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Review Paper / Derleme

A Survey on the Design of Autonomous and Semi Autonomous Pesticide Sprayer Robot

K.Gayathri DEVI[a], C.Senthil KUMAR[b], B.KISHORE[c]

[a]Professor, Dr.N.G.P Institute of Technology, Coimbatore, Tamilnadu,India
[b]Assistant Professor, Dr.N.G.P Institute of Technology, Coimbatore, Tamilnadu,India
[c]Assistant Professor, Dr. Mahalingam College of Engineering and Technology, Pollachi,India
gayathridevik@yahoo.com

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Abstract: In a developing country like India, agriculture is the most important occupation. It is critical to increase agricultural efficiency and productivity by replacing laborers with intelligent robots that use cutting-edge technology. The hardware specifics and execution of the pesticide spraying robot by many researchers are surveyed in this study to provide a comprehensive report in framing a cost-effective solution for farmers. The consolidated table will give u a quick overview about the factors needed for the implementation such as hardware, technology used and the disadvantages. The goal of the survey is to create a smart prototype pesticide spraying robot with low-cost components such as microcontrollers, sensors, motors, and terminal equipment that can be used by all farmers across the country to protect them from hazardous pesticide chemicals, reduce labour costs, and improve agricultural efficiency.

Keywords: **Robotic, IoT, Arduino, microcontroller, ultrasonic sensor, motor drive circuit, relay circuit**

Otonom ve Yarı Otonom Pestisit Püskürtücü Robot Tasarımı Üzerine Bir Araştırma

Öz: Hindistan gibi gelişmekte olan bir ülkede tarım en önemli meslektir. İşçileri en son teknolojiyi kullanan akıllı robotlarla değiştirerek tarımsal verimliliği ve üretkenliği artırmak çok önemlidir. Çiftçiler için uygun maliyetli bir çözümün çerçevelenmesinde kapsamlı bir rapor sağlamak için bu çalışmada birçok araştırmacı tarafından pestisit püskürtme robotunun donanım özellikleri ve uygulaması incelenmiştir. Konsolide tablo, donanım, kullanılan teknoloji ve dezavantajlar gibi uygulama için gereken faktörler hakkında size hızlı bir genel bakış sağlayacaktır. Anketin amacı, ülke genelindeki tüm çiftçiler tarafından zararlı pestisit kimyasallarından korunmak, işgücünü azaltmak için kullanılabilecek mikrodenetleyiciler, sensörler, motorlar ve terminal ekipmanı gibi düşük maliyetli bileşenlere sahip akıllı bir prototip pestisit püskürtme robotu oluşturmaktır. maliyetleri ve tarımsal verimliliği artırmak.

Anahtar Kelimeler: Robotik, IoT, Arduino, mikrodenetleyici, ultrasonik sensör, motor sürücü devresi, röle devresi

1. Introduction

Agriculture is one of the most important occupations in a developing country like India. Advancement in the field of robotics has widened its applications in agriculture-related activities. Automation provides a traditional profession with improved efficiency, precision along with safe cultivation practices. The figure 1 shows the two methods of spraying pesticide to the field. The

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ORCID ID: [a]0000-0003-1625-1835; [b]0000-0001-7942-1171; [c]0000-0003-1918-9774

first method involves carrying the pesticide at the back and spraying to a selective location by the human. The second method involves a vehicle with pesticide carrying unit, both the cases involves human who may be affected adversely by the hazardous chemicals in the pesticide

Figure 1. Methods of Pesticide Spraying technique

The major goal of this project is to develop a low-cost, high-efficiency pesticide spraying robot that will limit the amount of time people are exposed to toxic chemicals that are harmful to their health. The Robot will replace laborers for spraying of pesticides/fertilizers. The robot will be either fully automatic or semiautomatic, with the farmer controlling it via a radio. This approach entails creating a prototype employing microprocessors, sensors, motors, and terminal equipment to provide farmers with automated assistance. The goal of this proposed project is to increase farmer safety when performing crop-related activities such as spraying chemicals, fertilizers, and pesticides, and to make it available to all farmers across the country.

