The Smart Toilet Wheelchair Design Based on Automatic Bagging Cleaning System

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Abstract. With the improvement of living standards, the global aging population and the increase in the number of people with disabilities in the lower limbs, the demand for intelligent wheelchairs is rising. For the elderly and lower limb disabled groups, the design of intelligent toilet wheelchair with automatic bagging cleaning system was proposed. The design solves the problem of toilet access for people with reduced mobility, and breaks through the self-balancing 180° full lying flat angle adjustment limit of intelligent wheelchairs and the inconvenience of getting in and out of bed. Based on the full-body scanner model and ergonomics, combined with structural and functional analysis, its feasibility is verified, which has practical value for the intelligent wheelchair industry, bringing convenience to special groups and improving the quality of life.

Keywords: automatic bagging cleaning system; intelligent toilet wheelchair; Self-balancing 180° lying flat; Infrared induction lifting

1 Introduction

With the acceleration of global aging and the exponential increase in the number of people paralyzed due to diseases and accidents, smart wheelchairs have become one of the hot topics in the field of research. The intelligent wheelchair is composed of the machine body and the intelligent control system, and contains multiple intelligent modules for braking, adjusting the seat up and down, GPS positioning and other functions. At present, the smart wheelchairs on the market lack the function of self-balancing 180° flush with the bed, and due to the small contact area of the seat lifting pushrod, the smart wheelchair is easy to roll over during use, and the lack of consideration for the user's excrement cleaning and other problems. Based on the FBS (Whole Body Scanner) model and ergonomics, an intelligent toilet wheelchair with automatic bagging and cleaning of excrement is designed, which can achieve self-balancing 180°, infrared induction lifting to the same level height as the bed, and can automatically bag and clean

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the user's excrement, which solves the daily care problem caused by the user's inconvenience. As a result, the quality of life of the disabled with reduced mobility and paralysis in the elderly population has been greatly improved.

2 Overall Product Design

2.1 Product Structure Analysis and Design

The wheelchair design is based on the FBS (Full Body Scanner) model, and the design of the smart wheelchair takes a user-centric approach. Starting from functional requirements, the connection between function and behavior is established by mapping user actions to behavioral actions (e.g., petting, massaging, squatting, and foot extension) [1]. Utilize FBS patterns for iterative analysis to identify gaps between functionality and behavior and bridge those gaps by modifying the structural design. This multi-level mapping solution, including function-behavior mapping and behavior-structure mapping, optimizes the design of smart wheelchairs. Finally, the knowledge of ergonomics is applied, considering the interaction between the human body, the machine and the environment, and the rational allocation of the operational functions of the man and the machine to achieve the best ergonomics.

The intelligent wheelchair has the functions of real-time detection of obstacles, automatic bagging and cleaning of excrement, self-balancing lying down 180°, infrared induction lifting, etc., which can help the elderly with reduced mobility and the disabled with paralysis of the lower limbs to avoid obstacles in a timely and accurate manner, reduce the probability of accidents, and improve the safety and convenience of the daily life of the elderly and the disabled with paralysis of the lower limbs.

Combining a smart wheelchair that can lie flat with a toilet that can automatically bag and pack, a smart toilet wheelchair that can automatically bag and pack is created. Taking smart wheelchairs as an example, compared with traditional wheelchairs, smart wheelchairs are more functional and easier to use. In 1986, the United Kingdom developed the world's first intelligent wheelchair, and since then the field of intelligent wheelchairs has flourished. The research of intelligent wheelchairs in China began in the 80s of the 20th century and has a history of more than 30 years, but it has been found that the following problems are common in the current intelligent wheelchairs on the market: lack of self-balance lying 180°; The lifting range is small, and it cannot be lifted to a height that is convenient for users to move; Lacks the ability to clean excrement. Referring to the characteristics of intelligent wheelchairs and automatic bagging and packing toilets, this paper proposes an intelligent toilet wheelchair with automatic bagging and packing based on the FBS (whole body scanner) model and ergonomics [2].

2.2 The Overall Design Scheme of the Automatic Bagging Cleaning Excrement System

According to the ergonomic design requirements, the automatic bagging and cleaning excrement system adopts the following design scheme:

1) The wheelchair seat cushion is provided with a device for carrying urine and urine, the equipment is driven by a motor, and the controller selects infrared induction and voice recognition system, which is programmed into C language.

