FPGA-based Emotional Behavior Design for Pet Robot

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Abstract. This paper introduces a design method of emotion behavior for pet robot. In order to increase the amusement, the pet robot also design with ears, mouth, facial expression plane, and vision system, so that it can do some emotional behaviors. This paper is also proposed a hand gesture recognition algorithm on the pet robot, that makes it can do naturally interaction with human and learn the emotion. These applications are designed and controlled with a FPGA (Field Programmable Gate Array)-based processer. From the experiment results, we know the pet robot execute the human's command as very well.

Keywords: Hand Gesture Recognition, Pet Robot, Emotional Behavior, FPGA.

1 Introduction and Background

In recent year, the robot technique is researched and developed. Many kinds of robot have its own characteristic and feature. Pet robots with lovely behaviors let them easily to enter human's life [1]. In addition, the pet robot with more intelligence is beginning to be presented to the public [2-7].

In this paper, a pet robot with 16 degrees of freedom (DOFs) is proposed. One vision system, one facial expression, the hand gesture recognition, and the emotion behavior are built in a FPGA-base system. Hardware/Software co-design method is used to accelerate the image recognition. So that the pet robot can recognition the hand gesture from human and do the emotion behavior. The section 2 relates the FPFG-based pet robot design method. The section 3 proposes the hand gesture recognition function. The section 4 explains the design of motion and emotion structure. Then section 5 shows some snapshots of the experiment.

2 FPGA-based Pet Robot Design

In order to testing and verify the opinion, this paper designs and builds a pet robot. The pet robot has four legs, a head, two ears and a mouth. There are 16 DOFs and each joint consists of a high torque and gear. The frameworks of pet robot are mainly fabricated from Acrylonitrile Butadiene Styrene (ABS). The ABS stuff has the two characteristics that easy to process and light to reduce the weight of robot. There are 2 DOFs on the ear, 1 DOFs on the neck, 1 DOFs on the mouth, and 3 DOFs in each leg. The photograph and the device of pet robot are shown in Fig. 1 and Fig. 2, respectively.

The mechanical views of pet robot are showed in Fig. 3. The mechanical structure is designed and implemented so that the implemented pet robot can do some motions, like walk forward, squat, shake hand, and raise leg.

Fig. 1. Photograph of the implemented pet robot.

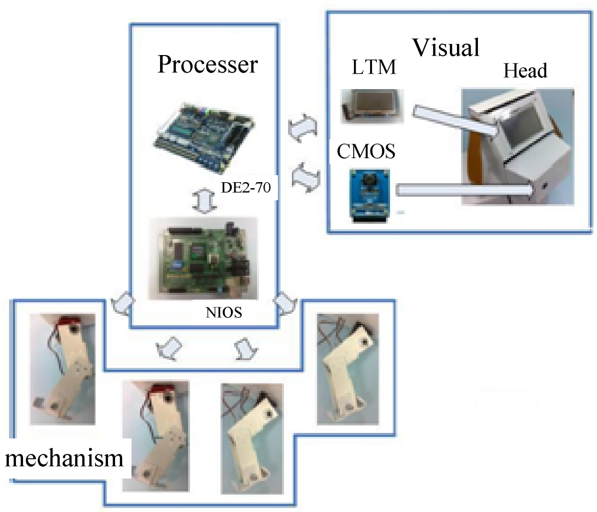
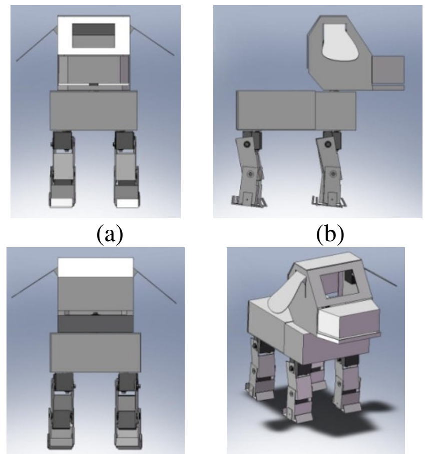


Fig. 2. The device of pet robot.



