ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)

Vol 9, Issue 7, July 2022

Doctor On-Board

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Abstract— ***Healthcare is an important aspect of human life. In developing and backward countries, the quality of healthcare is very poor. It has been instructed by WHO & Governments to get vaccinated to be safe from the attack of COVID-19. But due to lack of resources and manpower of doctors & nurses, the process of vaccination is taking a very long time to reach the mark globally.***

This project solves the above said problem by making it easy for everyone to get vaccinated irrespective of the shortage in manpower. The name "DOCTOR ON-BOARD" has been generated for this project because it contains the whole setup of vaccination on a table. By utilizing the components like motors, sensors and actuators it is possible to create a robotic arm. In turn, sensors will detect the position of the human arm and the robotic arm injects the medicine without any interference of doctors. This reduces the workload of humans which results in the increase the productivity of Mankind.

Index Terms—Mechatronics, Medical Robotics, Robotics, Vaccination.

I. INTRODUCTION

Medical Robotics is one of the most important and vastly developed branches of Robotics all around the world. This primarily focuses on Articulated Medical Tasks that are difficult to be performed by humans. The main key point that must be followed in the Medical Industry is preciseness and accuracy, which can be attained by robots more than humans.

There is a high chance of error if a task is performed by humans, as humans don't perform or calculate any mathematical equations before performing tasks, humans perform the task based on the experience but robots perform the tasks mostly by the mathematical model (Like Trajectory planning etc.) which results in low error rate.

As we know this world is a nonlinear place where everything is vague. There are places where proper facilities for medical purposes are provided and there are places where no proper facilities are provided. To overcome such nonlinearity, we can use medical robotics. Which will improve the standard of Health Care irrespective of the territory or region.

It is impossible for robots to overtake the medical/ Healthcare Industry as healthcare is a sensitive area where high intelligence is required for taking on spot decisions, which cannot be done by robots even if they are given high level training with different technologies.

We can conclude by saying that we cannot eliminate the traditional method of healthcare but we can instead bring robotics in this field and take advantage from its precise performance of tasks and meet the demand that is being generated in this world.

II. MOTIVATION AND DESIGNING

The name "DOCTOR ON-BOARD" has been generated for this project because it contains the whole setup of vaccination on a table without any human interference. This manipulator needs contribution from both mechanical, electronics and computer science part. The flow of the work to build it will be in following way:

- Detection/ Spotting the deltoid muscle to be pierced using sensors
- Cleaning/ sanitizing the part that is to be injected.
- Picking up the Syringe, filling in the Medicine, injecting in the spotted location and disposing the syringe.

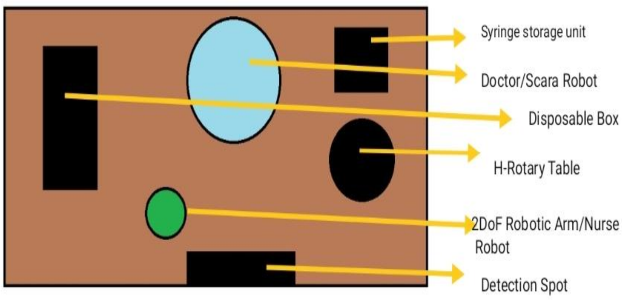

Fig.1. Structure and representation of all the individual parts of project

Syringe Storage Unit: It is a rotary table but in horizontal way which will store the stock of syringes

Doctor Bot: It is a scara bot which is the most important of all other parts, it performs the injection part.

Disposable Box: It is where can syringe is disposed after the injection is finished

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H-Rotary Table: It is a horizontal rotary table where the medicine is stored.

Nurse Bot: It is a 2DOF bot, which will sanitize the part which should be injected.

Detection Bot: It is frame/part which helps in detection of deltoid muscle. This is second most important part.

