Design and development of 5-dof robotic arm with a mechanical gripper

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***Abstract*— The objective of this study is to conceive and construct a robotic arm possessing five degrees of freedom (DOF). This endeavor may be divided into three distinct phases: the design phase, which entails conceptualizing the arm's structure; the control logic phase, which involves formulating the algorithms necessary for governing the arm's movements; and the hardware mechanism phase, which encompasses the selection and implementation of the components responsible for controlling the motion of the arm's links and joints. In order to regulate the movement, a mobile application has been created, utilizing the Bluetooth module HC-05 for transmission, which provides a range of roughly 10 meters. The code has been implemented in the C++ programming language, allowing for either automated or manual control of the motion through the mobile application. The Arduino Mega microcontroller is employed for the purpose of establishing a connection between the wireless controller and the robotic arm. The utilization of 3D printing technology is employed in the advancement of a robotic arm. The prototype that has been built is anticipated to address the issue of manual object choosing and positioning.**

Keywords*— *Bluetooth, Microcontroller, 3D printing, Wireless Controller

I. Introduction

The industrial sector is expanding quickly. As a result, industrial automation is crucial in today's environment. Pick and place mechanisms are necessary for all automated operations to transfer and rotate goods on production tables or conveyors. Robotic arms, however, are fixed at one point and are unable to travel to other areas, unlike a human worker who may pick up a product or material, carry it to a separate workstation for a different operation, and then deposit it on another. [1] The robotic arm is a sophisticated mechanical device that replicates the motions and uses of the human arm. It is frequently utilized in manufacturing and other fields where the accurate and precise performance of repetitive tasks is required. In comparison to human employees, the robotic arm offers several benefits, such as the capacity to operate constantly, a decrease in human mistake rates, and an increase in productivity. The use for which a robotic arm is intended determines its design. The end-effector, the arm, and the base are the three basic parts that make up the majority of robotic arms. The arm's end-effector is the portion that engages with the outside world and carries out the necessary function. The end-movement effectors and location are controlled by the arm, while the arm is supported by and stabilized by the base. A robotic arm is built using a variety of materials, including steel, titanium, and aluminum. Electric motors, pneumatic actuators, hydraulic actuators, or a mix of these are frequently used to power the arm's joints. The robotic arm's control system is made up of sensors, actuators, and a CPU that interprets input signals from the user or the environment into the proper actions. [2]

Functionality-The end-effector and control system programming are what determine how well a robotic arm works. Many applications, including welding, painting, and pick-and-place tasks, can be accommodated by the end design. effector's Programming methods like teach-pendant programming and off-line programming can be used to operate the robotic arm. The robotic arm's movements, such as moving, grabbing, and releasing things, are conducted in a certain order according to programming. [3] Types and Applications: Based on their construction, motion range, and payload capacity, robotic arms may be divided into many varieties. Robotic arms of the articulated, Cartesian, cylindrical, polar, and scara varieties are the most prevalent. Each kind is ideal for particular uses and has benefits and disadvantages of its own. [4] Articulated robotic: Since they feature a jointed construction and a high degree of freedom, articulated robotic arms are ideal for applications that call for flexibility and mobility. They are frequently employed in material handling, painting, and welding.

-Cartesian robotic arms can be used for tasks that call for accurate, repeated motions and have a rectangular workspace. They are regularly utilized in packing, assembly, and pick-and-place processes.

Robotic arms with circular workspaces are appropriate for uses that call for a large payload capacity. They are frequently employed in demanding material handling and assembly tasks. Polar robotic arms are appropriate for applications requiring a high level of accuracy and precision because they use a polar coordinate system. They are frequently employed in medical procedures including imaging and surgery. Scara robotic- While they have a smaller range of motion, scara robotic arms have a similar construction to articulated robotic arms. They are appropriate for tasks like pick-and-place operations and assembly that need great speed and accuracy. [5]

However there are challenges: The high cost of development, the complexity of the programming, and the safety issues surrounding the interaction of the robotic arm with people have all been difficulties for the development of robotic arms. Recent technological developments, such as the creation of collaborative robots that can operate securely with people, have nonetheless solved some of these issues.

