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The evolution of smart sprayer system for agricultural sector in Malaysia

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ABSTRACT

This study presents the development of a smart sprayer system featuring a microcontroller, ultrasonic sensors, and a Wi-Fi module for agriculture. This system enables 360° movement capabilities and facilitates the activation and deactivation of the sprayer pump remotely. The system offers remote control functionality through smartphone integration, effectively mitigating the need for direct physical contact with hazardous chemicals during the spraying operation. The results demonstrate the efficient operation of the smart sprayer system. The average spraying efficacy is estimated to be 95%, surpassing that of conventional spraying methods, as evidenced by prior research studies. The system is accessible for remote operation via a user-friendly interface, facilitated by the integrated internet of things (IoT) and microcontroller. As anticipated, it successfully executed 360° movements, obstacle detection, water level indication, and remote control of the sprayer pump.

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1. INTRODUCTION

In the transformation of fourth industrial revolution, Malaysia's agricultural sector is transitioning towards smart automation systems to address the challenges associated with traditional farming practices, notably in crop spraying [1], [2]. The conventional agriculture spraying method have long been plagued with challenges which are not only labor-intensive and time consuming, but also result burden in physically activities, and high resource wastage in large and medium scale agricultural operation [3], [4]. The labor-intensive nature of conventional spraying methods has strained the availability of manpower, exacerbating overall productivity within the agriculture sector. These methods typically demand more time to cover huge agricultural areas [5], [6]. The spraying style also poses health risk to farmers who handle the work conventionally. Conventional work causes prolonged time of spraying, which leads to musculoskeletal disorders resulting in chronic pain and reduced productivity among farmers [7], [8]. The conventional method in spraying also results in excessive resource wastage, as a significant portion of agrochemicals fail to reach the intended plants and pests effectively [9], [10]. The quality of crops can be compromised by the inefficiencies of conventional spraying methods, which often unable to adhere to proper spraying procedures [11], [12].

Numerous researchers have engineered smart agricultural systems and automations, offering innovative alternatives aimed at modernizing the agricultural sector and addressing the challenges posed by traditional agricultural practices [13]–[15]. In [16], the study aims to perform plant-protect operations using an unmanned aerial vehicle (UAV) based automatic control spraying system. The system used a highly integrated and ultra-low power MSP430 single-cip micro-computer with an independent functional module. In comparison to the study referenced in [17], the researchers devised a comprehensive and resilient methodology for autonomous robot navigation within crop fields utilizing light detection and ranging (LiDAR) data. Their approach hinges on extracting lines from two-dimension (2D) point clouds employing the PEARL-based method. However, the incorporation of intricate algorithmic systems in both studies may impact the affordability of the systems, rendering them potentially unsuitable for small-scale urban farmers due to their elevated cost. Additionally, these innovations lack the inclusion of water level indicators, a feature present in our system. Water level indicators play a crucial role in helping farmers gauging water availability, enhancing the system's utility [18].

Therefore, this paper introduces a smart sprayer system constructed on a radio-controlled car chassis. This system is designed via AutoCAD 2023 software and programmed using Arduino IDE software. The wireless fertilizer and pesticide spraying operations are operated through a NodeMCU module. With a wireless-control range of up to 150 m, the system's operations and functionalities are detailed extensively in subsequent sections of this paper.

2. SMART SPRAYER SYSTEM DEVELOPMENT

2.1. Smart sprayer system operation

Figure 1 illustrates the operational flowchart of the smart sprayer system. The operation of the system lies on its control functionalities including movement, obstacle detection, water level indication, and spraying operations. A relay switch governs the precise activation or deactivation of the sprayer pump, ensuring accurate dispersal of liquid agrochemicals. A liquid level sensor monitors reservoir levels, prompting an alert via a buzzer when levels are low, signaling the need for agrochemical replenishment remotely. When liquid levels are adequate, the system transitions into user-controlled spraying mode via the IoT Wi-Fi module. For obstacle detection, users can redirect the system's path using wireless remote-control movements. Upon completion of operations, deactivation is achieved by switching off the Wi-Fi module, while the battery is recharged for subsequent use. This integration of components empowers the smart sprayer system to deliver programmable spraying operations, remote movement, obstacle detection and liquid level indication capabilities effectively.

