Robotic Arm Imitating Human Hand Movement

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Abstract: Robotics is the branch of technology that deals with design, construction, operation and application of robot. This paper discusses the hardware design and software configuration of a robotic arm having four degrees of freedom. The project consists of a mechanical arm which imitates the nearby human hand to produce the same motion. It uses concepts of video processing and servo control to achieve this task. The results and research scope of the project has been summarised.

Keywords: Robotic arm, gestures, contour, degrees of freedom

I. INTRODUCTION

The world today is driven by machines of various kinds. Machines assist humans in performing different tasks ranging from simple to more complex ones and they are an indispensable part of our lives. A Robot is defined as a machine that is capable of performing a variety of often complex human tasks on command or by being programmed in advance.

Imitation is the ability of an agent (living or artificial) to observe the actions of another agent and try to act like it. Imitation is a commonly observed behavior among human beings as it is a powerful tool for transferring knowledge between individuals. The study of imitation in robotics has been motivated by both scientific interest in the learning process and practical desires to produce machines that are useful, flexible, and easy to use[1].

Nowadays, robots are increasingly being integrated into working tasks to replace humans especially to perform the repetitive task. In general, robotics can be divided into two areas, industrial and service robotics. International Federation of Robotics (IFR) defines a service robot as a robot which operates semi- or fully autonomously to perform services useful to the well- being of humans and equipment, excluding manufacturing operations. These robots are currently used in many fields of applications including office, military tasks, hospital operations, dangerous environment and agriculture. Industrial robots have been widely used in factory automation. On the other hand, in the final assembly in automobile factories, many tasks are still completed by humans due to the difficulties and costs associated with automation [2]. Besides, it might be difficult or dangerous for humans to do some specific tasks like picking up explosive chemicals, defusing bombs or in worst case scenario to pick and place the bomb somewhere for containment and for repeated pick and place action in industries. Therefore a robot can be replaced human to do work. We have programmed the robotic arm to imitate the human hand movement.

II. LITERATURE SURVEY

The robotic community has explored the topic of imitation on a wide assortment of platforms, including physical robots and sophisticated physics-based simulations. Humanoid robots can engage in physical and social imitation tasks and serve as extremely compelling demonstrations. They are also expensive, challenging to build, and require continual maintenance. Some systems are primarily upper torsos, some are full-body systems, some are only a head with a vision system, and some have an expressive face. Simulations produce results that are more easily replicated, as the software can often be shared among researchers. The primary difficulty with simulations is in transferring results from simulation to physical robots. Solutions that tend to work even in complex simulations often fail in the real world because of the inherent lower fidelity of simulations. A few collaborations exist allowing researchers who work mostly with simulated humanoids to test their theories and implementations on actual robots. There are various ways in which a robotic arm may be controlled. In the past there have been many researchers working to control robotic arm through computer terminals, Joysticks, even interfacing them with the internet so they can be controlled from anywhere in the world. Usually most of the robotic arms are controlled by sensors and accelerometers which require direct connections to the human arm [3][4]. This process is time inducing and cumbersome. This project, on the other hand makes use of camera to capture the video of the moving arm. Hence it does not require any device to be attached to the human arm which makes the task simple and efficient.

III. METHODOLOGY

A. Skin color detection

There are more than 150 color-space conversion methods available in OpenCV. We can say that a color-space is a combination of a color model and a mapping function. For color model, we can understand any mathematical model that can be used to represent colors as numbers (e.g. RGB(255, 0, 0) represents the red color). YCrCb is used widely in video and image compression schemes. YCrCb stands for Luminance, Red-difference & Blue-difference chroma components respectively. Firstly, for skin color detection we need to know the skin range to tell it apart from the surrounding. This range varies with the light intensity hence after taking a number of samples, we took it as min_YCrCb=np.array([0,133,77],np.uint8 and max_YCrCb=np.array([255,173,127],np.uint8. For color conversion, we use the function cv2.cvtColor(Image,flag) where flag is conversion type. After conversion, cv2.inRange function is used which returns a binary mask, where white pixels (255) represent pixels that fall into the upper and lower limit range and black pixels (0) do not [5].