III. DETECTION OF DELTOID MUSCLE

An Ultrasonic sensor is used to spot the ends i.e., elbow and the ball and socket joint, through which the ratio is calculated to find the vaccination spot. A platform near the ball and socket joint which can be adjusted as it has a linear motion, once the ends of the arm is fixed, the ultrasonic sensor finds the distance between the platform and the topmost part of frame. By this we can determine the height of arm which will indeed result in detection of deltoid muscle.

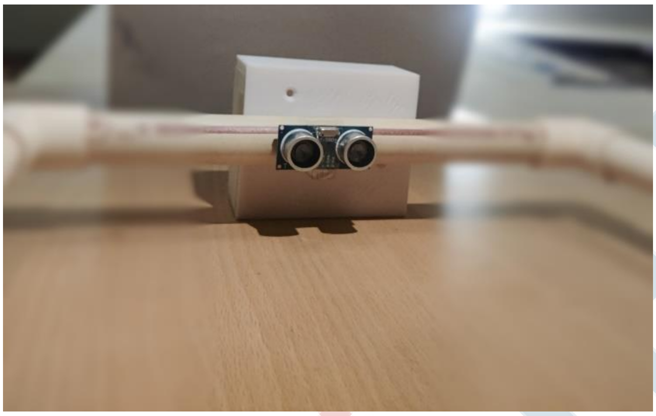

Fig.2. Bottom View of detection system using PVC pipes and Ultrasonic sensor.

This frame is built to place the arm under that conveniently and the ultrasonic sensor will perform its work and sends the information to Nurse Bot and Doctor Bot.

Fig.3. Front view of detection system ultrasonic sensor

The white box consists of an Arduino for processing and a Node MCU for transfer of information. (Bluetooth module can also be used)

IV. DESIGN AND WORKING

The Doctor bot is a SCARA Robot, which is 4 degrees of freedom robot. It is the most important part on the whole setup, as it has many functionalities. Step by step functionalities are:

1. Picking up the syringe from Horizontal Rotary Table
2. Finding the detection spot and sending the spot to doctor bot
3. Filling the medicine into the syringe
4. Piercing into the arm (at Deltoid Muscle)
5. Releasing the fluid into the arm using the end effector attached at the end effector
6. Disposing the syringe
7. 1Repeating process for next person

A. Forward Kinematics

The forward kinematics is required to find the position and orientation of the tool tip once the parameters of the actuators are given.[1] It is a procedure by which the angles are given to the arm and the position of the end effector is detected. D-H Parameter approach is used here.

Procedure to follow using Denavit-Hartenberg convention [2].

The travel from the base frame to the end-effector frame is achieved by moving across two consecutive frames placed at the joints. The set of four parameters relates the transformation between Frame *i* to Frame *i*+1 by *di*, *θi*, *ai* and *αi*,

Table 1. D-H parameters of the Doctor Robot.

S. No	*θi*	*di*	*αi,*	*ai*
1	0	d	0	0
2	*θ2*	-h2	0	L2
3	*θ3*	-h3	0	L3
4	*θ4*	-h4	0	0

Forward Kinematics matrix:

$$^{i-1}T_i = \begin{bmatrix} \cos\theta_i & -\sin\theta_i\cos\alpha_{i,i+1} & \sin\theta_i\sin\alpha_{i,i+1} & a_{i,i+1}\cos\theta_i \\ \sin\theta_i & \cos\theta_i\cos\alpha_{i,i+1} & -\cos\theta_i\sin\alpha_{i,i+1} & a_{i,i+1}\sin\theta_i \\ 0 & \sin\alpha_{i,i+1} & \cos\alpha_{i,i+1} & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

Here the first joint is Prismatic then there is a rotary joint which is at a distance below and there is another rotary joint which at one more step below and there is an end effector and there the actuator with a hook attached near the end effector.

