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Goods Movement Robot Prototype Design with Wheel Arm System

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Abstract: One of the uses of robotics technology that is developing is in the field of warehousing, with robots transferring vehicle goods used in the industrial world, especially in the warehousing section. The item transfer robot has 2 navigations, namely on the wheeled part, namely the robot can maneuver in all directions without the need to rotate the body of the robot (holonomic robot). Then one of the robots that is used quite often in the industrial world is the arm manipulator. Robots that have a physical shape like a human arm and a degree of freedom (Degree of Freedom). The transfer robot system is controlled remotely using an IoT-based smartphone using the ESP32 Wemos D1 R32 module as the robot's driving brain and ESP32-Cam as the robot's drilling visual. Several robot tests are carried out to ensure that the designed robot can run properly. From the results of functional testing, parts of the robot can run well. The robot can walk through commands from a smartphone, the gripper on the arm manipulator can grasp objects and the ESP32-Cam can display images to the smartphone.

Keywords: Arm Manipulator, Holonomic System, IoT, Robotics.

1. Introduction

Developments in the 20th century were very fast, especially in the field of science and technology which had a major impact on the pattern of human life, one example is robotics technology. Every country is competing to do a lot of research to find the latest technological innovations that make efforts [1] to use robots in human life easier and more efficient. Utilization of robots that are currently developing, one of which is in the field of warehousing. A goods moving robot is a vehicle that is generally used in the industrial world, especially in the warehousing sector. The existence of technology that is able to move goods automatically will be very helpful in carrying out every process in the warehouse.

The goods moving robot has 2 navigations, namely on the wheeled part, the robot can maneuver in all directions without the need to rotate the body of the robot (holonomic robot). With good maneuverability in all directions, this robot can perform important tasks in crowded environments with static and dynamic barriers, such as in factories. Then one of the robots that is often used in the industrial world is the arm manipulator. This robot is widely chosen by the industry because of several advantages, namely having a physical form like a human arm and degrees of freedom (Degree of Freedom).

In this research, a 4-DOF arm manipulator is combined with a wheeled robot. Overall, the purpose of this research is to design a goods moving robot with a wheeled arm system.

2. Literature Review

2.1. Wheeled Arm Robot

Robot comes from the word "robota" which in Czech (Chech) means slave, worker or coolie. A robot is a mechanical device that is capable of carrying out physical tasks, either under the control of human supervision, or which is carried out with a series of pre-defined programs or artificial intelligence (artificial intelligence) [2]. In general, there are various types of robots, one of which will be discussed in this thesis report is the wheeled robot and the arm manipulator robot [3].

A wheeled robot is a construction robot with a characteristic of having an actuator in the form of a wheel to move the entire body of the robot, so that the robot can move from one point to another. Arm manipulator robot or also known as arm robot is a type of robot that has a structure in the form of arms and claws (digger) [4]. This type of robot is commonly used in industry to lift heavy objects.

From the explanation above, the wheeled arm robot is a combination of the functions of the wheeled robot and the arm manipulator robot, so that the two are complementary where the arm manipulator robot can be assisted by its function by moving from one place to another. The research conducted in this final project is to design and build a wheeled arm robot which is a combination of wheeled robot and arm manipulator robot [5]. The wheeled robot is the base of this system so that the robot can move both forward and backward or turn left and right, while the arm manipulator robot is placed on the wheeled robot base which functions like a human hand. Users can perform commands/input using an application made with the MIT App Inventor to control a robot that acts as a goods mover [6].

There are various types of robots with various functions they have. Even though they differ in terms of shape, size, and function, all robots have the same basic components. These components support the work or function of a robot which is usually in the form of electronic and mechanical components [7]. Even though it consists of two different types of components, these two components are actually related and interact with each other so that it can also be said that a robot is composed of electromechanical components.

1) Mechanical Components
   This mechanical component is a component that produces movement in the robot. The number of these components is not too much when compared to the electrical components. However, its application is sometimes difficult depending on the shape and pattern of the direction of the robot's movement. The more complex the movements that a robot can perform, the more complicated the mechanical structures used are. Tools that can be classified into mechanical components include Chassis, DC Motor, Gear, Mecanum wheel, Servo SG90, 3D Printing, supporting components for robot formation such as bolts, nuts and others.
2) Electrical Components
   The electrical components used are the XL4015 module, 18650 type battery and cable.

