Service Robot Based on Kinect and Motion-sensing Technology

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Abstract. To take care of the disabled and the elderly, this paper designs a robot based on Kinect and motion-sensing technology, which can reproduce the motion of human. The skeleton of human can be tracked using Kinect. By this function, we can capture the parameters of human joints, so that the angle of arms can be converted into the motive parameter of mechanical arms. The bending sensor is used to collect the bending states of the human fingers, thus the bending parameters can be converted into the parameters of the mechanical claws. Though these technology, the robot can reproduce the motion of human in real time.

Introduction

At present, there are more than 200 million people who is over 60 years old in china, and more than 25 million people who is disabled. They cannot take care of themselves [1]. Due to their families have not enough time to help and care for them, and the shortage of care giver, these people are not well taken care. To solve this problem, researchers are trying to take care these people by human-computer interaction technology.

The human-computer interaction technology refers to the effective communication of human-to-computer using computer input and output devices, and all possible information channels [2]. With the rapid development of the somatosensory technology, human-to-computer interaction is no longer limited to the mouse and keyboard. The Kinect sensors can accurately capture two-dimensional images and depth image [3], and thus operators can control the terminal with his body motion, which makes the human-to-computer interaction more natural and efficient.

In this paper, we designed a service robot based on the Kinect and motion-sensing technology. Operators can monitor the home and remotely control the robot to help the elderly and the disabled to do housework.

Design of Robotic System

The robotic system consists of four parts: the motion-capturing system, the motion-acquiring system, the motion-mapping system and the robot-controlling system. As is shown in Figure 1.
The motion-capturing system uses the Kinect camera to collect coordinates of the human joints, obtains human motion information and uploads the coordinates to the database.

The motion-acquiring system can acquire bending parameters of the fingers by using bending sensors.

The motion-mapping system analyzes data of joints and bending parameters of fingers and gets the parameters of mechanical arm or mechanical claw so that the robot can perform human motion.

In this paper, the robot is equipped with camera, temperature sensor, humidity sensor and smoke sensor, whose mechanical arm is 6 degrees of freedom, left hand is a bionic mechanical claw and the right is a mechanical clip. Robotic walking system is wheeled structure.

**Mapping between Human Arm of Mechanical Arm**

**Kinect Sensors**

Kinect is an interactive device that integrates many advanced vision technologies. Kinect has several sensors which include infrared projector, color camera and infrared depth camera, as shown in Figure 2. The infrared projector can project near-infrared spectrum proactively, when it irradiates to a rough object or penetrates the frosted glass, the spectrum is distorted to form a random reflection spot, which can be read by infrared depth camera; Infrared depth camera can analyze the infrared spectrum and create depth images; The color camera is used to capture color video images [4].

Kinect camera can collect data of human joints. Based on Kinect action recognition algorithm, we can obtain motion data of human arm and convert it into the robot motion data.

**Collect the Coordinates of Joints from Human Skeleton Images**

In order to form human skeleton system, in this paper, we track the human 20 joints and the three-dimensional coordinate of upper body’s 10 key joints in real time.

After Kinect obtains the depth image, we distinguish between the human body and the background from the depth image. Then subdivide the body into the head, limbs,
torso and other areas which includes 32 parts, from which we can identify human 20 joints, as is shown in Figure 3.

![Figure 3. The human joints recognized by Kinect.](image)

In Figure 3, the 10 joints marked with the rectangle is the key joints in this paper, including the head, neck, shoulder, shaft and wrist joints.

The skeleton space coordinate system is the three-dimensional space coordinate system in meters, and the origin is the center point of the color camera. When the operator faces to the camera, the right is the positive direction of X-axis, the upward is the positive direction of Y-axis, the backward is the positive direction of Z-axis, and the coordinate system is the right-handed coordinate system, as shown in Figure 4. When the operator is in the effective range of the Kinect camera, the position of the human body in the coordinate system is shown in Figure 5.