(a) (b) (c) (d)

Fig. 3. Mechanical design of the pet robot. (a) Front view, (b) Side view, (c) Back view, and (d) Bird view.

We use FPGA as a controller center of pet robot. It proffers sufficient space for designer. In this paper, a DE2 development board is used as our experiment platform. The Cyclone II 2C70 FPGA Chip on DE2 platform is used and placed three soft-core processors on it. The three processors are used to process the image recognition, motion control and emotion learning, respectively. The vision processor is used to process the hand gesture recognition from the vision system of pet robot. The motion processor is used to analyze the motion data and control the motor. The emotion learning processor is used to analyze the environment information and learn emotion.

Designing multi-processer in the FPGA chip has three advantages and it is described as follow:

First, the processers can share the peripheral component. Sometimes we use same component to process different situations, this design can share the peripheral component, like timer, sensors, I/O port, and reduce the areas of circuit of the pet robot.

Second is that the processors can share the same memory. Memory sharing can reduce the time of moving data and gat newest information at real time.

Finally, it provides a good Hardware/Software co-design platform. This design can reduce the software design complex of Nios II and raise the system performance. Generally, to design software is easier than hardware, but the hardware circuit execution speed is faster than software execution. Therefore, in this paper, the Hardware/Software co-design method is proposed to promote the effect.

In order to maintain the real-time image recognition, the processer execution speed is as soon as possible. Generally, the frequency of Nios II in DE2 development board is less than 200Mhz and not enough to real-time process the image recognition. Therefore, this paper uses a Hardware/Software co-design method to accelerate image recognition. Fig. 4 shows the image recognition flow chart with Hardware/Software co-design method. The processing of hardware circuit includes the function of Image Capture, Geometric Transformations, and Edge Detection. The processing of software includes the Binary Image block and Hand Gesture Recognition.

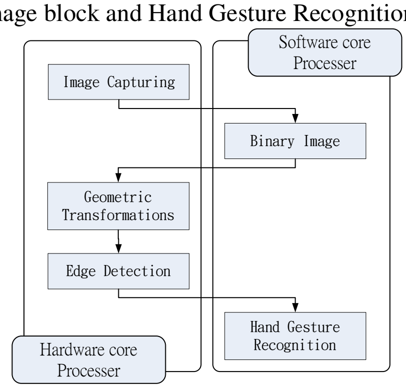


Fig. 4. Image recognition with Hardware/Software co-design method.

3 Hand Gesture Recognition

In this paper, a hand gesture recognition function is designed to connect human and pet robot. The function flow chart of the system is shown in Fig. 5. According to the number of fingers, the pet robot can understand the human command and do the corresponding motion.

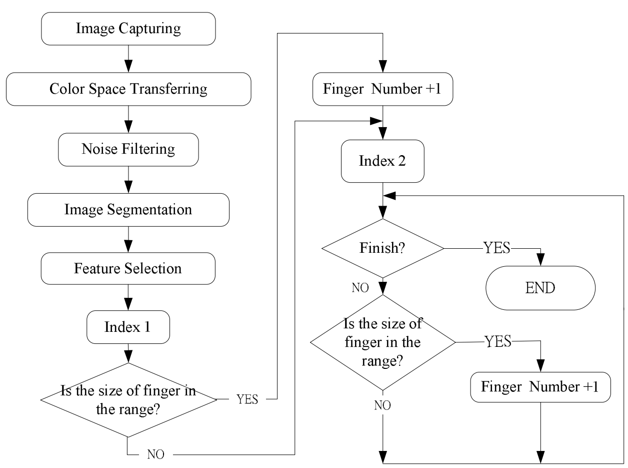
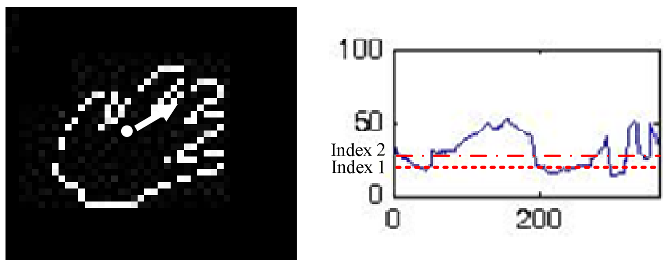


