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Development Of Robotic Arm On An Omnidirectional Base

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Abstract

Robotics and automation have evolved into an industry's basic requirements. The primary goal of this project is to create a working prototype of a robotic arm mounted on an omnidirectional wheeled vehicle. In the manufacturing industry, this aids in the transportation of various materials. It is primarily intended for lifting an object with high accuracy and repeatability from and to a specific location. It can be fully controlled by a worker using specialised software or instructed to repeat a process in a loop.

Keywords— robotic arm, omnidirectional base, high accuracy, pick and place.

I. Introduction

Robotics is becoming increasingly important in industrial domains because of their technical applications. Robots are commonly utilised to do repetitive and unpleasant activities. On the one hand, a robotic arm is used to lift small objects in a repetitive motion in an assembly or packing line. On the other hand, mobile robots' ability to move through a particular operational environment is critical. This project demonstrates how a five-axis robotic arm and an omnidirectional base can work together to improve the arm's performance. The arm's light material lifting task and the mobile base's ability to move instantly in any direction would be ideal for any industrial application.

The main objective focuses on shifting an object with high accuracy, which is an important requirement for industries manufacturing products involving electronics. The goal is to achieve it more quickly by lowering the vehicle's turn ratio. The Mecanum wheel is an omnidirectional wheel with a zero turn ratio and the ability to move without turning. When this particular wheel is used on a vehicle to transport objects in an industry, it helps to eliminate the majority of the issues described above. The automation is taken to the next level with the addition of a little memory to remember past motions. This memory will enable the robot for attaining the repeated motion. This helps to make the robot semi autonomous.

II. RELATED WORK

A significant amount of research has been conducted in the areas related to the Development of a Robotic Arm on an Omnidirectional Base.

Olaf Diegel et al [1] described an improved design for an omni-directional Mecanum wheel. The proposed design was expected to improve mobile robot efficiency by reducing frictional forces and producing higher performance. An Autonomous Omnidirectional Robot developed by Yanfei Liu et all [2] was analysed to learn the design, developing and testing of an omni-directional robot designed to meet the requirement of moving omnidirectionally at a particular speed.

Other research work in this area has also been analysed, The Design and Development of a Robotic Arm for Lifting Mechanism developed and demonstrated by A.N.W.QI et al [3] was used to investigate the design and development of a light material lifting mechanism with four degrees of freedom controlled by Arduino. The IOT-based wheeled robotic arm was investigated in order to learn more about how to use the Internet of Things to control robots using an app called Blynk. Abhilash V et al [6] developed a pick-and-place robotic arm with an ordinary wheeled base. In this project, the robotic arm is the most important component. With the help of four servo motors, the robotic arm travels in the desired direction.

III. SYSTEM COMPONENTS

The robot is made up of a four-wheel robotic vehicle with a robotic arm mounted on top. To accomplish this, a variety of components are selected and used. Before selecting the components, the required calculations are done.

A. Wheels

The prototype's movement is controlled by the wheels. The robot's mobility is given extra attention because it must utilise as little area as possible while moving on the floor.

Normal directional movement is achieved with conventional wheels, while the omnidirectional mobility is achieved with special wheels which are Omni wheels and Mecanum wheels. Mecanum wheels can carry high load and have less turning ratio. Hence they are chosen. Fig. 1 shoes the appearance of Mecanum wheels.

Fig. 1. Left and Right Mecanum Wheels

The chosen mecanum wheels are available in various diameters. The load carrying capacity of the Mecanum wheels differ with their respective diameters.

There are eight rollers for wheels with a diameter of 40 to 60 mm, making the wheel smaller. The robot's friction and weight capacity increase as the number of rollers increases. Hence, the wheel with diameter of 80 mm and 9 rollers is chosen.

B. Motors for Robotic Arm

The arm’s links are needed to be rotated for 180 degrees. Hence, the servomotors are selected for the convenience. Also, servomotors are small in size and compatible with the servomotors for the robotic arm. The motors are selected by calculating torque. The torque is calculated by using various parameters such as Length of link (L), Mass of Link (M), Mass of actuator (M) and Torque in kg.cm (T).

The required torque for the motors should be between 0.27 kg.cm and 9 kg.cm. The regular servos such as SG90 and MG996R have the maximum torque of 2.5 kg.cm and 11 kgm.cm respectively are selected and used accordingly.

The SG90 Micro Servomotor is a compact servomotor with a high output. which is suitable for Robotic Arm's Gripper, Wrist pitch and Wrist roll. The appearance of the micro servomotor is shown in Fig. 2.

