Human Arm Simulation Using Kinect

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***Abstract*— In this presented work, a mechanical arm system is implemented which utilizes Kinect gesture recognition as the interface between human and robot arm. The movement of the human arm in 3D space is captured using Kinect, processed using MATLAB and simulated on the mechanical arm using servo motors, controlled by microcontroller.**

***Keywords*— Gesture Recognition, Simulink, Kinect Sensor SDK, Image Processing**

I. INTRODUCTION

Computers play a crucial role in our lives. Today, our lives have become dependent on the technology. The idea of our work has come from applications which may be used in the area of medicine, i.e. where the presence of human can contaminate the production process, for instance, where controlling any device remotely is necessary. Inspired by applications which may be used in the area of real time controlled systems, i.e. robotic arms, medicine robotic arms, robots, medicine robots and adaptive robots, home automation systems, gesture recognition systems obtained with markers. The main motive is to discover the capability to Kinect and tests the accuracy of its human skeleton recognition system.

The long term goal of this project to develop a remotely operated robotic arm, operated using Kinect and both the remote systems are connected via network(Internet), requires a human-friendly interface that transfers information of guidance or other types or commands. In the field of gesture recognition and robotics, many studies have been carried out on adapting gesture as an ideal communication interface in the Human-Robot Interaction (HRI) context.

II. OBJECTIVES AND PROBLEM STATEMENT

The objective is to develop a interactive mechanical arm that is operated by the gestures of human arm. In the presented work, a remote robot control system is described that utilizes Kinect based gesture recognition as human-robot interface. The presented work provided the evaluation of control robot arm using based gesture recognition as human-robot interface. The movement of the human arm in 3D space is captured, processed and simulated on the mechanical arm. Joint angles are calculated and sent to Arduino microcontroller which controls the robotic arm. The project tests for the accuracy of the robot arm with respect to human arm.

In the proposed work, a remote robot control system is described that utilizes Kinect based gesture recognition as human-robot interface. Through gesture recognition we are trying to improve the usability of the robot in different fields with reduced cost. This robotic arm can do variety of tasks, unlike the robots being used in industries today which perform a fixed task only.

Fig. 1: Kinect Sensor

A. Kinect sensor

In the presented work, we use The Kinect Sensor was developed by Microsoft and Prime Sense, shown in Fig. 1, It is a hardware device used to control the Microsoft XBOX-360 game console without any kind of controller that the user has to hold or wear. Kinect is a device that can interpret specific gestures, making completely hand free control of electronic devices possible by using an infrared projector and camera and a special microchip to track the movement of objects and individuals in three dimensions. The device features a "Depth sensor, RGB camera and multi-array microphone running proprietary software", which provide full body three dimensional motion capture, voice recognition and facial recognition capabilities.

The depth sensor consists of an infrared laser projector combined with a monochrome CMOS sensor, which captures video data in 3D under any ambient light conditions. The sensing range of the depth sensor is adjustable, and the Kinect software is capable of automatically calibrating the sensor based on the physical environment, accommodating for the presence of the user.

Skeleton tracking is one of the important features of the Kinect sensor. Kinect uses depth stream to detect the Skeleton tracking of human in front of camera. Due to this process Kinect can establish the positions of various

