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AUTOMATED DELIVERY ROBOT SYSTEM DESIGN FOR OFFICE USING ESP32 TECHNOLOGY

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ABSTRACT

The emergence of Industry 4.0 has brought about major changes in various industries, including the use of Internet of Things (IoT) technology. One of the technologies of Industry 4.0 is IoT (Internet of Things), which allows the connection between tools and other devices. The use of smart robots as a solution for task completion in office areas is increasing rapidly. This smart robot can be equipped with sensor modules and ESP32 microcontroller processing modules to enhance its functionality. In addition, integration with smartphones through Android applications and websites allows this robot to be controlled and monitored remotely (online). The design of this IoT-based delivery robot with the integration of the ESP32 microcontroller and advanced sensors shows promising potential in improving convenience in offices. The use of TCS34725, infrared sensor, and HC-SR04 Ultrasonic Sensor enhances color detection and object recognition capabilities, enabling the execution of tasks as a delivery robot in an office environment. Integration of Android app and website as online control and monitoring function of the robot with real-time.

Keywords: *ESP32, line follower, office environtment*

1. INTRODUCTION

In recent years we have entered the early stages of a revolution that will fundamentally change the way we live, think, work and interact with one another. These changes were predicted, but they are actually happening at an incredible speed. Modern man wants everything immediately and quickly, which is a big change compared to the previous industrial revolution. The emergence of Industry 4.0 is seen as an era of technological disruption with widespread automation and connectivity in many industries, causing major changes [1].

One of the most visible technologies from Industry 4.0 is Internet of Things (IoT), which enables connections between different entities in the context of Industry 4.0. Currently, all parties involved have access to relevant information and data on an ongoing basisreal-time. IoT has paved the way for widespread connections between devices and systems, enabling rapid information sharing and smarter decision making. This offers excellent opportunities to increase efficiency and productivity in various fields [2]

At the same time, the office environment is also undergoing major changes due to the rapid development of technology. Demands to improve efficiency, productivity and comfort of office space are increasing. In this context, the use of smart robots as a solution for task delivery in office areas is increasing rapidly. This smart robot is equipped with advanced sensors and the latest technologies such as the ESP32 microcontroller processing module to enhance its function and efficiency. In addition, integration with smartphone via the Android app and website allows the robot to be controlled and monitored remotely (online).

Robot smartphone line followers based on ESP32, which connects to smartphones via the Android APP and web, can automatically follow the route and deliver goods efficiently. The ESP32 microcontroller processing module acts as the brain of the robot, controlling motors and sensors, and communicating with smart devices via WiFi. Apps and sitesweb Android allows control and monitoring of robots online real-time, allows users to easily manage and monitor the delivery of goods in the office area. robots is "An Automatically controlled, reprogrammable, multipurpose, programmable manipulator in three or more axes, which may be either fixed or mobile for use in industrial automation applications".

ESP32 based smart delivery robot, which connects to smartphones via apps and siteswebAndroid, offers great potential for increasing efficiency, productivity, and easier management of goods in office space [3]. Users can easily monitor and control robot performance online real-timethrough the application, set the route that will be passed by the robot and check the location and status of shipments via smartphones or through website which can be accessed through various devices.

2. RESEARCH METHOD

A procedure is designed in order to conduct this study. This involves (1) planning, (2) analysis (3) development, and (4) testing.

Planning

The planning phase is conducted to assess the feasibility and scope of this project. In addition, we will define the threats, constraints and integration of this project. Based on this information, we can determine the objectives of this project.

There are several outlines that can be decided upon, based on the initial research at this stage. This research was conducted at the Telecommunication Laboratory of Tarumanagara University. The purpose of this design is to create a Smart Robot Delivery Driver for Office Areas. This research also aims to allow receiving multiple inputs from the user, thus allowing the user to control the robot to move from one room to another.

Analysis

A further study is conducted in order to observe existing prototype and determine its benefits and pain points. It is done by comparing three different literatures related to the project. The survey was conducted by studying the literature and comparing the tools that have been made with the designed tools.

