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Original Article

Design of a Spraying Module for Backpacks through Automation in the Tambo Valley Region - Arequipa

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Abstract - *Fumigation is one of the most important activities in agriculture. The manual spray bag is the most used spraying tool, with prices above 100 dollars. The constant use of manual spray bags presents health problems in the lumbar areas and the joints of the hands. This research aims to develop and implement a battery-powered fumigation module for manual pumps to reduce physical problems for farmers in the Valle del Tambo in Arequipa, Peru. The module is implemented on the one hand with a leveling of variables with the water level census, and on the other one with the process of the system by power stage. The module is implemented with an Attiny85 microcontroller, 0.48Mpa electric pump, ultrasonic sensor, and power Mosfet. A 12v 7Ah battery powers the system, and the motor is controlled through PWM signals. The farmers approved the module of the Valle del Tambo area and verified the implementation operation, contributing to the approach to technological innovation in the zone. As a result, the module implementation was obtained in 3 manual spray bags of 10, 16, and 20 liters of capacity with an efficiency of 8 hours/hectare, adequate use of the battery, and an ideal temperature for the implemented circuits.*

Keywords - *Backpack sprayer, Attiny85, PWM, Farmers' health.*

1. Introduction

Fumigation is a primary factor in Agriculture; for that reason, manual commercial fumigators with a gasoline engine or electric consumption are used. Using any fumigator implies a physical effort that triggers important health problems [1]. In addition, the price of the sprayers is above $100 [2] since they need to control the drop size applied to each crop.

Among the agricultural activities, manual fumigation is the most harmful due to vibrations and unbalanced physical effort in the body [3], [4]. The most affected parts of the body are the lumbar area 36% and the hands 30% caused by constant overexertion and vibrations in specific parts of the body [5] found that, without counting other triggering diseases such as arthritis, rheumatism, hernias, or even cancer [6]. Battery fumigation systems present evolution in agriculture [7], [8] and a reduction of overexertion in small farmers [9]. However, its high cost presents an economic problem in investment, and different designs of fumigators and sprayers have the same drawback [10], [11].

The objective of this research is to develop a battery-powered fumigation module coupled with manual pumps to reduce physical problems for farmers in the Tambo Valley, as well as to generate a technological introduction to this area of Peru through a correct control of the fumigation flow to the sowing of rice, wheat, and potatoes. For that, a 0.48 MPa (Mega Pascal) motorized pump at 12v will be used, which will be controlled by a control system through the Atiny85 microprocessor, thus regulating the necessary power for crop fumigation and the use of a 12v battery with the necessary capacity to work autonomously during a day of agricultural work. The module will be designed independently to be implemented in the different models of spray bags purchased by farmers.

Control systems are an integrated set of hardware and software in charge of managing and optimizing the operation of a system. Currently, most daily technology has a control system, focused mainly on systems of linear variables and research areas such as biomedicine or medical instrumentation, as well as in the present research work to control the supply of agricultural fluids.

The present research is structured like this; in section II, the methodology carried out for the prototype development is described in greater detail. In section III, the results will be evidenced; in section IV, the methodology and results of the proposed background will be discussed; in section V, the conclusions will be displayed, as well as recommendations of the research work.

2. Literature Review

The demand for crops increases day by day; for this reason, in the investigation of [12], the current implementations of aerial and even terrestrial robots were studied in the face of the vulnerable conditions that farmers find in the field, in addition to risks to their health, including cancer. As a result, they analyzed Trutlebot based on Matlab, also the field robot named Agrobot, a terrestrial robot with an image processing algorithm that helps harvest various agricultural products. Concluding that the world of innovation in agriculture is on the right track for farmers and not taking away their work.

The indispensable tools in agriculture are the fumigators. In [13], due to the scarce agricultural technology in India, they develop a personal agricultural pesticide sprayer with solar energy, using low-consumption foggers for 17 v (volt) photovoltaic cells and a 12v battery. They worked based on crops of cotton, onion, and green fields to maintain adequate and constant spraying capacity. As a result, they obtained a portable device with a capacity of one hectare per day, inferring that using a 20w (watts) solar panel and a 12v battery is adequate for these purposes. Furthermore, as a continuation of his research in [14], he added the previous function of his fumigator to a Drone, which he supplied with 8000mAh LiPo cells and a more precise spray nozzle. The correct application of chemical aggregates to low crops is obtained, concluding that pesticide application costs are reduced in addition to biological effects in its application.