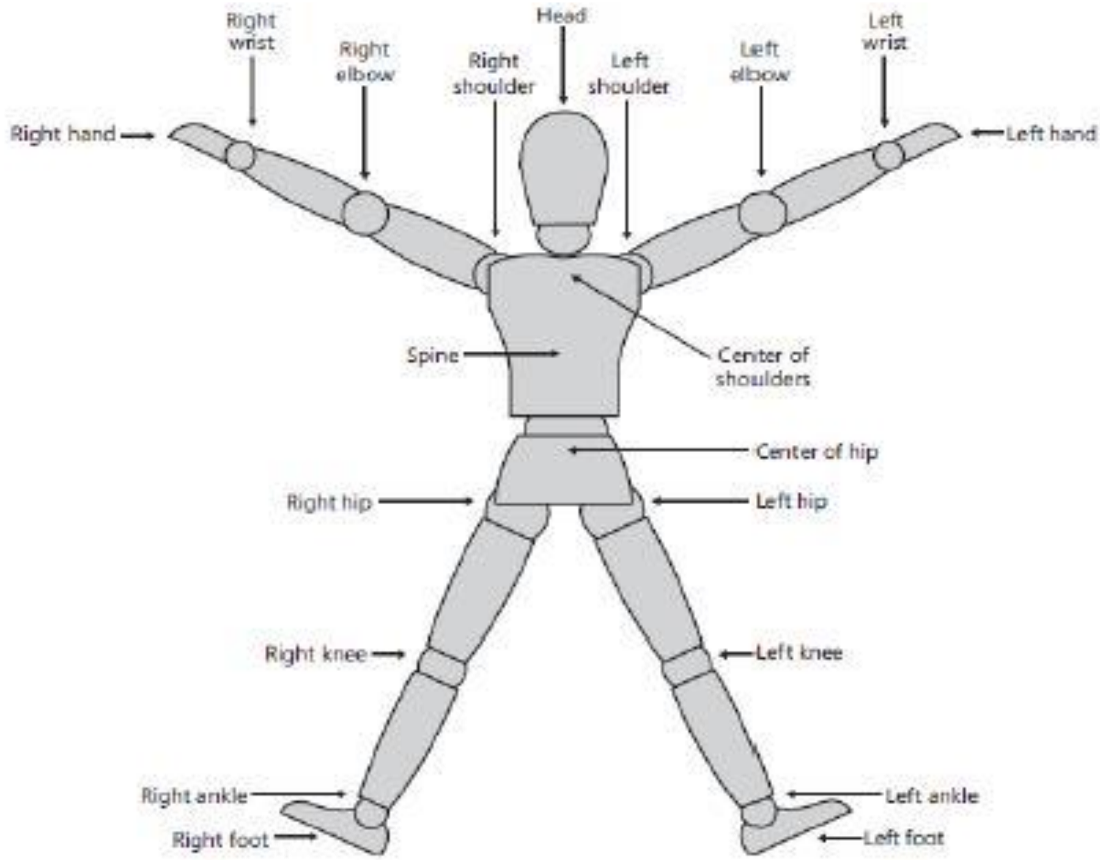

Fig..2: The Twenty control points of a Skeleton

skeleton joints on a human. A skeleton of human consists of 20 different positions, one for each joint of a human body as shown in Fig. 2.

For each of the 20 joints, corresponding value of x, y & z axis is given as output (Refer figure 3). These coordinate values can be used to calculate the angles between various joints.

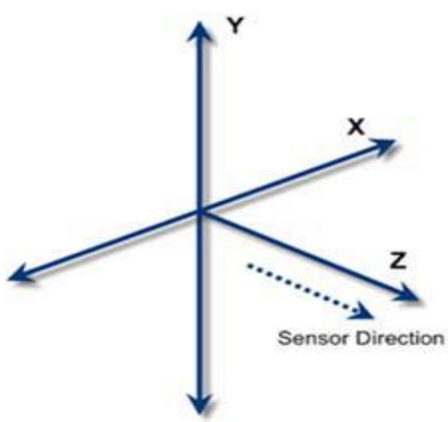

Fig. 3: x, y & z axis in 3D space

III. LITERATURE SURVEY

In the proposed work, the author compared two approaches of producing human-like gestures by upper body humanoid robot. The work showed how the Kinect sensor can be used to train humanoid robot to perform complex body movements. [1]

In the paper, the author implements a humanoid robot which can be controlled remotely using the Kinect Sensor. Their work has shown the rich way of interacting with the robot and a non-expert user can easily operate the system as well. [2]

In the presented work, the author emphasized on the gesture based natural human-robot interaction, which is a powerful approach of operating mechanical robots. The author developed a client/server network interface to operate dual arm robot from remote location. The paper highlighted how the cost effective Kinect can be employed in field of robotics. [3]