ISSN (Online) 2395-2717

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$$T1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T2 = \begin{bmatrix} \cos\theta 2 & -\sin\theta 2 & 0 & L2\cos\theta 2 \\ \sin\theta 2 & \cos\theta 2 & 0 & L2\sin\theta 2 \\ 0 & 0 & 1 & -H2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T3 = \begin{bmatrix} \cos\theta 3 & -\sin\theta 3 & 0 & L3\cos\theta 3 \\ \sin\theta 3 & \cos\theta 3 & 0 & L3\sin\theta 3 \\ 0 & 0 & 1 & -H3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T4 = \begin{bmatrix} \cos\theta 4 & -\sin\theta 4 & 0 & 0 \\ \sin\theta 4 & \cos\theta 4 & 0 & 0 \\ 0 & 0 & 1 & -H4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

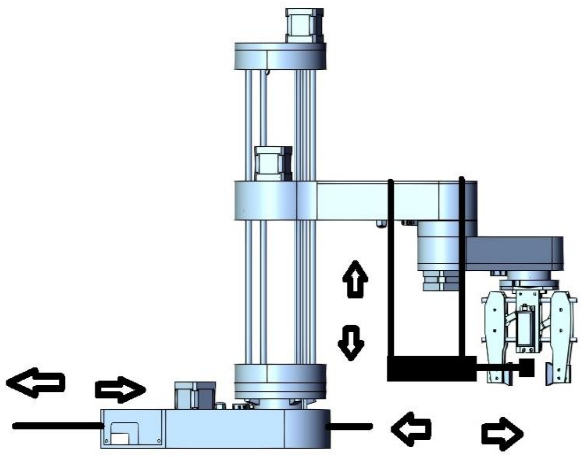

Fig. 4. Image of the Doctor Bot with actuator attached at end effector with a hook

The black colour hanging part represents the actuator which is attached with hook, when the end effector holds the syringe the hole of the syringe couples with the hook of the actuator and which will lead to the to and fro motion which will help in injecting the medicine.

B. Inverse Kinematics:

When we are given the end effector positions, then finding out the angles between the links is called inverse kinematics, it is one of the tough tasks.

Inverse kinematics of robot derived by solving for values of joints parameters (θ 2, θ 3) and values of two links parameters (d 1, d 3).

Calculation of θ_2 angle,

$$C_2 = \frac{p_x^2 + p_y^2 - a_1^2 - a_2^2}{2a_1a_2}$$

$$S_2 = \text{sqrt}\ (1 - C_2^2)$$

$$\theta_2 = \text{arcos}\ (C_2)$$

$$\theta_2 = [-1\ \ 1]$$

This can be similarly worked with another angle.

C. Jacobian

The Jacobian matrix in robotics is used for many calculation methods such as

Smooth trajectory planning and execution

Singularity determination

Derivation of dynamic equations of motion

Torque calculations.

The linear and angular velocities of the SCARA robot can be found in terms of joint velocities. The linear velocity can be defined in terms of the position of the end effector. After conducting the intermediate operations, the Jacobian matrices are obtained.

D. Control System.

A control system manages, commands, directs, or regulates the behavior of other devices or systems using control loops.

Steps followed:

- Selection of control structure.
- Forming Transfer Equations for Each Motor.
- Tuning PID controller.
- Output Graph.

There are many types of controllers namely proportionality controllers, integration controllers, derivative controller and many more but we are using PID controllers for our application. It is one of the, best proven controllers as it can control the ups and down's and avoids kinks in output graph as it has all three i.e., proportionality, integration and derivation integrated in it.

We have used Simulink to draw the control structures and complied it to get the output graph.

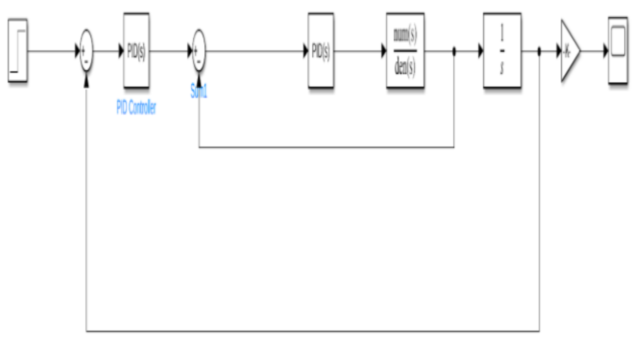

Fig. 5. Control Structure used for all the three motors of Doctor Bot.