2) The automatic clamshell control technology selects a two-phase four-wire stepper motor, and cooperates with the reducer to realize the self-flipping technology. When the motor rotates 4 times, the shaft of the motor will drive the mechanical structure connected to the cover to rotate half a turn through the reducer with a reduction ratio of 8:1, so as to realize the function of opening the cover, and when the motor rotates half a turn in the same direction, the cover will be closed.

3) The infrared induction detection circuit is composed of infrared module, R1 (resistance 1), RP (potentiometer), LED1, etc., when separated from the wheelchair cushion, the infrared module receives the reflected signal, the output point level of the infrared module is zero at this time, and the current conduction of the trinite by using RP and infrared module is utilized, so as to excite the relay, and thereby control the motor to drive the mechanical structure to carry out the flip cover.

4) The automatic bagging and packing device combines infrared induction technology and mechanical clamshell technology, and cleverly realizes the automatic clamshell technology through the hardware system and motor drive, and the overall operating principle is shown in Figure 1.

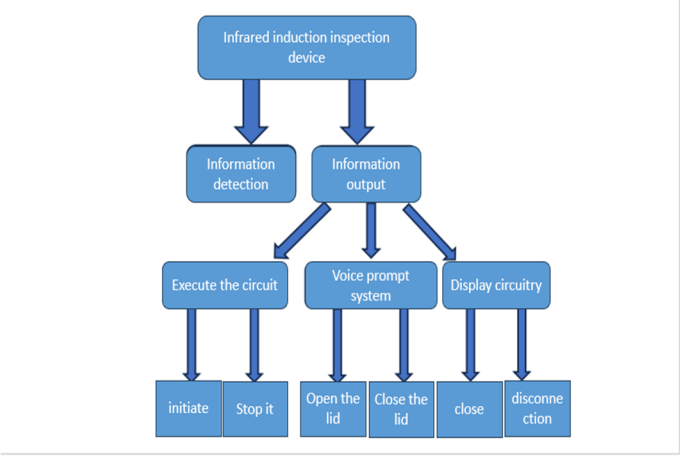

Fig. 1. Infrared sensing detection device

The above parameters have been proven to meet the application requirements of automatic clamshell technology. The automatic bagging and strapping unit accessories are printed by a 3D printer.

2.3 Self-Balancing 180° Lying Flat System Design

This self-balancing 180° lying flat system uses a simple mechanical structure design, which is mainly composed of inclination sensor, microcontroller, analog steering equipment and mechanical structure. Among them, the embedded microcontroller mainly accepts the inclination data output by the inclination sensor in real time, and processes it after computational filtering. Then, by controlling the simulated servo rotation mechanism, the control system body can be adjusted to the maximum balance angle. This design makes the lie flat control system easier to operate and has good balance. The design is shown in Figure 2:

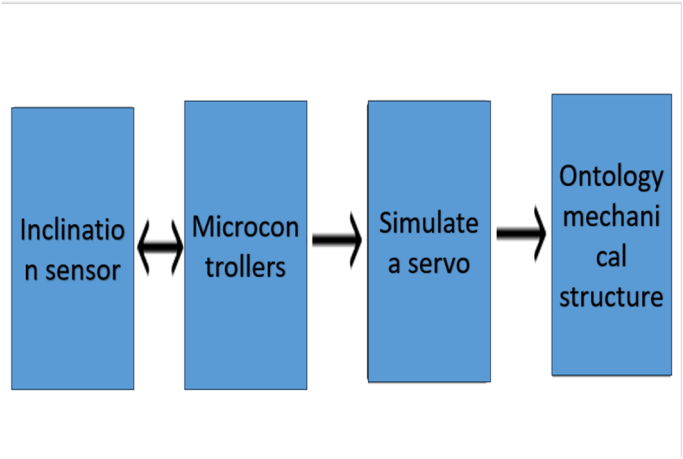

Fig. 2. Self-balancing 180° laying system structure

2.4 Brake System Design

The braking system is the most important guarantee for the safety of wheelchair driving, the people who use the wheelchair are usually the elderly or paralyzed people with reduced mobility, the wheelchair is their legs, when taking the wheelchair, the user ties all their safety to the wheelchair. In the manual wheelchair, the lever principle is used to close the brake pad to the wheel hub to complete the brake, and the extension rod is often added to save effort for operation, but the lever is easy to be damaged and needs to be checked frequently to ensure safety; With the development of technology, most of the electric wheelchairs replace the previous braking method with electromagnetic brakes. Electric wheelchairs equipped with electromagnetic brakes are more flexible and easy to use, the braking system is sensitive, the inertia is small, and the safety performance is more reliable.

