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Robot Arm Performing Writing through Speech Recognition Using Dynamic Time Warping Algorithm

V. Manoj Kumar, D. Srii Hari Thipesh*

Department of Mechanical Engineering, SRM University, Chennai-603203

P A P E R I N F O

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A B S T R A C T

This paper aims to develop a writing robot by recognizing the speech signal from the user. The robot arm constructed mainly for the disabled people who can't perform writing on their own. Here, dynamic time warping (DTW) algorithm is used to recognize the speech signal from the user. The action performed by the robot arm in the environment is done by reducing the redundancy which frequently faced by the robot arm with high accuracy in both velocity and position in its own trajectory.

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NOMENCLATURE

N	*Newton*	Kg-m	Kilogram meter
mm	millimeter	K-Hz	Kilo-Hertz
N-m	Newton-meter		

1. INTRODUCTION

A robot arm is an electromechanically controlled mechanism, usually programmable, similar to a human arm. Joints connect the links of manipulators allow either rotational motion. The joints of the robotic arm form a kinematic chain. The end of the kinematic chain is called end effector [1-3].

The construction of a robot arm which is capable of performing writing operation by recognizing our voice mainly consists of two parts.

• Speech to text
• Text to an action

The communication between two humans is by speech, the natural and efficient method [4-6]. The biggest problems in speech recognition are avoiding strange noisy sound caused by con-catenation. Such recognizing problems are overcoming by using DTW and Mel frequency cepstral coefficient (MFCC) where signal convert to text takes place [7]. Then, a microcontroller unit (Raspberry Pi 3) receives the text. The text signal from the LABVIEW 2016 is converted into mechanical action by using Python programming language. The servomotor connected to microcontroller unit controls the movement of the pen attached to the end effector of the robotic arm [8]. The objective of the present work concludes that by an implementation of a writing robot system in robot machining can make it more human-friendly, entertaining and robust in operation. It can also improve the cost effective-ness of the operation when implemented in industries for applications such as automobile painting, can printing, etc. A 4 degree of freedom (DOF) robot with formerly mentioned applications is proposed here for the writing purpose. In addition, the above papers explain about the

*Corresponding Author's Email: *thipesh91@gmail.com* (D. Srii Hari Thipesh)

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redundancy problem in robot and how to avoid it too [9].

2. METHODOLOGY

2. 1. Hardware Arms are typically defined by different parameters like axes, DOF, kinematics, accuracy, motion control and workspace of the robot before it performs writing [10]. An end effector is necessary for actual environmental interaction. End effectors are typically chosen based on the application; some common choices are grippers, sprayers, grinders, welders, etc., Here, it is choosing for performing writing.

The speech signal was given as input from the user using a microphone. A PC sound cord connected to microphone converts the analog signal to the suitable digital signal for processing. Then, the obtained digital signal of the spectrum is compared with preprogrammed signal by record voice of particular set of words, and then we get Fast Fourier Transform of all set of words of Mel's coefficient value. For, this process we use DTW algorithm [11]. Then, the output text is transferred to the next level [12].

2. 1. 1. Motor Specification Here, we used 11kg torque servomotor for base and link 1 with specifications given below:

Operating voltage: 4.8-7.2 Volts

Operating speed: 0.18sec/60° for 4.8V (minimum)
0.14sec/60° for 7.2V (maximum)

Stall torque: 11kg/cm for 4.8V (minimum)
16kg/cm for 7.2V (maximum)

Weight: 56gm

For end effector, we use 9g servomotor with 2.2kg torque with specification given below

Operating voltage: 3.5-6 V

Operating speed: 0.12sec/60° for 4.8V (minimum)
0.10sec/60° for 7.2V (maximum)

Stall torque: 1.8kg/cm for 4.8V (minimum)
2.4kg/cm for 7.2V (maximum)

Weight: 11gm

The total process of my project is explained in following block diagram in Figure 1, respectively.