At last, in the control structure the gear ratio is multiplied for consistent output. Two PID controllers are used here [4].

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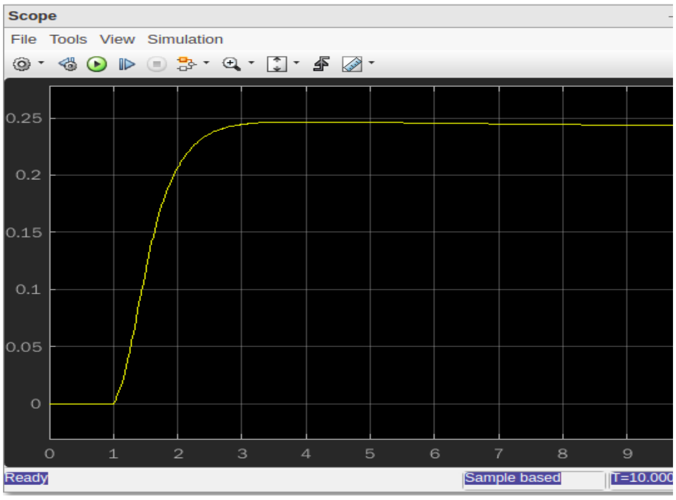

Fig. 6. Output graph of the control structure after tuning with PID controllers.

The output is a clean curve and it takes just less than 4 seconds to reach the required angle without any kinks [5].

The integration of physical model and control structure for simulation.

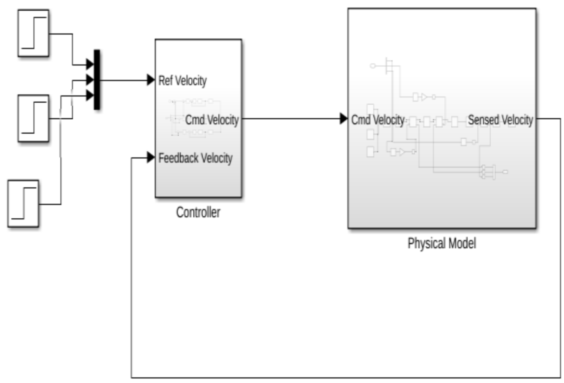

Fig. 7..Integration of control structure and physical model.

Here 3 inputs are for the 3 motors and end effectors work is just to hold the syringe.

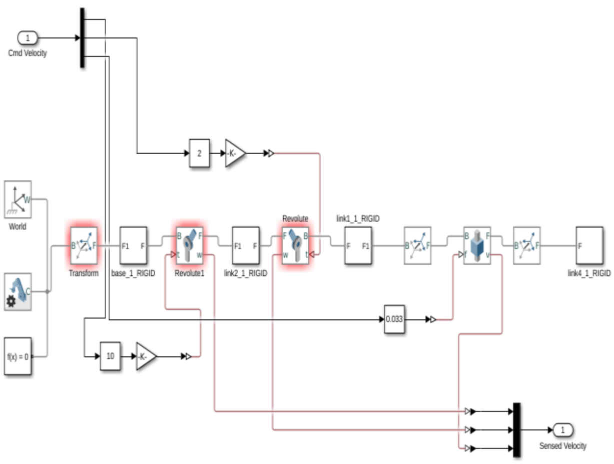

Fig. 8. Physical Model of the Doctor Bot.