2.5 Obstacle Avoidance System Design

This design uses a low-cost, easy-to-operate ultrasonic sensor to realize the obstacle detection and obstacle avoidance function. This sensor has the ability to recognize transparent objects and reduce external interference, which can effectively help wheelchairs avoid collisions and collisions with obstacles. The system is mainly composed of ultrasonic sensors, PLC (programmable logic controller) and motor. Ultrasonic sensors are used to detect obstacles ahead, and when an obstacle is detected, the sensor emits a high-current signal. The PLC processes this information by receiving and translating it, and then outputs the PWM (Pulse Width Modulation) information to adjust the servo so that the wheelchair can turn left or rightto avoid obstacles. An automatic manual operation button is set on the human-computer interaction interface, which is used to switch the working mode of the wheelchair. When the auto-run button is on, the system activates the automatic obstacle avoidance function and makes the corresponding steering operation according to the signal output by the sensor. When the manual button is on, the steering drive needs to be manually carried out, and the user can control the direction of movement of the wheelchair in other ways. The automatic obstacle avoidance system designed in this way can provide a safer and more convenient wheelchair experience, help users avoid collisions with obstacles, and realize autonomous obstacle avoidance navigation functions [3]. The specific control process is shown in Figure 3.

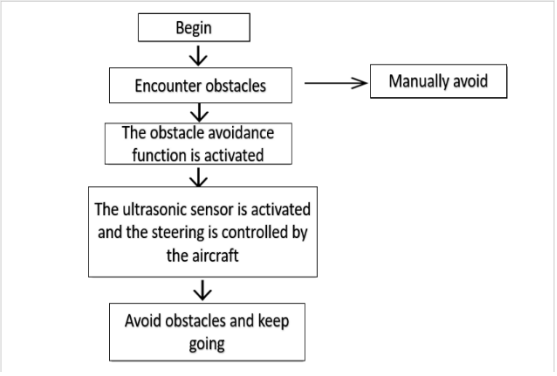

Fig. 3. Wheelchair Obstacle avoidance flowchart

3 Product Structure

In order to perform mechanical simulation and dynamic analysis, the 3D model of the wheelchair can be built with SolidWorks to provide an important basis for the feasibility study. During the modeling process, the universality of the wheelchair needs to be fully considered to ensure that the model can represent various types of wheelchair structures. Building an accurate 3D model will provide accurate input data for subsequent mechanical simulations and dynamics analysis, and help evaluate the performance and behavior of the wheelchair, as shown in the figure. The intelligent toilet

wheelchair mainly includes five parts: the body structure, the adjustment mechanism, the structure of the automatic bagging cleaning excrement system, the structure of the self-balancing 180° lying flat system and the lifting structure, as shown in Figure 4.

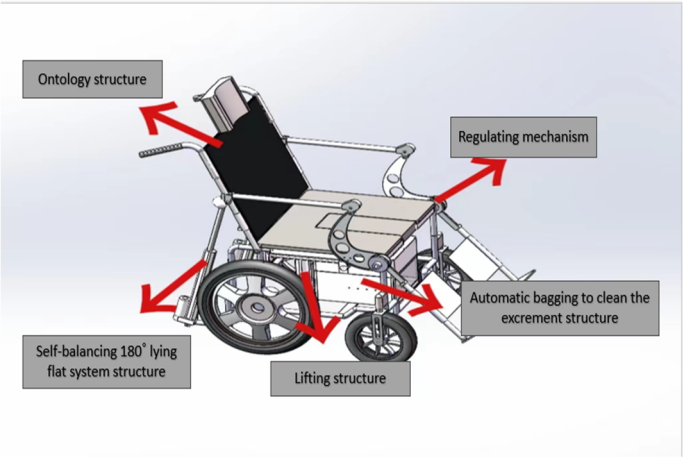

Fig. 4. Wheelchair modeling diagram

3.1 Ontology Structure

Among them, the body structure is composed of a backrest, a seat cushion and a tripod, and an industrial aluminum alloy material with high specific strength, light weight and strong filling capacity is selected, and the specifications are shown in Table 1. The rear end of the seat cushion is connected to the backrest by the first hinge, and the front end is connected to the tripod by the second hinge. (as shown in Figure 5)

