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Design and Study of Solar Powered Agricultural Robotic Sprayer for Horticulture

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ABSTRACT: Horticulture is the fastest growing agricultural sector with high capital investments and profits in India. Crop care and protection is a crucial part of horticulture and there is a lack of mechanization in this operation. Uniform and optimized pesticide spraying quality can be achieved using autonomous pesticide spraying robots consisting of microcontrollers, motors, pumps, and operational cost can be reduced by harnessing solar energy for operation as solar energy is abundant in India. Such robots can help to reduce health risks to farmers and are an environment-friendly option for sustainable development.

KEYWORDS: Horticulture, Solar power, pesticide sprayer, Arduino.

I. INTRODUCTION

In any country in the world, the manpower lies in the young generation of that country. In India, more and more of the young generation migrate to the cities seeking a better lifestyle. This leads to the labour shortage in the rural areas of the country. Automation in agriculture can be employed to cater shortage of skilled labour.

Horticulture mainly includes the production of fruits and vegetables, spices and condiments, ornamental, plantation, medicinal, and aromatic plants. Crop care and protection is an important task of horticulture. In the Indian agricultural equipment market, types of pesticide sprayers available are knapsack sprayer, power knapsack sprayer, tractor-drawn boom sprayer, aero-blast sprayer, etc. Knapsack sprayers are to be carried on shoulders in the field for spraying which causes fatigue and muscle pain. While using these types of sprayers farmers are exposed to pesticides and pose a risk of inhaling them or direct contact of pesticides with eyes may occur if suitable protective gear is not used. Since using safety gear may cause inconvenience to do certain operations in agriculture, a robot can be used for pesticide spraying operations.

Tractor-drawn boom sprayers or aero blast sprayers are bulky in construction and can only be used in big crop plantations. These sprayers are unsuitable for application in greenhouses or small crop plantations with limited space. Hence a versatile and medium sized robot is required so that it can be used in various arrangements.

Solar Powered Agricultural Robotic Sprayer for Horticulture (SPARSH) works on a simple principle i.e. harness the solar energy which is abundant in India with the help of solar panels and charge the battery fitted in the robot. The battery fulfils all the power requirements of the Robot including running the pump, running the motors to navigate the robot, etc. Precise control of pump and motors is done using Arduino Nano and H-bridge motor drivers drive the motors. A charge controller is used in the system to overcome the problems of overcharging as well as undercharging of the battery. Thus SPARSH will work even in the remote areas where there is electricity shortage without interruption in the spraying process. Provision of charging the battery through AC power supply is also available to charge the battery during cloudy days.



II. LITERATURE REVIEW

Current practices in pesticide spraying pose a hazard of occupational poisoning of pesticides to spray workers. The study shows exposure to pesticides has reduced platelets count by 33% in volunteers of age group 18-50 years [1]. Due to such health hazards, there is a need to reduce human involvement in pesticide spraying. As horticulture is a fast-growing part of agriculture in India and demand for quality products has increased, improvement in traditional practices is a way to meet those demands. The current status of mechanization in horticulture, specifically in horticultural fruit crops and flowers, plant protection and fertilizer applications and intercultural operations are done manually [2]. As these operations are done manually, there is a possibility for error which may hamper the quality.

India is a solar belt country and on average receives 3.0 to 7.5 kWh/m² energy in one day in various parts of India

[3]. Since solar energy is abundant in India, it would be a better choice for energy than fossil fuels. In long term, solar energy would be more economical considering the rise in fuel prices.

Recognizing this need, many primary solutions were published by academia but these solutions were primary and had a need for human operators to carry the solar panel and rest of the equipment for spraying pesticides. On the other hand, some of these solutions did not require humans to carry the equipment but lacked automation. These robots were remote controlled with a constant need for a human operator to operate the robot remotely.

The existing solutions to the pesticide spraying problem which use solar energy are of three types: the first type is to use a DC pump to spray pesticide which is powered by a solar panel and carry pesticide tank on back with solar panel overhead [4] [5] The direction of pesticide spray is controlled by the operator with handheld nozzle. The second type is to mount a tank and solar panel on a push-cart and this cart is to be pushed by an operator while simultaneously controlling the direction of spray [6] The third type is to use an RF module or Wi-Fi module to control a robot that sprays pesticide through fixed nozzles [7] [8] Challenge in such robots is that range of RF modules or Wi-Fi modules is limited. Additional infrastructure like a Wi-Fi network or range extenders is required to operate such robots.

The nozzles of the sprayer need to be at an angle between 45 to 75 degrees with horizontal according to the height of crops [9]. Mounting nozzles at a fixed angle with adjustable height of nozzle mount can also be a method to mount nozzles for spraying pesticides.

