

# Tele-Operated Anthropomorphic Arm and Hand Design

Namal A. Senanayake, Khoo B. How, and Quah W. Wai

**Abstract**—In this project, a tele-operated anthropomorphic robotic arm and hand is designed and built as a versatile robotic arm system. The robot has the ability to manipulate objects such as pick and place operations. It is also able to function by itself, in standalone mode.

Firstly, the robotic arm is built in order to interface with a personal computer via a serial servo controller circuit board. The circuit board enables user to completely control the robotic arm and moreover, enables feedbacks from user. The control circuit board uses a powerful integrated microcontroller, a PIC (Programmable Interface Controller). The PIC is firstly programmed using BASIC (Beginner's All-purpose Symbolic Instruction Code) and it is used as the 'brain' of the robot. In addition a user friendly Graphical User Interface (GUI) is developed as the serial servo interface software using Microsoft's Visual Basic 6.

The second part of the project is to use speech recognition control on the robotic arm. A speech recognition circuit board is constructed with onboard components such as PIC and other integrated circuits. It replaces the computers' Graphical User Interface. The robotic arm is able to receive instructions as spoken commands through a microphone and perform operations with respect to the commands such as picking and placing operations.

**Keywords**—Tele-operated Anthropomorphic Robotic Arm and Hand, Robot Motion System, Serial Servo Controller, Speech Recognition Controller.

## I. INTRODUCTION

THE design of a human body is so complex that to build a comparable machine, our technology will need to advance significantly whereby, with the current understanding and knowledge, engineers can only attempt to mimic the form of the human body. Thus, it is called the humanoid robot. A humanoid robot is an autonomous robot which its overall appearance is based on a human body [1]. It can adapt to changes in its environment or itself and continue to perform what it is asked to. This is the main difference between humanoid robots and any other kind of machine robots which are usually used in the industrial fields.

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This paper addresses designing of a tele-operated anthropomorphic robotic arm and hand which consists of the robotic shoulder, elbow, arm, wrist and fingers. The robotic arm is designed to be similar with a human arm with seven degrees of freedom where each part of the arm is actuated with servo motors. Besides, this design will be a versatile robotic arm system to give the robot the ability to manipulate objects for instance, simple pick and place operations. Moreover, many other components would need to be included to create a machine that would even come close to having the capabilities of a human arm.

The robotic arm will be controlled by a serial servo controller circuit board that is base on a Programmable Interface Controller (PIC) 16F84, a type of flash programmable microcontroller. The main objective of designing using a microcontroller is that a large amount of electronics needed for certain applications can be eliminated. The PIC is considered as the brain of the whole device that operates in a close loop control process. This controller board is used to interface the arm to a personal computer (PC). On the other hand, the interface software that runs on the PC is written in Visual Basic 6. The advantages of using this interface software are that the structure of the language is simple and graphical user interfaces (GUI) that are connected to handler functions provided by the application are easy to be developed. Using a microcontroller in conjunction with a personal computer provides enormous control and flexibility to the robotic arm [1].

A speech recognition control system capable of controlling the robotic arm using voice commands is also constructed in this research where hands-free operation is desired. The ability to communicate with a robot through speech is the ultimate user interface. When a robot obtains the ability to recognize words, it is well on its way to becoming a true humanoid. This speech recognition control circuit to be built provides a simple and effective means for humans to specify a task for the robot to acquire new skills without any additional hard coded programming.

Robots have become important over a wide range of applications--from manufacturing, to surgery, to the handling of hazardous materials. Consequently, it's important to understand how they work, and what problems exist in designing effective robots. The following of the report will cover up from software programming to hardware development. Besides that, evaluations and future work of the project are also included.

## II. DESIGN, CONSTRUCTION AND ASSEMBLY OF THE ROBOTIC ARM

The robotic arm was designed to resemble the human arm that is able to grip, pick and place various objects. The design of robotic arm involves few major components which include the rotating base, shoulder, elbow, wrist and gripper [2].

