Design of Home Service Robot for Pet Caring

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Abstract. Pet dogs are good friends in people’s home living. Some people sometimes are inconvenient to take care of pet dogs. A smart robot for caring pets is designed in this paper. The robot can actively interact with the pet dog in the way of serve and relieve the separation anxiety of the pet. During the serve process, the multi-stage gears and rack meshing transmissions are used to achieve near, medium and long-range launch modes with stable convenience performance. The structure of this companion pet robot is displayed. It is mainly composed of feeding system, serve system, grasp system, driving system and real-time monitoring system. It is demonstrated here with the feasibility of the machine function and the rationality of the structure design is analysed. The robot will support a good convenience help to pet caring in home living.

1. Introduction

Pets have become an important family member that relieves the pressure of work and life and increases the fun of life. Therefore, companion pets have become more and more concerned by pet owners [1]. For an example, when the owner is inconvenient to take care of the pet dog, the pets in the home are likely to be hungry. The robot will feed the pet dog. If the pet dog is at home alone, the pet owner cannot understand the pet's status. Caring pets is a necessary way to ensure pet's physical and mental health. At present, pet products on the market have a single function and a simple structure, which cannot meet the needs of users [2-4]. The similar service robot is needed in home living for the special requirements [5]. There are a few reported service robots or automatic machines for the requirements [1-6]. A smart robot is designed to accompany pets, which can easily accompany play, free walking, automatic feeding, real-time monitoring and other functions.

2. Overall design

According with the user’s service requirements, the whole work flow chart is shown in figure 1 for the overall design. The robot determines the position of the pet through the infrared device, and the serve system sends out the toy ball. If the pet dog holds the toy ball and puts the toy ball into the entrance, the sensor issued a reward feeding signal and rewards the dog food. It aims to accompany the pet to play and train the dog's ability to play ball. If the dog does not put the toy ball into the goal gate, the robot will place the toy ball into the goal gate through the grasp system.

The caring pet robot is mainly composed of feeding system, serve system, grasp system, driving system and real-time monitoring system. The robot applies a support platform to connect the various modules and provide overall body support. The serve system uses a two-layer frame-shaped cuboid and the feeding system is behind the serve system. The grasp system uses a four-degree-of-freedom robotic
arm. The real-time monitoring system is composed of an external camera at the top of the fuselage and a sensor control circuit embedded in each system. The overall structure is shown in figure 2.

| Machine work flow chart |
|-------------------------|
| Real-time monitoring system | Serve system | Grasp system | Feeding system | Driving system |
| Image acquisition, sensor information collection, voice broadcast | Accompanying play and serve mode | Auxiliary recycling toy ball | Daily feeding, feeding rewards | Provide full range of machine movement |
| Monitor pet location | The robot will send the toy ball | Pet dog holding a toy ball | Grasp system assisted recycling toy ball | Provide daily feeding |
| Does the dog put the toy ball into the goal? | No | Yes | Issue a reward feeding signal | |
| Reward pet dog feed | |

Figure 1. Machine work flow chart.

Figure 2. Overall structure diagram.

1. Feeding system 2. Real-time monitoring system 3. Serve system 4. Grasp system 5. Driving system
3. Part design

3.1. Feeding system
The feeding system consists of a grain storage tank, an adjustment mechanism and a conveyor. The feeding system has two main functions. One function is to provide the pet with the daily amount of food and the other one is to provide rewards for the pet. Grain storage tank is used to storing dog food. Adjustment mechanism is used to adjust the amount of dog food. Conveyor is used to transporting dog food to the plate. The overall structure of the feeding system is shown in figure 3.

The adjustment mechanism is mainly composed of an upper disc loading grain cylinder, a lower disc loading grain cylinder, a support rod piece, an incomplete gear set, a gear and a rack. The servo motor is used to drive the incomplete gear set to drive the grain loading tray, and the rack and pinion drive is used to drive the grain loading tray to move up and down. Thus, the conversion and distance adjustment between the filling cylinders are realized, and the purpose of adjusting the amount of dog food is achieved. The adjustment mechanism is shown in figure 4.