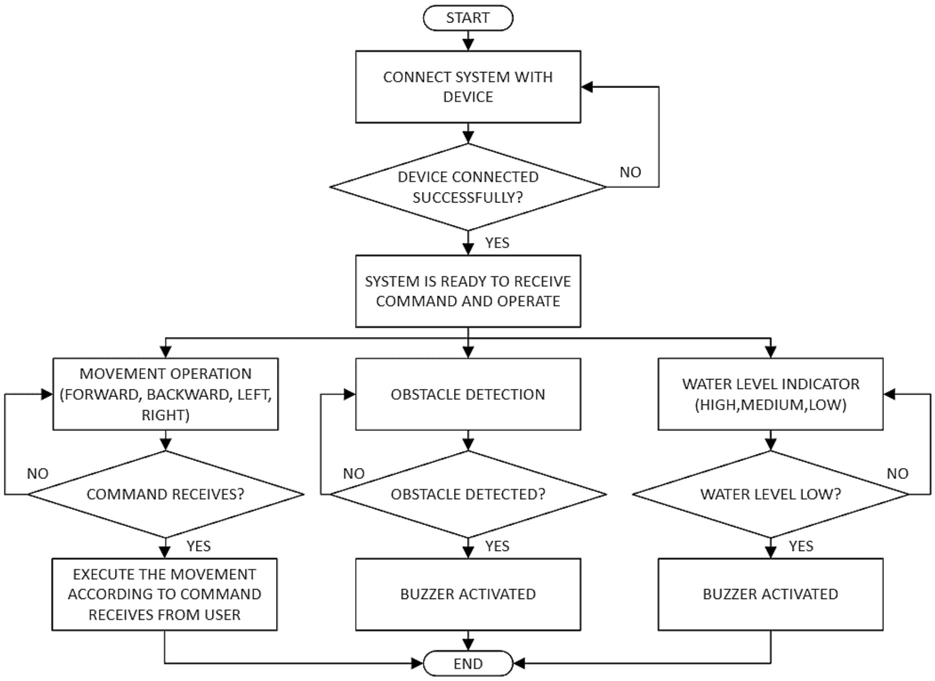

Figure 1. Flowchart of the smart sprayer system operation

Figure 2 shows the external part of the system consists of a switch, two nozzles (left and right), a water tube, a sprayer stand, two ultrasonic sensors, two buzzers, two Arduino uno, off-road tires, RC-car chassis, water tank, water pump, led indicator, and internal component casing. There are two Arduino uno used to activate each of the ultrasonic sensors for the obstacle sensor and water level indicator. The obstacle sensor is mounted in front of the smart sprayer system, while the water sensor is put on top of the water tank cover. The water tank has a capacity of 1,000 ml which is mounted on the rear of the system. The spraying nozzles can be adjusted manually by twisting the nozzle so it can meet the desired spraying shape needed by the user. The water pump is triggered via smartphone and the NodeMCU ESP8266 will control the relay and supply 12 V to the water pump when activated.

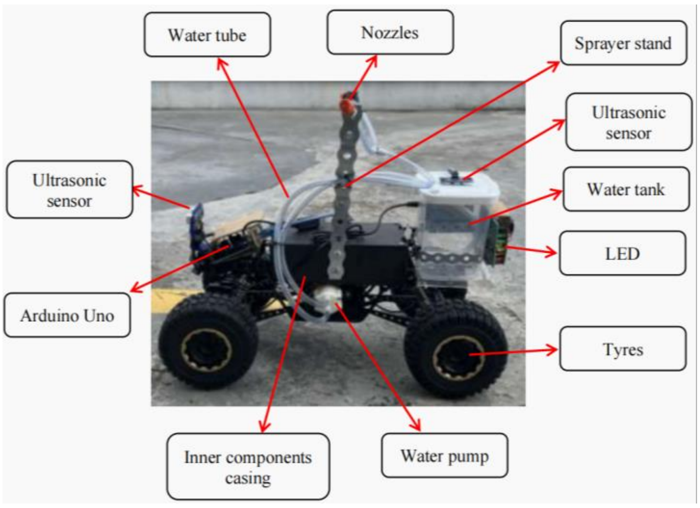

Figure 2. Side view of the system

3. RESULTS AND DISCUSSION

3.1. Movements

As depicted in Figure 3, the smart sprayer system exhibits versatile movement capabilities, enabling remote control for forward, backward, left, and right motions. This provides users with flexibility to tailor system operation to specific spraying needs in agricultural areas. The integration of obstacle detection functionality also enhances operational safety by promptly alerting users to potential obstacles 1 feet in front of the system and enabling avoidance maneuvers to prevent accidents and system damage. A comparative analysis with [19] reveals the implementation of a line detection system in their setup, limiting adaptability and rendering the system unsuitable for outdoor tasks due to the absence of obstacle detection. Similarly, Mashori *et al.* [20] introduced a wirelessly controlled system without obstacle detection functionality, that was a critical feature incorporated into this study's design. Notably, this study also features 360° movement capability, affording users enhanced maneuverability to navigate obstacles seamlessly and manage system mobility effectively within agricultural environments.