2.2. ESP32 Wemos D1 R32

ESP32 is a microcontroller introduced by Espressif Sistem, a company based in Shanghai, China. Using TSMC as the core for producing a large 40nm microchip which is the successor of the ESP8266 microcontroller.

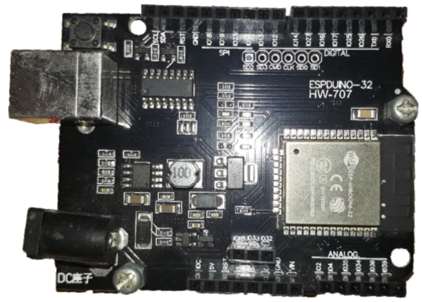

Figure 1. Wemos D1 R32 ESP32 Series Microcontroller Board

The ESP32 generation uses the Tensilica Xtensa LX6 microchip as the core in both single-core and dual-core modes. This board is hardware that is "open source" so that it can be made by anyone. This microcontroller has a CPU core as well as faster Wi-Fi, more GPIO numbers, and supports dual-mode Bluetooth Low Energy [7].

The ESP32 Series Wemos D1 R32 has the same shape as the Arduino UNO with a size of 6.8x5.3cm/2.68x2.09 inch with a working voltage of 3.3v DC (but the input voltage can be supplied from 5v-12v). Program uploading from the computer to the ESP32 D1 R32 is also the same as Arduino UNO using a Type-B port and you don't need to press the BOOT button like on the usual ESP32 because the ESP32 D1 R32 is already equipped with the CH340C IC. Several shields from Arduino UNO can also be used on the ESP32 Wemos D1 R32.

2.3. Motor DC Shield ESP32 Wemos D1 R32

When making a prototype, most people use components and cables that are arranged on a breadboard and connected to a microcontroller, but when the prototype is made into a tool that is ready to be marketed/sold, it will be difficult if you are still using a circuit made on a breadboard. Several electronics companies make modules that have different functions that can be easily installed on a microcontroller board, making prototyping very easy and practical. These modules that can be installed on a microcontroller board with certain functions are called Shields. Examples of shields that already exist and are sold on the market are shields for controlling DC motors (shields used in this project), shields for connecting to the internet (using Ethernet), communication shields using Bluetooth, shields for connecting to LCDs and many more [8].

The shield that will be used on DC motors is used to facilitate the use of prototypes and maintenance of circuits. Because this shield can run 4 DC motors and enhance the functions of the ESP32 Wemos D1 R32 according to the needs of this research project. DC motor shields can be built independently with a system similar to the DC motor shield on the Arduino UNO. This shield contains two L293D ICs which have been assembled almost exactly the same as the Arduino L293D shields. It's just that the difference is that there is an additional IC 74HC595 (to add an output pin) on the Arduino UNO l293D shield. Following are the appearance and specifications of the Shield ESP32 Wemos D1 R32.

2.4. ESP32-Cam

ESP32-Cam (OV2640) microcontroller which has the same specifications as ESP32 Wemos D1 R32 and ESP32 in general. It's just that the ESP32-CAM has a small camera board with a board size of only 27x40.5x4.5mm. ESP32-CAM can be widely used in various IoT applications [9]. For example, in smart home devices, industrial wireless control, QR wireless identification, wireless positioning system signaling, face recognition, object detection and other applications. The following shows the ESP32-Cam.

(a) (b)

Figure 3. ESP32-Cam:
(a) Front View
(b) Rear View

With its small size, the ESP32-CAM has the disadvantage of not having a driver/IC to upload programs to this microcontroller. therefore an external FTDI programmer driver or Dev Board USB to TTL CH340 is used (which is used in this study). The following shows the Dev Board USB to TTL CH340.

2.5. Framework of Arduino

ESP32 can be programmed using several frameworks such as Arduino, Espressif IDF, Micropython, LUA, etc. In this project, we will use the Arduino framework (PlatformIO) because this framework is quite popular and can be used for other microcontrollers as well. With a popular framework, it means that there are also many communities or forums that discuss this, so that if one day we have a problem during development, many can support it [10].

To use the Arduino framework, the Arduino IDE is usually used, but in this project the author will use the PlatformIO IDE. This is done because PlatformIO IDE has many advantages when compared to Arduino IDE. PlatformIO IDE is actually a plugin that can be installed on several code editors that can be used including: VSCode, Atom, Sublime Text, Eclipse, NetBeans, etc. The code editor can run on either Windows, Mac or Linux OS, so this PlatformIO IDE can also be used on these three OS (cross-platform).