III. METHODOLOGY

The problem statement was selected after doing a detailed observation of tools involved in ongoing practices for crop maintenance in agriculture. Lack of automation and more involvement of humans in the process was identified as a problem to improve the process. Considering the wide range of crops, peculiarities, and complexities for each type of crop was a major challenge along with soil and weather conditions. Hence target crops were identified as horticulture crops for the project to implement a solution. Market research for existing solutions was done to shape the idea of an intermediate robot for pesticide spraying in horticulture. Shortcomings in existing or similar proposed robots in various journals were rectified. The methodology used here is designing and manufacturing a model then simulating results to prototype and performing analysis by considering standard components used in the prototype. The study of operational feasibility in the average environment and return on investment for economic feasibility was done to identify the most suitable farming procedure and crop for this project. A study of scope for future improvements and updates was done considering technological advancements like AI and IoT.

IV. EXPERIMENTAL RESULTS

Considering all shortcomings in current practices and existing solutions, the model is designed for SPARSH. Firstly to tackle the lack of automation in existing solutions, SPARSH employs the Arduino Nano board with ATmega328 microcontroller having AVR architecture and clock speed 16 MHz and 32 KB of flash memory to store a program. The basic working is that the robot is programmed according to the layout of the field in which spraying is to be carried out. SPARSH is a four-wheeled robot each wheel driven by a DC motor through an H-bridge motor driver that receives digital input from Arduino. Turning of the robot is achieved by differential braking method that is one side motors are driven in a forward direction while other in reverse to achieve turn. DC pump also receives an input signal from

Arduino to start and stop pesticide spraying through nozzles. All of these components are powered by a Li-ion battery pack which is charged by a solar panel through a charge controller.

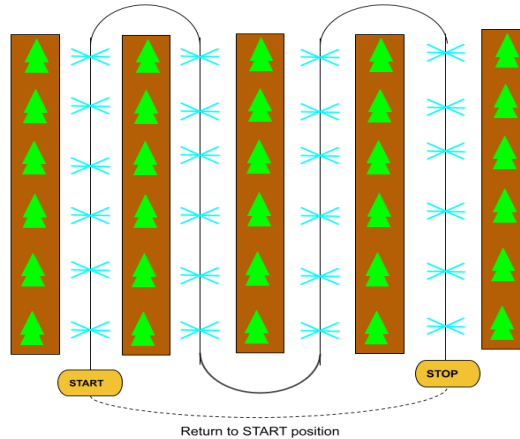


Figure 1 the layout of the test field

The test field consisted of four aisles between five rows of crops. For the test field, the robot is programmed and

