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A Development of Pesticide Spray Robot

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ABSTRACT – *The agriculture industry has identified pest management in fertigation-based farms as a challenging task. Innovations in pesticide spraying technologies are crucial, as manual methods are laborious, inefficient, and hazardous due to chemical exposure. Therefore, this research introduces a pesticide spray robot. The design focuses primarily on flat surfaces. The development consists of three main layers: the development and integration layer, the communication layer, and the application layer. An ESP32 is used as the main controller, while the Android ESP Bluetooth Dabble app enables communication and control via Android smartphones. The robot's performance was tested and validated on a real fertigation farm at Kebuniti Politeknik Sultan Azlan Shah. Results show that the robot can be controlled using the Dabble application and can communicate over a Bluetooth network generated by the ESP32 at a maximum distance of 20 meters. Additionally, the robot can move on various types of flat surfaces, including uneven farm roads, at up to 30% of its maximum speed. In the future, this robot has the potential to revolutionize pest control, improve crop health and productivity, and eliminate the need for human labor and worker exposure to chemicals.*

KEYWORDS: Pesticide spray, agriculture, farm, Android, robot

1. INTRODUCTION

The agricultural sector is expanding periodically, as by the end of 2050, it is anticipated to accommodate the rapid increase in population. The prediction indicates that reliance on agricultural yields to accommodate population expansion is concerning, as the global population is projected to increase by more than one-third, or 2.5 billion individuals.

Pests such as mites, snails, and maggots are typically present on farms, utilizing plants as their food supply and breeding grounds. The problem can be mitigated or managed with the periodic use of pesticides. The worker will physically spray the farm while wearing safety gear, moving from crop to crop to apply the spray. This strategy results in inefficient practices and exposes individuals to harmful substances while spraying. Even with protective gear, a worker may face catastrophic consequences, since research indicates that such gear does not eliminate chemical exposure but just mitigates its extent (Kassim et al., 2020). The World Health Organization (WHO) predicts around three million cases of pesticide poisoning annually, resulting in the deaths of 220,000 individuals, mostly in underdeveloped countries (Vardhan et al., 2014; Adhav et al., 2019).

Previous study on Pesticide Sprayer Robot Prototype navigation used Arduino Mega, (2 Amp 7V-30V L298N), and a 12 VDC 7.0 AH rechargeable battery. The system's brain, the microcontroller, runs C++ programs written in the Arduino IDE to control the prototype's sequencing and functioning. In remote manual mode, farm workers may use the Blynk app on their phones to control the robot's movement and spray pesticides, and it is limited in distance coverage (Chaitanya et al., 2020). Another app that is available to control a robot is the Dabble Application. Dabble is an open-source platform and can control movement with multiple application modules (Agilo Research, 2024).

Besides that, Kassim et al. (2020) developed an organic pesticide robot using a 12V/70W diaphragm water pump. The water pump can convey up to 10L of organic pesticide from the water tank to the spraying nozzle, as compared to the pesticide robot developed by Mashori et al. (2023) that uses a 12V/100W water pump that can only convey up to 1.5 L.

Thus, based on the review, a pesticide-spraying robot for agricultural purposes is introduced. The robot can navigate between crops according to the farmer's instructions via the open-source Dabble application downloaded from the Android app store. With the Dabble application, the robot can be controlled around the agricultural field up to a maximum of 20 meters. The pesticide robot applied a 12V/100W diaphragm water pump, as it can convey up to 1,500 ml of organic pesticide. By utilizing the pump, the maximum weight of the robot is suitable to be handled on flat surfaces with a speed up to 30%. The robot features a cost-effective component, enhancing productivity, safety, and fulfilling labor demands in agricultural applications. Figure 1 illustrates the Pesticide Spray Robot performing its task at a vegetable fertigation farm to distribute the pesticide over the area.

