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ISSN: 0193-4120 Page No. 5235 - 5242

Design and Development of Three DoF Solar Powered Smart Spraying Agricultural Robot

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Article Info
Volume 83
Page Number: 5235 - 5242
Publication Issue:
March - April 2020

Article History
***Article Received**: 24 July 2019*
***Revised**: 12 September 2019*
***Accepted**: 15 February 2020*
***Publication**: 27 March 2020*

Abstract

In recent years the agricultural industry is revolutionized by automation and robotics that has resulted in reduction of labor and production costs with increased agri produce to meet the market demand. Manual spraying of pesticides and herbicides to crops and weed inhibitors onto the field are harmful to both humans and the environment. This paper proposes a solar powered, flexible, semi-automated pesticide spraying robot with three Degrees of Freedom (DoF) in movement. The micro-spraying system is operated by an Android app via Bluetooth. The robot is designed to spray pesticide/insecticide directly onto individual lesions minimizing wastage leading to reduced consumption of chemicals hence making the system cost effective and environmental friendly. The targeted pesticide delivery prevents dispersion of chemicals in the environment. A prototype is developed and tested on different terrain conditions and is found to operate efficiently

Keywords; *DoF, Pesticides, Robot and Spraying sprinklers*

I. INTRODUCTION

Worldwide, automation in modern agriculture is gainingpopularity as traditional farming methods are tedious, repetitive and less efficient. Manual tasks starting from sowing of seeds, fertilizer dispersal, cultivation and pesticide/herbicide spraying to harvesting are laborious processes. Agri-robots are used in nursery planting, crop weeding, insecticide spraying, irrigation, crop monitoring and analysis, thinning, pruning, sorting, picking, harvesting, injection of medication for soil sterilization against weeds, fungi, bacteria and viruses. Off late robots are also used to dry various types of grains like wheat, rice, oats, cornmeal, barley and others. [1] Robots are designed to uproot weeds based on computer vision as the tractor moves forward. This completely eliminates use of harmful chemicals. In developed countries farmers experience shortage of agricultural labor force while traditional farming in developing countries fail to meet the required efficiency levels in supplying agricultural produce as demanded by the market. These problems can be addressed by robotics and advanced sensing technology. Thus using robots in agriculture has become a necessity rather than novelty. They operate efficiently with minimal human intervention reducing monotony in repetitive tasks with increased productivity due to continuous supervision and control of agricultural field operation. It is reported that in the next five years, market for agri-robots and drones with embedded computer vision and analysis capability would reach $35 billion [2].

Various methodologies of technical farming is presented in [3]. The impact of robotics in every sphere of human activity has seen an accelerated growth over the past few years bringing huge transformation in our life style and work practices with increased safety and efficiency [4] and [5].

Among the various tedious agricultural processes spraying of insecticides, pesticides and herbicides on to the crops has become inevitable to protect crops

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against insect/pest invasion and prevent loss of produce. Use of chemical sprays is of major concern as it is hazardous to both human health and the environment. In general, most of the agriculturists use human operated knapsack sprayers that require more time to cover a given area. [6]. Motorized sprayers can cover a much larger area in a stipulated time [7]. During this process, though the farmers take lot of precautionary measures like wearing gloves, masks and outfits, sprayedchemicals will adversely affect their health. Therefore, use of autonomous robots provide a safe environment for farming, along with increase in efficient production of agri-products due to increased level of monitoring and control of agricultural fields.

Robots for various agricultural tasks such as harvesting, cultivation of crop, weeding, and spraying pesticides are discussed in [8-13]. The features of any agricultural robot are classified as: Guidance, Detection, Action and Mapping. Guidance refers to robo-navigation; Detection assimilates surrounding information; Mapping extracts field features; and Action ensures the completion of the intended task. All four featuresof an agriculture robot are independent in nature [14]. A camera in an intelligent WiFi based pesticide spraying robot proposed in [15] monitors the crop and ~~the robot~~ is controlled through a mobile phone asshown in Fig 1.