The main considerations taken during the design process was to design a robotic arm that assembles the human arm, able to stand alone, size should be similar and not too bulky, light and the overall cost should be low.

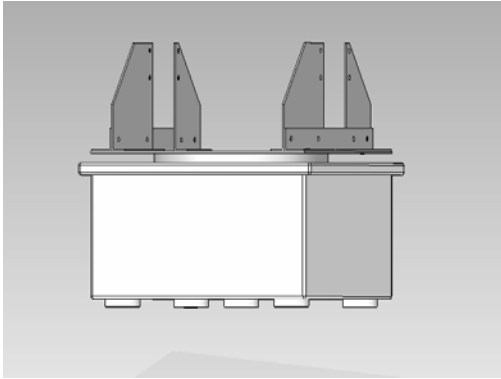


Fig. 1 Rotating Base Attached onto a Lazy Susan Bearing

The design of the rotating base is shown in the Fig. 1. It consists of metal plates attached to the left and right side. The centre is hollow to reduce material usage and the overall weight. The base of the robotic base is attached on a 6 x 6 inch lazy Susan bearing which allows it to rotate freely which is almost frictionless. It is also used to evenly distribute the weight of the robot arm. The lazy Susan bearing is then placed on a utility box. A single large-scale servo motor that is able to support up to 25kg/cm torque is used to power the rotating base. A high-torque servo motor is needed to support the entire weight of the robotic arm and objects that is gripped with the gripper. The servo motors used for movements of the arm are able to rotate to a maximum 180 degrees from horizontal to vertical each side.

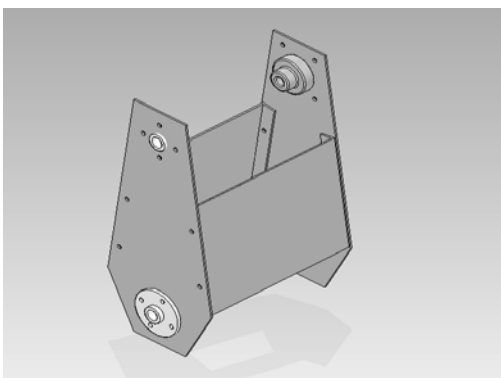


Fig. 2 Shoulder Assembly with a Ball Bearing

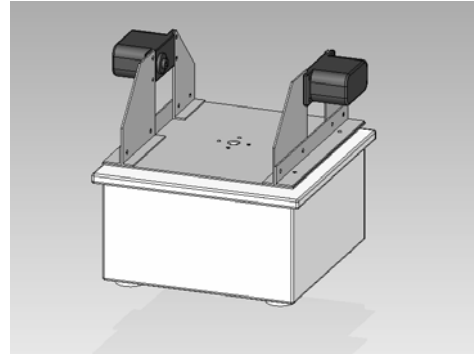


Fig. 3 Two Servo Motors to Support the Shoulder

The design of the shoulder fully assembles the human arm as shown in Fig. 2. The metal plates used to connect the left side and right side is designed to have smaller dimension that does to cover the entire length of the sides. This is mainly to reduce material usage and weight of the shoulder but at the same time ensure that the size is able to connect the left side and right side rigidly. The movement of the shoulder is supported by two large-scale servo motor working together simultaneously. These motors are also able to move 180 degrees. The two servos are attached to the rotating base as shown in Fig. 3. A ball bearing is attached to the top of one side to support the elbow components.

