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Remote control of a serial manipulator using a depth camera

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Abstract

In this study, a serial robot arm was manipulated in real-time using a depth sensor. The xbox-Kinect sensor is used as a depth sensor. Kinect data was transferred to an industrial computer and processed. A three-axis serial robot arm was developed, and experiments were carried out on this developed prototype in real-time. The drive of the three-axis robot is provided with RC servo motors and these motors are controlled by Arduino Uno R3 board. To find the joint angles, the image obtained from the Kinect camera has evolved into a skeleton form through the image processing program developed in the ARDUINO-Processing environment. Vector elements are defined on the human limbs of which posture is to be calculated. The angles between the limbs were obtained by applying trigonometric operations to these vectors. The reference angles were sent to the Arduino Uno R3 board, and the servo motors that provide the movement of the robot were controlled according to these angle values, and the movement of the system was ensured. As a result of the experiments, it has been observed that the robot arm can imitate the movements made instantly.

Keywords: Depth sensor; serial robot; kinect.

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1. INTRODUCTION

With the developing technology, robot systems are widely used in industry. Robotic systems are indispensable technology for accelerating production, increasing quality standards, and places that may cause danger to humans [1]. Image processing-based control of robots has been a frequently studied subject in recent years, to minimize human-made defects and to produce higher-quality products. Image processing-based control systems are a technology that has been used for a long time in humanoid robots as well as industrial robots [2-10].

ASIMO is one of the known humanoid robots, produced by HONDA's Research and Development Center in Japan. Image processing-based control systems are used to detect human and object movements [11,12]. The spread of image processing technology also encourages the production of new-generation camera technologies. The new generation camera systems produced for use in robot technology are equipped with features such as sensors, faster response, and depth perception [13-17].

1.1. Purpose of study

This study aims to analyze how a serial robot arm can be manipulated in real-time using a depth sensor.

2. METHODS AND MATERIALS

The Kinect depth sensor used in this study makes it possible to detect moving or stationary objects and to obtain depth information about the environment [18-20]. The Kinect depth sensor used in this study makes it possible to detect moving or stationary objects and to obtain depth information about the objects. Using the approach proposed in the study, a real-time robot that mimics human body movements or a system that can learn and work offline can be developed. The robot developed within the scope of this study was primarily designed in 3D in a computer environment. The design output is given in Fig 1. The real fabricated system is given in Fig 2.