![Figure 3. Overall structure of feeding system.](image1)

1.Conveyor  2. Adjustment mechanism  3.Grain storage tank

![Figure 4. Adjustment mechanism](image2)

1.Incomplete gear set  2.Support rod piece  3.Upper disc loading grain cylinder  4.Lower disc loading grain cylinder  5.Grain bottom cover  6.A gear and a rack

3.2. Serve system
The main function of the serve system is to accompany the pet to play and train the dog to play ball. The serve system consists of loading ball mechanism, ejection mechanism and shifting mechanism. This system is used for loading and ejection of toy balls. The multi-stage gear and the rack mesh drive are used to achieve the short-range, medium-range and long-range ejection modes. Therefore, pets can get variety of play modes to improve the interaction between pets and robots. Loading ball mechanism is used to store toy balls. Ejection mechanism is used to launch the toy ball at different speeds. Shifting mechanism is used to provide different gear positions for the ejection mechanism. Its overall structures of the serve system are shown in figure 5.

The ejection mechanism consists of a ball barrel, a micro racket, a spring, a multi-stage gear and a rack. The multi-stage gear is connected with the motor, and the motor provides power for the multi-stage gear rotation movement. The multi-stage gear drives the rack to make a linear motion, thus driving the miniature racket compression spring to realize the launch of the toy ball.

In order to satisfy the need of the spring to provide sufficient elastic potential energy for launching the toy ball in the ejection mechanism, it is necessary to calculate some parameters of the spring. The toy ball selected for this product is made of natural rubber. Check the data to get a natural rubber density of 0.92 g/cm³, the diameter of the toy ball as 50 mm. The entire moving process is a completely elastic collision. The mass of the toy ball is 0.06 kg. The mass of the racket is 0.04 kg and the average ball speed is 10 m/s. The calculation according to the formula shows that the speed before hitting the ball is
12.6 m/s. The parameters of the spring are analyzed. $K$ is the spring stiffness. $\Delta x$ is the maximum compression of the spring with the maximum compression of the spring as 0.08 m. The spring stiffness can be calculated. According to the conservation of energy theorem, we get $K = 992.25$ (N/m).

$$K \Delta x^2 / 2 = m_2 V_0^2 / 2$$

According to the above calculation, the diameter of the spring wire is designed here with 2.5 mm, the outer diameter of the spring 15 mm, and the maximum length 158 mm.

The shift mechanism includes a gear set, a crank slider mechanism, and a shift lever. The slider of the crank-slider mechanism is driven by the driven lever, and the slider achieves left-to-right translation in the chute, thereby driving the shift lever to move left-to-right and achieve the function of switching between three gears. The shifting mechanism structure is shown in figure 6.

3.3. Grasp system
The main function of the grasp system is that if the dog does not hold the toy ball and does not put the toy ball into the goal, the system will use the robot device to clamp the toy ball into the goal after the toy ball launching. Its structure is mainly composed of a base, a mechanical arm and a mechanical claw. The independent movement of the robot, such as lifting, telescopic, and rotating, is called the freedom of the robot. Freedom is a key parameter in robot design. The robot has characteristics the more degrees of freedom, the greater the flexibility of the robot and the wider the versatility. The robot has four degrees of freedom, and the grasping mechanism (ball catcher) of the hand can be opened and closed freely. It can carry out the action of grasping, moving, and putting the toy ball. The overall structure of the grabbing system is shown in figure 7. The number degree of freedom of the institution,

$$F = 3 \ n - (2 \ P_l + P_h ) = 3 \times 4 - (2 \times 4 + 0 ) = 4$$

where $F$ is the degree of freedom of the institution. $n$ is the active component. $P_l$ is the lower pair and $P_h$ is the high pair.