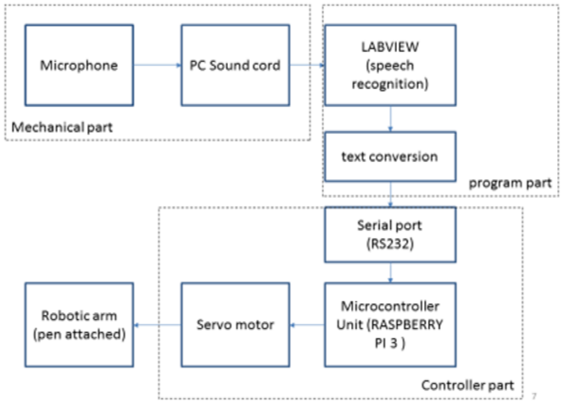


Figure 1. Block diagram

2. 2. CADD Model of the Robot The CADD model of the robot designed in SOLIDWORKS software is shown in Figure 2.

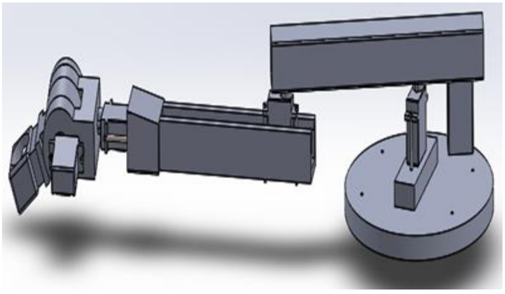


Figure 2. CADD model of the robotic manipulator

2. 3. Software The software used for speech to text is LABVIEW 2016 and dynamic time warping algorithm does it. The programming section makes use of the DTW which is explained in detail as follows.

2. 3. 1. Speech Signal When we produce the speech sounds from our lungs, air flow passes through glottis and then throat and mouth as shown in Figure 3. The speech signal which is excited in three methods depends upon speech signal.

- voiced excitation
- unvoiced excitation
- transient excitation

A speech signal is characterizing as follows, [13-16].

1. The bandwidth of the normal speech signal is 4 KHz.
2. A frequency ranges of the periodic signal is between 80Hz and 350Hz.

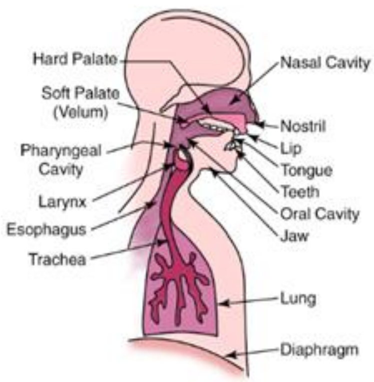


Figure 3. Human speech production system

3. The peak of the spectral distribution of energy at (2n-1) * 500Hz; n=1,2,3, …

By producing sound from our speech production, the outcome will be classified by typical waveform of voiced speech and unvoiced speech shown in Figure 4 respectively.

2. 3. 2. Dynamic Time Warping Algorithm In signal processing analysis, DTW algorithm is used to measure similarities between two spectral speechsignals which may vary in time, frequency and speed. In a temporal sequence of audio, video and graphics data or any other data to a linear sequence, DTW has been applied [17-20]. A popular application is automatic speech recognition, speaker recognition, and online signature recognition. The 1D DFT was defined as:

$$yk = \sum_{n=0}^{N-1} \times n^{e^{-j2\pi kn/N}} \quad (1)$$

for $n = 0, 1, 2, \ldots, N-1$
where, x = the input sequence, N= the number of elements of x, Y = the transform result.
The frequency resolution, or the frequency spacing between the components of Y, is:

$$\Delta f = \frac{f_s}{N} \quad (2)$$

where, f_s is the sampling frequency.

The recognition process of MFCC explained in following block diagram in Figure 5.