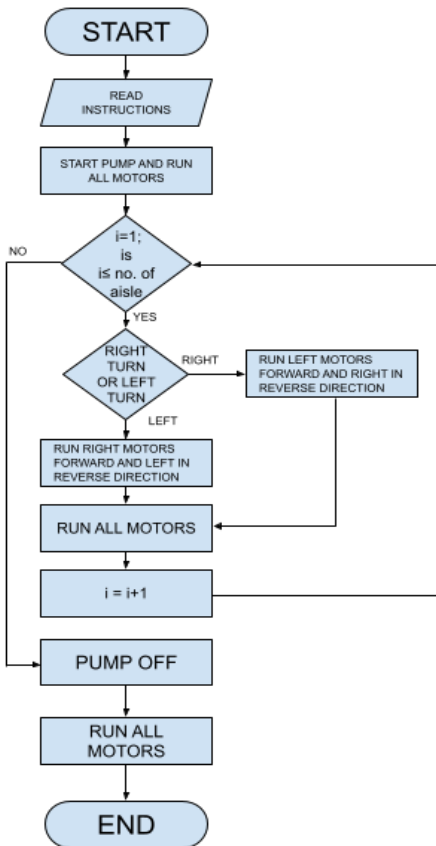


Figure 3 Flowchart of working of SPARSH

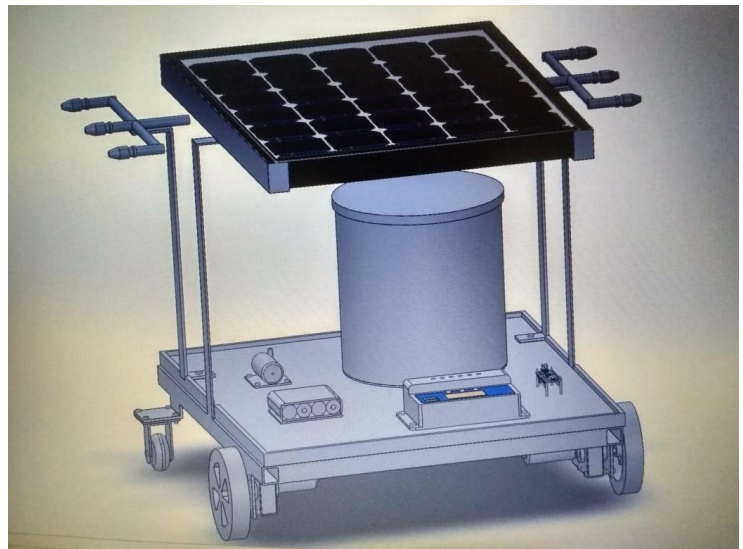


Figure 2 Isometric view of SPARSH assembly

started at 'START' then it moves forward spraying pesticides till the end, and then it takes the right turn by differential braking. After taking a turn it continues and repeats the cycle taking alternate turns and in the end returns to the start position. The program will be different for different field layouts.

The 3D model of SPARSH with actual dimensions and subjected to actual loads in structural analysis in LS-DYNA gave results that the design is safe with the factor of safety 1.5 and maximum Von-Mises stress-induced is at corners with magnitude 2.4057 N/m^2 while maximum stress induced in solar panel holder is 20.6344 N/m^2 , which within the safety limit.

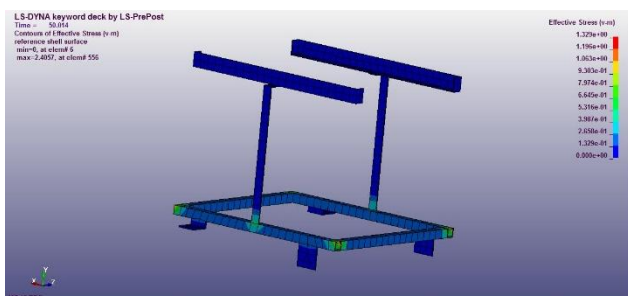


Figure 4 Stress analysis of SPARSH frame

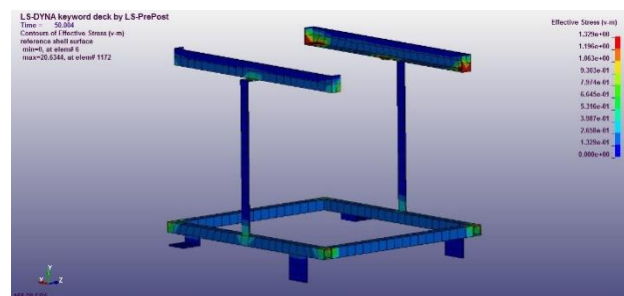


Figure 5 Stress analysis of SPARSH frame with a solar panel holder

V. RESULTS AND DISCUSSION

The designed body of SPARSH considering the soil and environmental conditions was found out to be suitable for operation in horticulture with little lack of planeness in terrain. Stress analysis and simulations proved that design is safe for operating in irregular areas. Automation in SPARSH requires thorough dimensions of the field and the robot is suitable for organized plantations. A primary knowledge of Arduino programming is required at this stage of the robot. Considering the cost of materials and manufacturing the initial investment for this robot will be around ₹10500 and the operating cost will be the only cost of pesticide used. The hand-operated knapsack sprayers cost between ₹1000 to 3000 but pose a greater risk to the operator and require more physical effort. Power knapsack sprayers i.e. knapsack sprayers with a petrol engine to pump pesticide cost between ₹10000 to 12000 and they have very high operating costs due to petrol as fuel. SPARSH can be modified according to needs and may become a tool for rural employment.

VI. SCOPE FOR FUTURE DEVELOPMENT

- SPARSH can be equipped with a mobile application interface to control various functions and providing inputs.
- A GSM activation system also can be introduced to activate the robot remotely over a cellular network.
- Implementation of AI can be done by attaching cameras and sensors. Similarly, by taking pictures of crops while spraying and using ML regular crop health data can be maintained.

VII. CONCLUSION

In conventional spraying methods, a full-time human operator is needed whereas, SPARSH does not need a full-time operator. An operator required only to start the robot hence, expenditure on the daily wage of one person can be eliminated. Since SPARSH harnesses solar energy, the share of the cost of energy is also subtracted from the operating cost of the robot. SPARSH is suitable for operating in fields with small and medium plantations like greenhouses, floriculture, grapevines, banana plantations, etc. SPARSH can be an environmentally friendly alternative to tractor-based sprayers with sustainable development.



VIII. ACKNOWLEDGEMENT

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