![Figure 4. The coordinate system of Kinect.](image)

We use Visual Studio 2010 to build WPF project and program based on C# language. Show the coordinates of the human skeleton and the 10 key joints in the computer window so that we can observe changes of the human joint coordinates. Uploading coordinates of joints into the database, from which the raspberry pi can get data and send it to STM32 which converts joints data into robot motion data. The flow chart is shown in Figure 6.

![Figure 5. The human body in Kinect coordinate system.](image)
Figure 6. The flow chart of getting human skeleton points by Kinect.

The final result is shown in Figure 7.

![Figure 7. The result of the program.](image)

The Mapping Relationship between Human and Robot

We get the XYZ coordinates of joints by Kinect and relate coordinates to the pulse width modulation signals which control the mechanical arm. Mechanical arm and its structure are shown in Figure 8.

![Figure 8. Mechanical arm.](image)

By controlling the three servos shown in Figure 8, the mechanical arm can
reproduce the operator’s motion in real time. Servo1 and Servo2 are used to track the motion of the human shoulder joints: Servo1 controls mechanical arm to swing up and down and the Servo2 controls mechanical arm to swing left and right. Servo3 is used to control the flexion of the mechanical elbow.

The angles of the operator's arm joints in the coordinate system are shown in Figure 9. Joint of shoulder can be seen as stationary when the operator's arms are moving, and we use the changes of angle $\beta$ to control the rotation of the Servo1, use the changes of angle $\alpha$ to control the rotation of the Servo2 and use the changes of angle $\theta$ to control the rotation of the Servo3, so that the robot can reproduce the various basic motion of human arms.

![Figure 9. The position and angle of the human hand in the coordinate system.](image)

After several experiments, the angle $\alpha$ is in the range of 0 to 90 °, the angle $\beta$ is in the range of -90 ° to +90 ° and the angle $\theta$ is in the range of 45 ° to 135 °. We convert the different range of angles into different pulse width modulation signal to control the motion of the mechanical arm.

**Mapping between Human Hand and Mechanical Claws**

Operators can wear data gloves to control the mechanical claw and the mechanical clip to grab objects. The master chip of the data glove is STM32, which is used for data acquisition and transmission. We send data to the raspberry pi by using serial communication and transfer motion data to the server. The STM32 processes the data and control the robot to complete the corresponding motion. Data glove is shown in Figure 10.

In this paper, the mechanical claw is humanoid hand, each mechanical finger is equipped with a servo which can be individually controlled. Data gloves are equipped with several bending sensors to control the motion of different mechanical fingers. We put the bending sensor in series with the circuit, when the human fingers are bent, the resistances of bending sensors are changed, so through analog-digital conversion, the voltage values are also changed. These voltage values correspond to different duty cycle pulse width modulation signal, which can convert the motion of the human hand into the motion of mechanical fingers. The relationship of mapping is shown in Figure 11.
Robotic Motion Experiment

The robotic motion experiment platform includes 6 degrees of freedom robot arms, mechanical claw, Kinect camera, data gloves, and master computer.

Test 1. Mapping between Human Arm and Mechanical Arm

Arm’s motion mapping between human and robot are shown in Figure 12. In Figure 13, the mapping relationship of human fingers and mechanical fingers are shown as Figure (a) and (b); Figure (c) displays situation that the mechanical claw is open when the index finger is not bent; Figure (d) displays situation that the mechanical claw is closed when the index finger is bent.

Conclusion

This paper designs a robotic control system based on Kinect and motion-sensing technology, which is composed of the motion-capturing system, the motion-acquiring system, the motion-mapping system and the robot-controlling system. In the motion-capturing system, we use Kinect to collect the coordinates of the human joints and calculate the angle of the joints. The corresponding pulse width modulation signals are generated according to the different bending angles so that we can control the rotation of the robotic servos, which realizes real-time mapping between mechanical arms and human arms. In the motion-acquiring system, we use the bending sensor to collect the bending data of hands, and these data can be converted into controlling signal to control the mechanical claw, thus the motion mapping
between human hand and mechanical claw is realized. Experiments show that the robot designed in this paper can reproduce the human motion in real time, and its motion has good stability.

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