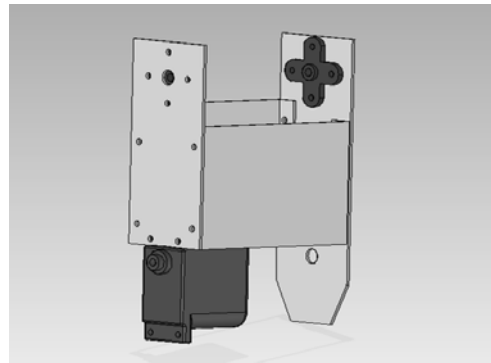


Fig. 4 The Elbow Assembly with a Single Servo Motor

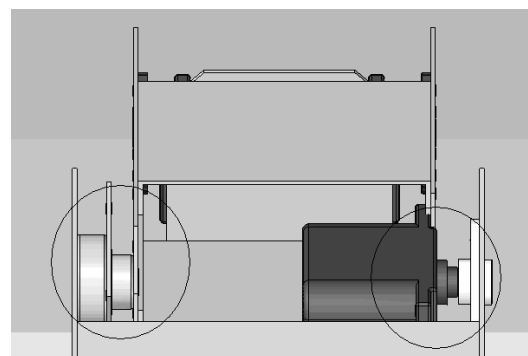


Fig. 5 The Connections between the Elbow and Shoulder

As for the elbow, it is only supported by a single large-scale servo motor as the weight it need to support is much reduced. It only needs to support the wrist and the gripper and it is mounted to one side of the elbow assembly. The other side is supported by a ball bearing attached to the shoulder as mentioned above. The design of the elbow is shown in the Fig. 4. A ball bearing was selected as it is easy available and it does not cause any friction and unwanted noise that might appear when two parts collide with each other. The connection between the elbow and shoulder is shown in Fig. 5.

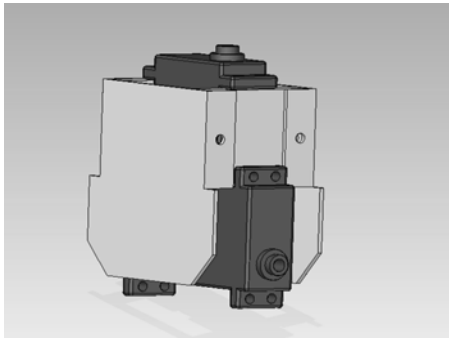


Fig. 6 The Wrist Assembly with Three Standard Servos

The wrist is made up of three standard servo motors which supports up to a maximum 3.7kg/cm torque and movement of maximum of 180 degrees. The two servos attached side by side are to move the wrist by 180 degrees and the servo attached at the top is to control the movement of the gripper. The wrist was designed as light as possible as it is supported by standard servos. The design of the wrist is shown in Fig. 6.

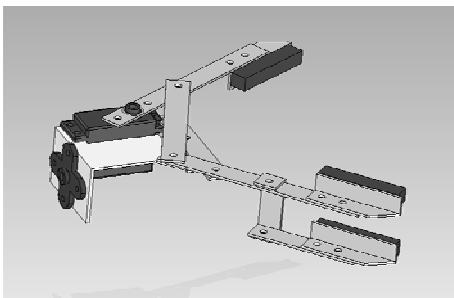


Fig. 7 Three fingers Gripper Assembly

Finally, a gripper was designed so that it is able to pick and place objects. A three-fingered gripper that only uses a standard servo is designed. The design involves one finger directly from the servo and two other fingers connected through a direct mechanical linkage as shown in Fig. 7. The gripper is capable of a 10-inch grasp. A three-fingered gripper was chosen as a five-fingered gripper requires more than one standard servo.

Due the space limitation and weight considerations, a simple three-fingered gripper was preferred and at the same instance, it is able to grip objects firmly.

### III. FABRICATION AND CONSTRUCTION OF THE ROBOTIC ARM

The material used to fabricate the body of the robotic arm was chosen to be aluminum as it is a light weight metal, rigid, cheap compared with stainless steel and easy available in the market. It is also resistance to wear and rust. Another important point why aluminum was chosen mainly because it is easy to fabricate as the components of the robotic arm require a lot of bending and hole drilling process. The thickness of the aluminum was chosen to be 1.5mm thick. This thickness of material is common and the price is reasonable. This thickness is suitable for the robotic arm and after bending and drilling, the material is still rigid and strong. The fabrications of the individual parts are sent to a fabricator to manufacture the parts [3].

