Household smart cat litter box

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Abstract. With the change and development of the times, more and more young people live alone in the cities, and with the pressure of work, they are often lack of company. Cats are docile in nature, like keeping neat and tidy, and don’t need too much time with their owners, so keeping pet cats is more convenient for most of people. Therefore, pet cats are very popular among young people, more and more young people start to keep pet cats as companions. In addition, with the improvement of people's living standards, the average family can also afford to raise a cat. Whether as a companion to a child or a member of the family, pet cats are also very popular in ordinary families.

According to the surveys, most families now have some pets. But obviously it’s a problem for these families to deal with the excrement of the cats. Because of the heavy smell, every time shoveling the feces will cause a lot of trouble to people. What’s worse, the smell of feces will evaporate in the air, causing air pollution. In order to solve the above problems, we designed a smart litter box that can separate and completely seal the cat feces. It solves the problem of the difficulty in handling cat feces and the heavy smell of cat feces, and can maximize the utilization of household space. Through the fully automated function and effective human-computer interaction function of this litter box, people can greatly save the time and energy spent in processing cat feces.

1. Research background and significance

1.1. Research background

At the end of January 2019, Frost&Sullivan, the world's largest corporate growth consulting company, released its monitoring data on the global pet market in 2018. In 2018, the number of pet users in China reached 99.78 million, and the proportion rose to 22%. The number of pet cats in 2018 was 67 million. The scale of China's pet market has further expanded to RMB 172.2 billion. In addition, the number of cats has been rising continuously, and is increasing at a certain rate every year. While the national pet market continues to expand, the living standards of pets in China are gradually improving. The data proves that the cost of raising a cat is lower than raising a dog.

The popularity of pet cats in the crowd is self-evident, but there are many troubles and problems in raising cats along with happiness. Whether it is to take care of the cat’s health problems, to vaccinate it, bathe, and deworm it regularly, or to endure its damage to the house’s things and hair loss everywhere, these troubles are all cat owners must face. Among them, the biggest task for cat owners is to clean up the cat's feces. Cleaning up the feces is also the last thing many people want to accept and do. At present, the main method of cleaning the feces is by hand shoveling. Therefore, when shoveling the feces, they have to endure the stench to clean up. Many people who are just starting to raise cats find it difficult to accept.
At present, the number of cats is increasing rapidly. The traditional ordinary cat litter boxes on the market can no longer meet people's needs for more diversified and smarter cat litter boxes. Therefore, there is a great need for more intelligent, more diversified and more convenient cat litter boxes that could come to the cat family and give people a better experience in the process of raising cats.

1.2. Research significance
As more and more families start to keep pet cats, the demand for litter boxes will become more diversified and high-quality. At present, the cat litter boxes on the market are often simple in function and simple in structure, or are not suitable for ordinary households. The fully automated litter box designed and developed by this project team has been designed on the basis of the previous design and perfected with more sophisticated functions, which can truly realize the function of cleaning pet cat feces without human involvement. With less time spent on dealing with cat feces, people who raise cats at home can realize the fun of raising pet cats rather than trouble. With the development trend in recent years, the number of pet cats will increase, and the demand for litter boxes will also increase. The fully automated litter box we designed and researched can stand out from the ordinary litter box and bring people a different experience.

2. Overall design

2.1. Mechanical structure design
The design of the mechanical mechanism is the core of the research on this litter box. The research on the mechanical structure that meets the requirements of good sealing effect, stable separation, convenient feeding, light weight, small size, and complete functions is the focus of research. The mechanical structure of the system mainly includes: the litter separation module of the upper box of cat litter, the sealing module of cat litter of the lower box, the sand sending module of the lower box, and the overall movement module of the lower box. The overall shell of the litter box is a spherical shell constructed of synthetic polyvinyl chloride, and is equipped with a rotatable inner shell, which can complete the function of separating the excess cat litter in the inner shell from the cat feces adhered to the cat litter. What’s more, it transports the cat litter from the lower box to the upper box as a supplement. In the sand feeding module, the entire conveyor belt is lifted by the winding wheel, and then the cat litter is transported upwards by the conveyor belt into the inner shell. The sealing mechanism drives two hot-melt rods to fuse and seal the garbage bag by means of a centered double crank slider mechanism, thereby realizing a garbage bag to be used multiple times continuously and improving the utilization efficiency of the garbage bag. The entire lower box is driven by the guide rail to drive the slide box to move left and right, and the synchronization belt drives the overall in and out of the inner box, which is convenient for users to replenish cat litter in the cat litter storage box and replace garbage bags.