FIGURE 1: Pesticide spray robot hardware

2. METHODOLOGY

The responsibility of controlling and managing plant growth in good condition from the early to the harvest stage is crucial. Therefore, the development of full functionality of a Pesticide Spray Robot is an important task. In this study, the development of pesticide spray robots is summarized in Figure 2. The development of the robot is divided into three main layers: Development and Integration, Communication, and Application layer.

The Development and Integration layer includes different types of hardware and software. The hardware includes a microcontroller, motor, and water pump, while the software includes the Arduino IDE and Dabble Application. Both hardware and software are then integrated to enable full functionality of the robot and enable the robot to execute tasks. The core physical components inside the robot are the motors for movement and the pumps for spraying pesticides. This physical component is integrated with programmed instructions to control the robot’s operations.

The Communication Layer uses Bluetooth technology to enable wireless control of the robot. This allows the user to send commands, such as movement directions or spray activation, remotely from a smartphone Dabble Gamepad Application. These programs define the movement, the timing of its spraying, and how it responds to input or environmental conditions.

The Application Layer represents the robot's functional implementation in the application of pesticides on crops. The robot will control its movement through the plant rows for accurate spraying, reducing pesticide waste and promoting environmental sustainability. The spraying process will be optimized by improving efficiency, reducing labor, and minimizing human exposure to toxic chemicals. This layer demonstrates the practical implementation of robots in agriculture, highlighting improvements in production, safety, and precision. Each layer collaborates to produce fully operational and efficient pesticide spraying.

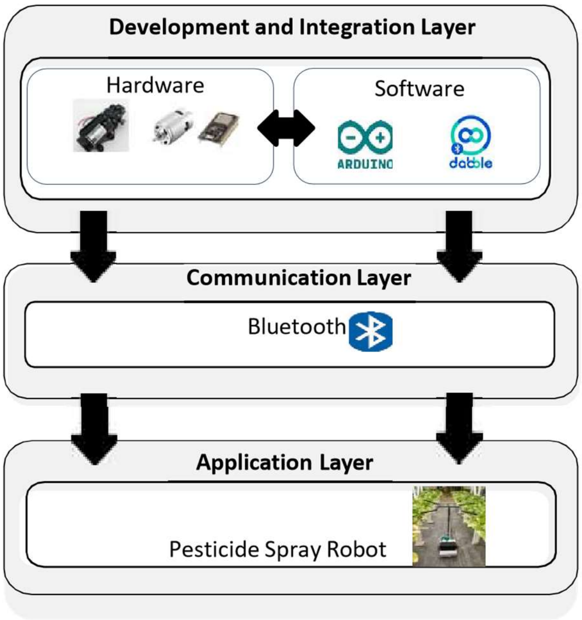

FIGURE 2: Pesticide spray robot architecture

2.1 Pesticide Spray Robot Hardware

Figure 3 illustrates the length, width, and height measurements of the Pesticide Spray Robot, 40 cm, 25 cm, and 94 cm, respectively. The dimension of the Pesticide Spray Robot is determined to be 40 cm because the vegetable plants are about two feet when they have reached maturity. The design is done using 3D Software, and the development of the Pesticide Spray Robot is based on the design. The specification of the robot is shown in Table 1.

Figure 4 shows the overall system overview of the Pesticide Spray Robot. It illustrates the connection between two different systems that will be combined inside the Pesticide Spray Robot. The development of the Android Control Pesticide Spray Robot consists of two parts where the navigation system and the spraying system. The connection between the controller robots to hardware in the designed robot is crucial and plays a major role in making a robot function as desired. Miscommunication between the electronic components can affect the malfunction of the designed system, contributing to the deviation of the operation from achieving the objective.