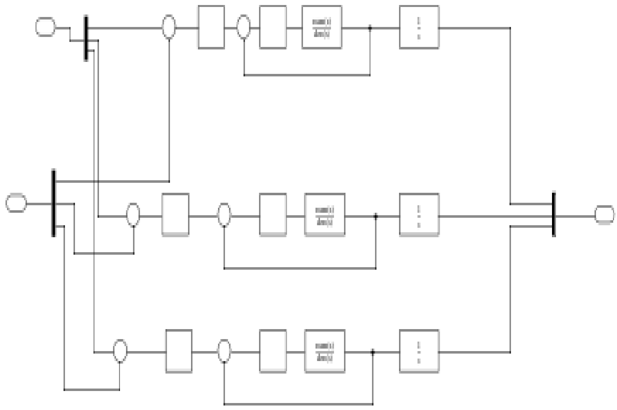

Fig. 9. Amalgamation of all the three-control structure for the three motors.

E. Modified Syringe and Actuator

The syringe is modified by attaching a ring at the end by which the actuator can hook into it and control the syringe. After the end effector reached the final point, the actuator will hook itself in the ring attached at the end of the syringe and it can move the syringe forward (injecting) and backwards (to take medicine in the syringe)

Fig.10. Modified syringe with a hook to lock with the actuator.

The actuator is also attached with a hook on it as it should control the syringe located at the end effector.

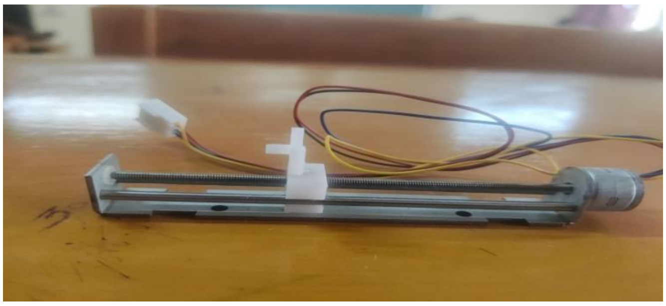

Fig. 11. Modified actuator with a hook to perform the forwards and backward motion after locking with the hook in the syringe.

F. Relative Motion Between Arms

The moment of syringe piercing (not the flow of medicine into body), piercing represents the piercing of needle part inside the arm before injecting will be done using the relative velocity of rotary motor 2 and rotary motor 3. When rotary motor rotates clockwise which turns the arm towards right with some velocity and with same velocity if the motor 3 turns anti clockwise with same velocity, the end effector holding syringe will move in straight line. Or even the vice versa between motor 2 and 3 will result same but the velocity must be same.

G. Hardware and Software Modules

Nema-17 motors are used and MG996R servo motor at end effector. The prismatic joint is sliding across 4 smooth rods with help of a lead screw.

In software modules we have used Arduino module as programming was done in Embedded C. the total programming part was to program to detect the deltoid muscle and transfer the information about the deltoid muscle to the doctor bot. Another programming is done for the doctor bot for its flow of work and then the actuator is actuated to either remove the medicine from the bottle or to inject the person.

V. FURTHER WORKS

There can be some advancements done in this project. There are mainly two advancements:

- To integrate ANN (Artificial Neural Networks) and image processing to find the position of deltoid muscle.
- Converting the 4 DOF robot to 6 DOF for better accuracy.

VI. ACKNOWLEDGEMENT

We owe a debt of profound gratitude to all the professors of SASTRA University who helped us in this project especially Dr. Anjan Kumar Dash, Dr Badri Narayanan, Dr M Ganesh who contributed with their expertise.

VII. CONCLUSION

The Mechanical side of the project, which is the fabrication, selection of hardware, 3D Printed parts, Forward Kinematics, Inverse Kinematics was properly formed and performed. A vast and detailed mathematical model is built which helps the working of the motors, actuators and in total the working of the manipulator properly.

A control structure has been built with two loops of feedback which can help the manipulator to be accurate as much as possible.

Hardware components are selected in such a way that it can bear somewhat heavy weights too. By integration of all this this whole setup can be used for vaccination/Injection purposes.

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