3. KINEMATIC ANALYSIS

The kinematic model of the robotic arm is represented by a set of equations which allows estimation of robot's evolution on its trajectory, determination of its position and orientation and elaboration of possible control strategies. All motions of the robotic arm have divided into translation and rotational components.

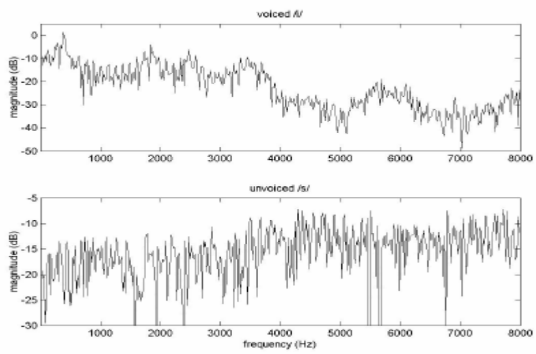


Figure 4. Sample waveform of voiced and unvoiced speech

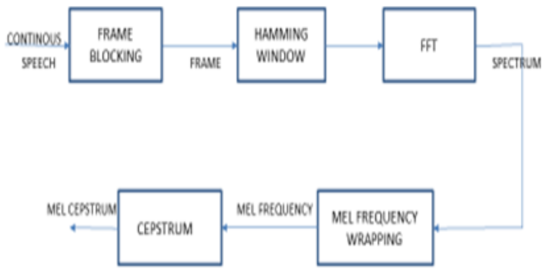


Figure 5. MFCC (Mel Frequency Ceptral Coefficient)

Translation is the displacement of robotic arm's center. Rotation is concerned with the rotational movement of each joint's axis [21-23].

The frame diagram and D-H table for the writing robot of RRRR configuration is shown in Table 1 and Figure 6, respectively.

TABLE 1. D-H Parameter

i	a	α	a	ɵ
1	a1	0	d1	ɵ1
2	a2	α2	d2	ɵ2
3	a3	α3	d3	ɵ3
4	0	0	0	ɵ4

Where, a = link length
α = link twist
d = link offset
ɵ = joint angle

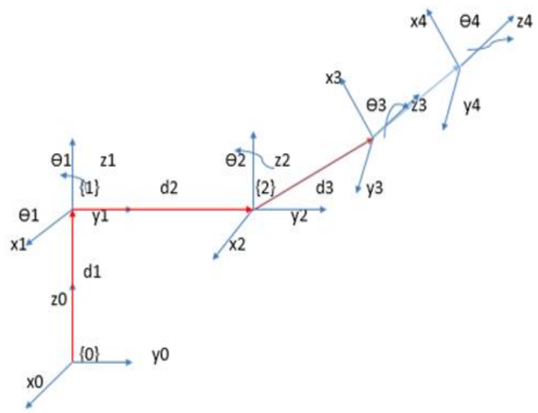


Figure 6. Frame diagram of RRRR robot

$$0T4 = 0T1 \times 1T2 \times 2T3 \times 3T4$$

$$0T4 = \begin{array}{cccc} C123*C4 & S123 & C123*S4 & (S123*d3)+(C123*S3)+(C12*a2) \\ S123*C4 & C123 & S123*S4 & (C123*d3)+(S123*a3)+(S12*a2) \\ -S4 & 0 & C3 & d1+d2 \\ 0 & 0 & 0 & 1 \end{array}$$

Following figures depict the kinematics analysis of the robot with RRRR configuration and the workspace analysis obtained via MATLAB is shown in Figure 7.

