Arduino based Voice controlled Robotic Arm

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Abstract— The aim of this work is to present an inexpensive, light-weight and easily controlled robotic arm based on Arduino Uno. The peculiarity of the arm is it fully voice operated, in other words it responds to the instructions given by the human operator. Although there are many approaches to make the robot work without controlling it manually but unlike other approaches the voice based approach renders more accuracy and efficiency to the robot to perform delicate tasks. The robotic arm is made up of three modules: The arm, the arduino microcontroller, and the voice module. The arm contains three rotary joints and an end effector, where the rotary motion is provided using the servomotor. Moreover, the robot can be operated in two modes, manually using potentiometer shafts and automatically using instructions. Arduino is programmed in such a way that selecting one mode will disable the other.

Keywords— Arduino Uno; Potentiometers; Servo motors; end effector

I. INTRODUCTION

A Robot is a programmable, self or manually controlled device with mechanical, electronic and electrical components. More generally, it is a machine which has the capability to perceive a set of different conditions and decide upon a course of action based on the condition. Current robots are equipped with the advanced sensory systems which mimics the human brain and allows them to perform tasks more efficiently.

Robots are not just machines but indispensable part of large scale industries like manufacturing, automobile, and defence, performing nearly all kinds of tasks varying from an invasive surgery to carrying heavy loads.

Robotic arms are the manipulators which resemble a human arm and can perform all the intricate tasks like welding, trimming, picking and painting. Moreover, the biggest advantage is their ability to work in hazardous areas which are not accessible by the human operator. The primary goal of this project is to help industries cut down on worker error and labor costs and achieve better results. But with some structural modification it can be helpful to the differently abled with their daily chores.

Although, there are many ways to achieve wireless control like Keypad control, Gesture control, and vision based techniques are also used but are time consuming and requires a lot of technical expertise and domain knowledge. On the contrary, the voice based approach is not only simple but helps the user to control the arm, with the high level of abstraction from the robot programming language, making it seamless to operate these engineering marvels.

The rest of the paper is structured as follows: Section II cites the related work, the background and addresses the problem statement. Section III summarises the hardware employed. Section IV focuses on the software and the programming methodology. In Section V we have provided the working and the results and lastly we complete the paper with future scope and conclusion in section VI.

II. RELATED WORK

In this section some of the latest research papers are cited to provide clarity and build foundation for our work on robotic arm.

In [1] a 6-DOF Jaco robotic arm is designed with the objective to achieve the needs of elderly and physically challenged people. It is based on an intuitive approach of adaptive manipulation which uses an algorithm to map user’s hand movement, tracked by a Leap Motion controller, and the Jaco arm. The paper is solely based on achieving Human Computer Interaction or HCI for smooth manipulation of the robotic arm.

In [2] a method based on controlling a robot using accelerometer is proposed by the authors. The accelerometers are attached to the human arms which track the arm movement (postures) using an Artificial Neural Network (ANN) trained with a back-propagation algorithm. The peculiarity of the robot is its low response time which is nearly (160 milliseconds) and its recognition rate which is about (92%).

[3] demonstrates an Adaptive Control based approach for training a 4-DOF robotic arm using Artificial Neural Network (ANN). The procedure involves uniform sampling of the coordinates of the robot’s joints and the end effector in joint space at regular intervals. These coordinates are then preprocessed to form a jacobian matrix which is passed as an input to the neural network to yield the upper and lower joint limits which is used to maneuver the arm. The peculiarity of this robotic arm is the design of its controller which successfully compensates the loading effects with an absolute error of (5 millimeters).

In [4] demonstrates a procedure to design and program a robotic arm to perform the delicate tasks of identifying and dismantling suspected objects like (bombs) and other harmful weapons.
The arm is controlled using a bluetooth device connected to the microcontroller used to actuate the DC motors. It also supports an Android based Graphical User Interface(GUI) for achieving remote operation.

[5] illustrates a voice-activated robot based on speech recognition with the ability to move at any point within its reach. The robotic arm is capable of identifying the current state of the block kept on the surface which is to be moved from one location to another. Moreover, the paper also addresses the “BLOCKS’ WORLD” problem in the field of AI. Also the arm has the capability to recognise 256 words or commands and respond within a record time.

[6] presents an innovative concept to design a robotic arm which senses the myoelectric signals from the muscles to actuate the motors. The signal is measured with the help of electrode patches which are attached to the user’s arm. The EMG module is composed of complex circuits including an amplifier, a transmitter and an on-chip RAM. Its peculiarity is the contactless control which enables the user to operate it from a certain distance. The wireless technology is based on Bluetooth 4.0. Also the robot uses an ARM based processor (NUC140VE3CN) to control the arm.