Fig. 5. The function flow chart of the hand gesture recognition system

Fig. 6 shows the simulation of hand gesture recognition. Fig. 6(b) is the distance chart calculated by Eq. (1) and Eq. (2). In general, the thumb is shorter than other fingers. Therefore, we use two index values to separate the thumb and the other fingers. The index 1 value is smaller than the index 2. Index 1 just uses to find the thumb. The appropriate range of the index values will be chose. The number of the fingers is gotten by add the number of the appropriate range.

$$angle = \tan^{-1}(\frac{Y}{X}) \quad (1)$$

$$distance = \sqrt{X^2 + Y^2} \quad (2)$$



(a) (b)

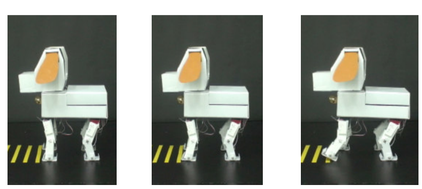
Fig. 6. The simulation of hand gesture recognition: (a) center point of the object, (b) distances from center point to the edge with index.

4 Motion and Emotion Structure Design

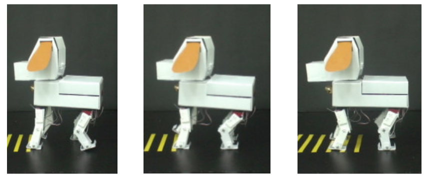
In this paper, a pet robot with six motions and six facial expressions are designed. The pet robot will be given vary emotion expression by combining the six motions and six facial expressions. The design of motions and facial expressions are showing as follow:

(a) Motions

Motion is designed to let the pet robot doing corresponding human command. Some snapshots of the walk forward motion, wave hand motion, wave head motion, raise leg motion and stretch motion of the pet robot are shown in Fig. 7 to Fig. 11.



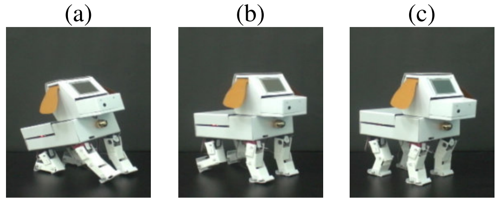
(a) (b) (c)



(d) (e) (f)

Fig. 7. Walk forward motion.

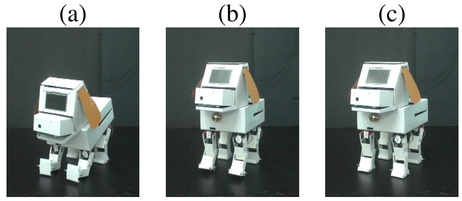
(a) (b) (c)



(d) (e) (f)

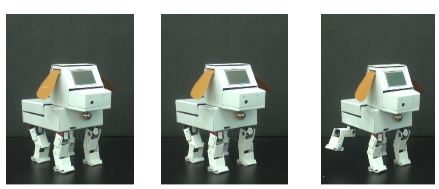
Fig. 8. Wave hand motion

(a) (b) (c)

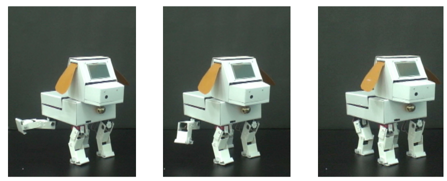


(d) (e) (f)

Fig. 9. Wave head motion

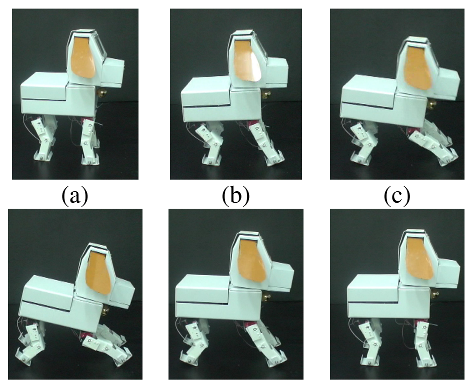


(a) (b) (c)



