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Design And Implementation Of Anthropomorphic Robotic Arm

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ABSTRACT
The report focuses on the design and demonstration of an anthropomorphic robotic arm with seven degrees of freedom using readily available low-cost components to perform different real time human hand applications. The robotic arm consists of a shoulder, elbow, wrist and a five-finger gripper. It can perform different gripping actions, such as lateral, spherical, cylindrical and tip-holding gripping actions; each finger has three movable links. The actuator used for the robotic arm is a high torque dc servo motor and the five-finger gripper consists of five cables placed like tendons in the human arm. Implementation is done using a human hand glove which senses the motion from sensor technology to produce a proportional analog voltage, digitized via the microcontroller Atmel ATmega32. The microcontroller then through the processed signal controls the mechanical structure that is the robotic arm.
Keywords – Actuator, Anthropomorphic, Degree of Freedom, Microcontroller, Sensor Technology,

I. INTRODUCTION

The importance of robotic arm in all manufacturing industries is growing. Robots have replaced human beings in a wide variety of industries. Robots outperform humans in jobs that require precision, speed, endurance and reliability. In related work, Nicholas Thayer and Shashank Priya presented the biomimetic design and performance of a 19 DOF robotic humanoid hand, the dexterous anthropomorphic robotic typing (DART) hand [1]. Similarities between human joints and robot joints were highlighted in terms of basic functional characteristics such as independent joint and finger control, range of motion, output forces, weight and speed. Another important characteristic in this design was maintaining the human form because tasks such as tying shoes, holding mugs, opening doors and typing on keyboards are tailored for human hands.
Haiying Hu et al describe a master-slave tele-operation system [2] which is developed to evaluate the effectiveness of tele-operation in tele-robotics applications. The operator wears a data glove augmented with an arm-grounded force feedback device to control the dexterous hand and utilizes a Space ball to control robot arm. Most of dexterous hands are tele-operated by data glove [1] [2] while others are controlled by moving the operator’s arm with tracker mounted on the wrist [3]. This system tracks the human hand through the use of vision system, which has the advantage of being non-intrusive at a penalty of cost and complexity.

Samuel Schuler et al using Dexterous Robot Arm (DEXARM) presented the design and development of a joint [4].A new type of 3 DOF arm using tendon drive and fine motor control was developed to mimic biology's arm structure by Klug et al [5]. The design proposed in the paper [5] is a unique implementation of tendon drives with built in compliance. The problem that they were trying to eliminate is the need to use very rigid, large links to prevent arm flex. With their link and actuation design, they can use less rigid links and also be more human friendly. Scaling from 3 to 7 DOF is clearly a challenge for them that have not yet been solved. The work of Tondu et al on a seven DOF arm provided necessary anthropomorphic background needed for our project. In their project [6], they chose to use opposing air muscles as actuators. This arm served as the closest analogy to the arm described in his thesis.
Zhe Xu et al [7] presented the design of an anthropomorphic robotic finger system that has the potential to become a close replica of the human finger. The system has three main components: a modular design of three highly biomimetic finger joints, a series of simplified pulley-based tendon mechanisms, and a pneumatic actuation system with low friction and inertia and high force output. In "Cora: Anthropomorphic Robot Assistant"[8] the researchers used an off the shelf, light weight 7 DOF arm from Amtec. The goal was to use the robot in conjunction with different sensors to look at interactions between the robot and its environment. Loredana Zollo et al [9] proposed bio-mechatronic approach to the design of an anthropomorphic artificial hand able to mimic the natural motion of the human fingers. The work specifically addressed the optimization of an existing artificial hand prototype by identifying the detailed refinements needed on the design of one finger in order to obtain an improved biomorphic behavior with respect to the natural hand. In the area of anthropomorphic robotics, there have been a string of noteworthy research efforts worth

mentioning. While not meant to be a complete list, the following presents a snapshot of the field.