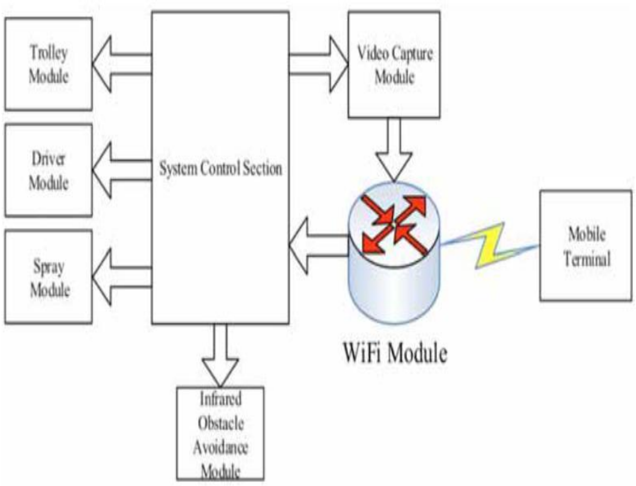

Fig. 1 Block diagram of the System

The paper presents, design and development of a three DoF solar powered robot for spraying herbicides pesticides/insecticides on to the crops. The sprinkler is designed for adjustable height with forward and reverse motion enabling targeted delivery of spray even to inaccessible plant lesions without wastage thus preventing the undesirable dispersal of chemicals into the atmosphere. It is integrated with an Arduino microcontroller to control the movements and functions through an android App. The controller and the navigation enabling motor units are powered by a solar photovoltaic system. Hence the developed robot is a green, cost effective in terms of labour and quantity of pesticides and an efficient spraying system safe to both humans and the environment.

II. METHODOLOGY

Design of Robot

The design of the spraying includes: 1) Chassis 2) Sprinkler System 3) Driver circuit and controller 4) Power supply unit 5) App development for remote control.

1) Chassis Design: CATIA is used to design the chassis shown in Figs.2a, 2b and 2c with suitable ground clearance for free movement on different terrains. Isometric view of robot chassis is shown Fig.2a, front, left and top view are shown in Fig. 2b, Fig. 2c and Fig.2d respectively. The choice of the materials used in the prototype are based on cost and physical properties. The chassis is made with 2mm thick mild steel (MS) plate. An elevated platform is provided on the chassis supported on four studs each of 10mm diameter and 220mm height. The driver circuits, controller and a battery are mounted on the platform. The movement of the entire assembly is enabled by four wheels of 10mm diameter each. The configuration of sprinklers can be suitably adjusted depending on the type of crop.

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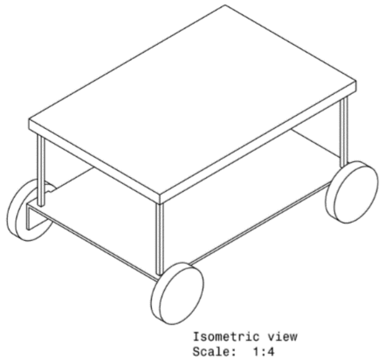