Future advancements in the field of robotic arms include the development of self-learning robotic arms that can adapt to different environments and tasks without the need for programming. [6] An embedded system is a collection of computer hardware, software, and maybe other mechanical or non-computer pieces that are used to carry out a particular task. An embedded system is a microcontroller-based, software-driven, dependable, real-time control system that is marketed into a competitive and price-conscious market, autonomous, or human or network interactive, working on a variety of physical variables and in a variety of situations.[7] A standard commercial or scientific application, a PC or UNIX software system, or a computer. the system used largely for processing are not examples of embedded systems. Systems that are both high-end and low-end embedded [8].

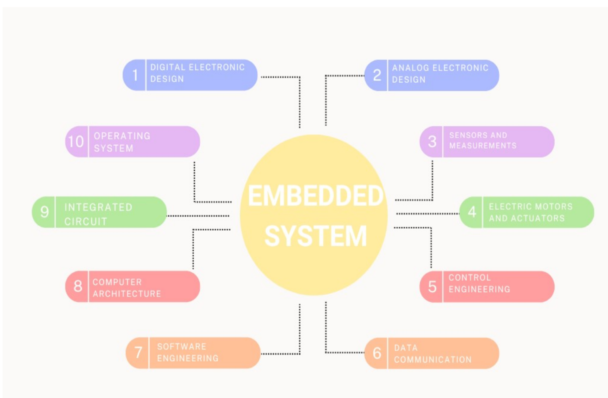

Fig-1 Embedded System Framework

II. DESIGN

For designing the robotic arm we will use AutoCAD Fusion 360

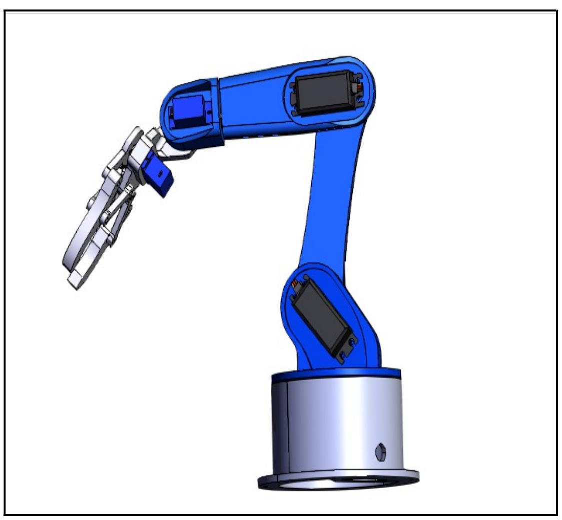

Fig 2- 3D CAD model of the robotic arm

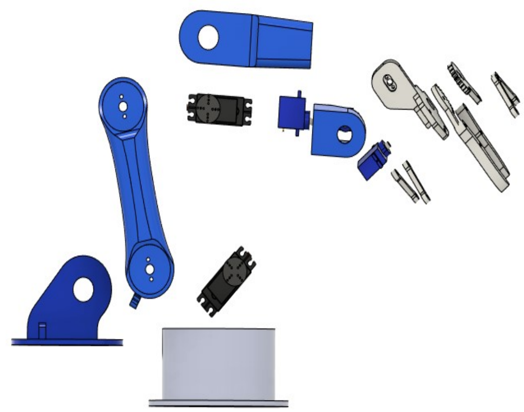

Fig 3- Exploded 3D view of the robotic arm

Calculation- One of the six actuators on the arm opens and closes the gripper in the kinematic model, which does not count as a degree of freedom. The total degree of freedom for the entire system is five, with one degree of freedom for each of the five spinning actuators. The relation: represents the Gruebler-Kutzbach equation, which mathematically expresses the DOF of the arm. [9,10]

$$A = 3 * (b - 1) - 2 * M1 - M2 \quad (1)$$

where M1 is the number of joints with one DOF and M2 is the number of joints with more than one DOF, A is the

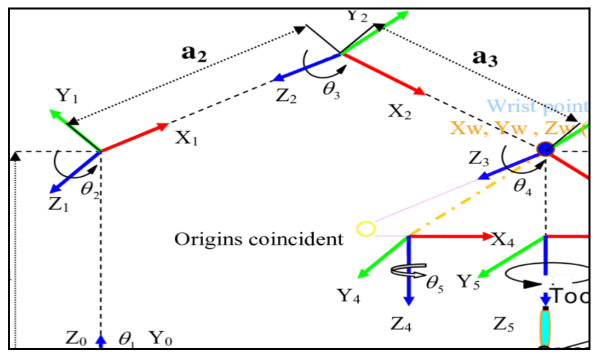

Fig 3- Axis and joint movement representation [10]

system's DOF, n is the number of links (including the base frame), and b is the number of links.