Similarly, with a variety of models of manual sprayers on the market, [15] proposes a photovoltaic supply system for the Microner sprayer to use renewable energies in agriculture, for which he designs LabVIEW simulators of the SKN- 3000, integrates a 12v battery and a control circuit for the conditioned motor pump. Obtained a 7-hour work system with an additional 18% energy use due to its photovoltaic supply system. They concluded that a photovoltaic system was essential for fumigation work during the fieldwork period.

Most sprayers base their design on carrying the weight on the farmer's back. In [16], the proposed way is to design pest management through a 4-wheel vehicle with ultrasonic sensors that detect obstacles. They had a 12v 130 psi pump that performed the fumigation and PWM control for the application in 100 chili plants. They obtained favourable results with the application, highlighting the importance of ultrasonic sensors for the navigation system and including a pressure control for better performance in the future.

However, in [17], the authors indicate that to avoid most of the physical effort of the farmer in China, using a remote-controlled vehicle with an autonomy of 50 hours for the use of a sprayer with fuzzy logic fuzzy control for the correct fumigation of rice crops. They obtained control of up to 500 meters of distance and a delay of 0.5 Hectares per hour, thus concluding that an unmanned vehicle greatly supports agriculture.

In summary, the different works related to this research were analyzed; they focus on reducing farmers' secondary effects when subjected to extreme temperatures or overexertion caused by the fumigation process. In addition, the processes used in the research are similar to our work by coupling existing technologies to agricultural tools that adapt the farmer to technological innovation. What achieves a broader vision of our research and development of spray bags for farmers in the Tambo Valley Arequipa.

3. Methodology

This section developed the various steps for creating the battery-powered spraying module for spray bags with a control system applied to the spraying mode.

3.1. Study Area

The study area is located in the southern part of Peru, 135km from the department of Arequipa, province of Isla, district of Cocachara, the annex of Santa Rosa Chica. Its favourable climate for agriculture has oscillating temperatures with a minimum in July to August of 15 ° C and a maximum of 28 ° in January to March [18]. The Santa Rosa Chica annex has more than 60 farmers with their land, in addition to a large number of agricultural workers who present their services to the work in the area. 3 farmers offered to lend their work tools to implement the battery-powered sprayer module.

3.2. General System Diagram and component description

The module's operation responds to a closed loop control system, represented by a flow diagram in figure 1. Where the main operation of the system is explained, on the one hand, there is the declaration and leveling of variables. On the other hand, the system process.

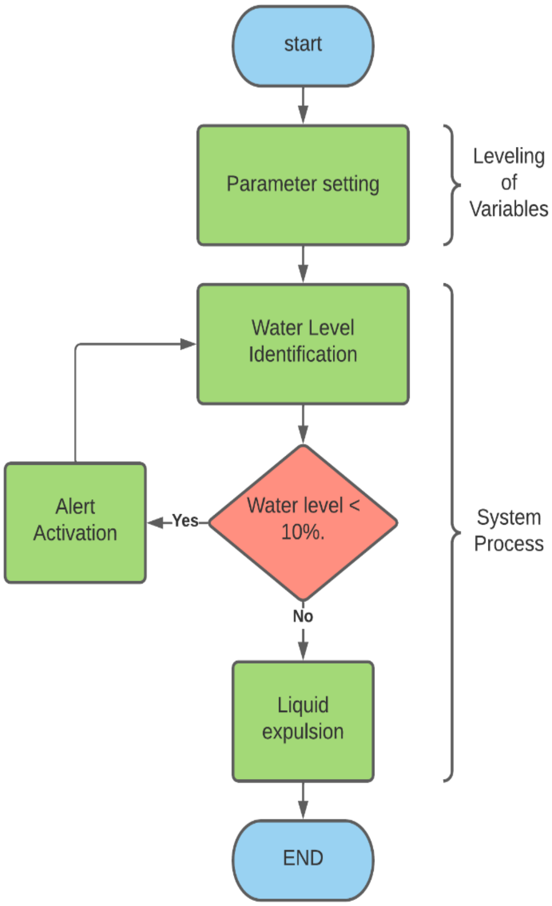

Fig. 1 Flow Chart

The following sections describe the assembly procedure for each stage, considering the electronic components' characteristics and implementing the respective block diagram.