3. 1. Force and Torque Calculation

3. 1. 1. Calculation For Link 1

Force Required = Load (In Newton's) x Acceleration due to gravity
= 2.45 N x 9.81
= 24 N
Torque required = Force x Perpendicular Distance
= 24 N x 200 mm
= 4.8 Nm
= 0.48 Kg-m

3. 1. 2. Calculation For Link 2

Force Required = Load (In Newton's) x Acceleration due to gravity
= 2.2 N x 9.81
= 22 N
Torque required = Force x Perpendicular Distance
= 22 N x 155 mm
= 3.41 Nm
= 0.341 Kg-m

3. 1. 3. Calculation for Tool Holder

Force Required = Load (In Newton's) x Acceleration due to gravity
= 1.6 N x 9.81
= 16 N
Torque required = Force x Perpendicular Distance
= 16 N x 80 mm
= 1.76 Nm
= 0.176 Kg-m

4. EXPERIMENTAL ANALYSIS

The experimental analysis of speech to text is done by LabVIEW 2016 and letter analysis graph of robot movement in manual are shown in Figure 8. For letter analysis we have to create own template to measure angle as shown in Figure 9.

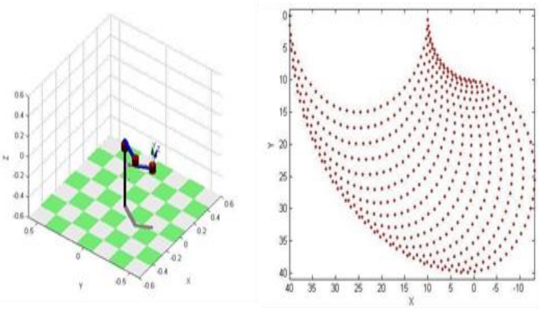


Figure 7. Kinematic analysis and Workspace analysis

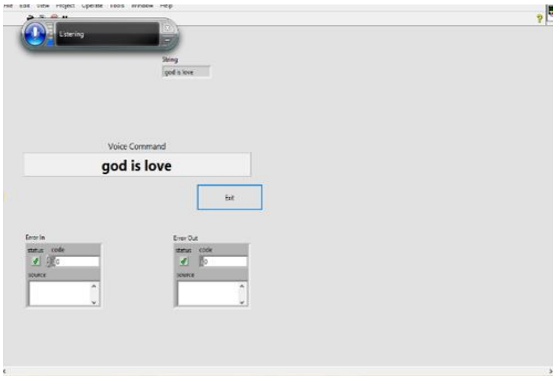


Figure 8. Speech to text in LabVIEW 2016

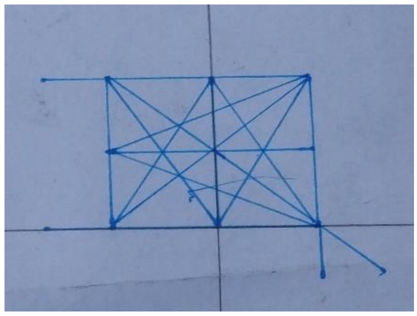


Figure 9. Template of alphabets from A-Z

The pencil is fix in each link of robot and the robot links are move by method of teach pendant according to template to find the angle of each motor which is shown in Figure 10. By measuring the angles of each motor we can easily control the movement of robot and reduce the redundancy faced by robot.

The letter analysis made for each and every letter. Then, we have to plot graph for every letter and analyze the movement of robot and redundancy that faced by robot in movement. The letter analysis of alphabets is shown in Figure 11.

5. IMPLEMENTATION OF ALGORITHM

To control dynamic motion in robot manipulator, it requires the actual production of trajectory and dynamic parameters (e.g., position, velocity, and acceleration) [24-27].

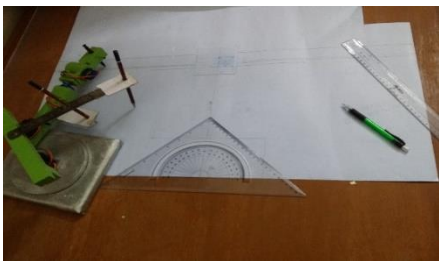
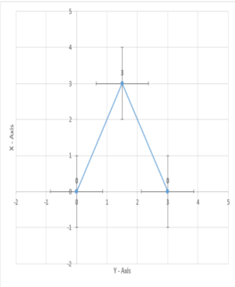
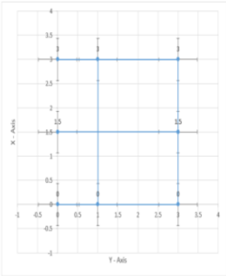