II. BLOCK DIAGRAM AND FLOWCHART

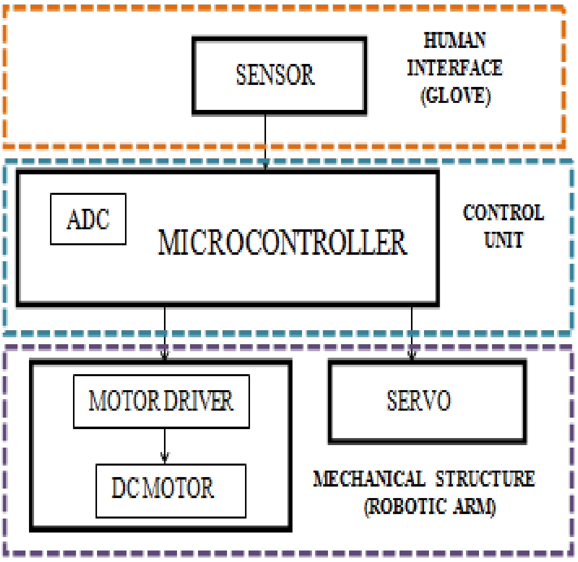


Figure 2.1: Block diagram

From figure 2.1, we can observe that the output of the sensor technology which is attached to the glove is amplified if necessary and then sampled using inbuilt ADC within the controller and is processed to the servo motor which would affect the mechanical structure. The analog voltage needs to be amplified to make the microcontroller understand of the change. The amplified signal is fed to the driver circuit which drives the motor to rotate to corresponding angle for a corresponding input.

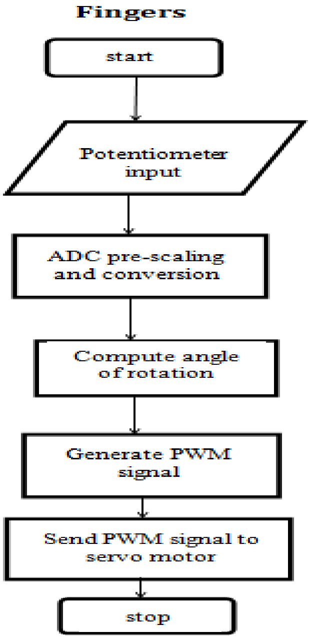


Figure 2.2: Flowchart of working of finger

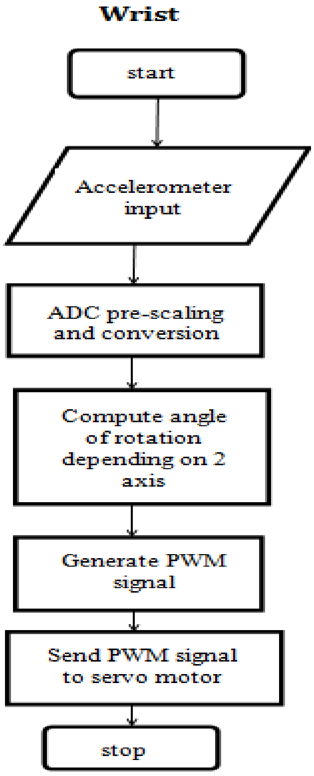


Figure 2.3: Flowchart of working of Wrist

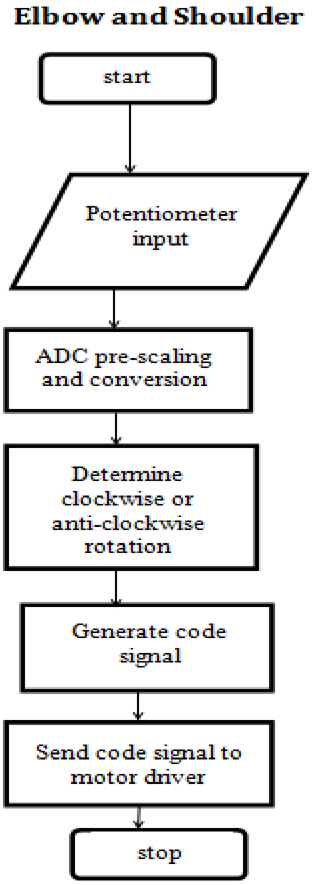


Fig 2.4: Flowchart of working of Wrist

Initially the user has to wear the glove that controls the robotic arm and leave that part of his arm in rest position for initial calibration of the sensors. Switch on supply of the device the ATmega32 microcontroller is programmed to constantly check for any incoming analog inputs from different sensors placed at various locations. If there is no motion made by the user, the input to the microcontroller will remain constant and it will continue the same cycle of scanning over and over again. If there is any kind of motion made by the user's arm that is measureable (i.e. greater than or equal to the threshold value input voltage), the following process takes place. As the user moves any part of his arm the various sensors (i.e. Potentiometer, Accelerometer) develop a change in the potential. These potential differences if measurable are analog in nature and are fed to the atmega32 microcontrollers ADC input pins. The input fed to these pins are then converted to 8/10 digital output values and stored in the ADCH/ADCL register depending on left-shift or right- shift operation. Once the digital outputs through these registers are obtained they can be used to generate the appropriate PWM signal for motion of mechanical arm.