3.4. Driving system
The driving system is mainly composed of a chassis, Mecanum wheel, servo motor, three-stage decelerator, battery system and battery pack. Each wheel is equipped with an independent servo motor, and each motor is connected to a three-stage reducer, realize forward, traverse, oblique, rotation
combination and other movements through different speed and steering of each wheel. The driving system is shown in figure 8.

![Grasp system overall structure](image)

![Driving system](image)

**Figure 7. Grasp system overall structure.**

**Figure 8. Driving system.**

### 3.5. Real-time monitoring system

Real-time monitoring system mainly includes external equipment, sensor equipment, control circuit system and so on. The control sensing unit and the sensing unit are equipped with sensing components and external equipment that sense the ambient information on the housing.

The sensing component is mainly composed of three parts infrared device, photoelectric sensor and timing sensor. Infrared devices are used to detect obstacles and monitor pet locations. Photoelectric sensors are used to sense ambient light changes. It determines if it needs to turn on the lighting. The timing sensor is equivalent to a timing switch. When the pet dog does not put the ball into the target location in the specified time, it will send out the pick-up signal. Then the robot goes to clip the toy ball and put it into the target location. If the pet dog puts the ball into the target location in the specified time, the sensor issues a reward feeding signal, then the feeding system will provide a certain amount of dog food to the dog.

The external equipment is mainly composed of three parts LED light, multi-angle cameras and friendly speaker. The lights could provide night lighting. Multi-angle cameras are used for pet monitoring. The speaker is used to pre-record the owner's warning. When a pet behaves badly, such as biting something or dangerous happening, the robot will use the friendly owner's voice to warn the pet and prevent the pet from doing so.

The control circuit system uses STM32 CPU as the core processor, which builds a high-performance hardware platform for general-purpose units for robot control. At the same time, according to the needs of the servo motor control signal, a differential signal sending and receiving circuit is designed to improve the anti-interference performance of the hardware system. From the perspective of multiple embedded hardware circuits, the design unit of each hardware circuit is analyzed in detail to further improve the stability of the circuit.

### 4. Conclusion

This product is a smart robot that used for the caring pets. The product functions are used to help pets to play friendly, provide daily diet and monitor pets in real time. It has great value in market development of home living service robot with pets’ helpers. It provides great convenience for the elderly people and busy officers to keep pet lovers. The design of the robot is based on the feasibility of the machine function and the rationality of the structural design. It could also cooperate with microprocessor
technology as a control device, which improves the stability of the hardware system. The structure of the design is compact and reasonable with modular overall. The development and prototype testing of this product will be carried out in the future research.

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References
[1] Park C.W., Seon JH., Kim JH., Kim JH. 2017 Pet Care Robot for Playing with Canines Robot Intelligence Technology and Applications 4. Advances in Intelligent Systems and Computing, vol 447, ed Kim JH., Karray F., Jo J., Sincak P. and Myung H. (Springer, Cham) p 299-306
[2] Bedaf, S., Witte, L. D. 2017 Robots for Elderly Care: Their Level of Social Interactions and the Targeted End User. Stu Health T & Inf 242 472-78
[3] Kim, J.-H., Choi, S.-H., Kim, D., Kim, J., and Cho, M. 2009 Animal-Robot Interaction for pet caring. Proc. IEEE Int. Symp. on Computational Intelligence in Robotics and Automation (Daejeon: Korea/IEEE) p 159-64
[4] Chen, M., Liu, C., Du, G. 2018 A human–robot interface for mobile manipulator. Intel Serv Robotics 11 1-10
[5] Kalani, H., Akbarzadeh, A., Nabavi, S. N. and Moghimi, S. 2018 Dynamic modeling and CPG-based trajectory generation for a masticatory rehab robot. Intel Serv Robotics 11 1-19.
[6] Lakatos, G., Janiak, M., Malek, L., Muszynski, R., Konok, V., Tchon, K. and Miklósi, A. 2014 Sensing sociality in dogs: what may make an interactive robot social? Anim Cogn 17 387-97