Fig. 2. (a) Isometric view of chassis

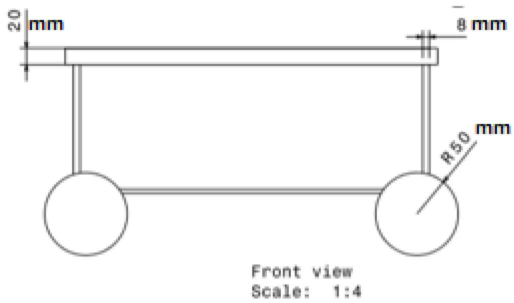

Fig. 2. (b) Front view of chassis

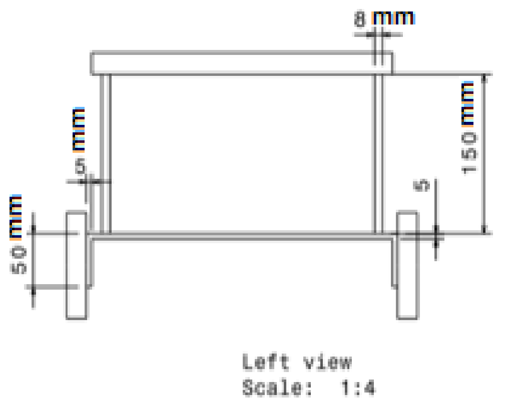

Fig. 2. (c) Left view of chassis

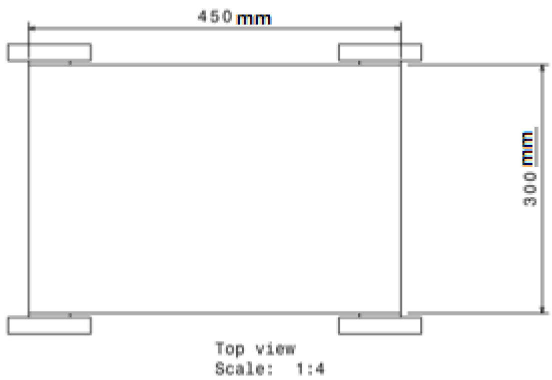

Fig.2. (d) Top view of chassis

2) Sprinkler System:The sprinkler system consists of two sprinklers at the top to cover the rows of crops in the field. High pressure, impact mechanism based auto rotating sprinklers are used to cover maximum area of crop cultivation as shown in Fig. 3.

Fig. 3. Irrigation sprinkler

The sprinkler system is designed to operate with three degrees of freedom (DOF).The first DOF operates the sprinkler in both upward and downward directions, second DOF operates the sprinklers inward and outwards horizontally and the third DOF is provided to operate individual sprinklers between 0^0 and 90^0. The **T** shaped assembly of the sprinkler is attached at the center of the front end of the chassis as shown Fig. 4.

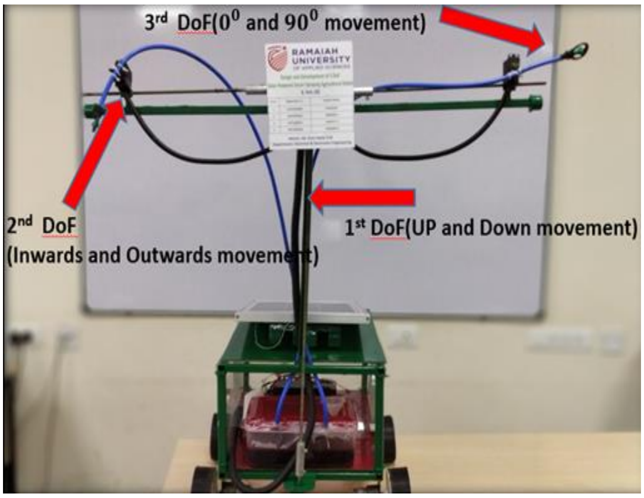

Fig. 4. Three DoF Spraying Robot

The sprinklers are connected to two 12V DC water pumps through a flexi tube to allow pesticides/insecticides be transferred from tank to the sprinkler head. The rate of spraying can be

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controlled by adjusting the voltage level of the pumps through the controller.

3) Driver Circuit and Controller Design:Motor driver circuits are designed using L298 IC's to control the movement of motors with respect toa reference signal. They operate up to 46 V DC with a peak current of 2A and each driver circuit can drive two DC motors. Hence a total of five driver circuits are used to control seven geared motors and two water pumps. The schematic of the motor drive circuit is shown in Fig. 5 and the assembled circuit in Fig.6.