The first survey used a journal entitled "Design and Implementation of an Autonomous Delivery Robot for Restaurant Services" [4] . The journal explains that the robot uses Arduino Mega as its microcontroller. For the robot viewer module, it uses an LCD Module. This design has not used IoT technology.

The second survey used a journal entitled "IoT Technology Involving Wheeled Line Follower Robot for Restaurant Services Automation" [5]. The journal explains that the robot uses Arduino UNO as its microcontroller. For the robot viewer module, it uses a web from a 3rd party. This design already uses IoT technology but still relies on a 3rd party as a link between the user and the robot. In addition, the robot is designed in 1 straight line that is circular.

The third survey used a journal entitled "Prototype Robot Waiter at Fast Food Restaurants" [6]. The journal explains that the robot uses Arduino UNO as its microcontroller. For the robot viewer module, it uses an LCD. This design has not used IoT technology. To run the robot the user must press the keypad to give a command.

After conducting a survey, a comparison of the tools that have been designed with the tools that will be made can be made. Comparisons were made to find out the differences between the tools to be designed and the tools in the survey, Smart robot using ESP32 for Microcontroller , PG36 for Motorcycle, IR Lines and RGB sensors TCS34725 for the detector line, Control from website , storage data using MySQL and Sensors Ultrasonic for detector object.

Development

Realization of the subsystem design of the smart robot delivery system for the office area is divided into the realization of the display module subsystem, the realization of the processing module subsystem, the realization of the driving module subsystem, the realization of the navigation module subsystem, the realization of the object detection module subsystem, the realization of the storage module subsystem

A. Realization of the Viewer Module Subsystem

Viewer module plays an important role as a user interface to access and utilize data in the system. The viewer module is implemented in the form of awebsitelocated atservershosting. Users can accesswebsite this through the browserwebon their device. The realization of the display module can be seen in Figure 1.

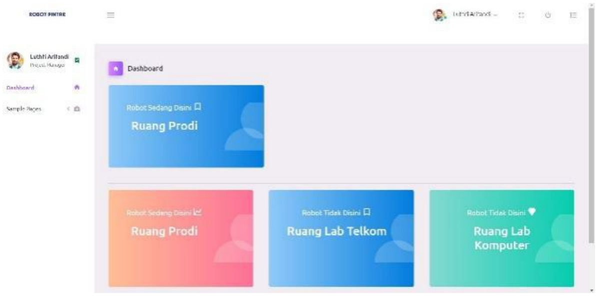


Figure 1 Viewer Module Realization

Websiteas a viewer module it is designed and developed using a programming language PHP, CSS, And JavaScript. PHP used as a programming languageservers-side to manage logic and data processing on the sideservers.CSS used to set the appearance and layoutwebsite to make it look attractive and consistent. JavaScript used to provide interactivity onwebsite, such as button validation, animation effects, or interaction with page elementsweb.

B. Realization of the Processing Module Subsystem

The processing module uses the ESP32 microcontroller. The ESP32 processor module provides powerful computational capabilities and is equipped with a variety of features to support application development IoT [7]. In this design, ESP32 is used to control various operational and functional aspects of the robotic system. The Processing Module is the brain of this robotic system. Realization of the design of the processing module can be seen in Figure 2.

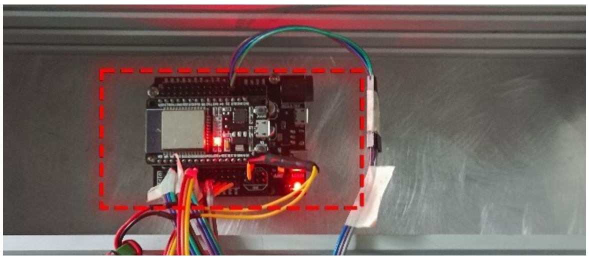


Figure 2. Processing Module Realization

With a combination of sophisticated hardware and flexible software, the ESP32 processor module provides the power and capabilities needed to control and process data in this robotic system.