2. Literature Survey

Mahapurush et al [1] proposed a solar operated automatic pesticide spraying robot to reduce the manpower and use of electricity. The author implemented the prototype as shown in the Fig 2 with Arduino, ultrasonic sensor,camera, motor drive circuit, relay circuit to pump the sprayer circuit and the battery powered with the help of solar panel. The robot is operated with transmitter and receiver operating at high frequency of 434 Mhz.

Figure 2. Prototype of solar powered Pesticide spraying robot[1]

It is an automated robot that is controlled by Arduino UNO R3. Automation of the robot is achieved by using ultrasonic sensors and Arduino UNO R3. DC motors are used for the operation of cutting of the grass. DC battery is used to power all the components of the system. As a second option, a water pump with a spreading nozzle is used for spraying pesticides.

Ranjitha et al [2] developed a robot that can sow seeds, mow lawns, and spray insecticides. Using a solar panel, all of the system's components are powered by solar energy. The robot is operated manually using a Bluetooth/Android App that provides signals to the robot for various mechanics and movement. As a result, it improves the efficiency of seed sowing, pesticide spraying, and grass cutting, as well as reducing the problem that farmers face when manually planting.

Ege Ozgul et al [3] created the "X-Bot," a low-cost semi-autonomous robot that uses current technical breakthroughs to do agricultural jobs with high efficiency and precision. The Arduino Mega 2560 microcontroller was utilized to automate the control of all the components. The motor driver is responsible for controlling the DC motor's speeds as well as the water pump that is attached to the nozzle. For path detection, three ultrasonic sensors are utilized buzzer is used for repelling insects.

Umayal et al [4] implemented a prototype that matches with our aim of implementing reduced cost pesticide spraying robot equipment that were implemented with motherboard consisting of, transmitter, receiver, PIC16F87X microcontroller optocoupler, driving circuit and the stepper motor. The transmitter board is implemented with IC (12E), carrier signal generator with frequency of 434 MHZ that modulates the signal and produces a modulated signal in accordance with command issued by the user. The information after passing through the mixer and the amplifier will be transmitted by wireless transmitter. The receiver device consisting of antenna is tuned to receive the transmitted 434 MHZ carrier signal followed by RF amplifier for the amplification that generates the appropriate command to the robot. The PIC microcontroller serves as the heart of the prototype that will drive the entire circuit by issuing command signal to the driver circuit to run the stepper motor which in activates the robot. Optocouplers ensure data is transmitted in one direction as it is optically coupled and also acts as a protection circuit because of the isolation characteristics with the driver circuit. This prevents the damage that may be caused to microcontroller because of the backward electromotive force.

Alireza Rafiq et al [5] used an algorithm to implement an autonomous robot a robot with an AVR microcontroller for controlling all the inputs and outputs of the system. Hot water pipeline tracks were placed along the rows to assist the robot navigate. A gearbox and shaft setup distributed power from two DC motors to two driving wheels. BASCOM-AVR version 1.11.9.8 is used to programme the microcontroller, whereas PROTEUS 7 professional is used to simulate the circuit.

Bernstein et al [6] modified the conventional robot to an ASD (Adjustable spraying device) for precise spraying of the pesticide on the leaf invariant of the shape and the size of the target leaf. The goal of this research was to build a spraying unit that could be put on a robot, as shown in Figure 3. It features a single spray nozzle with an automatically adjustable spraying angle, as well as a color camera and distance sensors, all of which are mounted on a pan-tilt unit. The spraying diameter will change depending on the target's form and size. The description and the application of the parts are

- Color Camera – To capture an target image in the crop
- Laser distance sensor (SICK DX35) – To calculate the distance between the target and the ASD unit. The unit will face the target's centre based on this measurement.
- Spraying Nozzle – The nozzle will be directed to face perpendicular to the leaf or the target of the crop such that the nozzle diameter is equal to the target diameter. It consists of two parts nozzle cup and an adjustable pesticide hose attached to the Nozzle base that will spray pesticide at defined intervals.
- Stepper motor – For the control of spraying diameter and is connected through gears to the Nozzle cap

In order to calculate the flow rate in the spraying nozzle with reference to the spray diameter and the spray diameter with reference to the angular location of the nozzle, two experiments were conducted. The spraying unit can run on its own or be mounted on a mobile robotic platform. Crop-specific target identification algorithms must be developed for complete robot operation.