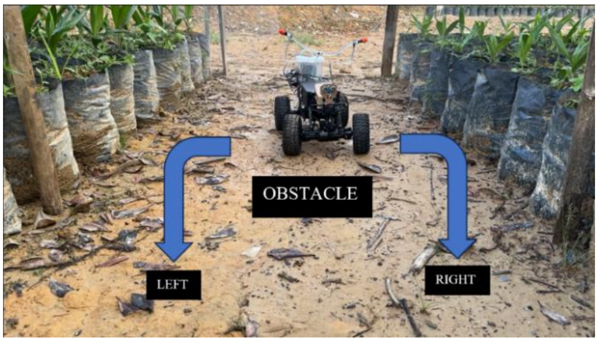

Figure 3. Movement of the smart sprayer system with obstacle

3.2. Water level indicator

The performance of the system includes a water level indicator as shown in Figure 4, that has significant use in agricultural tasks. This feature aids farmers in accurately gauging the volume of sprayable crops, thereby facilitating more precise application and resource management. The water level indicator delineates four (4) distinct conditions. When the water level reaches its maximum capacity of 1 liter, the LED lights illuminate green, indicating a full reservoir. Subsequently, as the water level decreases to 500 ml, the green LEDs dim, and yellow LEDs illuminate to signify a moderate water level. At the lowest level of 200 ml, the LED lights transition to red, signaling a low water level, while the other LEDs remain off. Upon complete drainage of the reservoir, all LEDs deactivate, and a buzzer is triggered to alert the user. The incorporation of a water level indicator, as depicted in Figure 4, represents a feature absence in previous studies such as [21]–[23]. Unlike these prior studies, which primarily concentrate on movement algorithms and sprayer capabilities, this study addresses the critical aspect of water level monitoring in agricultural spraying operations. This absence of water level indicators in previous references stands as a notable drawback, underscoring the significance of this study's comprehensive approach to operational monitoring.

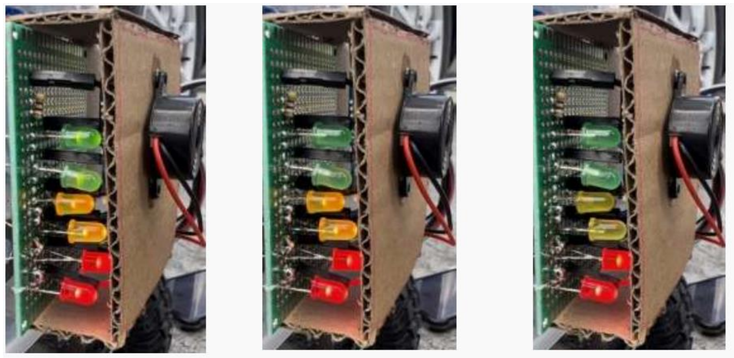

Figure 4. Water level indicators

3.3. Sprayer coverage area

The system features dual spraying nozzles, enabling simultaneous spraying capabilities on both the left and right sides with a maximum coverage area of 1.5 m². The system offers flexibility in adjusting spraying sizes by simply twisting the knob to suit varying field conditions. The efficiency of the coverage area for both nozzles is detailed in Table 1. It is evident that efficiency is significantly influenced by the timing of the spraying operation, with optimal results observed during morning and evening sessions. This variability can be attributed to factors such as wind direction, weather conditions, wind velocity, and sprayer pressure. Accordingly, farmers can utilize this information to select the most opportune time for spraying operations, thereby maximizing the system's spraying capabilities.

Table 1. The efficiency of the sprayer based on the time of the operation

Time	Left		Right	
	% Error (%)	Efficiency (%)	% Error (%)	Efficiency (%)
8AM	0	100	4	96
9 AM	0	100	0	100
10 AM	10	90	8	92
11 AM	10	90	9	91
2 PM	9	91	10	90
3 PM	10	90	10	90

3.4. Comparison with previous studies

Table 2 delineates the disparities between this study and previous research. In studies [24] and [25], the reported sprayer efficiencies stand at 80% and 90%, respectively. In contrast, this study achieved a sprayer efficiency of 95% compared to others. This improvement can be attributed to the implementation of a dual nozzle setup, allowing simultaneous spraying on both sides, and consequently saving time. Furthermore, while IoT functionality is absence in [24] and [25], this study integrates IoT capabilities, enabling wireless control of sprayer activation and incorporating a monitoring system featuring obstacle detection and water level indicators. Ghafar *et al.* [24] utilized a GoPro camera for path navigation, while Sandikar *et al.* [25] employed a color sensor for leaf condition identification. The limitations of the GoPro camera lie in its range estimation capability, potentially leading to accidents if users are unfamiliar with its operation. Whereas the color sensor's accuracy is constrained by variations in leaf color attributable to differing brightness levels in the environment. Conversely, this study incorporates ultrasonic sensors for obstacle detection in its performance.

Table 2. Comparison with previous studies

Studies parameters	[24]	[25]	This study
Sprayer efficiency	80%	90%	95%
IoT	Not available	Not available	Available
Sensors	GoPro	Color sensor	Ultrasonic sensor
Obstacle detection	Not available	Not available	Available
Water level indicator	Not available	Not available	Available

4. CONCLUSION

This paper develops the IoT-enabled smart sprayer system tailored for agricultural applications, featuring a user-friendly interface. This innovation holds significant potential for the agricultural sector, particularly for small-scale operations, as it reduces dependency on labor-intensive conventional spraying methods and enhances crop quality through more precise application of agricultural chemicals. The integration of IoT technology not only facilitates remote operation but also minimizes physical engagement with the equipment. The system's dual nozzle design and effective monitoring capabilities, including obstacle detection and water level indicators, ensure comprehensive coverage and efficient use of resources. Future work could focus on further enhancement of the system's autonomous capabilities with the integration of artificial intelligence to predict optimal spraying times and patterns.

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