B. Contour formation

A contour refers to the outline or silhouette of an object. Now to detect the hand, we need to know the approximate area of the contours formed. If the area is smaller than it, then it is not considered. After a number of samples and appropriate distance between the camera and the user, we found out that areas greater than 10000 are considered. Area of contour is same as number of pixels inside the contour. It can be found out using cv2.contourArea() function [6]. Contour Approximation will remove small curves, there by approximating the contour more to a straight line. This is done using cv2.approxPolyDP() function which basically reduces number of points to operate.

C. Convex hull

Once the approximation is over, Convex Hull is next. This will look similar to contour approximation, but not. Here, cv2.convexHull() function checks a curve for convexity defects and corrects it. Generally speaking, convex curves are the curves which are always bulged out, or at-least flat, and if it is bulged inside, it is called convexity defects.

D. Serial communication

After getting the points of interest on the skin region (shoulder point, elbow point, wrist point and finger points), serial communication between raspberry pi and Arduino is carried out. This requires a USB cable for connection between the two boards. In python program, serial module is imported for serial communication. For sending the values, ser.write('value') is used for sending it serially.

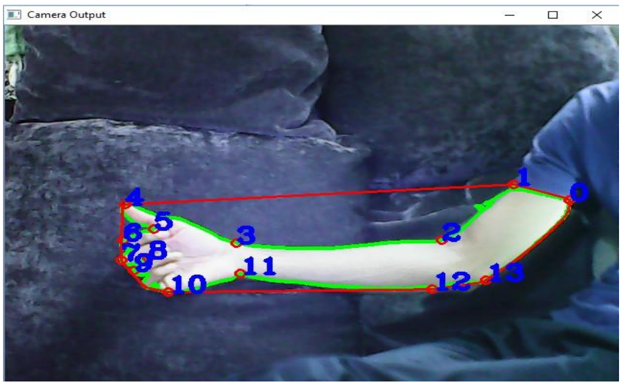

Fig 1: Hand detection

IV. IMPLEMENTATION

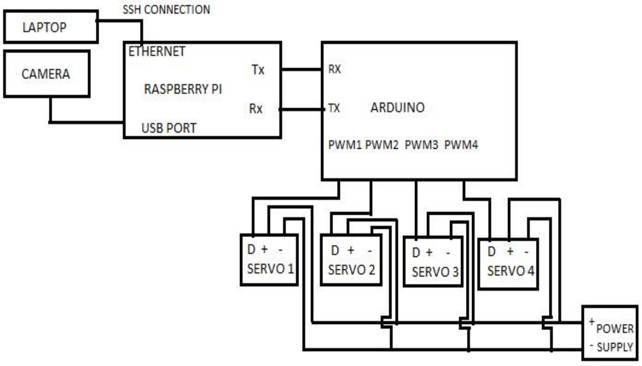

Fig 2: Block diagram

Hardware Used:

A. Raspberry pi 2 Model B

The Raspberry Pi is a series of credit car sized single-board computer developed in England, United Kingdom by the Raspberry Pi. Since it has an ARMv7 processor, it can run the full range of ARM GNU/Linux distributions, including Snappy Ubuntu Core, as well as Microsoft Windows 10.

B. Arduino Mega 2560

The Arduino Mega is a microcontroller board based on the ATmega1280 . The Arduino Mega has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The Atmega1280 provides four hardware UARTs for TTL (5V) serial communication. A Software Serial library allows for serial communication on any of the Mega's digital pins.