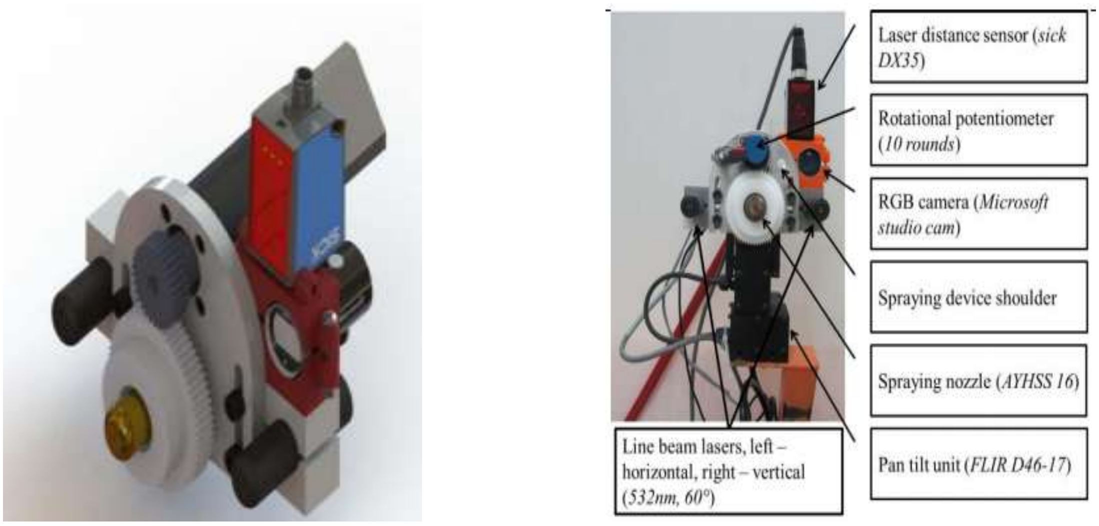

Figure 3. Spraying unit

Yan Li et al [7] concentrated on developing an automated technique for detecting and locating pests in order to obtain pest location and information for plants in a greenhouse. Binocular stereo was utilized to place the pest. The difference in color characteristic between the bug and plant leaves retrieved by picture segmentation is used to identify the infestation. The position of the pest has been determined using picture segmentation and binocular stereo vision methods. The pest's job is to direct the robot to spray pesticides for a greenhouse autonomously. The DSP board controls the spray nozzle, and data is transmitted between the chip and the computer at the robot through RS-232-C.

Chun-Mu Wu et al[8] proposed an intelligent spraying robot with a driver module, spray module, obstacle avoidance module, path planning module, and control module. Sprayer luffing mechanism is used for the sprayer to vary with spray target. The obstacle avoidance is done by using a camera lens, electronic compass, and ultrasonic sensors. For path planning GPS located the range of spray.
Sonal Sharma et al [9] suggested a prototype of the robot with parts labeled as shown in Fig 4 consisting of sensor unit comprising of temperature sensor , Humidity sensor and a soil moisture sensor, the heart of control unit ARM7 microcontroller, ZigBee module, spraying module, driver modules and a camera unit.

This autonomous robot was developed for the identification of plant disease, to monitor the growth of plant, for spraying pesticide, fertilizer and water. The steps involved are

- The camera unit is used for the capturing of leaf images, features extracted from the leaf by GLCM algorithm and the classification is done by SVM to identify the disease and the growth of the plant. It is implemented in MATLAB.
- For environmental monitoring temperature sensor , Humidity sensor and a soil moisture sensor are used for monitoring the water level of the ground.
- ARM7 is used for controlling the robot which receives the sensor output and the classification output. The assigned threshold value will be compared with the sensed value to determine the actions that should be done by the robot.
- ZigBee and GSM are used for the communication between the device and the robot.

