REAL TIME GESTURE MEASUREMENT OF HUMAN HAND FOR ROBOTICS ARM

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Abstract— In industry, Robotics needs precise control for handling various production activities. The proposed research is to measure the gesture grip value of both human hand and Robotic hand. The measured value of both human hand gripping and robotic hand gripping should be same. This leads for more perfection. Flex sensors are used to measure the value of gripping in both human hand and robotic hand. To achieve the exact control, camera visualizes the robotic hand activities from remote area. Pick and place of object is most significant task of robotic hand. Grip of robotic hand mimics human hand for handling different objects. The aim is to develop robotic hand handling of object similar to real human hand. The robotic hand design has 5 fingers 14 degree of freedom.

Keywords— Camera, Human-Robot Interaction, Gripper, Gesture, Grasping and Robotic Arm

1. INTRODUCTION

Robotics and robotic Arm plays vital role in the industries. Robots handles the products with the help of sensors such as acceleration sensor, EMG sensor, Gyroscope, pressure sensor, Tactile sensor, Tilt sensor strain gauge, Load cell, Proximity sensor, IR sensor, Ultrasonic sensor, Force Torque sensor, RGB color sensor [1] and [7].

The development of Vision based sensors at present achieves good performance of robotics using RGB camera, Kinet sensor, Oculus Rift, Leap Motion Controller. Human - Robot interaction by using human hand gesture is important for exact control of robotics [25]. Real time human hand control is used in some precious applications like surgery, nuclear power plant, disaster rescue, military, space research centre, and transmission line work. Preprogrammed robot cannot adopt with hazardous places. Some kind of situation needs exact human control where human does not enter into the hazardous place [4] and [6].

The virtual diagnostic and treatments can be done by the robotic hand which mimics the physical moments of doctor. The virtual surgical practice transform into robotics surgery such as virtual diagnostic and treatments [23] and [26].

The elderly peoples are difficult to handle daily activities due to hand grip strength problem. The loss of grip strength is a neurological hand disorder affecting the hand functionalities of people and patients [18].

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HRI (human robot interaction) uses many gesture sensors to control robotic hand. The flex sensors based hand gloves are used to measure human hand gesture in simplest and easy method to control robotic hand [19].

Image based gesture recognition provides better accuracy under proper lighting conditions. Image and vision based approach uses pre stored database. These types of methods are requires more memory space for database [20]. The interaction between human and robotic arm based on 3D vision system. The stereo camera used to track human hand signal as 3D scene and image. Vision sensor tracking also used tracking human intensions and grasping moving objects [21]. The human intensions can be measured by EMG pattern recognition to control myoelectric hand. EMG pattern recognition used for limb deficient people to perform daily activities [22].

2. RELATED WORK

The main problem of gesture controlled robotic arm is accuracy. Industrial robots are pre programmed or feedback based control [16]. The sensor glove measuring finger motion [2]. This sensor glove concept measures angle of the fingers [5].

Every one can communicate with gesture in day to day life. At some kind of situation not only the children, deaf and dump person , illiterate persons are doing gesture. The concept of gesture interaction between human and machine is to convert gesture movements into electrical signal using sensors. Electrical signals are measured from the sensor manipulated by computer or embedded processor to understand the useful information [9] and [17].

Gesture is an activity perceived by the flex sensor which is an analog form of signal. This analog signal is converted into digital signal to communicate with digital machine [3].

Soft robotic hand is developed and utilized in some industries. The design of soft robotic hand is based on the shape and size of the object [16]. The advantages of this type of robotic hands are flexibility and adoptability for handling objects. Capacitive touch sensor , rubber and suction type of materials are used in this soft grippers [8], and [10].

EMG sensor is used to measures electrical activities of human muscles for controlling robotic gripper for handling substance [11] and [12].

The development of visual sensors interface like camera. converts the real environment into virtual environment and further virtual environment into robotic environment to mimic as human hand gesture [14].