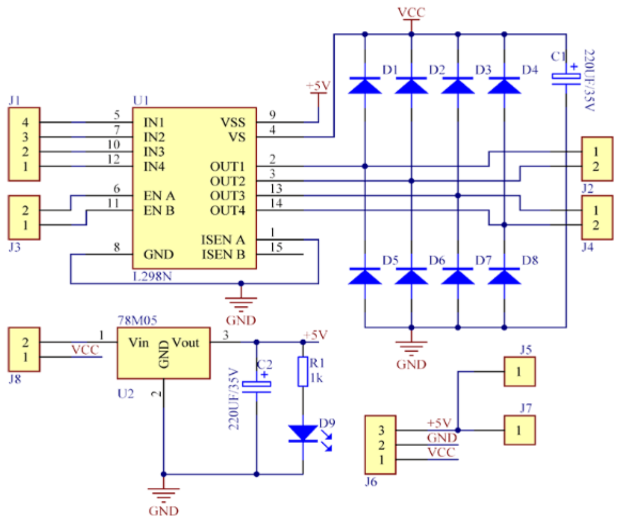

Fig. 5: Schematic diagram of motor drive circuit

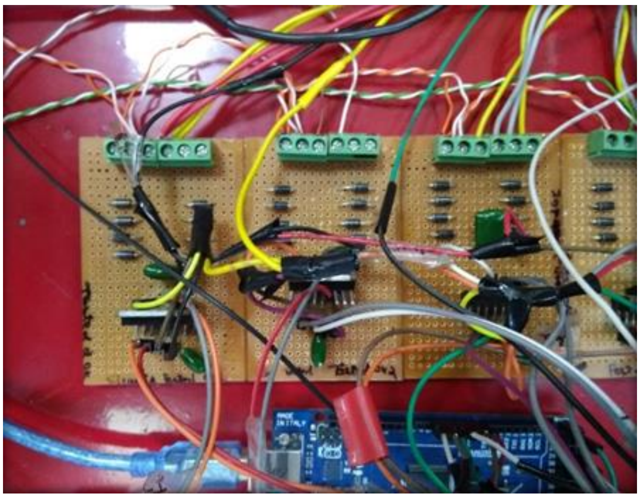

Fig.6: Assembly of L298 Motor driver circuit

four DC geared motors of 60 RPM are used for traction and three 500 RPM DC geared motors to drive the sprinkler assembly. The specification of DC motors and stepper motors are given in Table 1 and Table 2 respectively. Two servo motors provide the third DoF. These motors are directly supplied from the controller and hence do not require any specific driver circuits.

Table I: Specifications of DC geared motors

Speed	60 RPM	500 RPM
Torque	25 kg cm	2 kg cm
Voltage	6 to 24 (Nominal Voltage – 12V)	6 to 24 (Nominal Voltage – 12V)
No-load current	800 mA(Max)	60 mA(Max)
Load current	9 A(Max)	300mA(Max)

Table II: Specifications of stepper motor

Weight	55g
Dimension	40.7×19.7×42.9mm
Stall torque	9.4kg/cm (4.8v); 11kg/cm (6V)
Operating speed	0.20sec/60degree(4.8V) 0.16sec/60degree (6.0V)
Operating voltage	4.8V - 6.6V
No load operating current	170mA

Arduino MEGA is programmed to control the movement of the robot, spraying of pesticides and adjustment of sprinklers with three DoF. Based on the input signals given by the user, Arduino transmits the input from the user to driver circuit and subsequently to the motors and pumps.

4) Power Supply:The power supply unit consists of two 7Ah lead acid batteries connected in parallel to obtain requiredoutput current. The batteries are

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charged by the solar panel rated for 10Wp with grid supply as back up. A Pulse Width Modulation (PWM) charge controller from Luminous shown in Fig. 7 is integrated between the solar panel and battery to regulate the voltage and/or current with battery overload protection. The L298 motor driver circuits rated for 12V are powered by the battery and the Arduino while Bluetooth module and servomotors of the robot are powered from 5V buck converter. A 12 V input to the buck converter is 12V DC provided from the battery and the output is adjusted for 5V DC.

Fig. 7: Luminous Solar charge controller

5) App development:An Android App to control the robot movement is developed using MIT App Inventor tool. The tool has two sections namely the designer and block sections. Buttons, addition of text and screens can be created in the designer section with provision to edit the overall appearance of the App. The buttons are used process the information internally. The block section help create custom functionality for the App. The designed control App is shown in Fig. 8.