[7] presents a robust robotic arm designed controlled by hand gestures of the operator. The robot is controlled wirelessly with the help of a glove which consist of three primary components: an accelerometer, a flex sensor, and a wireless transceiver. The working is based on the Master-Slave configuration in which the Robotic Part (slave) is controlled by the glove (Master) with the flex sensors incorporated to measure the

In [8] an intuitive force-feedback based approach is discussed. The technology used to achieve wireless control is haptics which uses the force sensors and laser distance sensor to communicate the information about the gripper’s status to the teleoperator module on the glove. Magnetorheological Fluid (MR-Fluid) based actuator tracks the gripper force and the pneumatic pressure gives the operator distance information. It also addresses the major drawbacks of the Telemanipulation system and suggests some ways to optimize it for a remote environment.

[9] illustrates a 3-DOF manipulator based on utilizing the force information which is acquired by unpredicted pulling or pushing action applied to the robot during its interaction with the operator. The paper also sheds some light on DAQmx data acquisition programming which is a widely used method to create tasks and fetch the coordinates of every joint along with the end effector. Moreover, ODF (Open Dynamics Engine) is used to validate the concept and support the results produced by performing different experiments.

In [10] the authors have proposed a way to accomplish Human Computer Interaction (HCI) in electronic way (without mechanical sensors). The robotica arm is based on teleoperation i.e. wireless operations in which the arm replicates the motion of the master (human arm) synchronously with the help of image processing supported by MATLAB. SIFT algorithm is used for hand gesture recognition which is based on the principle of comparing the extracting the feature vectors from the gestures, comparing them and generate the actions.

A. Problem Statement

As we have mentioned about the various techniques used to control the robotic arm in the preceding section. In this section we address the pros and cons of implementing the voice control technique.

In 3D User Interface (UI) the speech input can be a very powerful control technique; It is natural, hands-free and can be combined with other system control techniques to form a multimodal input stream to the computer. These techniques are known to provide an interface between a user and a computer-based application allowing spoken interaction with the application in a seamless manner [11]. The advancement in the speech recognition engine enables it to produce a crystal-clear output even in the presence of the background noise and perturbations. Our paper addresses the fact that variability among speakers (especially the Pitch) doesn’t affect the output in any way. As such, for robotic surgery or handheld AR, dictating the text or numbers is a relatively light-weight method, though tiring, it keeps our hands free.

III. PROPOSED SYSTEM DESIGN

Fig1. Hardware Implementation of 3-DOF robotic arm

In this section we focus on the hardware involved in building the manipulator and the gripper module.
A. Designing the gripper module

![Fig 2(a)](image1)

![Fig 2(b)](image2)

![Fig 2(c)](image3)

![Fig 2(d)](image4)

B. Procedure for the designing process

![Fig 3](image5)

The gripper shown in Fig 2(e) is a Servo-electric gripper with two jaws and a servo motor MG996 attached at its base to control the jaws. Commonly used in industrial settings, the servo-servo electric grippers are easy to control equipped with a pair of flexible jaw to allow different material tolerances while handling parts. Apart from being cost effective they are clean as there are no air lines. Each component of the gripper is designed using SolidWorks software provided by Dassault Systèmes.
C. Designing the manipulator body

In this section we discuss about the designing procedure for the manipulator.

Fig.4 In the figures above the components are shown in the left section which comprise of the base (a), the U-shaped links (b) are used to make the shoulder and the elbow joint and the component shown in (d) is used to attach the gripper to the servo motor. In the right section the 3-DOF robotic arm (e) is shown.

D. Circuit components

1. Arduino Microcontroller

Arduino Uno: Arduino Uno is a medium sized, good, adaptable and breadboard neighborly Microcontroller board, created by Arduino.cc, in light of Microchip ATmega328P. Equipped with 14 digital and 6 analog pins, it has an operating voltage of 5V. With a Flash Memory of 32 KB and EEPROM of 1 KB it is the most commonly used microcontroller for mini projects.

2. Servo Motor
Mg996r Servo Motor - This is a metal gear servo motor. The metal winding have a very high torque at the expense of faster wear-out. With the operating voltage of 5V and the Maximum Stall Torque of 11kg/cm at 6V this is a decent contender for RC toys and robots. Unlike the Mg90S servo motor, this has rotation between 0 to 180°.

3. The Voice module

![Fig.7(a) The voice module](image1)

![Fig.7(b) Microphone](image2)

![Fig.7(c) ADSP-SC57x](image3)

**Voice Module** - The voice module shown in the figure above is one of the key components of this system. It works on the principle of serial data transfer when connected with the Arduino board. It comprises of a Digital Signal Processor (DSP) of SC57X series based on SHARC(Super Harvard Architecture Single-Chip Computer) architecture. It comes with ARM® Cortex-A5 system control capability, which provides high performance for complex applications demanding the latest advanced algorithms.