The joints (1, 2, 3, 4, and 5) and links (Z1, Z2, Z3, Z4, Z5, and Z6) of the arm are visible. As there are no joints with two DOF in the system, the M2 value is 0.

Therefore:

$$A = 3 * (b - 1) - 2 * M1 - M2 = 3 * 5 - 10 \Rightarrow (6)\ A = 5 \text{ DOF [11]} \quad (2)$$

III. METHODOLOGY

Figure 4A and figure 4B represent the actual robotic arm model created with the help of 3D printing. For a clear understanding of the links, both lateral and font view is represented.

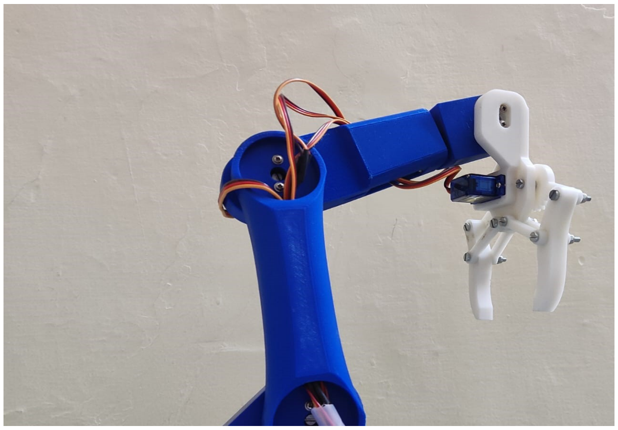

Fig 4A - Robotic arm model lateral view

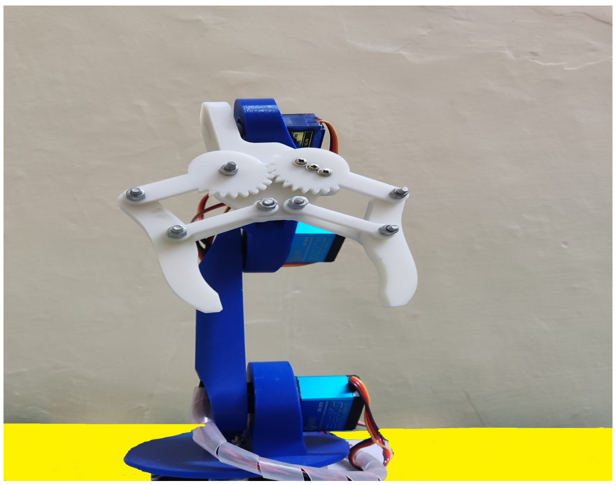

Fig 5- Robotic arm model front view

A. *Hardware Connection*

Circuit board- A customized circuit board was designed to fulfill our design requirement consideration, it provides the connection to the servomotor, steeper motor, and drivers
The circuit connection is shown in the following pattern[11,12]

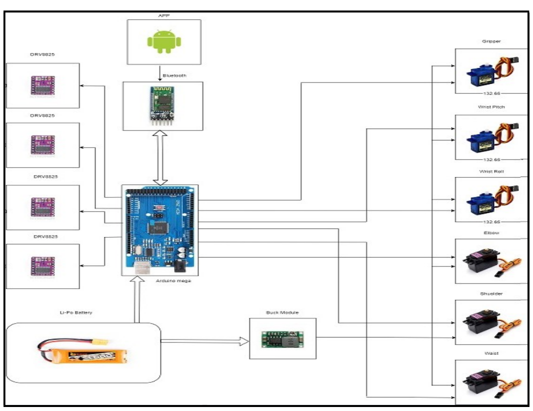

Fig 6- Electric circuit diagram connection

B. *CODE*

This section covers the programming for the robotic arm. The application used is called the Arduino IDE (Integrated Development Environment). The programming languages C and C + + are supported by the software. Programmers have access to a variety of input and output methods using the software libraries provided by the Arduino IDE. One way to include a library that is used to identify mathematical equations while programming is by adding # includes math. h> to the command line of the Arduino IDE,[13-16] for example. We created four programmers that show how the arm sensor works with various contemporary industrial forms of production by looking back at prior research.[17]

```
servo02.attach(3);
servo03.attach(4);
servo04.attach(5);
servo05.attach(6);
servo06.attach(7);


// Define baud rate of the Serial3 module
Serial3.begin(9600);
Serial3.setTimeout(5);
delay(20);
```

Fig 7- Sample Code for Arduino in C

Arduino Mega – Arduino—The open-source Arduino board, a microcontroller board, is built on an Atmega 2560 CPU. The expanding environment of this board executes the processing or wiring language. These boards have revived the automation industry because of their user-friendly platforms, which enable anybody with little to no technical experience to start by learning the skills required to operate and program the Arduino board. These boards may be used to expand many interactive things or connected to computer applications like Max MSP, Processing, and Flash.