Figure 10. Motor angle measurement analysis


LETTER - A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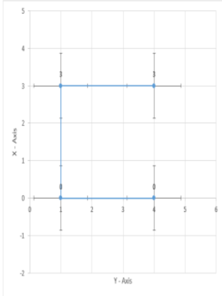
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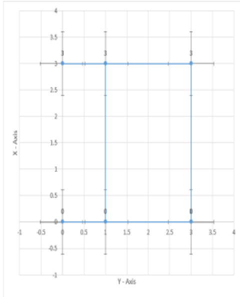
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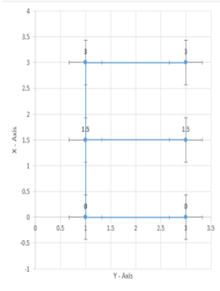
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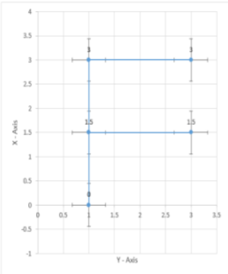
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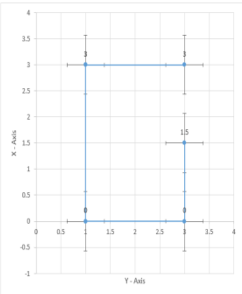
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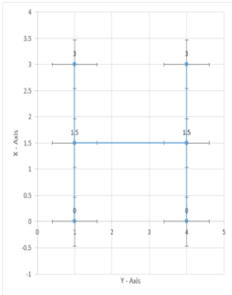
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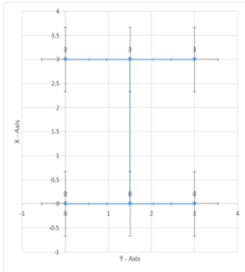
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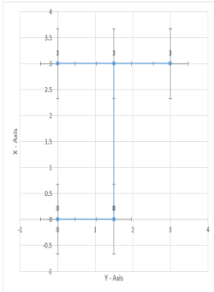
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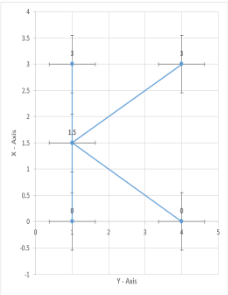
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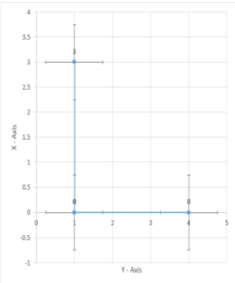
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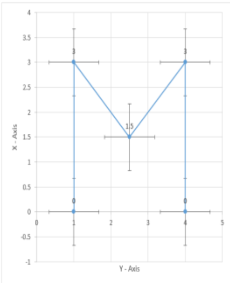
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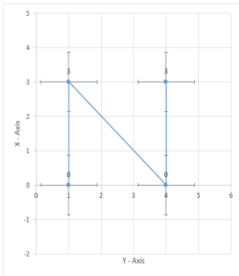
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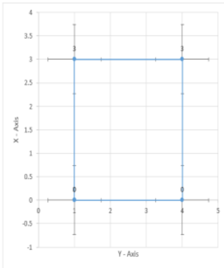
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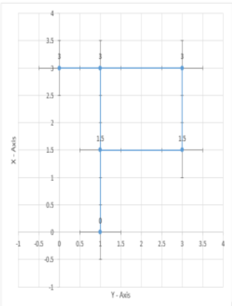
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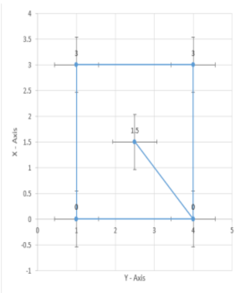
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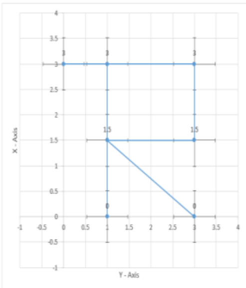
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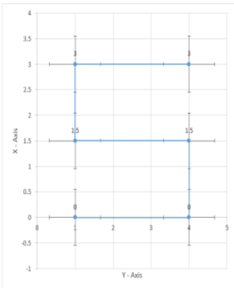
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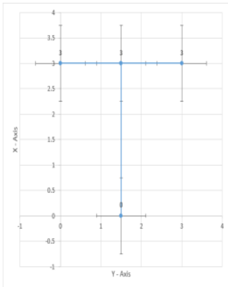
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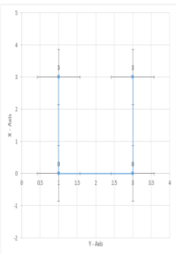
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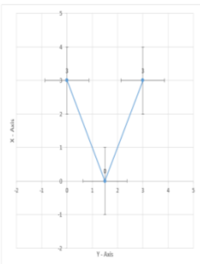
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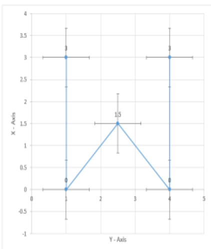
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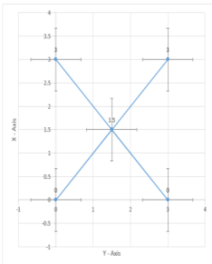
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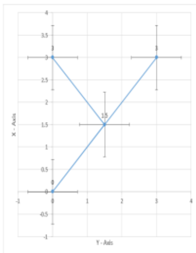
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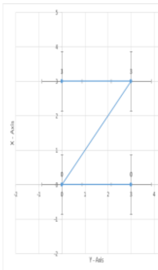
LETTER -Z