Fig. 2. SG90 Servomotor

The MG996R servomotor with stall torque of 11 kg/cm and stall current of 2.5 A is stable and shock proof. It is suitable for Elbow, Shoulder and Waist. Fig. 3 depicts MG996R servomotor.

Fig. 3. MG996R Servomotor

C. Motors for base

The base motor should be capable of providing movement for the robot. Considering various motors, stepper motors are chosen. Since, the stepper motors provide excellent control over speed and are highly dependable due to the motor's longevity.

For selecting the specific type of stepper motor, the weight of the robot should be calculated. Furthermore, the stepper motor must be capable of providing the required torque.

Since the Nema 17 stepper motor meets with the required torque of the motor with 4.4 kg-cm, it is chosen as a motor for the Omnidirectional base. Fig. 4 shows the appearance of Nema 17 motor. NEMA 17 steppers feature a recommended driving voltage of 12-24V

Fig. 4. NEMA 17 Stepper Motor

D. Stepper Motor Driver

The motor driver selected for controlling the stepper motors is DRV8825 which is shown in Fig. 5 along with its pin configurations. The step modes of the stepper motors are determined by the program of motor driver. Each motor driver can control upto two motors and has output capacity of 45 V and 2.5 A. The main feature of the motor driver is it shuts down the circuit, if it gets heated and also it will not allow overcurrent flow.

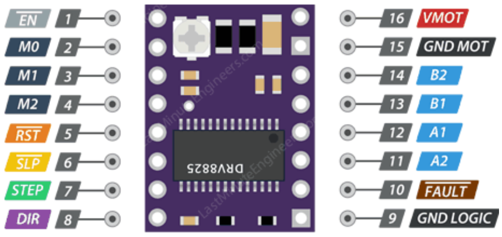

Fig. 5. DRV8825 Stepper motor Driver

E. Mirocontroller

Arm operation is handled by three SG90 servos and three MG996R servos. For base, there are four Nema 17 motors. A minimum of 14 output pins of microcontroller are required for operations. Therefore, an Arduino mega can be utilised, due to the availability of large number of pins.

The heart of the Robot is Arduino Mega (shown in Fig. 6) which is an open source microcontroller board. It uses ATmega 2560 as the microcontroller. This works with the operating voltage of 5 V with 54 digital pins. The Arduino Mega is primarily used in places where there is a need for more pins and more memory. The Arduino is brought to life with the use of USB cable or battery.

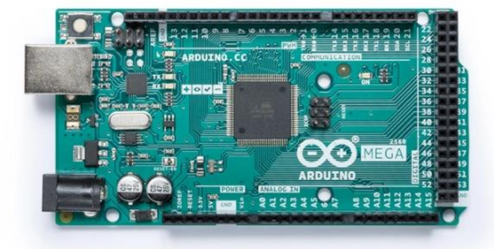

Fig. 6. Arduino Mega

F. Bluetooth Module

The robot is controlled by a custom app via bluetooth connection that connects the app and the arduino, thereby achieving base mobility and arm rotation. The module selected for Bluetooth connectivity is hc05, which requires an input voltage of 5V and communicates using a communication method called serial communication, so it can be easily connected to a controller or PC. Fig. 7 depicts bluetooth module.

Fig. 7. HC 05 Bluetooth Module

G. Battery

The power of the battery is finalised by calculating the current flow to the various components. The current requirement for Arm and Omnidirectional Base is 12.2 V and 11.4 V respectively. Hence the requirements are nominal voltage of 10 – 12 V, maximum discharge current of 20 A and Capacity of 1900 mAh. After observing all the batteries, the Lithium Polymer battery which is depicted in Fig. 8 is selected. The Lithium Polymer battery has nominal voltage of 11.1 V and capacity of 2200 mAh.

Fig. 8. Lithium Polymer Battery

H. Gripper

Robot grippers are devices that allow robots to take up and hold items. While considering a gripper, the gripping force is also noticed. The gripping force is the amount of force exerted by the gripper on the object. Gripping force is essential since it allows the gripper to grab the object with higher accuracy.

For calculation of the gripper force, three situations are considered.

- When the gripper is in the minimum aperture.
- When the gripper is in the medium aperture.
- When the gripper is in the maximum aperture.

The minimum gripper aperture determines the smallest object that can be gripped. The gripper in the minimum aperture position appears as shown in Fig. 9.