C. Servo Motors

Servo refers to an error sensing feedback control which is used to correct the performance of a system. Servo Motors are DC motors equipped with a servo mechanism for precise control of angular position. The RC servo motors usually have a rotation limit from 90° to 180°. But servos do not rotate continually. Their rotation is restricted in between the fixed angles. The servo motor can be moved to a desired angular position by sending PWM (pulse width modulated) signals on the control wire. The servo understands the language of pulse position modulation. A pulse of width varying from 1 millisecond to 2 milliseconds in a repeated time frame is sent to the servo for around 50 times in a second. The width of the pulse determines the angular position. For example, a pulse of 1 millisecond moves the servo towards 0°, while a 2 milliseconds wide pulse would take it to 180°. We are connecting control pin of servo to the PWM pins of Arduino Mega which can be programmed to generate PWM pulses.

D. Mechanical Design

The mechanical design of the robot arm is based on a robot manipulator with similar functions to a human arm. The links of such a manipulator are connected by joints allowing rotational motion and the links of the manipulator is considered to form a kinematic chain. The end of the Kinematic chain of manipulator is called as end effecter or gripper and it is analogous to the human hand. Our robotic arm has 4 degrees of freedom (DOF). The mechanical design was limited to 4 DOF mainly because that such a design allows most of the necessary movements while keeping the cost and the complexity of the robot competitive.

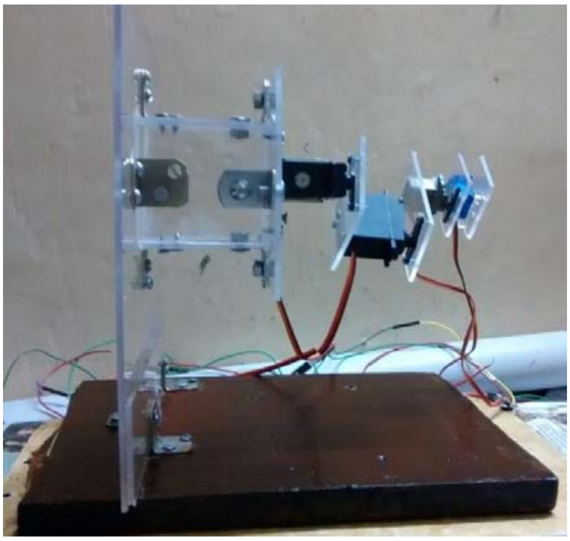

Fig 3: Final constructed robotic arm

V. RESULTS AND DISCUSSION

Thus we have accomplished the task of making the robotic arm imitate human hand movements in two dimensional space. Calculation of torque of the servo motors placed at various joints and material to be used for construction were the crucial part of our project. We had kept the length of the acrylic sheets as 15 cm but on practical implementation we found that servo motors placed at shoulder point caused a voltage drop in the circuit because of the heavy weight which could not be sustained by 12kg-cm torque motor. Finally the lengths were reduced accordingly. Calculation of skin ranges under various light intensities along with the minimum contour area had to be done for near accurate results. Lastly the serial communication between the two microcontrollers with appropriate value of the time delay had to be configured properly. Since servo motors need 15 milliseconds to reach a particular position according to the angle sent, the delay between two camera frames had to be increased to 0.1s.

VI. CONCLUSION

This robotic arm can be used in wide ranging applications such as entertainment, industrial, healthcare and consumer electronics. They can replace human workers in harmful, potentially dangerous environments such as mining. The elderly can use the arm to perform daily tasks without having to get up or move about. They can simply sit at one location and be able to control the arm through gestures. In the medical industry mechanical arms may be used to perform complex surgeries in the absence of availability of a doctor or in case of an extreme emergency.

VII. FUTURE SCOPE

The implementation of this project has helped in dealing with practical problems and in overcoming them. In the future we plan to include Iot (Internet of Things) to transfer the information so that it can cover a much wider area than at present. Our future scope is to implement the arm in three dimensional space and use these methods for designing a humanoid capable of imitating the full human body movements. This humanoid can further be used for various applications. They might also be used in situations where accuracy is of prime importance. The scope of this project in the future is huge and a major leap forward for mankind.

VIII. REFERENCES

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