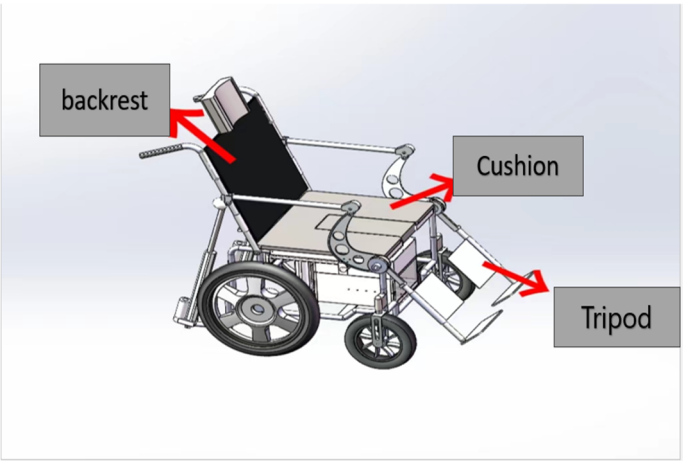

Fig. 5. Ontology structure diagram

Table 1. Technical Parameters

Wheelchair space	Length, width and height 88×60×93cm
Wheelchair specifications	European standard4040L-3.2,Wall thickness3.2mm,Meter weight1.74kg/m
Wheelchair surface treatment	Painting, spraying, plating
Wheelchair welding, gas shielded welding technology	Oxyacetylene gas welding is used to ensure uniform welding and no leakage welding.
Toilet specifications	The main pipe is made of high-quality steel pipes, and the diameter of 90mm, 45mm, and 30mm is made of high-quality steel.
Toilet surface treatment	After shot blasting and rust removal by the descaling machine, it is uniformly electrostatically sprayed with beautiful powder, and baked at a high temperature at a temperature of not less than 180°C
Toilet welding gas protection welding technology	The use of carbon dioxide gas shielded welding to ensure that the weld seam is uniform and there is no leakage

3.2 Regulating Mechanisms

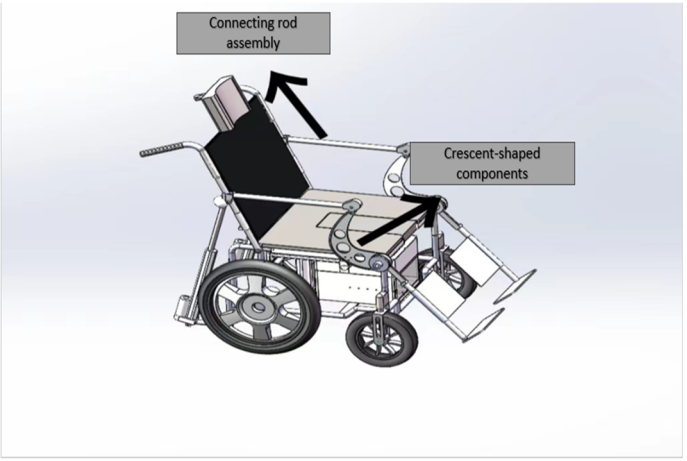

Fig. 6. Adjustment mechanism

As shown in Figure 6, the adjusting mechanism is assembled on the wheelchair body and is mainly composed of a connecting rod assembly and a crescent-shaped assembly. Wherein, the hinges of the connecting rod assembly are respectively arranged at the backrest and the tail end of the crescent-shaped assembly, and the head end of the crescent assembly is connected to the tripod at the same time. When the electric actuator on the self-balancing 180° lying flat system is activated and telescopic, the backrest inclination angle changes, and the tail end of the crescent-shaped assembly maintains a synchronized movement with the backrest through the connecting rod assembly, while the tripod follows the corresponding rotational motion of the joint at the head of the

crescent-shaped assembly. This mechanism ensures the linkage of the tripod with the backrest when lying down.