III. DESIGN STAGES

The microcontroller Atmega32 needs to be interfaced with following hardware units for project implementation.

3.1 Potentiometer

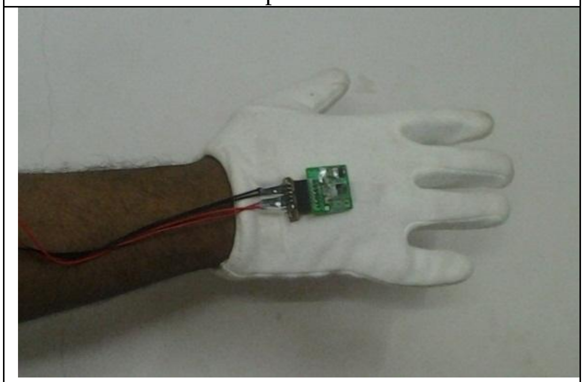
The potentiometer provides analog voltage values for the variation in slider of potentiometer. The generated analog voltage is converted to digital values by ADC within the microcontroller ATMEGA32. The ADC value is given by equation

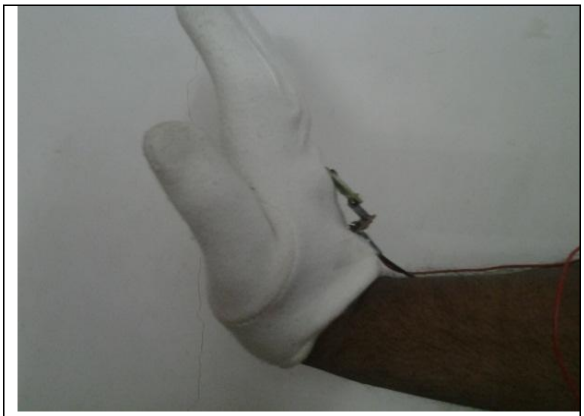
Fig 3.1: Mounting of potentiometer on Hand glove

3.2 Triple axis Accelerometer

The accelerometer provides analog voltages values for the 3-axis as per the variation of acceleration. Dynamic acceleration is chosen over static to overcome difficulty in small variation of motion and also emphasis the need of reference plane position. The choice of dynamic variation eases out the motion to a position and also eliminates re-initialization of reference position at startup. The analog values are digitized using in-built ADC of atmega32 which provides 10-bit resolution. The MCU has 8 ADC channels for provisioning of 8 analog inputs (ADC0-8) of which 3 are used for the axis variations in Fig. 5.3. The Data Direction registers of pins are pulled up to 0 to act as input. Sensitivity mode 0 is chosen from the below table 5.1. All three axes have been utilized for calculation of relative position of the accelerometer. Relative x and y position are computed using z as the reference axis.

Table 2: Reference controlling input for Accelerometer

 Side view of reference position
 Top view of reference position
 Downward motion


Upward motion


Left motion


Right motion

3.3 Servo Motor

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. The servo motor used is Futaba s3003. Each Finger of the arm uses a servo motor of 10 kg-cm torque. This enables it to carry a payload of at least 10 kg within a radius of 1 centimeter. Likewise, the wrist is equipped with a servo motor of 15 kg-cm which enables it to carry the payload as well as the fingers. The figures 3.1 and 3.2 demonstrate the placements of these servo motors into their respective position.