The teleoperation based free hand gesture or wearable hand gesture recognition requires feedback of sometimes to complete the object manipulation task. Information of human hand gesture acuires by vision based sensor such as camera. The gesture information send to remote site computer which process the received gesture information and control the robotic arm to perform like a human operator. The robot manipulator can be controlled by three methods such as direct control, tradded control and shared control by teleoperation. The goal of haptic feedback system increesing the human robot collabaration for the shared task [24].

3. PROPOSED WORK

Proposed system aims for exact control of robotic arm to achieve better accuracy using measurement of both human hand and robotic hand. This paper presents an implementation of flex sensor for robotic arm control with low cost [7] and [15]. The advantages are low cost and less hardware complexity. Both human hand and robotic hand measurement is used wherever high precisions are needed.

3.1. REAL TIME HUMAN HAND GRIP MEASUREMENT

The flex sensor is the primary input of PIC16F877A microcontroller placed in human hand of five fingers to measure the deviation of the fingers. Five distinct flex sensors are connected in five fingers of human hand by using hand glove. The output of each flex sensors is fed into the ADC (analog to digital converter) channels of PIC16F877A microcontroller.

Fig. 1 Human Hand Gesture Measurement

Fig. 1 shows human hand gesture measurement using flex sensor. PIC16F877A microcontroller has built in 8 channel successive approximation type ADC with 10 bit resolution. The measured value of each channel of ADC values displays through the 2 line 16 character LCD. Max232 IC is a voltage level converter IC used to communicate via RS232 Port. Zigbee wireless device connected in RS232 port is to transmit measured values of flex sensors to robotic arm placed in the remote area. When the threshold values of particular hand gesture reached, then user can press the threshold switch to transmit

useful gesture information. Program Code is written in “Embedded C” language using MPLAB IDE with cross compiler HI-TECH C PRO for the Pic10/12/16 MCU family.

Fig. 2 Human hand gesture conversion process

Fig. 2 shows the conversion process of human hand gesture. In this human hand gesture conversion process first step is to initialize all the inputs (sensors, switch) outputs (LCD) and UART communication used by the controller. Next step is sensor values measured by the analog to digital converter.

3.2. ROBOTIC HAND GRIP MEASUREMENT

The flex sensor is placed in Robotic hand of five fingers to measure the deviation of the fingers of robotic hand.

Fig. 3 Robotic Hand Gesture Measurement

Zigbee receives the hand gesture values of human hand from the control area. It compares the received hand gesture value with measured hand gesture value of robotic hand. When the received values and measured values are same then the robotic arm completes the task.

Fig. 4 Robotic Hand Gesture Control Process

Five distinct flex sensors are connected in five fingers of robotic hand by using hand glove. The output of each flex is sensors fed into the ADC channels of PIC16F877A

microcontroller. Fig. 4 shows the measurement of robotic hand in accordance with human hand gesture.

3.3. FLEX SENSOR

The working of flex sensor is based on the values of the resistance which varies, as the body of sensor bends from normal position. The amount of deflection is directly proportional to resistance.

Fig. 5 Flex Sensor and Deflection

Fig. 5 shows the deflection of flex sensor and its resistance variations at degree of bendings.

3.4. HAND SKELETAL

Fig. 6 shows the skeletal view of human hand. The phalanges, metacarpals and carpals forms finger of human hand.

Fig. 6 Skeletal View of Human Hand

The ulna and radius located between elbow and wrist joint are called as forearm. Five fingers consist of 14 bones. Palm formed by 5 bones and wrist contains 8 bones.

3.5. ROBOTIC HAND DESIGN

The design of robotic hand has five fingers. Each finger has separate servo motor to control robotic arm. Fig. 7(b) shows Servo motor can control three links and joints (distal, phalanges, metacarpals) of robotic hand. The design of robotic hand operates with 14 degree of freedom (DOF). Thumb finger has 2 DOF and residual each finger has 3 DOF.