The overall structure of the litter box is shown in Figure 1.

![Figure 1. Overall structure of the litter box](image)

2.2. Control system design
The design of the control system is an important part of the research on the smart litter box, and the control module is the focus of this part of the research. The system control adopts the cost-effective open
source single-chip Arduino MEGA 2560, which detects the power supply and uses the steering gear to adjust the rotation angle of the inner shell to protect the safety of the domestic cat, so that the domestic cat can ensure absolute stability in the inner shell and enhance the experience of use. ESP-32 carries out signal transmission and transmits the information inside the litter box to the owner immediately, which is more humane.

3. Module design

3.1. Upper box module
The upper box module is mainly composed of an outer shell, an inner shell, a sand dividing plate and a steering gear, as shown in Figure 2.

![Figure 2. Structure of the upper box module](image)

The module realizes the separation of cat feces and cat litter through the movement of the outer shell of the sphere. There is an oval hole on the outer shell of the whole sphere. The inner shell is a rotating shell, which is driven by the steering gear. Therefore, the inner shell can perform a 360° rotation in the corresponding plane. The inner shell is also punched in an ellipse to coordinate with the outer shell. At the same time, in order to ensure that the inner shell can have a better bearing capacity, we use foam cotton to fix the joint between the inner shell and the outer shell to ensure the stability of the two boxes and ensure that the steering gear only needs to drive the inner shell without bearing the weight of inner shell.

The litter separation board adopts a semi-closed and semi-leaky sieve model to separate the feces and cat litter to the greatest extent, so as to ensure that only the feces adhered to the cat litter will fall into the sealing mechanism of the lower box. The clean cat litter will remain in the semi-enclosed sand separator, which greatly improves the utilization rate.

3.2. Sealed module
The sealing module is composed of hot melt strip, crank slider, motor and insulation cloth, as shown in Figure 3.

![Figure 3. Structure of the sealed module](image)

In this module, we use a centered double crank slider mechanism to drive two hot-melt rods to seal and fuse the sealed bag, so as to ensure that the sealed bag can be used multiple times and does not need to be replaced every day.
Before the sealing mechanism is used, the user needs to put the corresponding sealing bag on the sealing mechanism. When the cat litter separation mechanism of the upper box separates the cat litter feces, it will fall into the bag of the sealing mechanism, and then through infrared induction. As a result, the worm gear self-locking motor drives the centered double-crank slider mechanism to clamp inward. When the two hot-melt plates are in contact, the energization condition is formed, and the hot-melt rod is heated so that the sealed bag is separated. Lift the hot melt rod to seal the upper part of the bag, thereby forming another prerequisite for forming a sealed bag. Through the hot-melt rod, the sealed bag can be used for a long time without multiple replacements.

The cat litter feces enter the sealed bag, and the hot melt rod completely seals the sealed bag, which can ensure that the smell of the entire cat litter separation and sealing process will not diffuse, and the user's experience of raising cats is improved.

### 3.3. Sand feeding module

The sand sending module is composed of a sand separating plate, a synchronous belt, a worm gear motor, a DC motor and a winding wheel, as shown in Figure 4.

![Figure 4. Structure of the sand feeding module](image)

The module is placed in the small box on the left side of the lower box. The entire cat litter supply mechanism can be moved on the optical axis through the motor to drive the linear bearing, and the positions of the supply mechanism and the sealing mechanism can be adjusted, so that two functions can be realized in the lower box at the same time.

The cat litter supply mechanism transports the cat litter to the upper box through the conveyor belt in the small box. First, the entire conveyor belt is lifted to the height of the upper box through the winding wheel. In order to accurately transport the cat litter to the semi-sealed slippery net of the upper box, the steering gear of the upper box needs to control the inner shell to reverse a certain angle accordingly, which can well cooperate with the overall transportation. At the same time, the motor is used to drive the movement of the conveyor belt, and the scraper is used to scrape the cat litter from the small box to be transported to the semi-closed slippery net of the upper box.