3.3. Leveling Variables

In this part of the System, the capacity of the fumigator was analyzed, which should be optimized. On the one hand, the volume in liters of the fumigation tank ranges from 12, 16, and 20 liters by standards. Considering this, the desired flow rate in the nozzle must be regulated since a special spray is required depending on each crop type or application.

Table 1. Description and specification of Attiny85

Microcontroller	Attyny85
Voltage	2.7v - 5.5v
A/D Channels	4 A/D 10 bit
Flash Memory	8KB
RAM	512 bytes

The module's electronic components respond in a necessary way towards the optimized use of a spray bag of various aspects. The battery power is under the needs of the device with a supply of 12v 7AH (Amps / Hour), with which it is predisposed to supply around 8 hours to the module.

Table 2. Description and specification of water

Water Pump	*DP - 521*
Voltage	12 v
Operating Current	2.0 A
Maximum Pressure	0.48 MPa
Maximum Flow	3.5 L/min

In the System, this parameter was graduated by a potentiometer that will be directly connected to the Attiny 85 microcontroller with the characteristics described in Table 1. At the same time, by digitizing the potentiometer, a PWM type output will be configured, which will be better described in a later stage. The PWM signal was regulated according to the analogy reading of the potentiometer. It will be processed by the 8 working bits, a range from 0 to 256, with which this pulse will be sent to the Mosfet 3205 and amplify the signal to a current of 3A.

Table 3. Description and specification of ultrasonic sensor HC-SR04

Ultrasonic Sensor Distance Measuring Module	HC-SR04
Voltage	5.5v
Operating Current	15mA
Farthest and Nearest Range	2cm – 400cm

After recognizing the variables, the recognition of the outputs is presented in the program, such as the LED indicator, and the current level of the water is established through the ultrasonic sensor. All this is to be able to prepare the variables for the control stage.

3.4. System Process

With the variables already established, we enter the Closed Loop System, which compares the variable measured in the previous stage of the water level and converts it into a PWM variable; this stage also has an amplifying part of the PWM output with an N channel Mosfet. The Mosfet will send enough current to regulate the motor pump. However, this water pump did not work linearly to the potentiometer reading, which is why logarithmic management is used with the efficiency of the water pump feeling more comfortable.

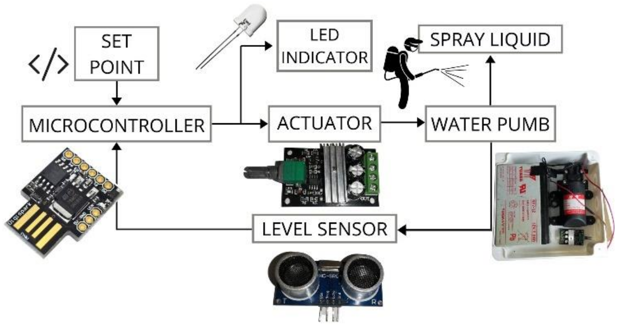

Fig. 2 Block Diagram.

Fig. 2 also shows the physical components used in the module design. On the one hand, the set point, the starting point of the system, is the variable entered into the Attyni85 microcontroller, which has the appropriate design characteristics since its compact size, low energy consumption, and easy programming facilitate its implementation. On the other hand, highlight the actuator stage as an important part of the module since they send the signal to both the LED indicator and the power PWM signal to the water pump. In addition, the continuous work of the water pump, Table 2, is thanks to the 12v battery, which will be coupled to this stage since it is closer to the stage with the most power in the module. Finally, the feedback from the HCSR-04 ultrasonic sensor will need an additional 5v power supply, characteristics in Table 3, which is powered by the regulator that also powers the Attiny85 microprocessor.