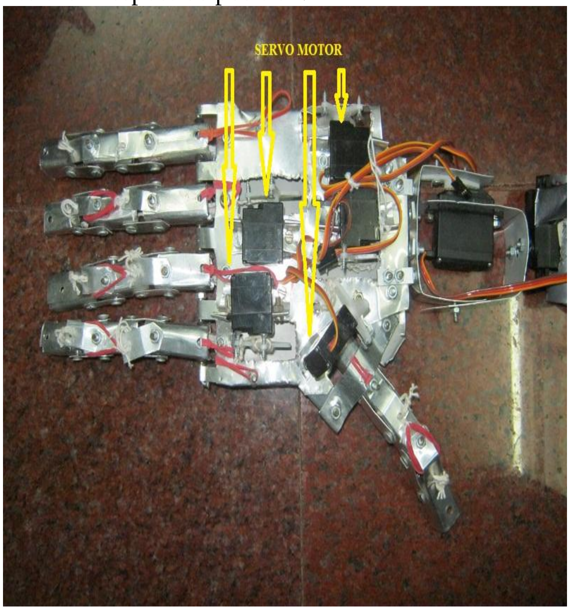


Fig. 3.2: Palm servo motors

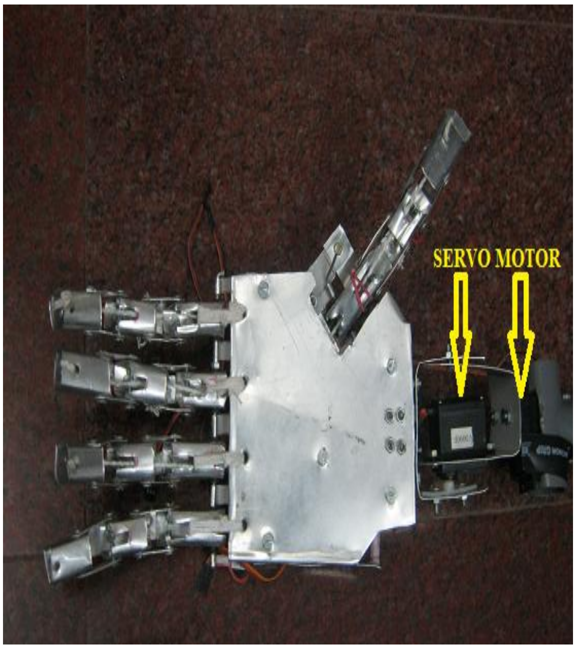


Fig. 3.3: Wrist servo motors

3.4 DC Motor

Since the load of the circuit from the elbow to the finger in the mechanical unit that is robotic arm is more for a servo motor to handle, the elbow and shoulder are implemented using DC Motors. Most DC motors are normally very easy to reverse. By simply changing the polarity of the DC input, the

direction of the drive shaft reverses. This property makes DC motors very popular among enthusiast people involved in robotics. In most cases, DC geared motors are used. The changeover process (reverse in direction due to reverse in polarity) can be achieved via a simple changeover switch (DPDT switch) or for a remote or electronic control, via a suitable relay. However, when we use microcontroller unit in our circuit, we don't need a relay. The necessary control signals will be generated by the control unit. This signal will be passed there is a microcontroller. Now, this control unit may/may not take in inputs (inputs as in from sensors, other digital inputs, etc.). Next, as per our programming, the MCU will generate control signals. The microcontroller will generate signals in form of HIGH (Vcc = 5v) or LOW (zero) but this voltage is insufficient to drive a motor. That's why we need to use a Motor Driver. A motor driver always has a battery input Vs (which depends upon the rating of the motor). In simple terms, what a motor driver does is that it directs the Vs voltage to the motors connected (or in fact, the output pins) to it. Thus, the motors behave as per the control signals generated using the control unit with the excitation from the external battery voltage. The most commonly used motor driver is the L293DSince the minimum current ratings required to drive the DC motor of our project is 2ma. Hence we have chosen L298 motor driver.
The point of doing torque calculations is for motor selection. We must make sure that the motor we choose can not only support the weight of the robot arm, but also what the robot arm will carry .The first step is to label your free body diagram (FBD), with the robot arm stretched out to its maximum length. Torque calculated here is torque at rest robotic arm (not in motion) .So rating of torque in servo motor is greater than calculated value.