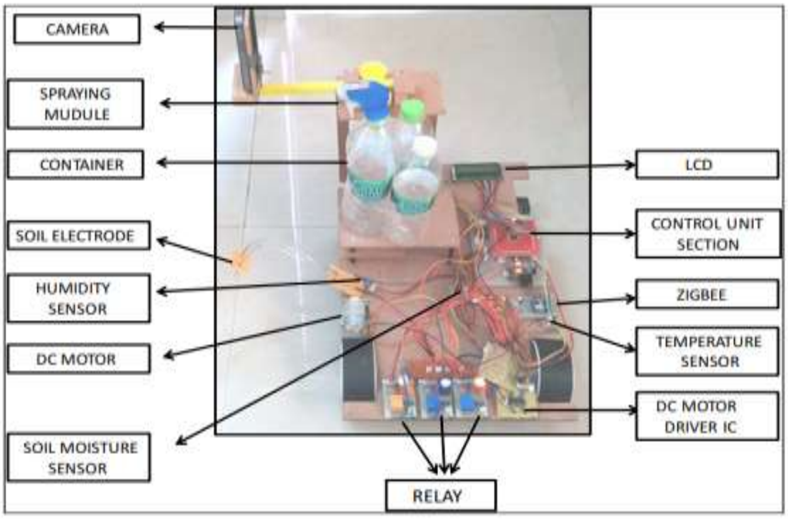

Figure 4. Hardware Assembly of the Robot[9]

Rajesh Kann et al [11] centered on a pesticide spraying robot with a mechanical sprayer. This robot uses an ultrasonic sensor to detect the target. It self-investigates and sprays the target. It uses an OTOS system in which showering gush can change the broadness. This uses the IC MAX23 to get the input from the sensor and gives the output. This gadget is placed on a mechanical sprayer for supplying pressurized pesticide. The entire system is powered by a power supply.

The robot was proposed by Tao Li, Bin Zhan, and Jixing Jia [12] can be utilized only in the greenhouse. This robot features a navigation system that incorporates controllers, electromagnetic sensors, an angle transducer, an induced wire, and a signal generator, as well as a real-time measurement of magnetic field strength. The IPC/104 bus is used by the control system. It is powered by a four-wheel independent drive system. The steering may be adjusted by adjusting the speed of the wheel motors to the left or right. It can make small bends at less than 0.5 m/s.

Victor J. Rincónaand and Paolo Balsari [13] planned to develop a remote controlled prototype for spraying pesticide for tomato crops. It is often used manually or automatically. It uses two electric motors of 1kW and two pumps. The sprayer has an air-assisted system, and the nozzle is often adjusted as a full cone or hollow cone nozzle. For hand spraying the nozzle have a 1.5 mm hole and 30° jet angle.

Tingkai Chen et al [14] enforced a pesticide spraying robot that can adapt to the height of the plant. It has a Microsoft camera which has a sensor. It can calculate height and change according to it. Arduino is used as a controller. It uses RGB and depth camera to calculate the actual height of the plant accurately. Three nozzles were kept on the side of machines. The command from the controller helps in the opening of the nozzle accordingly. Extreme spraying height is 900 mm with three nozzles open.

Peng Jain-sheng et al [15] designed a robot with trolley module, system control module, driver module, spray module, video capture module, WIFI module, infrared obstacle avoidance module. In STC11F32XE as core controller. It has anti-interference ability and low prices. The robot can move in variety of roads. Webcam video capture can cover the range 0-180 degrees. Maintenance and handling of a robot is easy. The robot movement is controlled by the mobile applications with the help of Wi-Fi.

A robot combining Robot Movement, Video Streaming, and Pesticide Spraying Mechanism was proposed by Chaitanya et al[16]. It makes use of a disease detection algorithm and to identify and classify the plant disease. Machine learning and image processing were used to aid in the identification of plant diseases. Solar-powered robots are also being developed to maximize the use of electricity [17].