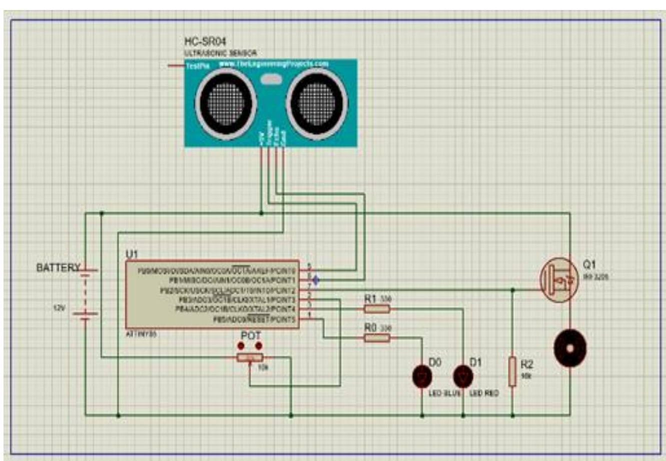

Fig. 3 Circuit simulation

The System will constantly measure the water level to compensate for the value of the potentiometer and set the required pressure. Also, when the water level is less than 10% of the container, it is indicated by an LED that the spray bag will need to be filled.

As a sample complement in figure 3, the Proteus simulation with the features and programming in operation. In addition to serving as a connection guide for the module assembly described above. In the operation of the circuit implemented in figure 4, there are 2 indicators: the green LED represents the operating status of the module, and the red LED represents the status below 10%. However, the system works with no load, so the Mosfet has no dissipation.

4. Results

The module for converting manual spray bags to batteries carried an adaptation process in several stages. First, the reception of the bags to be converted, in figure 4a shows the state of installation of the spray bag in which it began as an old, irreparable moto fumigator.

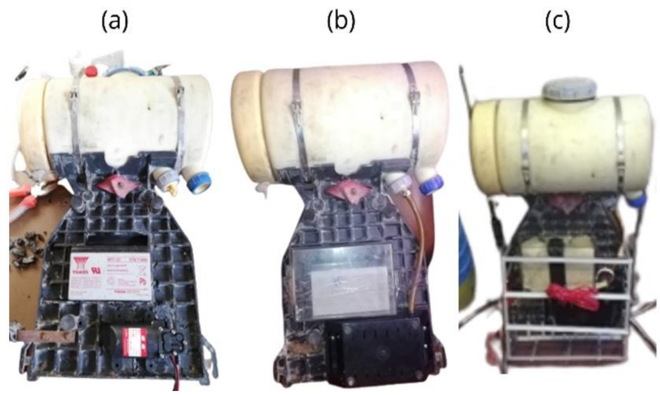

Fig. 4 Module installation process

Second, the connection of the battery, the motor, and the hoses was carried out without any problem. However, an upright frame had to be adapted for the bag figure 4b, since the farmer indicated that it would be extremely helpful for its structural operation, and the result of protection and structure for the coupling of the said pump with aluminum material is observed figure 4c.

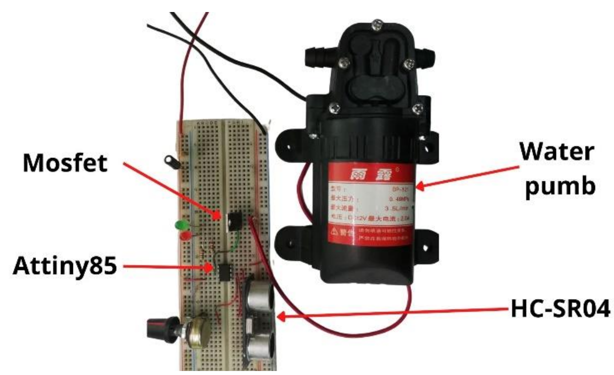

Fig. 5 Physical Circuit

Third, the implementation of the simulated circuit in Proteus was tested on a breadboard in figure 5 to observe that the voltage usage does not exceed the default values, also, consider the use of an external battery charger. In addition to Table 4, the average voltage variation was verified through the battery consumption, which directly relates to the Mosfet temperature.

Table 4. Results table

Average running time	7h
Average voltage	11.9v ~12.4v
Module temperature	25°C ~ 40°C
Efficiency	8 h/Hec

[a.] Collected in field research (Valle del Tambo, Arequipa)

Since the module's idea is to work in any spray bag, it was installed in 2 bags with different characteristics, one with a 16-liter capacity and the other with a 20-liter capacity. The 16-liter bag figure 6 has a space in its base where the module was installed without any problem.