Figure 11. Letter analysis of robot movement

In a mechanical point of view, a robotic arm replicating a human arm is Kinematic redundancy, i.e., a degree of mobility that possesses by its mechanism is higher than that given motion task in Workspace [28]. Kinematic redundancy obtains the avoidance of mechanical limits in robot joints, avoidance of obstacle while performing tasks, avoidance of singularity in motion, fault-tolerant operation, robot dynamics optimization, distribution of joint motions like a human arm, etc., [29-32]. The writing process was performed by receiving the output of spoken word from LabVIEW. By using end pint detection, we compare the both per-programmed signal with input voice signal as shown in Figure 12.

The flow chart of implementing writing process is given in Figure 13.

6. DESIGN CONSIDERATION

The writing robot setup is assembled of a right-handed robotic manipulator as an end effector with pen tip holder as shown in Figure 14 and a microcontroller (Raspberry Pi 3) and a laptop. Human assist the installation, and their role is to change the set of paper, and the signal given to the robotic arm performs writing. The human operator also controls the reset button and is capable of initiating the pre-calibration process if required.

7. RESULTS

By implementing the robotic manipulator in the experimental setup, the following output is obtained. We were working with the proposed aim of constructing the robotic arm write by speech recognition.

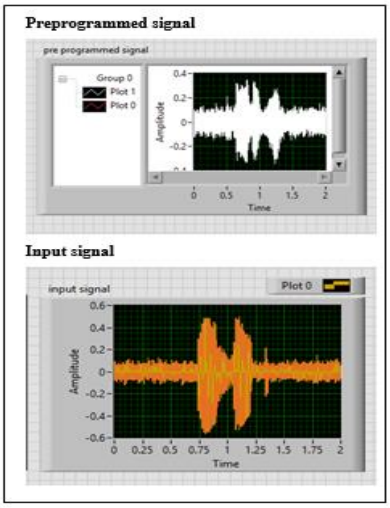

Figure 12. Matching preprogrammed and input signal Waveform

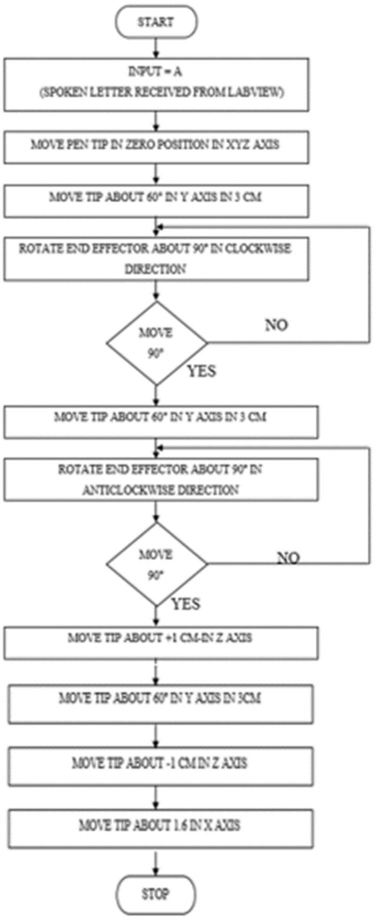

Figure 13. Flow chart for implementation of algorithm

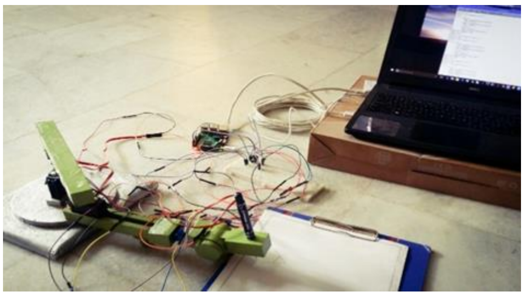

Figure 14. Fabricatied model of robot arm performing writing task