In the proposed system, the author used Proportional Derivative Control Based Algorithm (PD-control) to

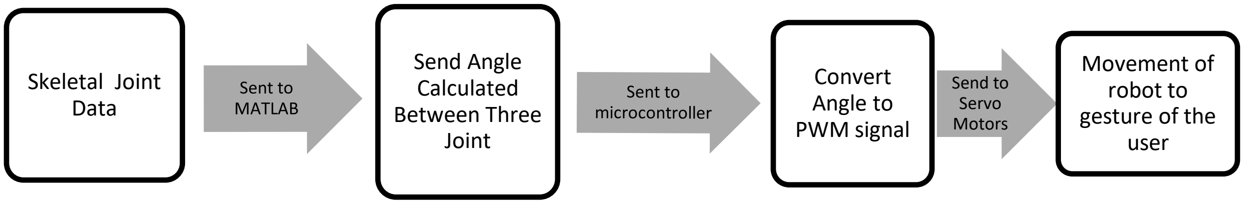

Fig. 4: The structure of the system

develop a manipulator robot that performs human gesture in accordance to the user. The system is an improved and better version of the existing system since it a reduced delay time. [4]

IV. STRUCTURE OF THE SYSTEM

Angle computation and data transfer from Kinect to the system and manipulation of robot using Arduino microcontroller are the two main parts in this entire system.

A. *User*

User determines the movement of the biped robot i.e. whether to move forward, backward, left, right or to kick the ball depending on the angles shown by user's hand.

B. *Kinect*

Kinect sensor is used as the input device. It captures the human motion in real time and transfers the data to the system for processing.

C. *Computer*

Computer processes the information received from Kinect and converts it into a skeletal images by Microsoft SDK toolkit. It then calculates the angle between the vectors.

D. *USB Serial Interface*

It sends the angles serially from the computer to the Arduino microcontroller using FTDI RS232 USB Serial device.

E. *Arduino Uno*

Depending on the angles received, the Arduino microcontroller is programmed to generate the PWM signals designed to move the servomotors to specific angles.

F. *Robotic Arm*

The combined movement of the four servos at the four joints gives the required angular movement for the robot. The servo motors used are Tower Pro 996R metal servo.

V. SOFTWARE

In the presented work we used c# to write the programs for our system, we employed the Kinect Sensor as depth sensor, using the Kinect Sensor SDK APIs to interface it for depth image analysis and control skeleton extraction. The Kinect SDK framework is an open source SDK used for the development of 3D sensing middleware libraries and applications.

Kinect SDK provides a driver for Kinect and an Application Programming Interface (API). Also, it offers a lot of basic functionality for analysis of the scene watched by Kinect.

We have used MATLAB's Simulink to interface Kinect with the robot arm. The skeletal image is captured, the joint coordinates are fetched, angles are computed in real time, and then it is sent serially by a FTDI device to the Arduino microcontroller which forwards the angular data to respective joints (servos), connected to it by PWM output pins. Simulink has a block structure for achieving the task of fetching coordinates, calculating angle and sending it using multiport switch via serial port (COM X) of the computer to which the FTDI device connected.

VI. DESIGN SPECIFICATIONS

The working of the Kinect based robot arm depends on the proper computation of angle using joints. The following section describes the various steps involved:

A. *Skeletal Image Capture*

In the initial step, the motion of user operating the system is captured by Kinect. In order to recognize the twenty control points of a human skeleton, the user needs to stand in front of Kinect at a distance of nearly 1m to 4m. The Kinect recognizes 20 joint position of the human body and output the 3D(x, y and z) coordinates of each. But here we only consider the following points, right shoulder(5), right elbow(6), right wrist(7), right palm(8) and shoulder center(3).