Londhe et al. [18] suggested a remote operated robot with microcontroller, motor driver, DC motors, camera. The robot is used to spray pesticides to the localized area of the pest affected plants. DC motors used to control the movement of the robot. There three stages in the robot, image capturing, image processing, and automatic pesticide spraying. The image processing is done by signal processing.

Gonzalez et al [19] developed a smart spraying automated robot that consist a mobile robot with the design of a conventional agricultural vehicle chassis that will interact with sprayer system and controlled by the system controller. The figure shows the advancement of the autonomous spraying robot.

Figure 5. Smart Robotic Spraying system

There are papers which analyze the application of autonomous spraying robot at all stages [20]. In order to optimize the path and design an autonomous model implemented with tractor connected with spraying unit and a centralized controller to coordinate the location and the function of all the subsystem further advancement were introduced by Hejazipoor et al [21].

Hejazipoor et al [21] proposed an automated spraying solution that calculates the volume of the plant and operated with four degrees of freedom for performing spraying operation. The sequence of the steps in this proposed method are plant identification, opening of the manipulator, capturing section wise images of the plant, estimation of the volume, and pesticide spraying The movement of the robot is designed such that it can move row wise and images are captured in sections and volume corresponding to the sections are calculated. This procedure is followed to ensure all the plants are sprayed uniformly. The restriction is that it can spray plants maximum to a height of 2.70m. The results of the experimentation with robot estimates the computational time of 54s when the plant is 1.7m. The validation of the method proposed is verified by keeping in the plants liquid-sensitive papers and checking the absorption level and it was concluded that the height of the plant does not affect the amount sprayed. The figure 6 shows the testing of the robot in real time scenario.

Figure 6. Testing of the Robot in real time scenario [21]

The research papers listed above aided in understanding the many systems and approaches used to construct an agricultural robot. Processors, transmitters/receivers, and spraying nozzles all fail to meet the required specifications in the design of the robots by the researchers. The above survey are effectively presented as the table in the next section for quick reference.

3. Literature Survey Table

3.1. Synthesis and Characterization

The table 1 gives the insight of the implementation details with respect to the hardware and the algorithm proposed by different authors. It also highlights the restriction for us to further develop a proposed model considering the disadvantages

Table 1. Consolidation report of Robotic Pesticide Sprayer

S.No	Reference	Implementation details	components	Remarks	Restriction of the paper
1	Mahapurush, S. V., Gudi, P., Patil, C., Gudi, S., & Jaggal, P. (2020)	Proposed to reduce manpower and electricity.	Arduino UNO R3, RF 434MHz Trance-receiver, Solar panel.	It reduces electricity by using solar power.	It uses the RF module to give instructions to the Robot within a limited range.The solar power for powering the modules is not sufficient for all climates.
2	Ranjitha, B., Nikhitha, M. N., Aruna, K., & Murthy, B. V. (2019, June).	Designed using a Bluetooth/Android app to perform seed sowing, grass cutting, and pesticide spraying.	Arduino (AT mega328), Solar panel, Bluetooth module HC-05, Relay.	It uses a renewable energy source and efficient resource utilization.	It does all works simultaneously, so pesticide spraying is not that efficient.
3	Ozgul, E., & Celik, U. (2018, May).	Spraying pesticides and repelling insects are actions accomplished.	Arduino Mega 2560, Ultrasonic sensors.	It aids in the more accurate and uniform application of pesticides and repellency of field's insect.	Controlling wheels on uneven terrain is tough, and the control loop algorithm may be subjected to errors, preventing the robot from spraying into a designated area.
4	BV, A., & Umayal, C. (2015, July).	To accomplish tasks such as insect identification, pesticide spraying, and fertilizer application.	PIC Microcontroller, Optocoupler, transmitter, and receiver.	The robot's control is user-friendly; unregulated pesticide application will harm crops, hence it incorporates variable spray rate control.	There is no flexibility in the specification for customizing or changing the pesticide spraying pipe.
5	Refight, A., Kalantari, D., & Mashhadimeyg hani, H. (2014).	To prevent humans from spraying toxic chemicals in the confined space of greenhouse.	AVR microcontroller, DC Engine, Moisture, and temperature sensor.	A large tank holds pesticides and vertical spray booms with several nozzles are elements of the spray system.	This robot cannot be used everywhere other than the greenhouse.