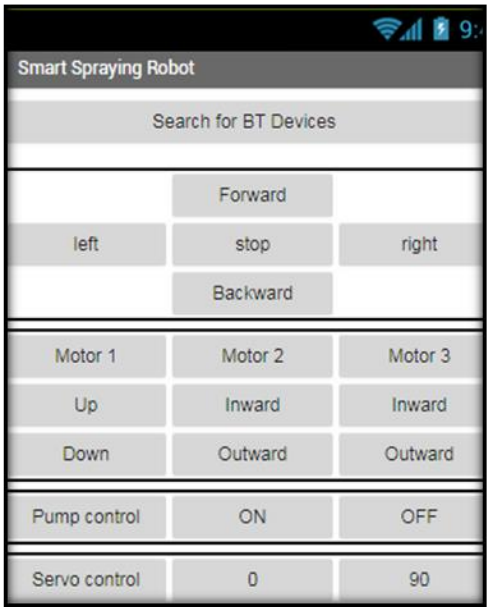

Fig. 8: App designed through MIT App inventor tool

A specific action would result based on the inputs given through the App. The four buttons at the top are used to control the robot movement. Motor 1, Motor 2 and Motor 3 buttons are used to control the DoF of the vertical and the horizontal movements of the sprinkler system. The water pumps are controlled by ON and OFF buttons and servo motors are operated by '0' and '90' buttons.

III. TESTING AND VALIDATION

The prototype of a three DoF robot, powered by solar energy and robot spraying pesticides on lawn is shown in Fig 9 and Fig 10 respectively. The system is aesthetically designed with user friendly control panel, is light in weight and portable. Solar panel of 10Wprating provides 10V, 0.38A on average. The battery can be charged from the grid during unfavorable solar conditions. The robot can be operated remotely by the mobile App on different terrains and the pesticide sprayed accurately on to the target without any wastage of chemicals. The 3-DoF sprinkler movement was tested and exhibited the desired functionalities. These operations validated the satisfactory performance of the App, Audrino controller, pwm charge controller, pumps, solar power module, motor drivers and the motors. It

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is observed that the time required for spraying is less since the robot does not swing the spraying nozzles while spraying as it is done in traditional spraying methods.

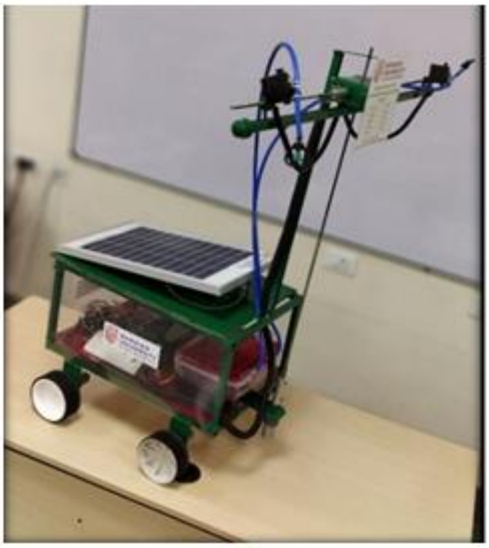

Fig. 9: Three DoF spraying Robot

Fig. 10: Three DoF spraying Robot on Lawn

IV. CONCLUSION

The design and development of a solar powered, remotely operated three degrees of freedom pesticide spraying robot for use in agriculture is presented in this paper. The prototype gave a fairly good rate of area coverage with a reasonably low operating cost. The system addresses the issue of dearth of agricultural labour and ensures safe agricultural practices by completely eliminating, handling of harmful chemicals by the farmer as it can be operated remotely. The proposed spraying robot is suitable for small and medium scale farmers. Large scale production of the spraying unit will reduce the cost significantly giving partial thrust to Indian agriculture practices.

The unit can be scaled up based on the requirement. The developed system can not only be used for spraying fertilizer, pesticides, fungicides, lawn watering but also for ground surface watering like cricket ground.

V. ACKNOWLEDGMENT

Authors would like to sincerely thank the Vice Chancellor and Management of M.S.Ramaiah University of Applied Sciences, Bangalore for providing all facilities required to carry out the present work

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