FIGURE 3: Pesticide Spray Robot design (left); developed robot (right)

TABLE 1: Pesticide Spray Robot specification

Item	Specification
Robot dimension	40cm x 25cm x 94cm
Robot weight	6.5kg without payload
Drive system	2-wheeled drive system
Power supply	24VDC lead-acid rechargeable battery
Payload	Max: 15kg

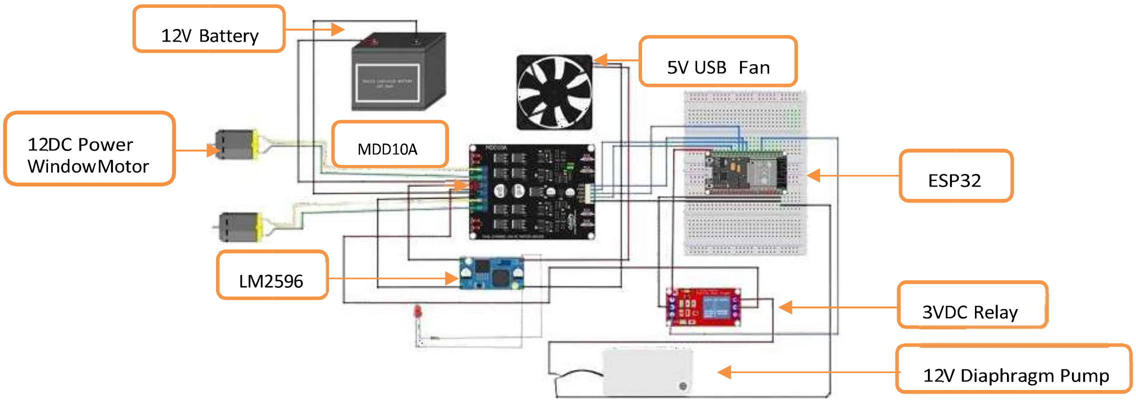

FIGURE 4: Pesticide Spray Robot system overview

2.2 Navigation System

The navigation system for the Pesticide Spray Robot comprises two 12VDC motor power windows with connection, an ESP32, a 10Amp 5V-30V DC motor driver (two channels), a 12V DC water pump with a 5m lift, a single-channel 12V relay, and a 12V buck converter. The microcontroller serves as the system's brain, with programs generated in C++ utilizing the Arduino IDE, subsequently uploaded to control the robot's sequencing and functioning (Adhav et al., 2019; Chaitanya et al., 2020).

The Pesticide Spray Robot feature is a remote manual operating mode. The Dabble App controller is an important component in controller mode, enabling the robot to navigate the farm autonomously and activating the spraying mechanism upon detecting a plant within range. Using the Dabble interface application, the Pesticide Spray Robot can be controlled by a mobile smartphone. Therefore, farm workers may easily browse and manage the robot's movement and spray pesticides by using the Dabble Gamepad Interface as shown in Figure 5.

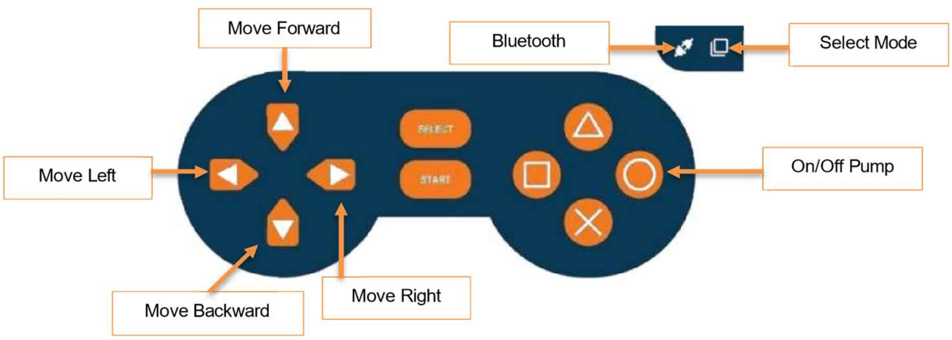

FIGURE 5: Dabble Gamepad interface

The operation of the Dabble Gamepad interface is explained below:

(a) Open the Dabble app on a smartphone and enable the Bluetooth connection

(b) Select the device

(c) Use the interfaced Gamepad to control the robot:

Up = robot moves forward

Down = robot moves backward

Right = robot moves right

Left = robot moves left

Circle = Pump ON/OFF

2.3 Spraying Process

A 12V/60W DC diaphragm water pump is a type of positive displacement pump that uses a flexible diaphragm to move water. It operates on 12 volts of direct current (DC), making it suitable for battery-powered systems or low-voltage setups. The 60-watt power rating indicates its energy consumption, which is efficient for small to medium applications. The pump works by creating a vacuum when the diaphragm retracts, drawing water into the pump. Once the diaphragm compresses, it pushes the water out, enabling continuous flow. This design allows the pump to be self-priming, meaning it can start pumping even if the inlet is fully submerged. The condition of the spraying system is controlled by a microcontroller, like the navigation part. The control movement of the robot and valve via the Dabble Gamepad simultaneously. The main components of the spraying are the spraying reservoir tank 5L, pesticide pump, two Single Channel Relays 12V, a tube, and four nozzles for spraying under crop leaves. The selection of a pesticide pump is crucial due to the pump's need to be able to push the pesticide out with the desired pressure. Therefore, the targeted plants, especially under the crop leaves, can be covered with a proper pressure spray.

A DC 12V/60W water pump was selected to transport 5 liters of organic pesticide from the reservoir water tank for a spraying operation utilizing a nozzle. A single-channel 12V relay board is linked to the microcontroller and the water pump. The input signal from the microcontroller prompts the relay contact to transition from ordinarily open (NO) to normally closed (NC), thus activating the spraying mechanism. The relay board was coupled to a single solenoid valve, which triggered the dual side spraying mechanism. The water pump will cease operation, and the solenoid valve will be de-energized at completion of the spraying procedure. Each spraying mechanism on the left and right sides is equipped with four nozzles that produce a mist, facilitating the rapid and effective application of insecticide on both sides of the farm.

2.4 Experimental Setup

The Pesticide Spray Robot requires testing in a real environment at a vegetable fertigation farm. The experimental setup at the vegetable fertigation farm, including roughly 80 vegetable plants, is currently undergoing testing. The experiment is carried out from previous research (Vardhan et al., 2014). Figure 6 illustrates the experimental configuration within the fertigation farms. The experiment is conducted to assess the capabilities of the motor, the valve, and the robot's mobility during spraying operations.

The Dabble Gamepad Interface facilitates the control of robot movement and direction at the maximum communication range with the Android application. The robot will behave according to the pressed button and be controlled via a Dabble App on a smartphone. The movement of the robot can be controlled in forward, backward, right, and left directions, and the activated spraying mechanism (spray left, spray right, and spray both) as shown in Figure 7. This experiment will measure the distance travelled by the Pesticide Spray Robot during movement. The distance will be documented to assess the performance of robots along the trajectory.