The construction and assembly of the body of robotic arm consists of few major components which include aluminum pieces, screws, nuts and washers. The construction of the robot arm begins with placing weights into the utility box to add stability to the base when the arm is mounted and during rotating operations. Then, hole a drill at one side of the box to allow the servo motor wire to go through. The centre of lid is cut to follow the dimension of the servo motor to make room to place the top of the servo. Then, the rotating lazy Susan bearing is place on the lid and it is ensure that the space around it is even on all sides.

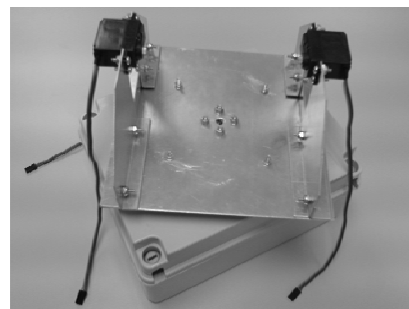


Fig. 8 Rotating Base Assembly with Servo Motors

Then, the individual parts used to form the rotating base is assembled together using screws, nuts and washer before attaching it to the lazy Susan bearing. Servo motors are attached to the body using servo horns that are provided with the servos. The entire rotating base assembly with two servo motors is shown in the Fig. 8.



Fig. 9 Shoulder Assembly

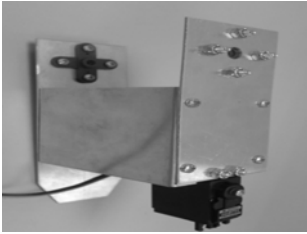


Fig. 10 Elbow Assembly

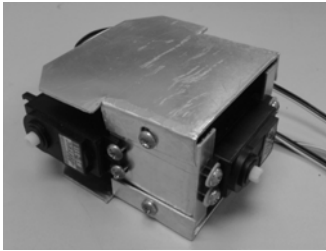


Fig. 11 Wrist Assembly

Next, the shoulder components are assembled together before mounting to the rotating base. This is followed by assembly of the elbow, wrist, and gripper components. The Figs. 9, 10 and 11 illustrate the completed assembly shoulder, elbow and wrist respectively.

Then all servo motors that are attached to the components are turned manually to determine the maximum limit. It is then manually positioned to the middle position. Finally, all components of shoulder, elbow, wrist and gripper are secure into position. As the motors are placed at their centre position, during the placement of the shoulder, elbow and wrist, the parts are ensure to stand horizontally so that after attachment, the robotic arm is able to move to the right and left position by 90 degrees each side.

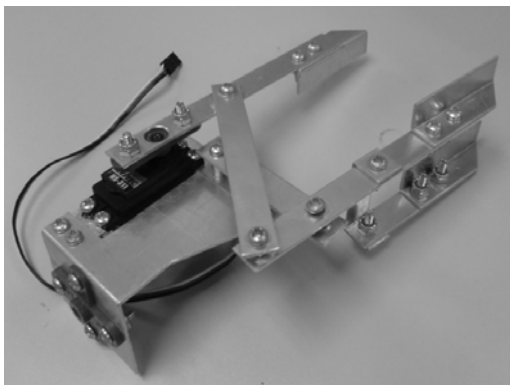


Fig. 12 Gripper Assembly

As for the gripper, the parts are tightened with enough force to allow the pieces to move freely without friction and unwanted sound but enough to hold the parts in place. The final step is to mount the gripper to the wrist. The final completed assembled robotic gripper is shown in the Fig. 12.

A serial servo controller board is constructed using PIC16F84A as the 'brain' of the controller [4]. This serial servo controller board will be used in controlling the robot

arm by mean of controlling eight servos via a serial connection to a personal computer (PC).