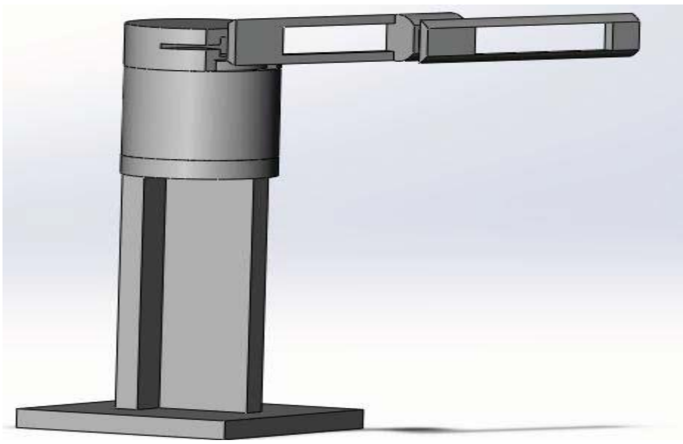


Fig 1. Solid model of the robot platform

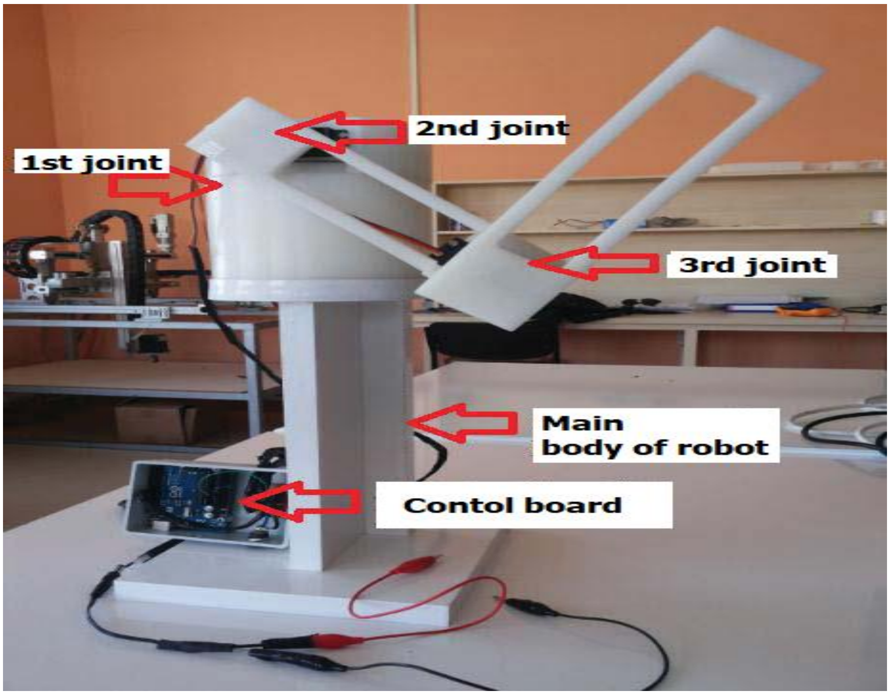


Fig 2. Developed robot arm

The Kinect sensor consists of three parts: the parts that emit infrared rays, the parts that detect infrared rays, and the parts that take visible images. Objects in the frame are detected with infrared rays and these data are translated into commands via CMOS sensors.

Infrared rays sent from the Kinect hit the objects in front of them and return, so the parts close to the Kinect come out brighter. An example image obtained using the Kinect sensor is given in Figure 3.

Fig 3. Example image obtained from the depth sensor

2.1. Skeletonization Process

The SimpleOpenNI library of the Processing 2.0b9 program is a library specific to the Kinect camera. By using the SimpleOpenNI library, operations such as skeletonization and finding joints can be performed as in Fig 4. As seen in Fig 3, the human silhouette obtained by the infrared rays emitted by the Kinect sensor is an image form that can be used for image processing in the Processing 2.0b9 program.

The posture shown in Fig 4 is called the starting position defined in the SimpleOpenNI library. After standing in the starting position in front of the Kinect camera, the skeletonization process begins. The program, which recognizes the human silhouette, draws black lines between the joints, representing the human limbs, after detecting the joint areas determined by red dots. Thus, the skeletonization process is completed [21].

Since the leg part was not used in this project, the skeletonization of the leg part was not performed.

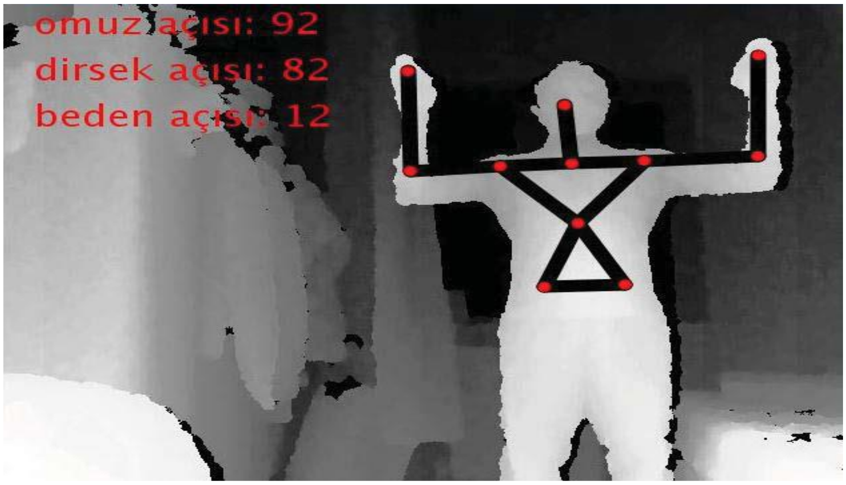


Fig 4. Skeletonized image

2.2. Angle Measurement Process

After the skeletonization process has been performed, vectors can be defined between the joints on the image. The length of the vectors gives the lengths between the joints. Using the lengths between the joints and the simple triangle connection, the angle of the 3rd joint was obtained according to the formula in Equation 2. The 3rd joint angle represents the elbow angle (Fig 5).