C. Realization of the Driver Module Subsystem

The drive module used in this design is a PG-36 Motor anddriver-his. This module is placed on the middle side of the robot which functions to drive the wheels connected to the PG36 motor. This module determines whether the robot turns right or turns left. The drive module is connected to the processing module via the motordrivers. Realization of the design of the drive module can be seen in Figure 3.

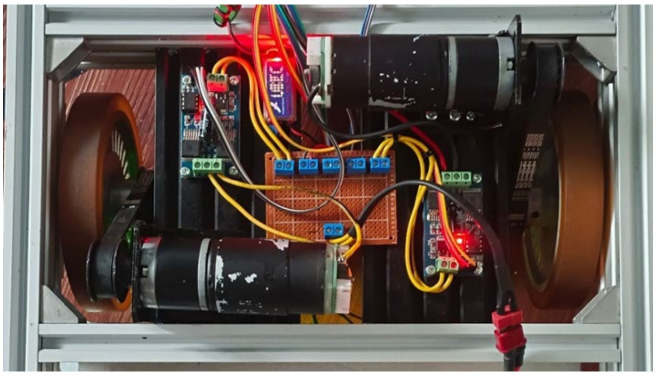


Figure 3 Realization of the Driver Module

This drive module consists of a PG-36 Motor anddrivershis. The PG-36 motor is a DC motor (direct current) which is usually used for applications that require considerable strength and torque. This motor is used to drive the robot wheel so that it can move forward, backward or turn. In addition to the motor, the drive module also uses driver motorcycle. Drivers the motor functions as a current and voltage regulator that goes into the PG-36 motor. Driver this allows the processing module to control the speed and direction of rotation of the motor according to the commands given.

D. Realization of the Navigation Module Subsystem

The navigation module used in this design is the TCRT5000 10 Infrared Sensorchannels. This module is placed on the bottom side of the robot which functions to detect the path under the robot. This module gives a signal to the system whether the robot should turn right or turn left. The navigation module is connected to the processing module. Realization of the design of the navigation module can be seen in Figure 4.

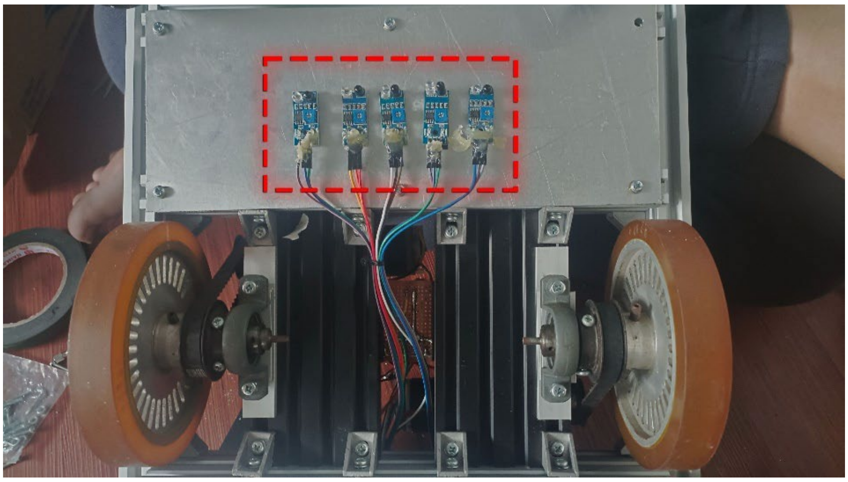


Figure 4 Realization of the Navigation Module

This navigation module uses the TCRT5000 Infrared Sensor with 10 channels. This sensor is specifically designed to detect infrared reflections from surfaces that lie in the robot's path. In this design, the infrared sensor is used to detect the path under the robot [8] .
This navigation module consists of a series of TCRT5000 infrared sensors which are placed parallel to a certain distance. When the robot moves over the track, the infrared sensor will reflect infrared light onto the track surface. If the robot is in the middle of the lane, all sensors will receive reflected infrared light with the same intensity. However, if the robot crosses the path boundary, the infrared reflection intensity on certain sensors will be different, indicating that the robot has deviated from the path.