3.3 Automatic Bagging and Cleaning of Excrement System Structure

The cushion cover slides open, and the bottom toilet (as shown in Figure 7) can be removed and the entire roll of toilet bag can be placed outside the bagging column, and then the bagging post can be reinstalled to reset it. The free end of the toilet bag passes through the gap between the double helix column mechanisms and enters the center position of the upper chassis. The two rotating columns of the double helix column mechanism pull the toilet bag to move downward; The inner circumference of the annular installation part is provided with vacuum suction cups, which move to the center and adsorb the surface of the toilet bag, and then move radially outward to gradually pull away the toilet bag; At the same time, the fan on the bottom surface of the top cover blows air into the inside of the toilet bag and opens the toilet bag completely; The cam of the cam mechanism pushes the lower chassis to move upward, and clamps the edge of the toilet bag together with the upper chassis; When the ultrasonic detector on the bottom of the top cover detects that the garbage inside the bag is full to a preset height, the rotating suction cup mechanism twists the top position of the toilet bag by rotating and cooperating with multiple vacuum suction cups. Two sets of hot melters inside the barrel shell seal the twisted parts; Then, the cam of the cam mechanism swings downward, the lower chassis is separated from the upper chassis, and at the same time, the vacuum suction cup also releases the adsorption of the commode bag [4-5]. The whole bag of garbage will fall to the surface of the roof of the telescopic tilting mechanism; The pneumatic push rod at the bottom of the telescopic tilting mechanism generates different strokes that push the top plate towards tilting in the direction of the baffle, thus pushing the entire bag of waste out of it. The double helix column mechanism re-pulls the new bag and completes the kitting step.

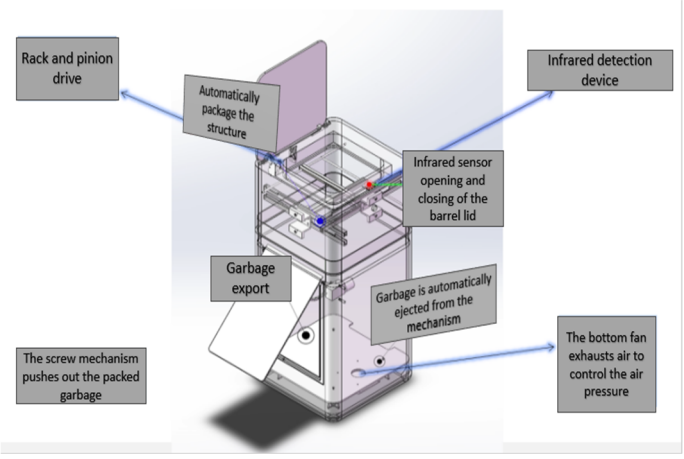

Fig. 7. Toilet

3.4 Self-Balancing 180° Lying Flat System Structure

For the structure of the self-balancing 180° lying flat system, a single electric push rod control system is adopted, that is, the lifting and clamping process of the electric wheelchair backrest is completed through the electric push rod, so that the back inclination angle after lifting is kept constant. The back is automatically adjusted at 0°~90° and can stay at any angle to realize the patient's lying flat and upright sitting function in the wheelchair, as shown in Figure 8).

The structure of the self-balancing 180° lying flat system consists of the following components: an independent linear actuator for the movement of the propulsion system, a back-lifting linkage connecting the pusher and a back-lifting crossbar to control the lifting and lowering of the back, a back-lifting crossbar that fits with the connecting rod to support and adjust the position of the back, and a back-clamping slot for fixing and adjusting the position of the back.

One end of the linear actuator is connected to the back clamping groove, the other end is connected to the back lifting member, and one end of the back lifting member is connected to the omnidirectional moving chassis, and the push of the linear actuator makes the back connecting rod unit rotate around the contact point of the connecting rod unit body in the middle [6].

