. The scheme system architecture is shown in Figure 6,
and the management and control system structure is shown in Figure 7.

4.2. Control system action function
The technical function realized by the structural design of the underground parking device is: when the
vehicle is parked, the owner parks the vehicle above the trailer carrier, the vehicle lifting and
transporting platform mechanism is lowered to the underground parking lot, and it stops falling at the
level of the parking disc, inside or outside A free parking space of the parking disk is directly facing
the carrying plane of the vehicle lifting and transporting platform mechanism and seamlessly docked.
The trailer carrying mechanism supports the vehicle to move from the carrying plane to the current
free parking space, and then the trailer carrying mechanism drops to not contact with the vehicle, and
then the trailer carrying mechanism Move out of the parking space to the vehicle lifting transport
platform mechanism, and the vehicle lifting transport platform mechanism rises to the ground to wait
for the next vehicle. When the vehicle picks up the car, the parking disc turns the parking space of the
vehicle to the carrying plane of the vehicle lifting transport platform mechanism. After the trailer
carrier mechanism drags the vehicle back to the vehicle lifting transport platform, the vehicle lifting
transport platform rises to the ground and the owner picks up the car.

According to the structural design and technical functions of the underground parking device, the
action function of the parking device control system is: the owner parks the vehicle on the parking
board. The parking board has two limits. The owner can park the vehicle to the set position and press the parking button. At the same time, APP generates parking space QR code data. When the elevator descends and meets the lower limit, it stops descending, and the trailer plate works. The trailer plate is controlled by the hydraulic cylinder. The trailer plate extends to the bottom of the vehicle. When the limit is triggered, the trailer starts to rise for a certain distance. Lift the vehicle until the gravity sensor reaches a certain level. When the pressure value stops rising, the hydraulic lever starts to extend, the parking inner disc has a high priority, and the hydraulic lever extends until it hits the small disc limit of its stroke and stops extending. Start to put the car down, and the pallet descends. After the pressure value returns to zero, the hydraulic lever starts to retract to the end limit and stops. At this time, the parking board starts to rise, and the PLC sends pulses to the servo drive while the parking board rises. The number and pulse frequency, the stepper motor rotates a parking space, at this time the owner's car has stopped. When the parking space of the inner disk is full, the large disk starts to stop. At this time, the hydraulic cylinder stretches to meet the large disk limit of its stroke and stops. The follow-up action is the same as the small disk parking method. The large disk must leave a space for the small disk to take out the car. Intelligent parking function. When picking up the car, the QR code generated by the APP is scanned by the code scanner. After that, the PLC controls the motor to select and locate the corresponding parking space, pick up the car and leave.

5. In conclusion
Aiming at the urban family car parking problem, based on the TRIZ theory, this paper extracts the technical contradictions in the parking problem of "more cars, small area", "high degree of automation, and complex installations". Features, pneumatic and hydraulic structure" 6 inventions and innovation principles, rationally design the structure of underground parking device and its management and control system to realize intelligent parking and intelligent management. The main innovations of this design are:

Small footprint: The parking device designs the traditional longitudinal, square, single-row parking spaces into radial, circular, and double-row parking spaces, which increases the parking spaces in the same area by 50% and minimizes the area of parking lot.

Parking is simple and convenient: Using this parking device, the owner only needs to park the car on the vehicle lifting transport platform, and the vehicle transport mechanism automatically transports the vehicle to the parking disk free parking space to achieve parking, or transports the vehicle from the parking position to the vehicle lifting transport platform to achieve pickup. The car does not require the owner to spend time and trouble finding a parking space, which minimizes the time cost of parking and picking up the car.

Intelligent management: The parking, car retrieval, and parking space management of this parking device is realized by the management and control system in the device, which is completely intelligent and does not require manual intervention. In addition, the parking disc can be used for parking and fetching family cars at the same time. The parking and retrieval of motorcycles, electric vehicles, and bicycles maximizes the utilization rate of parking devices.

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