2.6. Ngrok

Ngrok is an application that makes it possible to expose local servers to the public internet or can be said to be an application that bridges to break through existing firewall systems on the network and can also be used for purposes so that the local IP on ESP32-Cam can be changed to a public IP, so that the local IP address will be converted into a URL address, which can later be accessed via the Internet [11]. Ngrok provides a monitoring UI, so that all access traffic running on the server path can be properly monitored. The advantages and disadvantages of the ngrok service when accessing Local IP are in Table 1 [12].

Table 1. The Strengths and Weaknesses of Ngrok

Strength	Weekness
Can do local public hosting without having to use the services of a web hosting provider.	Every time you access the NGROK service, the duration of its use is limited to 8 hours.
Very easy configuration.	Requires internet connection.
In terms of its use, it can be monitored so that it is much safer and more comfortable.	The url domain for each access session will always change.

2.7. MIT App Inventor

App Inventor is a very good program created by Google and now developed by MIT. This program can be used to create and design Android applications based on Web pages and Java interfaces [13]. In building Android applications with App inventor it is divided into two parts, namely:

1) App Inventor Designer, used to select components for the application to be used.
2) App Inventor Block Editor, used to assemble program blocks that define how components should behave. In assembling a visual program, it looks like a puzzle.

2.8. Firebase

Firebase is an API provided by Google for storing and syncing data into Android, iOS, or web applications. Realtime database is one of those facilities which save data to database and fetch data from it very fast but firebase is not just realtime database it is much more than that. Firebase has many features such as authentication, database, storage, hosting, notifications and others [14].

Firebase has a main product, which provides a realtime database and backend as a service (Backend as a Service). This service provides application developers an API that allows application data to be synced across the client and stored in the Firebase cloud. Firebase provides libraries for various client platforms that allow integration with Android, iOS, JavaScript, Java, Objective-C and Node Js applications and can also be referred to as DbaaS (Databaseas a Service) services with a realtime concept. Firebase is used to make it easier to add features that will be built by developers. DatabaseRealtime is a cloud-based database in firebase and does not require SQL-based queries to store and retrieve data. This database is known to be very reliable and super fast in the process of updating data and synchronizing so that data is maintained even when the user is not connected to the internet even though the data is still being maintained [15].

3. Metodology

3.1. Research Flow

The flow of the research used in designing a goods moving robot with a wheeled arm system will be divided through several stages, namely:

1) Preparation of tools and materials: aims not to make mistakes in designing what will be done in the manufacture of tools.
2) Wemos D1 R32 ESP32 shield design: this shield design aims to control the 4 DC motors and servos.
3) Installation and design of a series of robots: uniting each part of the robot components into a single unit.
4) Programming/code: making robot commands that function to activate each pin used on the microcontroller used.
5) Making the MIT inventor application: creating a robot controller that functions to move the robot through data sent from Firebase to the smartphone and then the microcontroller.
6) Ngrok Configuration on ESP32-Cam: change the local IP address of ESP32-Cam to Ngrok IP which can later be displayed as Public IP.
7) Overall tool testing: testing the function of each tool from system design and direct testing in the field. Function testing is carried out using the black box testing method. Direct testing is carried out on the floor in various conditions, namely with a flat surface, incline and ground.

3.2. System Planning

At the beginning of the design process, a robot moving goods was formed, there were several stages, namely system design, namely block diagrams. This block diagram is a basic description of the system to be designed. Each part of the block diagram has its own function, by understanding the block diagram, the designed system can be built properly. The following is an explanation of the stages of block diagram design.

The design of this system block diagram contains inputs, processes, and outputs where the input is a signal provider, the process is a system or giving orders to a system and the output is a process for a signal sent. In this design input there is the ESP32-Cam module which is equipped with OV2640 cameras, ESP32-Cam and ESP32 Wemos D1 R32 as a microcontroller where there is a WiFi module inside which has been implanted and functions as a cellphone link, and the ESP32 Wemos D1 R32 microcontroller also functions as a processor of input and give orders to output.