We found that this type can readily be used by physically challenged people as it was compact. For obtaining higher levels of performance, we need to implement the microcontroller of higher memory levels. In other application, we include such basic functions as pick and place, lifting, etc., which enable the people to use it for daily life activities.

8. CONCLUSION

A robotic manipulator with the ability of writing is recreational use in robotics, and it also increases interaction between human and robot. Although there are several such robotic manipulators which can write provide to it, this project implies a robotic manipulator who makes use of the Mel Frequency Cepstral Coefficient by DTW algorithm [33-38]. It enables the robotic manipulator to write by recognizing speech with less complexity and to also provide satisfactory results over a flat surface. The robotic manipulator can find applications in the field of automobile automation, printing industry and disable people who can’t be able to write.

The calibration was done with a consuming time in the task, and if the writing surface is disturbed, the calibration won’t work. Moreover, a difficulty is calibrating arbitrarily shaped surfaces that not have constant geometry perfectly. This large snag in this project is to deal in the future.

9. ACKNOWLEDGMENT

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Robot Arm Performing Writing through Speech Recognition Using Dynamic Time Warping Algorithm

V. Manoj Kumar, D. Srii Hari Thipesh

Department of Mechanical Engineering, SRM University, Chennai-603203

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چکیده

این مقاله قصد دارد که یک ربات نوشتن را با استفاده از شناسایی سیگنال گفتاری از کاربر توسعه ببخشد. بازوی ربات عمدتا برای افراد معلول ساخته شده است که نمیتوانند خودشان عمل نوشتن را انجام دهند. در اینجا، الگوریتم انحراف زمان پویا (DTW) برای تشخیص سیگنال گفتاری از کاربر استفاده می شود. عمل انجام شده توسط بازوی ربات در محیط زیست با کاهش بار اضافی انجام می شود که اغلب با بازوی روبات با دقت بالا در هر دو سرعت و موقعیت در مسیر خود روبرومی شود.

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