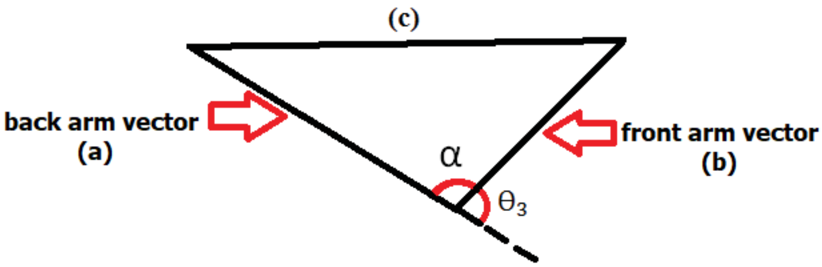


Fig 5. 3rd joint angle

$$\alpha = \cos^{-1}\frac{a^2+b^2-c^2}{2ab} \tag{1}$$

$$\theta_3 = 180 - \alpha \tag{2}$$

The angle of the 2nd joint is obtained by substituting the vertical lengths in the x and y directions of the vector drawn from the shoulder joint (Fig 6) to the elbow joint, in (3).

$$\theta = \tan^{-1}\frac{x}{y} \tag{3}$$

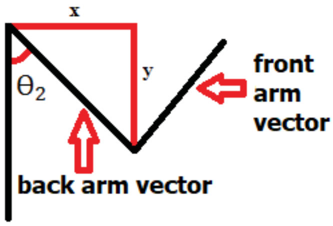


Fig 6. Shoulder angle

To calculate the angle of rotation of the body, the distance of both shoulders from the Kinect must be found. If the distances are equal, the body is in the zero position relative to the Kinect. Assuming one shoulder is fixed and the other is moved, the body is rotated at an angle and there is a difference in the lengths of the shoulders to the Kinect. This difference represents the x parameter in Fig 7. The y parameter represents the shoulder width, and the z represents the projection of the shoulder length according to the Kinect. The angle of rotation of the body is obtained by the formula in Equation 4.

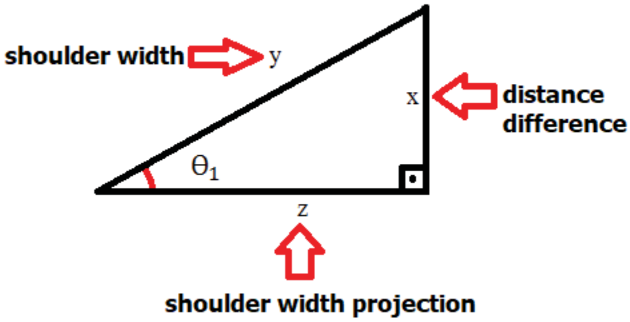


Fig 7. Body angle

$$\theta_1 = \cos^{-1}\frac{z}{y} \tag{4}$$

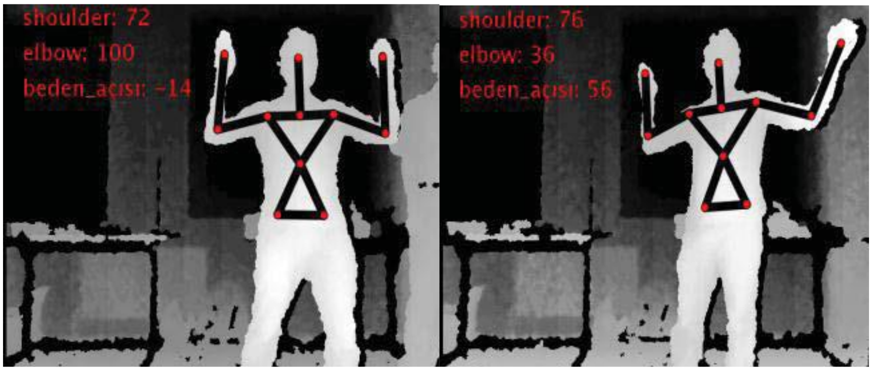
2.3. System Manipulation

The elbow, shoulder, and body angles obtained by processing the data received from Kinect were sent to the Arduino Uno R3 board via serial communication. Servo motors are driven over the PWM outputs of the control card. Thus, the system was manipulated by making instantaneous movements of the human arm. A special position is designed to stop the system. As a result of keeping the left hand closer than a certain limit value, the system stops. In this case, the system maintains its final position since no other angle values are sent to the servo motors.