Fig. 7 Robotic arm (a) front view (b) back view

Fig. 7(a) shows five servo motor to control fingers of robotic hand arranged in the palm of the robotic hand. Fig. 7 shows the design of robotic hand similar to the human hand skeletal view.

4. KINEMATICS OF ROBOTIC FINGER

Fingers of robotic hand have three joints and thumb finger only has two joints. Fig. 8 shows kinematics of robotic finger.

θ_1 angle of link 1(l_1), θ_2 angle of link 2(l_2), θ_3 angle of link 3(l_3)

Fig. 8 Kinematics of Robotic Finger

Position of forward Kinematics and inverse Kinematics

Position of 1st link is given by

$$P1(\theta_1) = \begin{pmatrix} \cos(\theta_1) & -\sin(\theta_1) & 0 \\ \sin(\theta_1) & \cos(\theta_1) & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (1)$$

Position of 2nd link is given by

$$P2(\theta_2) = \begin{pmatrix} \cos(\theta_2) & -\sin(\theta_2) & l_1 \\ \sin(\theta_2) & \cos(\theta_2) & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (2)$$

Position of 3rd link is given by

$$P3(\theta_3) = \begin{pmatrix} \cos(\theta_3) & -\sin(\theta_3) & l_2 \\ \sin(\theta_3) & \cos(\theta_3) & 0 \\ 0 & 0 & 1 \end{pmatrix} \quad (3)$$

Let $\omega = \theta_1 + \theta_2 + \theta_3$ since $C_{123} = C\omega$, $S_{123} = S\omega$, The solution for the forward kinematic problem is given by

$${}^0P(\theta_1, \theta_2, \theta_3) = \begin{pmatrix} C_{123} & -S_{123} & 0 & l_1 C_1 + l_2 C_{12} + l_3 C_{123} \\ S_{123} & C_{123} & 0 & l_1 S_1 + l_2 S_{12} + l_3 S_{123} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (4)$$

Kinematic equation for 3 link manipulator

$$X = l_1 \cos(\theta_1) + l_2 \cos(\theta_1 + \theta_2) + l_3 \cos(\omega) \quad (5)$$

$$Y = l_1 \sin(\theta_1) + l_2 \sin(\theta_1 + \theta_2) + l_3 \sin(\omega) \quad (6)$$

Position of link 1 is

$$X_1 = X - l_2 \cos(\theta_1 + \theta_2) + l_3 \cos(\omega) \quad (7)$$

$$Y_1 = Y - l_2 \sin(\theta_1 + \theta_2) + l_3 \sin(\omega) \quad (8)$$

Position of link 2 is

$$X_2 = X - l_3 \cos(\omega) \quad (9)$$

$$X_2 = l_1 C_1 + l_2 C_{123} \quad (10)$$

$$Y_2 = Y - l_3 \sin(\omega) \quad (11)$$

$$Y_2 = l_1 S_1 + l_2 S_{12} \quad (12)$$

Squaring both side of (10) & (12)

$$X_2^2 + Y_2^2 = l_1^2 + l_2^2 + 2l_1 l_2 C_2 \quad (13)$$

$$C_2 = \frac{X_2^2 + Y_2^2 - l_1^2 - l_2^2}{2l_1 l_2} \quad (14)$$

$$S_2 = \pm \sqrt{(1 - C_2^2)} \quad (15)$$

$$\theta_2 = \text{atan2}(S_2, C_2) \quad (16)$$

$$X_2 = (l_1 + l_2 C_2) C_1 - l_2 S_2 S_1 \quad (17)$$

$$Y_2 = (l_1 + l_2 C_2) S_1 + l_2 C_1 S_2 \quad (18)$$

$$S_1 = \frac{(l_1 + l_2 C_2) Y_2 - l_2 S_2 X_2}{\Delta} \quad (19)$$

$$C_1 = \frac{(l_1 + l_2 C_2) X_2 + l_2 S_2 Y_2}{\Delta} \quad (20)$$

$$\Delta = l_2^2 + l_1^2 + 2l_1 l_2 C_2 = X_2^2 + Y_2^2 \quad (21)$$

$$\theta_1 = \text{atan2}(S_1, C_1) \quad (22)$$

$$\theta_3 = \omega - \theta_1 - \theta_2 \quad (23)$$

5. EXPERIMENTAL RESULT

Fig. 9 shows the human hand with flex sensor for grip measurement and PIC microcontroller with LCD which shows the each fingers gesture ADC values on the display.