				As a result, the robot can spray insecticides on both sides of itself, encompassing a bigger area.	
6	Berenstein, R., & Edan, Y. (2017).	To accurate pesticides spraying capable of dealing with site-specific and different sized targets.	Pan tilt unit, spraying nozzles camera.	It is capable of reducing pesticides applied. By using this device, we can spray the pesticides efficiently and economically.	It consumes more time.
7	Li, Y., Xia, C., & Lee, J. (2009, July).	Proposed to get the location and information of pest and spraying pesticides automatically in a greenhouse.	Camera, nozzles.	By this method we can detect and position the pest so, controlling the pest is easy.	Because of the noises that could lead to measurement errors.
8	Wu, C. M., & Lu, J. T. (2017, May).	Robot reduced the usage of pesticide spraying and this inturn reduced the health hazards to humans caused by pesticides.	Driver module, spray module, obstacle avoidance module path planning, and navigation module, control module.	Monitoring orientation and tracking motion paths are possible. It provides good stability and reliability.	There is no specification for adjusting or changing the pesticide spraying pipe according to the specification.
9	Sharma, S., & Borse, R. (2016, September).	To monitor and detect plant diseases, as well as the use of pesticides in a controlled manner.	ARM7 microcontroller, humidity, temperature, soil moisture sensors.	This robot could identify plant diseases in real time as well as spray pesticides in a predictable rate.	Communication range, camera quality, and container capacity are the limitations of this robot.
10	Vikram, P. R. K. R. (2020).	To reduce the risk of manual spraying.	Ultra-sonic sensor, MAX232, LCD, power supply.	It reduces the direct manual risk	It still needs the tractor to be driven by humans which do not fully cut the risk of exposure to the pesticide.
11	Liu, T., Zhang, B., & Jia, J. (2011, July).	To cut the labor cost.	Electromagnetic sensor, position sensor, controller, signal generator.	The labor cost is reduced.	It works only in a certain range, change of environment requires a lot of further modification in the design.
12	Rincón, V. J., Grella, M., Marucco, P., Alcatrão, L. E., Sanchez-Hermosilla, J., & Balsari, P. (2020).	To increase the high-quality food by reducing the risk of human contamination in the greenhouse.	Robot spray, polythene tank, hydraulic circuit, electric motors.	It sprays pesticides for a predefined setting in the system	There is no obstacle avoidance technique if exposed to sudden obstacles.
13	Chen, T., & Meng, F. (2018).	It uses to measure the height of the plant and spray according to it.	Kinetic sensor, injection system, controller.	It does measures height and effectively sprays pesticide.	It has no specifications about turning of the vehicle.
14	Jian-sheng, P. (2014).	To improve the efficiency of spraying operation of robot.	Relay-SPST, L298 motor drives, Wi-Fi Module, Video Capture Module, Driver Module.	Lower Computer Program Designs, Robot performance in a variety of roads.	Flexibility of a sprayer is less.
15	Chaitanya, P., Kotte, D., Srinath, A., & Kalyan, K. B. (2020).	To minimize diseases within plant by efficient spraying with machine learning and image processing for plant diseases diagnosis.	Arduino UNO Microcontroller board, Float Sensor, Buzzer, Motor Control Board, DC Motor.	The integration of machine learning and image processing algorithm improved the diagnosis of plant diseases.	Solar Technology for self-recharge can also be implemented in future.
16	Londhe, S. B., & Sujata, K. (2017).	To spray pesticides to the localized area of the affected plants.	PIC16F8778 Microcontroller, Motor driver IC 293D, Pesticide sprayer.	Safety to Farmers and precision is maintained.	There is no specification about prayer.