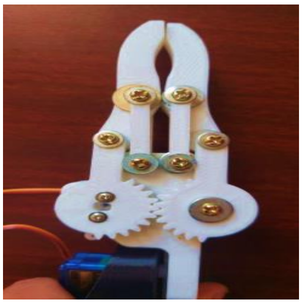

Fig. 9. Minimum Aperture Position

Initially, the torque's force must be determined, and this force must be perpendicular to the radius of rotation. This force is referred to as F.

$$F = 8.16 \text{ N}$$

However, this force is not in the direction of the gripper so the component of this force that is in the direction of the gripper, F_1 have to be calculated. For this, the angle α and calculate the component F_1 must be calculated.

$$F_1 = 3.57 \text{ N}$$

The equations for the horizontal and the vertical components of the gripper force are formulated and calculated.

$$F_{gripper} = 1.624 \text{ N}$$

The gripper force of the gripper in the minimum aperture is 1.624 N.

The gripper in the medium aperture position appears as shown in Fig. 10. The medium aperture position determines the mid-range shape of object that can be lifted.

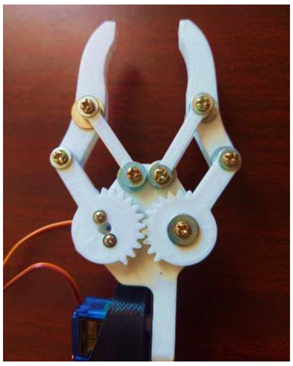

Fig. 10. Medium Aperture Position

Following the same steps used for calculating the gripper force for the minimum aperture, the $F_{gripper}$ is calculated as 5.009 N.

The maximum gripper aperture determines the largest object that can be gripped. The gripper in the maximum aperture position appears as shown in Fig. 11.

Fig. 11. Maximum Aperture Position

Further by taking the same steps, the $F_{gripper}$ is calculated as 20.052 N.

IV. Methodology

The flowchart explains the step-by-step procedure followed to attain the final objective. The formulated methodology is shown in Fig, 12.

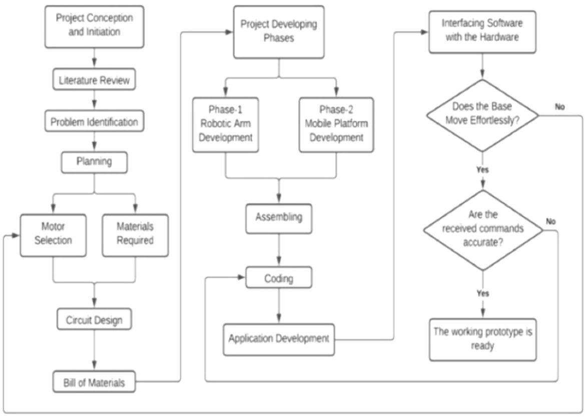

Fig.12. Methodology Flowchart

Initially, the problem was identified by surveying various publications. Then, as the first step, planning was done and the calculations for the required materials are completed. The favourable materials were chosen. The circuit was designed and the cost is estimated. The project is divided and completed in two phases and the coding is done. An application is developed for controlling the robot. The developed mechanical part and the software are interfaced and integrated and the robot is tested for any inaccuracies.

V. BLOCK DIAGRAM

Before designing the circuit, the essential parts of the robots are interfaced in the form of a block diagram. The appearance of the developed block diagram of the robot is seen in Fig. 13.

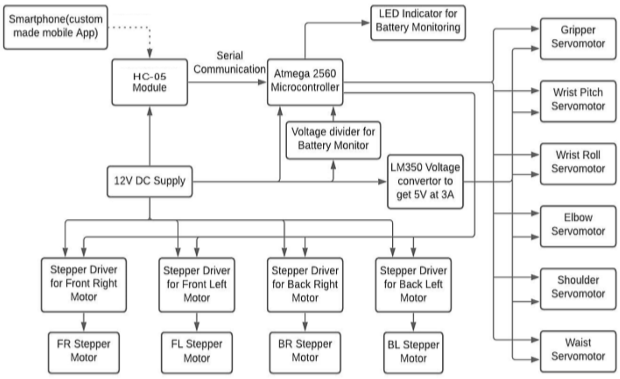

Fig. 13. Block Diagram

VI. CONCEPTUAL DESIGN

Conceptual design is the initial stage for designing the mechanical structure of the prototype. It is developed based on the generated concept and it lacks technical specifications. The software used to develop the conceptual design is Tinker CAD.

A. Robotic arm and omnidirectional base

At first, the conceptual overview of hand of the robot is generated. The robotic arm is 3D printed using the material called PLA or Polylactic Acid, as it can withstand high temperature.