E. Realization of the Object Detection Module Subsystem

The object detection module used in this design is the HC-SR04 Ultrasonic Sensor. This module is placed on the front side of the robot which functions to detect objects that are in front of the robot. This module gives a signal to the system whether the robot should stop because there is an obstacle or go ahead because there is no obstacle. The object detection module is connected to the processing module. Realization of the design of the object detection module can be seen in Figure 5.

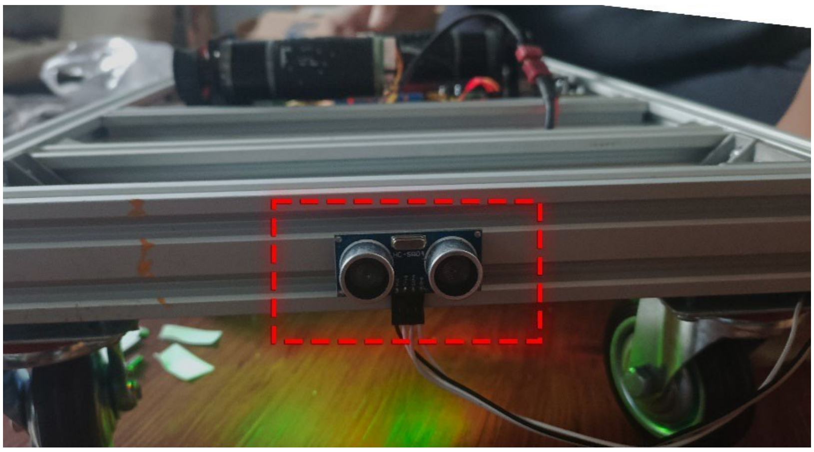


Figure 5 Realization of the Object Detection Module

The HC-SR04 Ultrasonic Sensor works on the principle of measuring distance by emitting ultrasonic waves and receiving their reflections. When the ultrasonic waves bounce back after hitting an object in front of the robot, the sensor will detect the time it takes for the waves to go and return. Taking into account the speed of sound, the sensor can calculate the distance between the robot and the object with sufficient precision.

This object detection module provides a signal to the robot control system, telling whether the robot should stop due to an obstacle in front of it or continue its journey if no obstacle is detected. This allows the robot to avoid collisions with objects and maintain safety in its operations.

The design realization of the object detection module can be seen in Figure 5, which illustrates the position and installation of the HC-SR04 ultrasonic sensor on the robot. Using this object detection module, the robot can accurately and responsively recognize the presence of nearby obstacles, enabling safe and efficient navigation in the work environment.

Testing

In the testing phase, the developed Smart Robot Delivery Driver will undergo rigorous evaluation to assess its performance and functionality. Various tests will be conducted to measure the robot's efficiency, accuracy in following paths without lines, color detection capability, and object recognition accuracy using the TCS34725, infrared sensor, and HC-SR04 Ultrasonic Sensor. The robot's integration with the Android application and website for remote control and monitoring will also be tested for usability and real-time responsiveness.

Performance tests will involve measuring the robot's speed, navigation accuracy, and ability to carry out delivery tasks efficiently. Color detection tests will evaluate the robot's capability to identify and differentiate between different colors accurately. Object recognition tests will assess the robot's ability to detect and avoid obstacles during its operation.

Furthermore, user testing will be conducted to gather feedback on the user interface, ease of control, and overall user experience with the robot's Android application and website. This feedback will help in identifying areas of improvement and enhancing the user interface for better usability.

The data collected during the testing phase will be analyzed to determine the robot's effectiveness in improving delivery efficiency and productivity in office areas. Any issues or shortcomings identified during the testing phase will be addressed, and necessary adjustments will be made to optimize the robot's performance.

3. RESULTS AND DISCUSSIONS

Hardware module testing carried out on delivery robots for office areas consists of testing the processor module, battery module, object detection module, navigation module, information display module, and the entire system.