(d) (e) (f)

Fig. 10. Raise leg motion



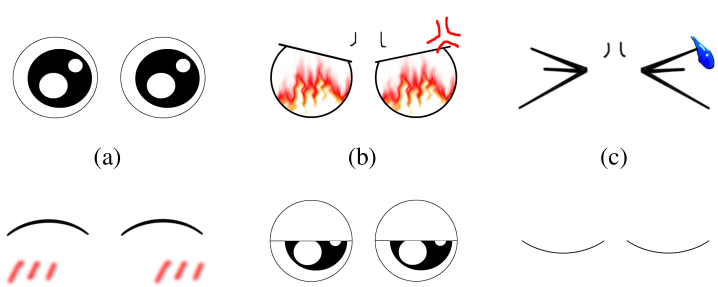
(a) (b) (c)

(d) (e) (f)

Fig. 11. Stretch motion

(b) Facial expressions

Facial expressions are designed and shown in Fig.12. The facial expression are indicated (a) normal facial, (b) angry facial, (c) nervous facial, (d) happy facial, (e) boring facial and (f) sleep facial, respectively.



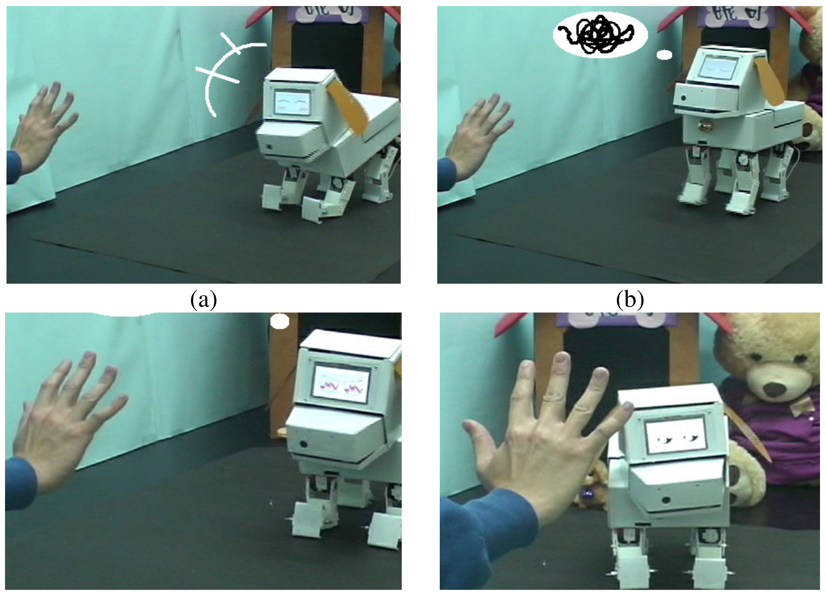
(a) (b) (c)

(d) (e) (f)

Fig. 12. Facial expressions

5 Experiment Result

Some snapshots are shown the experiment results in Fig.13. Once the human's hand is appearing in front of the pet robot, the pet robot will recognize the hand gesture and do the corresponding motions. If we continue sending same commands, the pet robot will out of patience. The angry facial or the boring facial will on the face. And the worst situation is the pet robot won't do any motion.



(a) (b) (c) (d)

Fig. 13. Emotion experiment. (a) Doing motion with happy facial, (b) Doing motion with normal facial, (c) Doing motion with angry facial and (d) No doing motion and with boring facial on face.

6 Conclusions

In this paper, a FPGA-base emotional behavior design for pet robot is implemented. So that the pet robot can use its vision system to recognize the hand gesture and do the interactive motions with human. The pet robot also has four legs, one mouth, one vision system, and one facial expression plane. By combining the motion and facial expression of pet robot, the pet robot can do vary emotion expression.

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