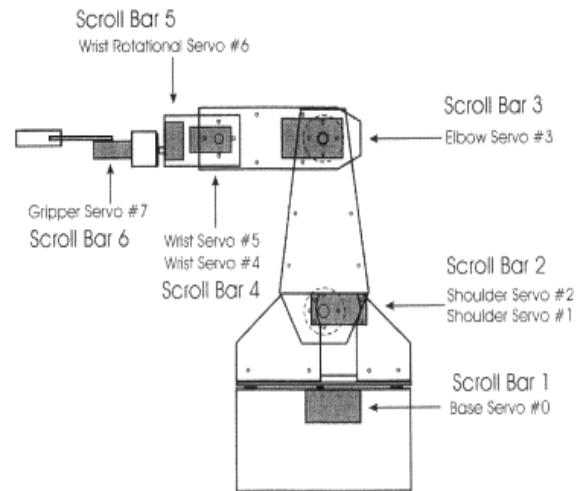


Fig. 13 Each Associated Scroll Bars and Robot Arm Joints

A small change on the scroll will make the robot arm react accordingly. The 'center' box under each vertical scroll bar corresponds for making the particular servo back to its centre position as shown in Fig. 13.

Each time when the position of the robotic arm is captured, next position is updated. When a number of positions are saved, it can be playback. The speed is always indicated and the robotic arm will move to the first position saved followed by the next position saved.

#### IV. THE ROBOT'S MOTION SYSTEM USING VOICE RECOGNITION CONTROL

The speech recognition circuit functions as a standalone circuit and it works independently from the robots main CPU. Hence, it does not take any processing power from the main CPU. Words are recognized through interrupt operations whereby the recognition line is connected to the robot's interrupt lines. This is much better than using polling operation that causes CPU overhead.

The main component of the circuit is the HM 2007 speech recognition chip. The HM 2007 chip is a CMOS voice recognition chip with voice analysis, recognition process and system control functions. The other major components are the 64K CMOS Static RAM chip, microphone, 12 button-keypad and 74LS373 chip. Data can be written and read from the SRAM chip and the 74LS373 functions as a latch with 3-state outputs. There are also two BCD to 7-segment converters used to display the output the words recognition. It functions as an indicator to user as the circuit is working properly.

The circuit is a speaker dependent system whereby it is only able to recognizing the individual that train the circuit. It a capable of providing high functioning output as high as 95% accuracy. However, there is constraint of the circuit concerning the style of speech it can recognize. For example, it can only recognize words that spoken separately with pause in between each word.

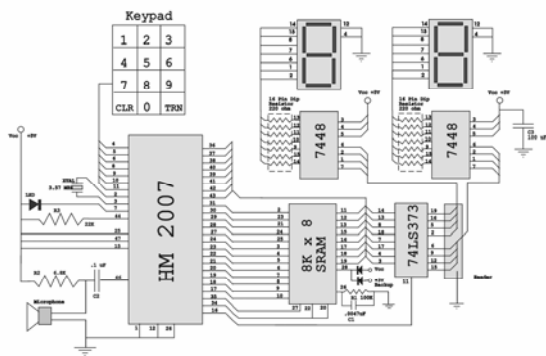


Fig. 14 Schematic Diagram of Speech Recognition Circuit

It is programmable to recognize 40 unique words of 0.96s length and a maximum of 20 words of 1.952s length. The length of the words affects the number of words able to be store in the 8K x 8 static RAM chip. The circuit is able to detect voice as far as one foot from the microphone. This speech circuit provides many advantages compared with other circuits as the response time is less than 300 ms, it requires only a 5 V DC power supply and it can support CPU mode and manual mode whereby the manual mode is connected to a keypad and CPU mode is connected to a microcontroller as shown in Fig. 14.