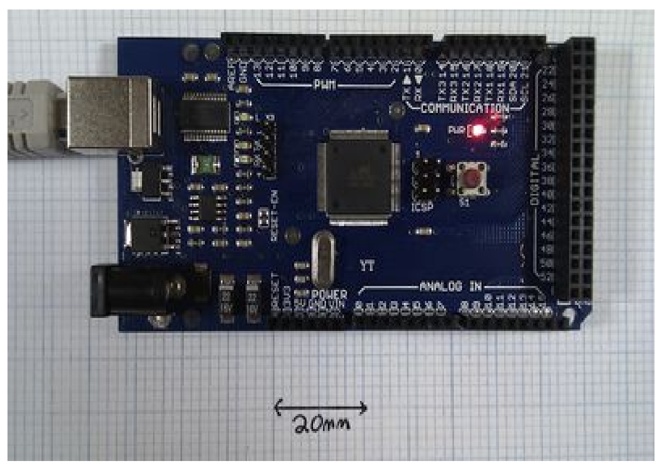

Fig 8- Arduino Microcontroller [15]

Mobile Application- For the mobile application we have used the MIT APP inventor, coding with the backend using the interface is quite convenient with the coding block, the coding for the app is done in C++. [18-22]

The application allows the movement of the robotic arm the mobile application is connected via Bluetooth connection and has a range of 10m. After coding the interface we convert our files into downloadable apk which can be downloaded and shared with multiple mobile phones.

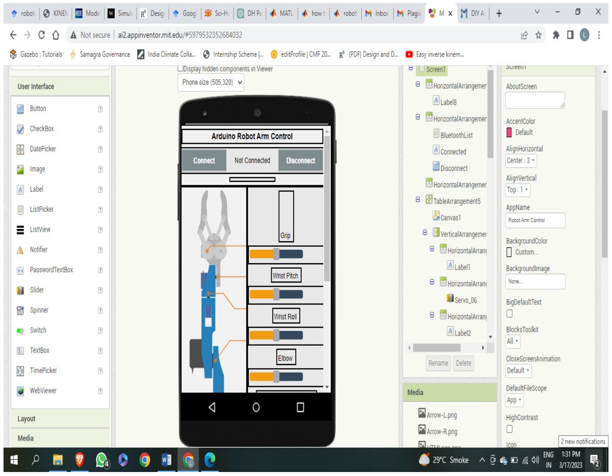

Fig 9A- Mobile Application Frontend

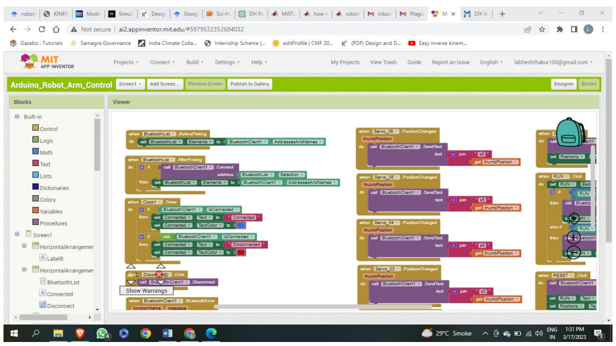

Fig 9B- Mobile Application Backend code with blocks

CONCLUSION

The investigators have successfully designed and built a robotic arm that possesses five degrees of freedom (DOF). The robotic arm's ability to manipulate and relocate objects is made possible by the presence of a mechanical gripper on the end of the arm. Utilizing an Arduino microcontroller makes it easier to manage motors and motor drivers in a system. This is because of the versatility of the Arduino platform. According to the results of the tests that were carried out, our robotic arm has proved that it is capable of moving in five different degrees of freedom (DOF). It is possible to save the coordinates of the robotic arm and then use them later for the purpose of automating processes. By utilising a mobile application, the management of position control may be made available on any mobile device that is equipped with Bluetooth capabilities. This accessibility can be achieved by using any mobile device.

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