The robot's arm has five degree of freedom and six axes which are actuated by servo motors. The robotic arm is planned to be controlled through smart phone using an android application with Bluetooth connectivity. The 3D design of the robotic arm is shown in Fig. 14.

Fig. 14. 3D Design of Robotic Arm

B. Omnidirectional Base

The mobile base facilitates the motion of the robot and it uses mecanum wheels which facilitates the omnidirectional movement. Pairs of wheels resist one another to spin side wards, similar to a worm gear. Mecanum wheels come in various sizes. These wheels allow the robot to move forward, backward, and immediately sideways.

The material used for the base is PVC or Polyvinyl Chloride, a polymer in which chlorine makes up more than half of the weight. The mobile vehicle is controlled through smart phone using an android application which is connected to Arduino board via Bluetooth.The 3D architecture of the base is shown in Fig. 15.

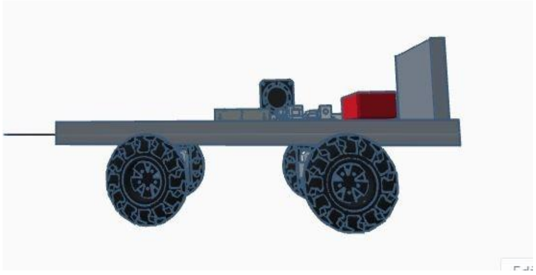

Fig. 15. 3D Design of the Base

C. *Robotic Arm on an Omnidirectional Base*

The concept of collaborating the roboti arm and omnidirectional base was generated as this collaboration is not only advantageous by making the mundane tasks easy but also reduce the usage of labours. The 3d design of the integrated robotic arm and omnidirectional base is depicted in Fig. 16. The front and the top view of the 3D model is shown in Fig. 17 and Fig. 18 respectively.

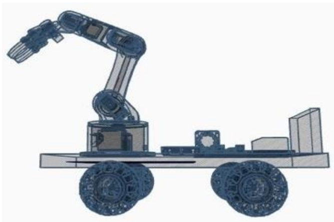

Fig.16. Side View

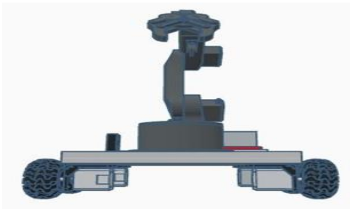

Fig. 17. Front View

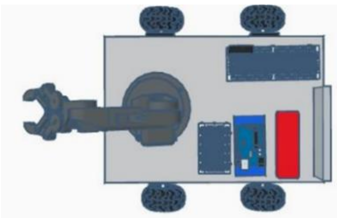

Fig. 18. Top View

VII. Application Development

An android application is developed for controlling the Robotic Arm and Omnidirectional base via Bluetooth. The platform used for application development is MIT App Inventor, which is an open-source. The user interface of the application allows the user to control the robot by using the application's buttons.

The Robotic Arm and Omnidirectional Base are controlled separately. The status of the Bluetooth connectivity ca be monitored The number of positions can be recorded, saved and executed which makes the robot to work autonomously. The speed of the stepper motors and the servomotors can be altered.

The application's apk file is downloaded and installed in a smart phone. The application developed for controlling the Robotic Arm and Omnidirectional Base is named as “Robotic Arm on an Omnidirectional Base”. The application logo and the appearance of the user interface is show in Fig. 19 and Fig. 20 respectively.

Fig. 19. Application Logo

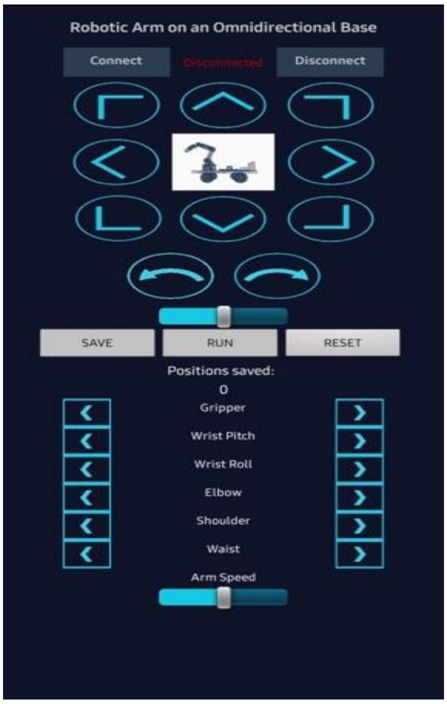

Fig. 20. Application's User Interface

VIII. Implementation and Testing

A. *Implementation*

The size of various components is used to determine the dimensions of the base priorly. The base illustrated in Fig. 21 is built of PVC which is 400 mm in length and 200 mm in width.