IV. Software Implementation

In this section we describe the working of the circuit and the core program responsible for controlling the arm. Entire procedure is divided into two phases.

A. Recording phase

The voice module can be configured by sending the commands via serial port after connecting it with an Arduino to the computer. Generally the module is configured to store 15 commands(instructions) at a time, 5 commands in 3 groups.

![Fig.8 Circuit Simulation for connecting Arduino and the voice module. The simulation is made using Fritzing software.](image4)

The voice module comes with -

- Digital interface - 5V TTL level UART interface
- Analog interface - 3.5 mm (mono-channel microphone connector + microphone pin interface)
- The various pins include a GND (ground pin), a VCC(Input voltage pin), RXD and TXD pins to send and receive data (bits).

As shown in Fig.8 the TX and RX of the Arduino are connected with the TXD and RXD pins of the voice module to establish a serial communication. The Arduino is connected to a laptop or a PC. To store the commands into the voice module H-term software is required which is supported by Windows OS. The module is configured by sending commands via the serial port. Serial data format: 8 data bits, no parity, 1 stop bit with the default Baud rate of 9600 bits/sec.

The voice module can be programmed to operate in two modes -

- Common mode
- Compact mode
1. Recording stage

| Parameters     | Value           |
|----------------|-----------------|
| Baud Rate      | 9600 bits/seconds |
| Parity bit     | None            |
| Stop bit       | 0               |
| Send format    | Hex             |
| Receive format | Char            |

Fig. 10 (a) General settings before recording instructions.

Comparing both the recordings of the same command it is stored in the desired group.

Fig. 10(b) H-term software UI

In Fig.10(b) the parameters which are needed to be selected prior to the recording stage. Each voice command has the maximum length of 1300 ms. Once the recording process starts it cannot be stopped until one group (5 commands) are recorded. When the user begins to speak the (D1) LED on the voice module flashes for about 400 ms and turns off. After the command is recorded successfully, the (D2) LED turns orange for about 300 ms. On failure the (D2) LED flashes 4 times within 600 ms. The voice instruction is recorded twice to match with the previously recorded instruction, after successfully comparing both the recordings of the same command it is stored in the desired group.

Fig. 10(c) Commands recorded in groups

B. Identification phase

In this phase the voice commands after recording are tested for validity.

Fig. 10(d) Identification of commands

After recording the commands each group is imported and every command is tested. To test the commands, the user is supposed to speak command in the microphone. If the command is correct then the UI will return the code corresponding to the instruction for eg. ON has code 13, when the user speaks ON in the microphone, the UI should show Result: 13 which means that the command is recorded and stored successfully.

The ADSP processor reduces the effect of noise on the recording process to a greater extent. It uses a high frequency filter for removing noise and quantising the signals to compensate the attenuation happening due to the noise and other perturbations.

V. Working And Result Analysis

In this project, five predefined words which are “Turn Right”, "Turn Left", "Stop", “Clamp” and “Release” were selected to determine the working of this robotic arm. Accuracy rate depends on various factors like noise, the environment, the number of speakers. In the environment with perturbations the performance and recognition rate
decreases significantly. Increasingly far off microphones will increase the number of mistakes and reduce the accuracy. The table shown below summarises recognition rate, the response time for the commands.

| Commands/Instructions | Recognition rate (Number of successful recordings/ Total number of attempts to record ) | Response time (seconds) |
|-----------------------|------------------------------------------------------------------------------------------|-------------------------|
| Turn Right            | 89 % (5 attempts to record)                                                              | 5                       |
| Turn Left             | 89 % (5 attempts to record)                                                              | 5                       |
| Stop                  | 92 % (3 attempts to record)                                                              | 3                       |
| Clamp                 | 92 % (3 attempts to record)                                                              | 3                       |
| Release               | 92 % (3 attempts to record)                                                              | 3                       |

Fig. 11(a) Response time and Recognition rate

VI. FUTURE SCOPE AND CONCLUSIONS

We presented a voice controlled robotic arm based on Arduino. This system combines the principle of speech recognition and robotics thereby improving the operator’s handling ability and is useful even for those who do not have experience about teleoperation. By using only voice module, it has a drawback, when used in the noisy environment the recognition rate reduces significantly.

Further improvements include incorporating machine learning algorithms for more flexibility and boosting the recognition accuracy. Also the robotic arm is easily integrable with a moving rover robot or any master device for various other applications.

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