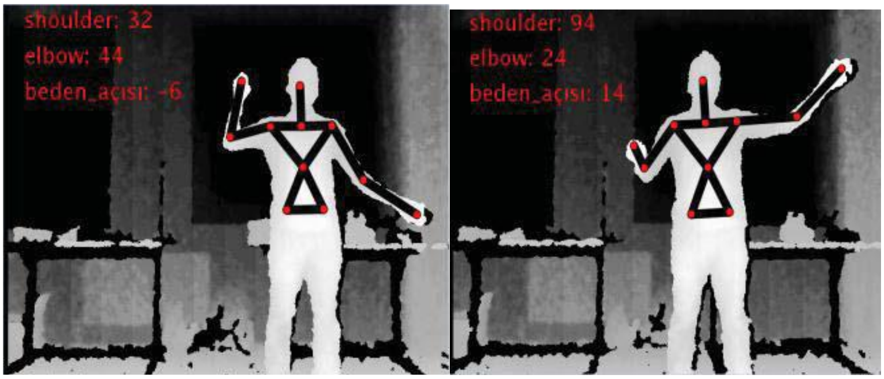
Fig 8. The movement to stop the system

3. RESULTS

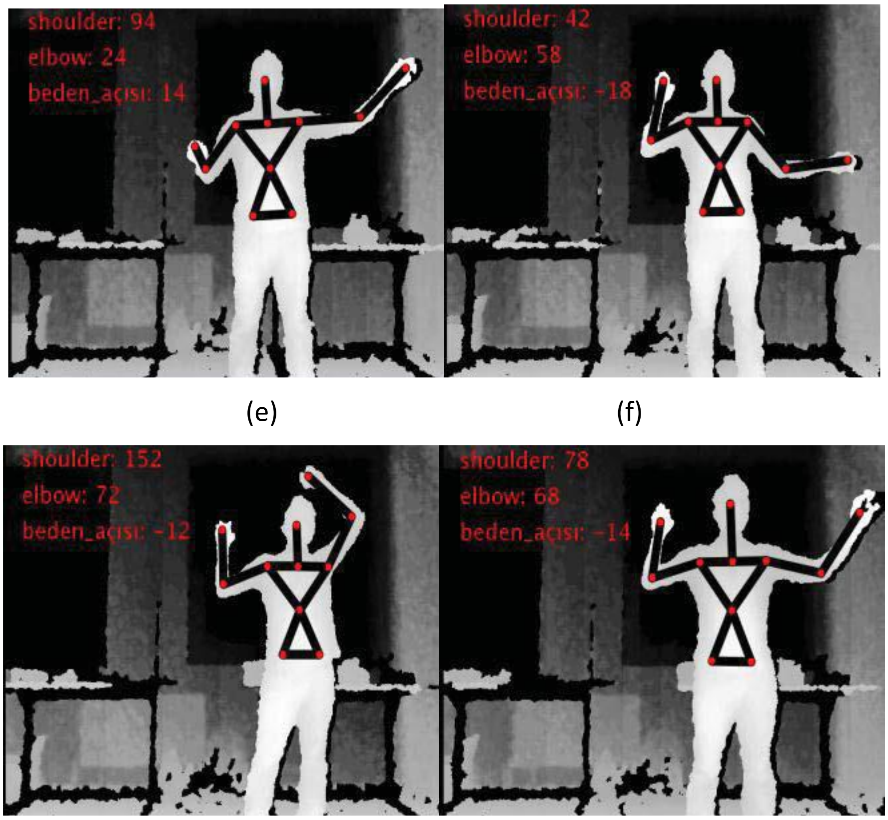
This section presents the results obtained with the Kinect. As a result of the study, it has been observed that the system can be successfully controlled using depth data. Black lines show vectors inserted into joints.



(a) (b)



(c) (d)



(e) (f)

(g) (h)

Fig 9 . Joint angles calculated at different positions

As can be seen in Fig 9, the developed system can successfully calculate joint angles at different positions of the joints.

4. CONCLUSIONS

This paper presented a comprehensive exploration of a human tracking scheme utilizing Kinect skeletonization. The integration of Kinect technology offers a non-intrusive and cost-effective solution for capturing human motion, providing valuable data for various applications such as virtual reality, gaming, and healthcare. The discussion delved into the methodology of skeletonization, highlighting its significance in extracting meaningful information about human movement.

The proposed tracking scheme demonstrated promising results, showcasing its ability to accurately capture and analyze skeletal movements in real time. By leveraging the Kinect sensor's depth information, the system achieved robustness even in challenging environments, contributing to its potential applicability in diverse scenarios.

Throughout the paper, we addressed key challenges associated with human tracking, including occlusion and noise in the depth data. The incorporation of filtering techniques and careful algorithm design proved effective in mitigating these challenges, enhancing the overall reliability of the tracking system.

The implications of this research extend beyond the scope of motion capture, as the developed scheme opens avenues for advancements in human-computer interaction, rehabilitation, and surveillance. Future work could explore optimization strategies, scalability to multiple users, and integration with machine-learning techniques for improved gesture recognition.

In essence, the presented human tracking scheme not only contributes to the field of computer vision but also holds the potential to reshape how we interact with technology and monitor human movement in diverse applications. As technology continues to evolve, the fusion of Kinect skeletonization with innovative algorithms is poised to play a pivotal role in shaping the future of human-centered computing.

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