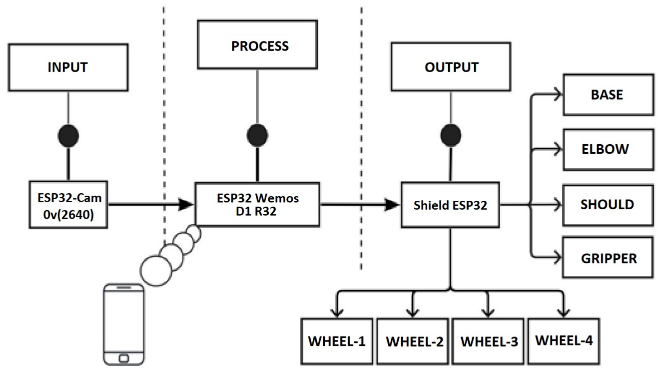

Figure 4. Block Diagram

4. Finding and Discussion

4.1. Prototype

The design of a goods moving robot prototype with a wheeled arm system can be seen in Figure 5.

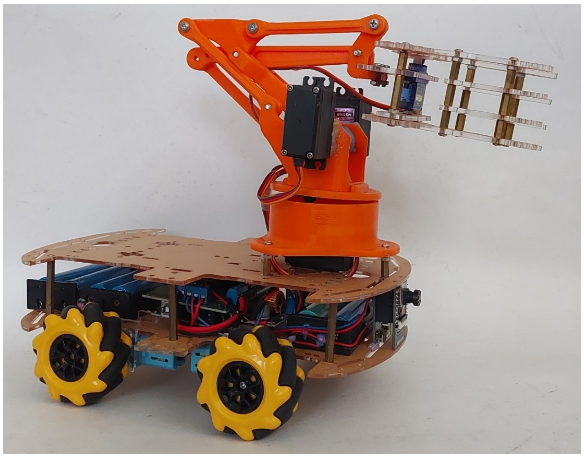

Figure 5. Full Design of the Goods Moving Robot Prototype

4.2. Testing the Direction of Robot Movement

This test is carried out to determine the results of the robot's movement with different directions of wheel rotation. The results of the test can be seen in the table which can then be used as a reference for the basic movements of the mecanum arm robot.

The wheel configuration is arranged as shown in Figure 8 to form an "X" shape.

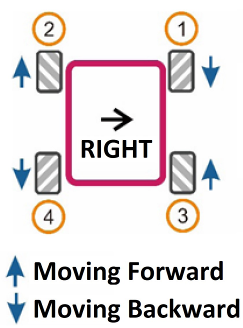

Figure 8. Mecanum wheel configuration

The choice of wheel configurations such as the letter "X" is based on the fact that this configuration is better in terms of consistency and speed in movement than other configurations.

Table 2. The Results of Testing the Direction of the Robot's Motion

Rotation Direction				**Mecanum**
Wheel 1	**Wheel 2**	**Wheel 3**	**Wheel 4**	
Moving Forward	Moving Forward	Moving Forward	Moving Forward	Moving Forward
Moving Backward	Moving Backward	Moving Backward	Moving Backward	Moving Backward
Moving Forward	Moving Backward	Moving Backward	Moving Forward	Turn Right
Moving Backward	Moving Forward	Moving Forward	Moving Backward	Turn Left
Moving Forward	Quiescent	Quiescent	Moving Forward	Moving Forward to Right
Quiescent	Moving Forward	Moving Forward	Quiescent	Moving Forward to Left
Quiescent	Moving Backward	Moving Backward	Quiescent	Moving Forward to Right
Moving Backward	Quiescent	Quiescent	Moving Backward	Moving Forward to Left
Moving Backward	Moving Forward	Moving Backward	Moving Forward	Rotate Clockwise
Moving Forward	Moving Backward	Moving Forward	Moving Backward	Rotate Counterclockwise

4.3. Robotic Arm Testing

This test is carried out to test the resistance of the arm manipulator. The test is carried out by making the robot arm manipulator parallel to the vertical axis, then the robot arm is left for 2 minutes. Figure 9 is the stage of testing the arm manipulator.