B. *Programming the microcontroller- Arduino Uno:*

The Arduino microcontroller is programmed using the Arduino programming language and the Arduino development environment (http://www.arduino.cc). The robotic arm will be controlled using Arduino Uno microcontroller. The Arduino is a microcontroller that can control simple electronics and sensors. To send/receive data to microcontroller, we need a serial transmitter/receiver device that could send data serially. We connect the 4 servo motors to PWM outputs of the microcontroller. Servo at shoulder horizontal position is connected to pin 5, Servo at shoulder vertical position is connected to pin 3, Servo at elbow is connected to pin 9 and the gripper to pin 10.

C. Calculating the angle using Vector DOT Product:

The robot is a mechanical device that consists of multiple rigid structures called Links, connected by joints. These joints and links (vectors) constitute a coordinate frame. The skeleton image program provides the coordinate frame and the various joint parameters of the person standing in front of the Kinect. The Skeleton image program is designed so that an arbitrary origin is set, a virtual coordinate system is constructed and the various coordinates of the joints are computed.

Robot arm servos are going to reproduce the angles of the user's shoulder and elbow. When we refer to the angle of the shoulder, it is the angle created between the joints torso, shoulder and elbow.

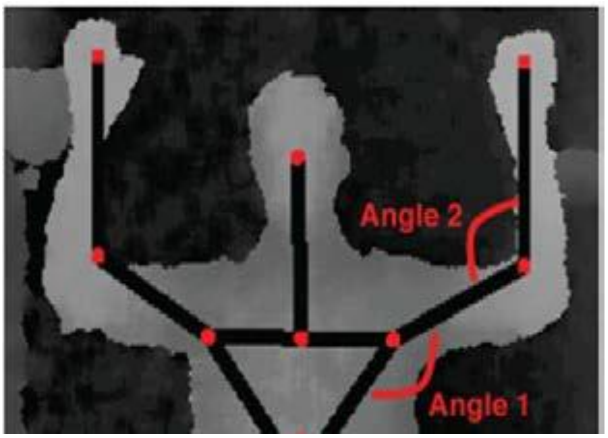

Fig. 5: Calculating angles

Also, the angle of elbow is created between the joints shoulder, elbow and hand. Kinect sensor provide the coordinates x, y, z of 20 joints of human skeleton system. Calculating the angle between three joints (two vectors) can define by:

$$\theta = \cos^{-1} \frac{\vec{A} . \vec{B}}{\|A\| . \|B\|}$$

where,

θ = the angle between three joints (two vectors)

A = Vector from joint hand to joint elbow

B = Vector from joint shoulder to joint elbow

D. Sending the data via USB port

RS232 FTDI USB serial device is used to send the data to the Arduino microcontroller. Serial communication is done here, by sending one angle at a time which is sequentially selected and sent using a multiport switch in Simulink.

VII. IMPLEMENTATION

Designed and developed a human arm simulation using Kinect sensor. The robot arm can perform hand gestures same as a human arm does. Here in this project, the robot imitates the gestures of a human arm so it can perform activities such as pick-n-drop, handling materials, welding, etc. remotely, without the physical presence of the operator at the location. The robot has a gripper attached to its wrist to perform these activities.

Fig. 6: Robotic Arm

VIII. APPLICATIONS

This arm can have following applications:

- At Nuclear Power Plants for handling radioactive substances
- For Space Exploration.
- For Human Surgeries, which can be done remotely, without the presence of doctor.
- Lifting loads at factories and construction sites

- Automatic metal cutting machines in particular desire profiles, which are located in high temperature zones.

IX. CONCLUSION

This study presented the interactive way between human and robots and help non-expert users to control the robot freely, making human-robot interaction much easier. The presented provides the evaluation of control robot arm using Kinect sensor where the joint angles are carried out. The joint angles are transmitted to the Arduino controller. Arduino controller receives the joint angles and controls the robot arm. The performance of the system is characterized using human input for different situations and the results show that system has the ability to control the robot by using Kinect sensor.

The two main benefits of this method are that, it's easy to develop and is of low cost. And the main advantage of this technique is that it requires only the Kinect Sensor for gesture recognition, and there is no need to use any controllers or inertial sensors to navigate the robot.

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