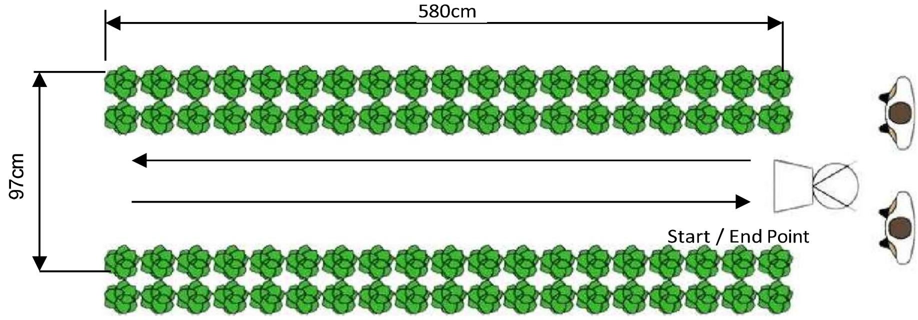

FIGURE 6: Experimental floor layout in vegetable fertigation farm

FIGURE 7: Dabble App controller to test run on the field

3. RESULTS AND DISCUSSION

Based on the experimental setup, the navigation system for a controlled pesticide sprayer robot was successfully implemented. Vegetable plants are planted on both sides of the path, and the distance between each vegetable is close. When the robot is switched on, it will proceed in a straight line until it reaches the first vegetable plant. The movement of the Pesticide Spray Robot is controlled using a Bluetooth network generated by ESP32. While a Dabble Application is used as an interface to send control commands to the ESP32. The purpose of this test is to determine the maximum distance at which the Bluetooth connection between the ESP32 and the Dabble application remains stable, as well as to evaluate the communication smoothness of robot control at various distances. Table 2 illustrates the distance capable of being communicated to control the robot with the Dabble application.

TABLE 2: Communication distance

Distance Robot Capable of Control	Detected
5 meters	Yes
10 meters	Yes
15 meters	Yes
20 meters	Yes
25 meters	No

Table 2 shows the robot's ability to communicate using a Dabble Application. It is successful to communicate 5, 10, 15, and 20 meters. However, at 25 meters, the robot is no longer able to communicate with Dabble apps. This indicates that the robot's maximum effective communication range is up to 20 meters.

For the surface type, vibration and speed limit the robot has also been tested to check the stability of the robot when movement. The main concern that needs to be highlighted is the stability of the spray nozzle pipe moving along the path. The speed limit can be reduced when facing an uneven surface, like a farm road. Details of experiments on different surfaces as shown in Table 3.

TABLE 3: Experimental testing on different types of surfaces

Surface Type	Vibrations	Speed Limit (100 %)	Spray Nozzle Pipe Stability
Cement Road	Low vibration due to a smooth and hard surface	30 %	High stability; minimal shaking
Tar Road	Moderate vibration depends on the surface condition	30%	Stable, with occasional minor shaking
Flat Ground Surface	Minimal vibration on level ground	30%	Stable, with occasional minor shaking
Farm Road	High vibration due to uneven, loose terrain	30%	Badly shaking; significantly unstable

Table 3 analyzes how different surface types affect vibrations, speed limits, and the stability of spray nozzle pipes. On cement roads, vibrations are low due to the smooth, hard surface, and the spray nozzle pipe remains highly stable with minimal shaking. Tar roads cause moderate vibrations depending on the surface condition, with the spray nozzle pipe being stable but experiencing occasional minor shaking. Flat ground surfaces have minimal vibrations on level terrain, and the spray nozzle pipe is mostly stable with minor shaking. Farm roads produce high vibrations because of uneven and loose terrain, leading to significant instability and bad shaking of the spray nozzle pipe. In all cases, the speed limit is set at 30% of the maximum to maintain the safety and stability of the robot.

4. CONCLUSION

The pesticide spray robot was successfully developed and offers a significant advancement in agricultural practices by reducing farmers' exposure to harmful chemical hazards. It provides a safer alternative to traditional manual pesticide application, enhancing worker health and reducing absenteeism. The robot also lowers labor costs by minimizing the need for multiple workers while ensuring efficient and consistent pesticide application across the field. Powered by the ESP32 microcontroller and utilizing Android ESP Bluetooth with Dabble for remote control, the robot operates smoothly and is adaptable to flat surfaces and various environmental conditions. The performance of the robot was tested and validated in a real fertigation farm at Kebuniti Politeknik Sultan Azlan Shah. Based on the performance, the developed robot can be controlled using the Dabble Application and communicated using a Bluetooth network generated by ESP32 for a maximum of 20 meters. Secondly, the robot can move on multiple types of flat surfaces, including uneven surfaces like a farm road, with up to a maximum of 30% of the speed limit. In the future, this research approach will enable us to revolutionize pest control, improving crop health and productivity while eliminating human labor and worker chemical exposure.

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