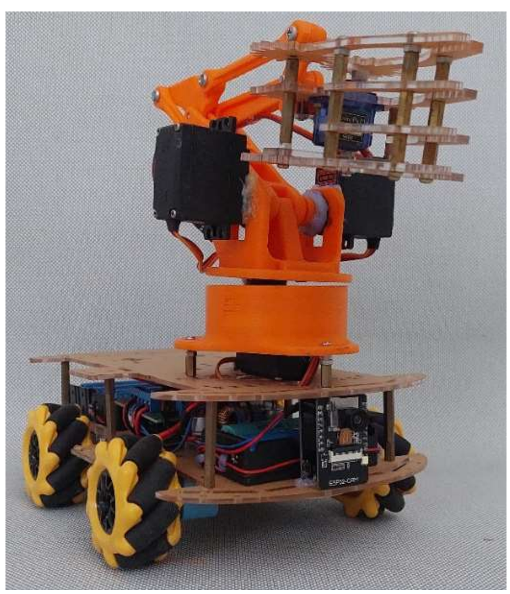

Figure 9. Testing the Robot Arm without Holding an Object

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The result obtained is that the robot arm is able to hold its own weight for 1 full minute. The result is enough to show that the MG996R servo can properly support the parts of the robotic arm manipulator.

Another test that was carried out was to test the arm manipulator robot to hold an object. In this test the object held is a block of boxes. Figure 10 is an image taken when testing a robot arm holding an object. The object that is gripped by the gripper robot arm has a diameter between 3.8cm wide, 3.8cm long and 2.5cm high.

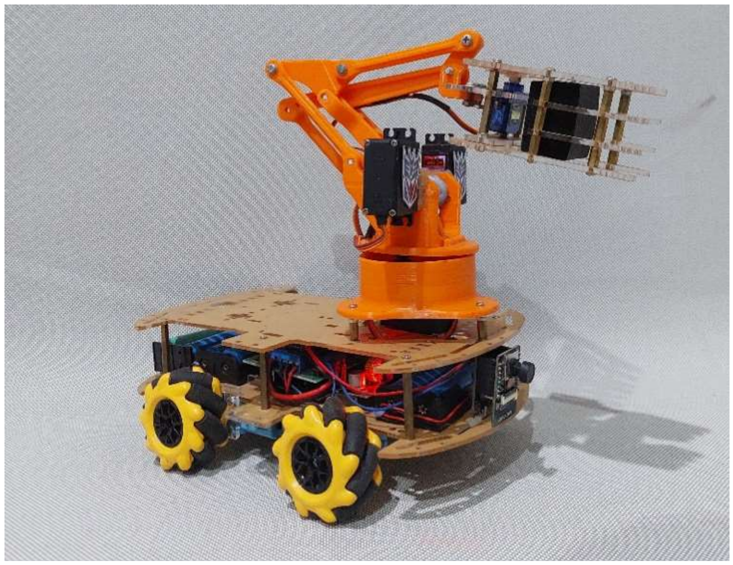

Figure 10. Testing a Robot Arm Holding an Object

4.4. Time Delay Response Testing

This test starts with the App Inventor application, which sends robot movement data with 10 directions of robot movement starting from a value of 0 to 10, robot speed data from a value of 300 to 1023, then data on the movement of the 4th servo from the robot arm. These data values are received by firebase then sent to ESP32 Wemos D1 R32. Here's a test view.

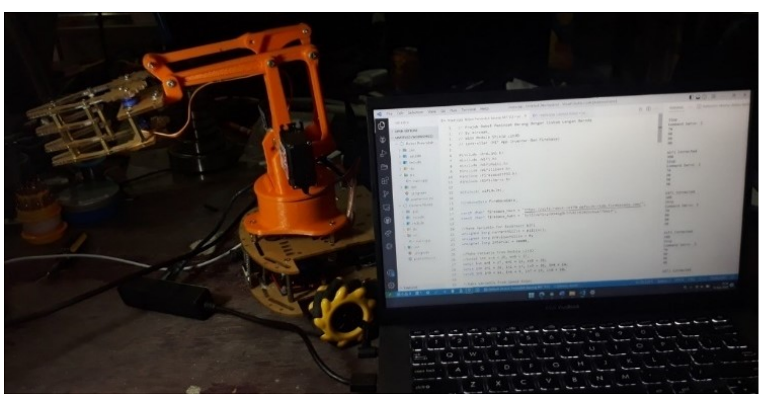

Figure 11. Display of the Terminal/Serial Monitor Testing

The data is converted to a binary value then the data is displayed on the PlatformIO terminal/serial monitor.

5. Conclusion

The designed system can work perfectly, where the motor shield driver can work with the ESP32 microcontroller. In addition, robots and robotic arms can be moved via the MIT App Inventor application on smartphones.

Based on the test, it is known that the average delay between the responses of the robot's movement to the smartphone command is:

- Indoor measurements produce a delay of 1.75 seconds.
- Outdoor measurements produce a delay of 1.30 seconds.

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