In the process of lowering and retreating, first the steering gear controls the inner shell to rotate forward at an angle to ensure that the supply mechanism can be accurately lowered from the upper box. Stop the motor that drives the movement of the conveyor belt, and use the winding wheel to place the conveyor belt as a whole in the small box.

The small box can be loaded with 5-10kg cat litter at a time, ensuring that it can be used for more than 20 days without frequent replacement of cat litter, which is convenient and labor-saving.

### 3.4. Lower box movement module

The lower box includes a lower box outer shell, an inner shell, a sliding box, and a sealing mechanism and a sand feeding mechanism inside the sliding box. The sliding box is fixed on a fixed plate, and the fixed plate slides left and right on the guide rail along with the guide rail slider. After the cat's excretion is completed, the cat's feces fall into the garbage bag of the sealing module. After the garbage bag is sealed by the sealing module, the sliding box slides to the other side with the fixed plate, so that the conveyor belt of the sand delivery module and the upper box is in the same horizontal position. At this
time, the device enters the working stage of the sand feeding module. When the sand sending module is completed, the sliding box moves back to the direction of the fixed plate and returns to the original position, ready for the next work.

The movement mechanism of the lower box is shown in Figure 5:

Figure 5. Structure of the lower box movement module

4. Innovation and advantages

4.1. Fully automated operation
This household smart cat litter box is a multi-functional intelligent product. The whole process from automatic separation of cat litter and cat feces adhered to cat litter to automatic sealing and packing of garbage to automatic supply of cat litter is fully automated. In the actual use process, infrared induction is used to sense the entry and exit of domestic cats to control the operation of the litter box. When the storage of cat litter in the next box is not enough or the garbage bags containing cat feces are accumulated too much, the device will automatically remind people to supply cat litter or throw away the garbage bag.

4.2. Effectively block odor
This project completely separates the feces that adhere to the cat litter from the cat litter through the litter separation mechanism. Using the combined action of the centered double crank slider mechanism and the hot melt rod, the entire sealed bag is sealed and closed by pressure hot melt to ensure that the smell of feces will not float in the air.

The centered double crank slider mechanism can smoothly and forcefully seal the sealed bag. The worm gear motor drives the crank slider to bring the hot melt rods close to each other, ensuring that the hot melt rods are in contact on the same surface. Thereby, energization conditions are formed, and the sealed bag is sealed and fused.

When the cat litter and feces fall into the sealing mechanism for the first time, the sealing mechanism directly seals the cat litter and the feces. It is different from other ordinary cat litter boxes that just put cat litter excrement in a bag without completely sealing it. Completely airtight can ensure that the overall smell will not spread. No matter how long it is left, the smell will only exist in the sealed bag and will not leak.

4.3. Human-computer real-time interaction
Pressure sensors are installed at the entrance and exit of the spherical shell. When the cat enters the litter box, the device gets a signal through the pressure sensor. After the cat has excreted, the litter box will start to operate after confirming that the cat has gone out. Secondly, we set up an ultrasonic sensor in the cat litter storage box. Due to the ranging function of the sensor, when the cat litter is reduced to a certain extent, the measured distance becomes longer and a signal is obtained, which is transmitted to the ESP-32. When the distance is greater than a certain value, the WeChat application that transmits the information to the mobile device will remind the owner to add cat litter. In the sealing mechanism, the garbage bag is counted once when the fusion sealing mechanism is fused, and when the number of times
exceeds a certain value, the owner is reminded to dump the garbage through the ESP-32. In this process, the machine will provide the owner with information about the cat litter box in real time, which can make people better understand the cat litter storage box, replenish the cat litter and dump the garbage in time, and realize the real-time human-computer interaction. The whole process does not require people to observe and operate by themselves, which completely liberates people's hands.

5. Application prospect and conclusion
With the increase of cat owners, many problems in the process of raising cats have also become prominent and plague cat owners. The disposal of cat feces is one of the problems. This household smart cat litter box integrates various functions such as cat feces processing and packaging, cat litter supplementation, and real-time interaction, providing a more mechanized, automated and intelligent solution for cat owners' cat feces processing problems. Compared with other cat litter boxes on the market, household smart cat litter boxes are more competitive and have a huge market space.

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