4. Conclusions

The survey summarizes the implementation aspect, the technologies employed, and the drawbacks in each study. The problem of spraying pesticides is addressed in the study article, which proposes solutions through the design and development of an autonomous and semi autonomous agricultural robot. This paper robustly survey the design aspects in the construction of an autonomous pesticide spraying robots that will augment the growth of the plant by incorporating various approaches for monitoring and an enhanced mechanism for spraying fertilizer, pesticide, and water that can be applied to different domains in agriculture.

The solutions that can be proposed based on the above survey to design a robot for spraying pesticides in agricultural fields and to monitor temperature and humidity variation may be categorized into four modules: sensing, control, driving and spraying module. The STM32 prime controller is the core of the circuit and to which all the devices are connected should be programmed effectively. The Sensing module includes an ultrasonic sensor, a temperature sensor, and a humidity sensor, control module includes an STM32, a NodeMCU, and a battery unit, driving module includes a motor controller and two dc motors and the spraying module includes two relays, two dc water pumps, a nozzle, and a sprinkler. Relays used for switch on and off the components. The pest spraying pipe, which can be either a pipe nozzle or a sprinkler, can be controlled through a mobile application to meet the needs of the farmers. The robot desined can be operated in two modes of operation: automatic and semi-automatic. The autonomous robot is controlled by the user via a smart phone application using IoT in which the NodeMCU unit that follows the user's instructionscan also be controlled manually. This survey concludes to provide cheap and efficient pesticide spraying robot for spraying pesticide in order to reduce the exposure time of the hazardous chemicals that damages the health of the farmers.

The above proposed work focusses on designing a low cost robot. According to the requirement, the spraying pipe can be selected, i.e., a spraying nozzle or a sprinkler, to enhance the spraying mechanism with high accuracy and efficiency. It's an automated robot, it's programmed to work on its own. As a result, after entering the values, it sprays insecticides across the field automatically. A mobile application can also be used to control it manually. As a result, the notion of robotic automation is used to create a pesticide spraying robot.

The above proposed literature review in the designing process can be extended to optimise the amount of energy that will be required to operate the robot. The irrigation method proposed by Selman et al.[22] is dependent on the parameter sensed by the humidity sensor in the agricultural field. This parameter tries to optimise the irrigation system by regulating the water flow to the plants in the field. In situations where there are diverse plant type in a field,individual moisture sensors can be implanted in each category of plant to convey the measured value of moisture content, and the irrigation system sprays the appropriate amount of water depending on the received value in a field. Solar panels and gel batteries are employed in the above system to provide energy to the sensors. There are also newly developed knowledge-based model to optimise energy consumption in water pumping systems through using solar power, and the water delivered to the plant is varied by the parameter sensed by the humidity sensor located in the irrigation field [23]. To obtain a long-term benefit, alternative technique of minimizing power consumption in schools would be to use photovoltaic systems. Sabri Ciftci et al. [24] constructed a 9.9 kWp grid-connected photovoltaic system (PVsyst) that can be erected on the roof to generate 13.13 MWh of power per year, among which 6.43 MWh is utilized by the customer and 6.70 MWh can be sold to the grid. Additionally, the energy consumption required to run autonomous and semi-autonomous sprayer robots is a crucial factor to be taken into consideration, and the strategies for modernisation and optimization given by Benjamin Aym-Otu et al [25] might be referred to in the literature.

The future work that can be explored for implementation are as follows

- control of a robot manually by the user via IOT through any mobile device.
- By expanding the capacity of the tank, the amount of pesticide carried by the robot can be increased. Pesticides can be sprayed over a bigger area without having to reload.
- For efficient pesticide spraying in vast fields, many robots can be linked together.
- Modernization and Optimization of energy required to power the sensors to be handled by the Solar panels and gel batteries.

Authors' contributions

Dr.K.Gayathri Devi - Preparation of the Paper
Dr.C.Senthil Kumar and Dr.B.Kishore - Both authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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