Testing and Analysis of ESP32 Processing Module

Experiments to ensure that the microcontroller processor is functioning properly and can connect to the WiFi network. This test was carried out by recording the status of the connected WiFi on each trial to see the success rate of the connection. In addition, the speed of the connected ESP32 was also measured to understand its performance in sending and receiving data. Table 1 below is the result of the test.

Table 1 The Test Results of the Processing Module.

Test	**Status WiFi**	**Connected View**	**Time Connected (second)**
1	connected	08:33:12.865 -> Menghubungkan ke RobotPintar 08:33:13.513 -> .. 08:33:14.023 -> Terkoneksi ke Wi-Fi! 08:33:14.023 -> Waktu yang dibutuhkan: 1.14 detik 08:33:14.023 -> IP Address: 192.168.141.145	1.41
2	connected	08:38:13.338 -> Menghubungkan ke RobotPintar 08:38:13.972 -> ... 08:38:14.976 -> Terkoneksi ke Wi-Fi! 08:38:14.976 -> Waktu yang dibutuhkan: 1.62 detik 08:38:14.976 -> IP Address: 192.168.141.145	1.61
3	connected	08:44:07.676 -> Menghubungkan ke RobotPintar 08:44:08.189 -> . 08:44:08.189 -> Terkoneksi ke Wi-Fi! 08:44:08.189 -> Waktu yang dibutuhkan: 0.51 detik 08:44:08.189 -> IP Address: 192.168.141.145	0.51
4	connected	08:48:50.997 -> Terkoneksi ke Wi-Fi! 08:48:50.997 -> Waktu yang dibutuhkan: 0.62 detik 08:48:50.997 -> IP Address: 192.168.141.145 08:48:50.997 -> 08:48:50.997 -> Menghubungkan ke RobotPintar	0.62
5	connected	08:48:53.019 -> Terkoneksi ke Wi-Fi! 08:48:53.019 -> Waktu yang dibutuhkan: 2.01 detik 08:48:53.019 -> IP Address: 192.168.141.145 08:48:53.019 ->	2.01
6	connected	08:50:09.744 -> Menghubungkan ke RobotPintar 08:50:10.378 -> . 08:50:10.378 -> Terkoneksi ke Wi-Fi! 08:50:10.378 -> Waktu yang dibutuhkan: 0.63 detik 08:50:10.378 -> IP Address: 192.168.141.145 08:50:10.378 ->	0.63
7	connected	08:52:40.977 -> Menghubungkan ke RobotPintar 08:52:41.480 -> ..... 08:52:43.485 -> Terkoneksi ke Wi-Fi! 08:52:43.485 -> Waktu yang dibutuhkan: 2.51 detik 08:52:43.485 -> IP Address: 192.168.141.145	2.51

Table 1 shows the test results of the processing module. The speed at which the ESP32 connected varied from 0.51 seconds to 1.33 seconds. The average connected speed in this experiment is about 0,75 s. The speed variation can be caused by several factors, including the distance between the processing module and the WiFi access point, the density of the WiFi network. The faster the connection, the faster the response given by the processing module in transferring data [9]

Battery Module Testing and Analysis

Battery module testing and analysis is carried out to evaluate battery life when used by robots with a variety of different loads. The battery module used has a capacity of 3000 mAh as many as 2 pieces with a DC voltage of 24V. This test aims to measure how long the robot can operate after the battery is fully charged by giving the robot a load.

Table 2 Battery Module Testing Results

Experiment	**Load given to Robot**	**Endurance (Minutes)**
1	2 Kg	240

2	5 Kg	235
3	10 Kg	229
4	20 Kg	221
5	30 Kg	209
6	50 Kg	193
7	75 Kg	158

Table 2 displays the test results of the battery module using a variety of different loads. Each experiment in the table includes information about the load applied to the robot and the battery life in minutes. As the load applied to the robot increases, the battery life tends to decrease linearly. This can be observed in the test results in the table, where the battery life decreases as the load applied to the robot increases.

Through the analysis of this test, an understanding of the relationship between the load applied to the robot and the battery life can be obtained. The data obtained from this test can be used to perform calculations and estimations regarding how long the robot can operate under daily use conditions with loads that are commonly encountered.