V. TESTING AND TRAINING THE SPEECH RECOGNITION CIRCUIT

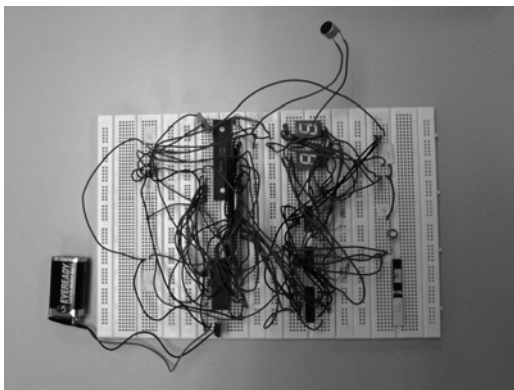


Fig. 15 Speech Recognition Circuit Constructed on Breadboard for Testing

The circuit shown in Fig. 15 was constructed into on breadboard for testing and training. Testing and training the HM 2007 chip in manual mode requires the keypad and microphone. When the circuit is powered on, the HM 2007 checks the static RAM and display “00” on the 7-segment and also lights the LED.

The system is in ready state and ready to be trained. Training procedures of the circuit includes:

1. Press “01” and the 7-segment will display “01”. Led will turn off.
2. Then press “train” and Led will on again.

3. Hold the microphone close to user and say training word.
4. If word is recognize by circuit, Led will blink.
5. Repeat the training word and “01” will be display if word is accepted.
6. Continue training with other words and train from “02” to a maximum of “40”.

The output is connected to a PIC microcontroller to read the all the 8-bit outputs from the circuit. The 8 outputs are taken from the output of the 74LS373 latch. The PIC is then connected to the serial servo controller circuit and control the movement of the 8 servo motors.

The circuit was constructed a few times and troubleshooting was done by ensuring all connections are correct and all necessary pin connections are connected.

VI. CONCLUSION

Tele-operated anthropomorphic robotic arm in the laboratory environment is built in this research. It can be further improved in order to perform more complex tasks. The current design of the robotic arm is restricted due to the limitations of the equipment, time and also cost. Several major changes can be done to improve the functionality and flexibility of the entire design.

It was tested and proved that each servo motor used in different parts of the arm, with maximum of 2 servos per part, each works well individually. On the contrary, when all the servo motors are connected together on the serial servo controller, it was found that 8 servo motors work perfectly, with the help of four different power sources used. The Fig. 16 shows the control panel of 8 servo motors.

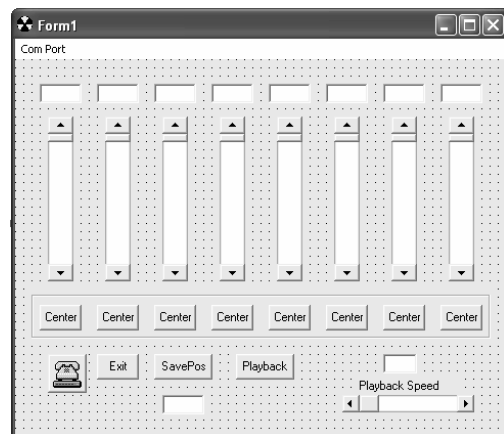


Fig. 16 Control Panel of Servo Motors

In order to select desired communication port sub menus are built under Com Port shown in the Fig. 16. Further, eight vertical scroll bars shown in the figure are to control 8 servo motors. Based on the servo motor in consideration, properties of each servo motor can be set with the attached vertical scroll bar menus which are activated by right clicking on each scroll bar. Once all these features are set, robot arm is in position to run provided that configuration set in the control panel is

properly compiled based on the ranges set according to servo motor manufacturer's values.

Speech recognition controller is built in order to achieve tele-operations. Fundamental operations using speech recognition controller are tested and are found that robot arm can be trained to do such operations. Therefore, this proves that synchronization of speech recognition controller and serial servo controller is possible.

The arm built can be improved based on the wiring connections between servo motors and the serial servo controller board. 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 robot arm built in this research.

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He has initiated research with Sports Biomechanics Centre, National Sports Complex, in which his research team carried out special research projects of national interest. Having engaged in this area of research, Interactive Multilayer Sensorized Smart Floor has been developed under his leadership and currently in the process of patenting the device. Dr. Arosha is the leader of MoU between Monash and National Instruments. He carried out various special research projects under this MoU which are mainly targeting industrial needs.

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