Fig. 9 Human Hand Gesture Measured Value on LCD

This ADC values may be coded for different hand gesture such as grab, close, release, and pinch for robotic hand. The values measured by flex sensor in human hand gloves Shows Table I.

Table I. Human Hand Gesture Measured Values for each Finger

Gestures	Measured human hand fingers gesture value (decimal)				
	Thump	Index	Middle	Ring	Pinky
open	12	12	12	12	12
close	09	09	09	09	09
pinch	11	10	12	12	12
Grab	09	09	08	09	09

Fig. 10 shows flex sensor values for each human finger at various hand gestures such as open, close, pinch, grab.

Fig. 10 Human Hand Gestures and its Sensor Values

Fig. 11 shows the robotic hand with flex sensor for grip measurement and PIC microcontroller with LCD which shows the each fingers gesture of ADC values on the display.

Fig. 11 Robotic Hand Gesture Measured Value on LCD

These ADC values of robotic hand and the ADC values of human hand is compared for different hand gestures such as grab, close, release, pinch for robotic hand. When these two comparison values are equal then it improve the performance accuracy.

Table II. Robotic hand gesture measured value for each finger

Gestures	Measured robotic hand fingers gesture value (decimal)				
	Thump	Index	Middle	Ring	Pinky
open	12	12	12	12	12
close	10	09	09	09	09
pinch	10	10	12	12	12
Grab	09	09	08	08	09

The robotic arm gesture values of each fingers measured by flex sensor. The sensor values measured at robotic hand shows Table II.

Fig. 12 Robotic Hand Gesture and its Sensor Values

Fig. 12 shows flex sensor values of each fingers of robotic hand at various hand gestures such as open, close, pinch, and grab.

(a) Comparison of human hand and robotic hand open gesture

(b) Comparison of human hand and robotic hand close gesture

(c) Comparison of human hand and robotic hand pinch gesture

(d) Comparison of human hand and robotic hand grab gesture

Fig. 13 Comparison of Human Hand and Robotic Hand Gestures

Fig.13 shows the comparison result of human hand gestures and robotic hand gestures. Fig. 13(a) shows open gesture of human hand and robotic hand, Fig. 13(b) shows close gesture of human hand and robotic hand, Fig. 13(c) shows pinch gesture of human hand and robotic hand and Fig. 13(d) shows grab gesture of human hand and robotic hand.

6. DISCUSSION

Both end measurement uses same sensors on both human and robotic hand since it produce same values for the same deflection of flex sensor at both end. When the both end measured ADC output value same then it achieves the exact control. The development of vision based sensors are detects gesture also produce vision and good accuracy with high cost. The proposed method of both end measurement produce good accuracy with affordable cost.

Robotic hand developed for testing such as human hand. It has 14 DOF. Thumb finger has 2 DOF and each other finger has 3 links with separate servo motor to control finger movement. This robotic hand model produces high accuracy for close (pick), open (place) and grab. This design is well suitable for pick and place related applications.

7. CONCLUSION

In this research work, the proposed concept of controlling robotic arm using both human and robotic hand measurements were performed with better accuracy. Both end measurement goes high precision for handling task by robotic arm.

The pick and place is the major operation in industries. So, this method produces better accuracy for open and close hand gesture. This paper measure the cooperation of human hand and robotic hand. The design of same sensor based hand gloves used at both end to measure the human and robotic hand performance and task cooperation. Many visual gesture sensors available present days but not affordable since this both end measurement method is better for exact control with low cost solutions.

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