Table 3: Torque of each DC Motor used

Sr.no	Part of the robotic arm	Minimum necessary (kg-cm)	Use (kg-cm)
1	Elbow yaw	15	25
2	Elbow pitch	9.1	10
3	Shoulder	41	45

Fig. 3.4: DC Motors in the elbow

Fig. 3.5: DC Motor in the shoulder

IV. Results

The hand glove Unit shown in the above Fig. 4.1 consists of Controlling glove, Potentiometer, Accelerometer, Microcontroller AVR ATmega32 and Wire connection. The actions traced by hand glove are performed by the mechanical unit that is robotic arm

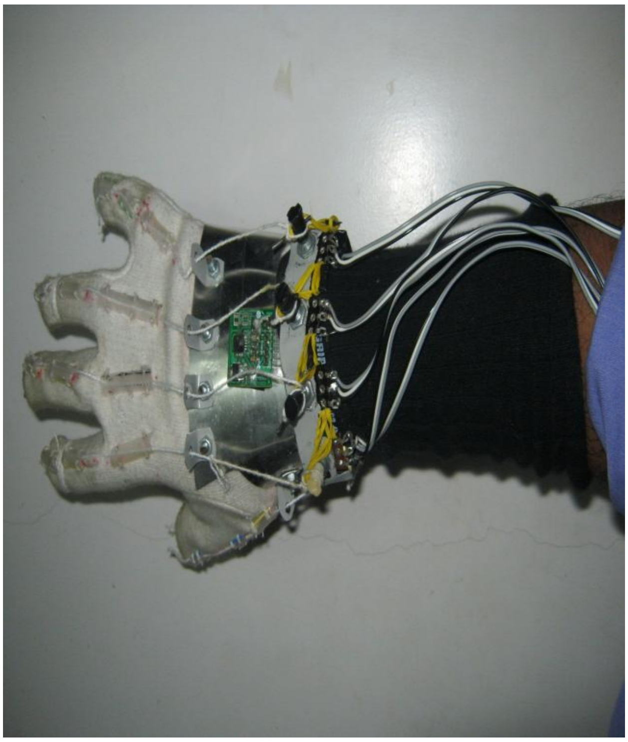


Fig. 4.1: Hand glove unit

Fig. 4.2: Mechanical unit

The mechanical unit in Fig.4.2 is the response machine for the input provided by Hand glove unit. It consists of DC Motors with motor-driver circuitry and Servo motor.

Table 4: Kinematics of Robotic Arm

Degree of Freedom	7
Payload Capacity(Fully Extended)	150gm
Maximum Reach(Fully Extended)	35cm
Rated speed(Adjustable)	0-0.3 m/s
Joint speed(Adjustable)	0-60 rpm
Hardware interface	manual wiring
Control Software	AVR Studio 4
Shoulder Pitch	180°
Elbow Pitch	180°
Wrist Pitch	180°
Gripper Opening(Max)	8cm

The robotic arm has seven servos which are controlled through the use of two microcontroller ATmega32. It could grab things approximately in a hemisphere of 50cm and is robust made completely with an aluminum sheet of 2.5mm. It is very user friendly because of the hand glove interface developed by us, even layman could operate it. It could lift objects up to weight of 200 gm. It enables the base rotation without the help of any gears or ball bearing, also using only low torque servo motors and one dc motor for rotating the whole body. This keeps the design of robotic arm gripper simple, as well as implementing the gripping mechanism without using gears. It can track the hand motion that is static as well as dynamic motion with efficiency.

V. CONCLUSION

Anthropomorphic robotic arm with seven degrees of freedom is built in this research. It is able to handle multiple levels of complexity and produce consistency in its application. The levels of complexity of robots is defined by the members used in it, number of limbs, number of actuators and sensors used and for advanced robots the type and number of microcontrollers used. The prototype built has low latency period, high flexibility and fast response to the user manual inputs. Robotic applications include material handling (pick and place), assembling, painting, welding, packaging, palletizing, product inspection and testing. Due to the limitations of the equipment, time and also cost, it can be further improved in order to perform more complex tasks. Several major changes can be done to improve the functionality and flexibility of the entire design of the paper.

This prototype can be further improved by using high power motor with high torque and also using light weight motors. While using in the field of medical, increasing accuracy and consistency while decreasing latency will be of prime importance. This can be done by using the robotic arm with tactile sensors, proximity sensors. The arm built can be improved based on the wiring connections between servo motors and the control unit. Instead of having so many wires tangling around, the wires can actually be properly sealed together with the servo motors. This will help make the connections more secure and safe. Above and beyond, to reduce the risk of short circuits and to develop a better aesthetic, wireless system can also be implemented into the design where interfacing with a host computer is not needed. RF transmitters and receivers can also be installed as part of the wireless system. This enables the robot to move in a wider range as compared to the robotic arm built in this research.

VI. ACKNOWLEDGEMENTS

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