In addition, this test can also help in determining more accurate energy requirements for robots with certain loads. By knowing the battery life in real usage situations, better planning can be done regarding battery usage and energy management in the robot system.

Object Detection Testing and Analysis

In this sub chapter, testing and analysis of the object detection module using the HC-SR04 Ultrasonic sensor is carried out. The test aims to ensure that this sensor can detect objects at a distance of 200 cm but give a stop command to the robot at a distance of 40 cm.

Table 3 Testing Results of the Object Detection Module Sensor

Test	**Distance**	**Trial Results**
1	200cm	Walk
2	100cm	Walk
3	80cm	Walk
4	60cm	Walk
5	40cm	Stop
6	20cm	Stop
7	10cm	Stop

Table 3 displays the test results of the HC-SR04 Ultrasonic sensor by recording the distance of the detected object and the results of the trials performed. Each trial in the table includes information about the distance of the object from the sensor and the response given by the sensor, marked as "Stop" or "Go". A "Stop" response indicates that the sensor has detected an object at that distance and the robot should stop, while a "Go" response indicates that no object has been detected at that distance and the robot can continue its movement. However, due to the large difference between 40 cm and 60 cm, the 2nd test was conducted.

Table 4 Results of the 2nd test of the Object Detection Module Sensor Trial Distance Test Results

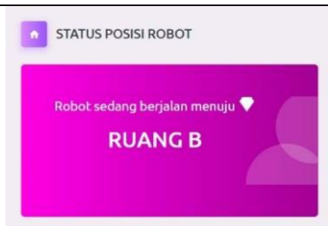
Test	Distance	Trial Results
1	60cm	Walk
2	58cm	Walk
3	55cm	Walk

4	53 cm	Walk
5	52cm	Stop
6	48cm	Stop
7	44cm	Stop

Information Viewer Testing and Analysis

Information viewer testing and analysis is conducted to ensure that the viewer module can provide accurate and precise information to the user regarding the position and status of the robot. The viewer module is responsible for displaying data about the position of the robot visually through a web display. This test aims to ensure that the viewer module can respond correctly to conditions and changes in the position of the robot. Table 5 Information Viewer Test Results

Table 5 Experiment Robot Condition Web Display

Test	Robot Condition	Appearance *web*
1	Go to point A	
2	Go to point B	
3	Go to point C	
4	Be at point A	

5	Be at point B	
6	At point C	

Table 5 shows the results of testing the information viewer by observing the robot's response in various position conditions. Each experiment describes the position of the robot on the way to a certain destination or in a state of being at the destination location. The results of each experiment are then displayed through a web view generated by the information viewer module. The first to third experiments describe the condition of the robot heading towards destinations A, B, and C. In each experiment, it is expected that the viewer module can correctly display information about the journey to the destination. Users can see through the web display that the robot is on its way to the specified destination.
The fourth to sixth experiments illustrate the condition of the robot at destinations A, B, and C. In this condition, it is expected that the viewer module can provide accurate information that the robot is at the specified destination location. Users can see through the web display that the robot has reached the desired location.
Through the results of this test, an analysis of the performance of the information display module is obtained. There is no difference between the robot's condition and that in the viewer module.

4. CONCLUSIONS AND SUGGESTIONS

The design of the smart delivery robot based on IoT with the integration of ESP32 microcontroller and advanced sensors shows promising potential in enhancing office performance. The use of TCS34725, infrared sensor, and HC-SR04 Ultrasonic Sensor improves color detection and object recognition capabilities, enabling accurate task execution in the office environment. The integration of Android applications and website facilitates real-time online control and monitoring of the robot.

Recommendations:

Implement Machine Learning and AI technologies to enhance the robot's navigation and object recognition capabilities for efficient path-following without lines.
Integrate smart delivery robots with data analytics systems to gather valuable insights for optimizing efficiency and productivity.
Enhance the robot's communication module to collaborate with other office devices, such as security systems, for improved coordination and obstacle avoidance during deliveries.

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