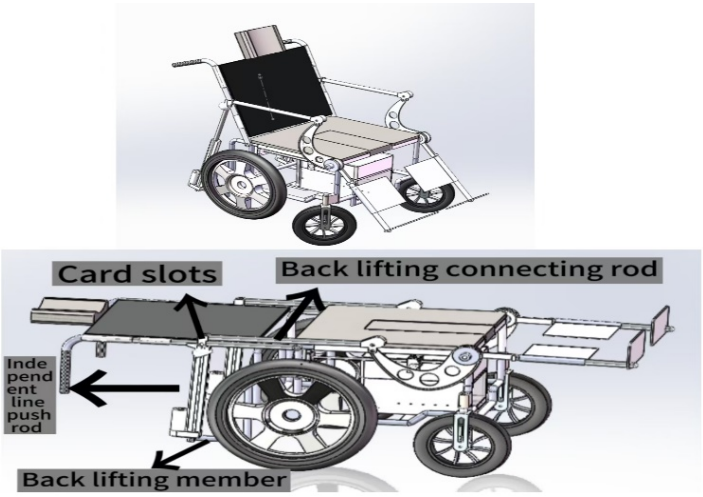

Fig. 8. The wheelchair is self-balancing and lying flat at 180°

3.5 Lifting Structure

The lifting device is installed between the seat cushion and the base, and is used for driving the seat cushion to approach or distance away from the base along the height direction. comprises a gas storage tank and a plurality of cylinders distributed at intervals, wherein the air storage tank is installed on the base and is connected with each cylinder. In order to ensure that the wheelchair can be lifted to the same level as the

bed, a combination of ultrasonic and infrared laser is used to adjust the lifting height of the wheelchair according to the different heights of the bed [7].

4 Experimental Validation

In order to verify the effectiveness and feasibility of the proposed system detection and operation and maintenance methods, a model was made and volunteers were invited to try out the wheelchair. As shown in Figure 9-13.

In summary, the toilet wheelchair has certain effectiveness and feasibility, and the average cleaning speed is 0.7 seconds.

Fig. 9. The wheelchair has just been activated

Fig. 10. The wheelchair achieves self-balancing 180° leveling

Fig. 11. The wheelchair is not lifted

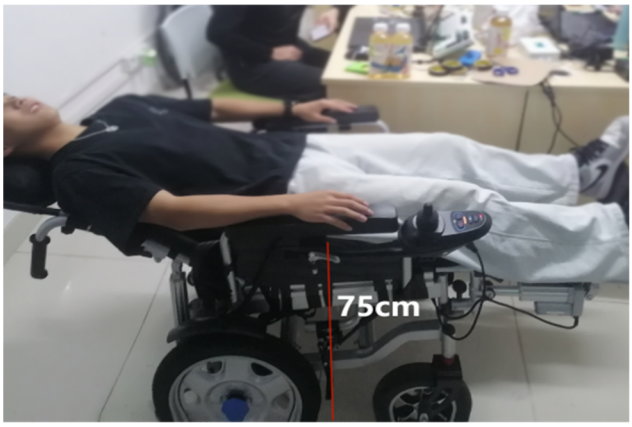

Fig. 12. Wheelchair raised

Fig. 13. Automatic bagging cleaning process

5 Conclusion

This intelligent toilet wheelchair integrates real-time obstacle detection, automatic bagging and excrement cleaning, and can achieve self-balancing 180° and infrared induction lifting to the same level height as the bed.

This smart wheelchair design has stable operation and good use experience, mainly for the elderly with limited mobility and disabled people with paralysis of the lower limbs. It can effectively cope with special scenes in daily life and improve the quality of life of users.

In addition, according to the demand, more modules can be added in the future to further improve the intelligence level of the wheelchair to meet the needs of users. This flexibility allows the wheelchair to adapt to different usage situations and provides more functionality and convenience for the user.

Acknowledgments

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References

1. Wu Qing, Wu Meng, Ai Xianfeng, et al. Structural design of intelligent wheelchair based on FBS model[J]. Packaging Engineering, 2022, 43(16):170-176.
2. Mark G, Eline B, Nikitha D, et al. Clinical and Ergonomic Comparison Between a Robotic Assisted Transfer Device and a Mobile Floor Lift During Caregiver-Assisted Wheelchair Transfers[J]. American Journal of Physical Medicine Rehabilitation, 2022, 101(6):561-568.
3. Fu Zidong, Shang Wen. A kind of intelligent wheelchair design[J].Modern Instruments and Medical Treatment, 2023, 29(04):41-45.
4. Tang Wenyang, Zhou Yingjie, Yu Benxing. A new type of intelligent trash can for automatic bagging and packing[J]. Digital technology and application, 2021, 39(07):132-134.
5. ZHAO Chunxue. Research on the design of intelligent toilet for aging[D].Changchun University of Technology, 2023.
6. WANG Yuping. Optimization design and research of intelligent wheelchair bed[D].Tianjin University of Technology, 2020.
7. Yang Ruihua, Huangfu Haoran, Marshal Kui. Footwear technology and design, 2023, 3(16):138-140.