Fig. 21. The base

As the base got ready and the required diameter of the wheels are calculated, the purchased 3D printed wheels parts are assembled. The appearance of the wheels is shown in Fig. 22.

Fig. 22. Omnidirectional Wheels

The 3d printed parts of the robotic arm is assembled. The appearance of the arm after assembling is shown in Fig. 23.

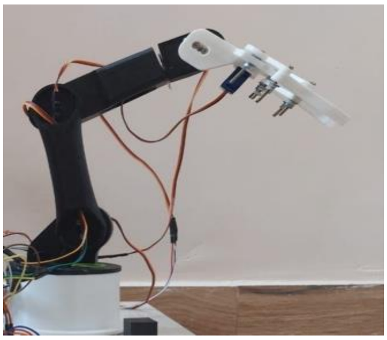

Fig. 23. Robotic Arm

The robotic arm is being installed now that the vehicle is ready. The various views of the prototype are shown in Fig. 24, 25 and 26.

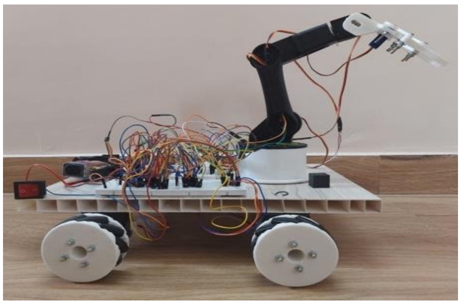

Fig. 24. Side view

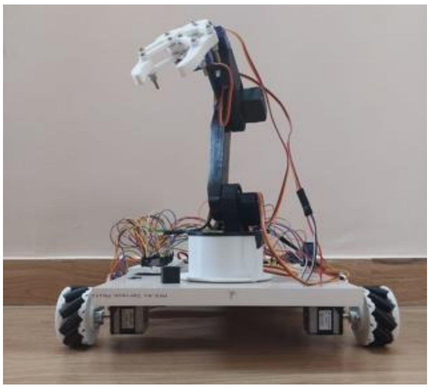

Fig. 25. Front View

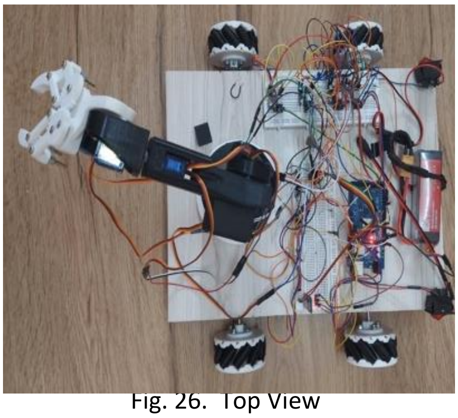

Fig. 26. Top View

B. Testing

As the implementation was completed, the prototype is ready and it is tested. The conditions to be fulfilled are discussed step by step.

- Initially the base’s mobility is checked and it is found to be appropriate.
- The precision of transmitting commands to the Arduino is tested in the built application. The prototype answered in a timely manner, implying that the custom-made application has a good connectivity with the prototype.
- Finally, the gripper's performance is is tested by having the arm to lift a 20-gram weight in cube and cylindrical configurations. The arm worked smoothly.
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IX. Conclusion

The project deals with the development of a robotic arm on a mobile platform to facilitate monotonous work on many industrial platforms. The main objective is to develop a robotic arm on an omnidirectional base to pick and place with high precision using an Arduino controller. The vehicle can be controlled via Bluetooth using a mobile application created with MIT app inventor.

The system is designed and developed within a certain period of time. The prototype is able to lift the given payload of any shape.

On one hand, the accuracy is high while picking and placing the objects, which is necessary is some applications. On the other hand, the mecanum wheels reduces the turn ratio, thereby reducing the time taken to complete a process. This also enables the vehicle to operate within a constraint location. Thus, the robot can be assigned for a repeatable process, which is included in the mobile application (through Save and Run buttons).

X. Further work

The medium of control can be through cloud instead of Bluetooth to facilitate operation from distance. Placing Cameras and interfacing with the mobile application will help the operator to operate from any part of the world. By including a storage box on the robot, the robotic arm can place multiple objects in the box which increases the productivity and reduces the time. Microcontrollers with inbuilt connectivity modules and custom-made PCB for the motors interfacing can reduce the size and weight.

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