Fig. 6 Wiring and installation of the module in 16L Fumigator

On the other hand, in the 20-liter spray bag, there was no space for the module's attachments to be installed. For this reason, it was installed independently in a 20x20x8 cm modular box shown in figure 7. The main advantage observed when installing in such a way was that the module could be attached immediately without disarming the bag.

Fig. 7 Modular system enclosure for backpacks without space

Figure 8 shows the final result of installing the 3 spray bags ready to be delivered to the farmers of the Tambo Valley sector, Arequipa.

Fig. 8 Fumigation backpacks with the fumigation module

With the completion of the implementation of the module in the bags, it was delivered to the farmers who volunteered for the application in the Tambo valley in figure 8. The operation of the spray bags was shown with pleasure, besides agreeing that the module can be used for bags of all sizes and dimensions, with the particularity of its portability and efficiency.

The spraying module for spray bags with the ease that it presented at the time of its installation, with the results obtained in Table 4 where it is specified in efficiency a that the duration time is 7 hours of operation with a performance of 6 hours per hectare governed to an average consumption of the motor, in other words, the motor does not work at 100% of its capacity.

Fig. 9 Tests with farmers in the Tambo Valley

It should be noted that this measured time is considering the time the farmer receives the indication through the red LED that the water level is running low and must go to fill his tank with liquid again.

5. Discussions

The research objective was to design and implement a spraying module for bags in the Valle del Tambo of Arequipa, Peru since the devices in the market demonstrate a high investment value for farmers [2]. Because of this, the developed module presents a deficiency at the time of installation since the installation of the electronic accessories must be isolated from strong environmental impacts such as heat, humidity, and dust, among others. However, this deficiency is overcome by isolating the module in a modular box.

Another inconvenience at the design time was not having an internal charger for the 12v batteries. It should be noted that this favored weight reduction, which is closer to our objective of reducing the efforts of farmers and the traditional ways of fumigating the field.

The designed module has a shorter duration due to the battery and the motor used, compared to [13], which has the advantage of having a lower consumption motor and battery support through its photovoltaic panel. On the other hand,[15] it differs from our research in the use of its small battery from 12v to 20 AH and the robust complexity of its system through the LabVIEW platform, which in our case was chosen for a more economical and versatile measure.

The applications of the module were carried out on farmers' land in the Tambo Valley. They were applied to rice crops, similar to [17], with the difference that in their application, they had a remote device capable of carrying out the various fumigations in the crops.

In addition, mention that the average operating time of our system with other investigations [10], [11] is below our system since the low consumption of the Attiny85 microcontroller and the use of PWM increases the efficiency of the system. This difference is important for the investigation since the farmers in the area need their tools with the same or greater hours/hectare ratio than their previous manual spray bag.

6. Conclusion and Future Work

The spray bag spraying module, from its design to its implementation, supports advanced and not-so-advanced farmers in the Valle del Tambo region in Arequipa with the ability to reduce physical effort, which reduces the impact on health such as lumbar or joints problems in the upper limbs and disseminating benefits of technology in this region.

This article demonstrates that the spraying module for spray bags complies with what is proposed by converting manual bags into battery-powered bags, avoiding their overexertion in farmers in the Tambo Valley area in the province of Arequipa. With operating results of up to 7 hours of autonomy and implemented in spray pumps of various capacities, including 10, 16, and 20 liters. It is necessary to mention that the module has the particularity of being scalable; it is to say that it can be installed in larger capacity containers or small gardens. It is suggested to the readers and scientific community to take this research to bring farmers closer to the automation of their crops, and various applications are given to the plant.

Much of the research was based on the design and implementation of the module, with the support of the farmers who donated their manual spray bags and repeatedly asked them about various aspects, such as the type of crop and the level of spraying required for its application, that finally a capacity of 8 hours per hectare was achieved.

However, there are limitations, such as using batteries integrated into the module with less weight. Also, integrating a mobile application interface can help farmers keep a record of the chemical components of their crops.

As a future study, it is intended to take this research for the application of the module as a project for farmers from various regions of the country and try to analyze the differences between smaller water pumps and the support of photovoltaic cells.

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