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Arecanut Tree-Climbing and Pesticide Spraying Robot using Servo Controlled Nozzle

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***Abstract* — The lack of availability of skilled and efficient labor is a huge problem in the agricultural sector, hence developing automated alternates is the need of the hour. When it comes to growing Arecanut especially in damp geographical regions use of pesticides is inevitable. This paper aims at the design of a rugged and light-weight Semi-Autonomous Robot which can ascend the areca tree with a single high torque driving motor and spray the pesticides through a Laser guided servo-controlled nozzle. The spring based gripping can adjust automatically according to the varying trunk diameter and provides the required traction for climbing the tree. It uses microcontroller ATMEGA 32 as the main processing unit for control, transmission and reception. HT12 Encoder and Decoder pair is used with RF transmitter/receiver pair. This robot is designed to be operable by a layman from a remote control. This can surely eliminate the problem of insufficiency of human labor and contribute to better quality and yield.**

Keywords — Areca tree, Servo motor, Pesticide, Spring Gripper, Atmega 32, Driving Motor

I. INTRODUCTION

Areca nut is one of the major crops grown in Southern parts of India. Besides India, which is the largest producer, China, Thailand Myanmar also contributes hugely to the produce. The major concern in this sector now is the lack of skilled labor and safety issues for spraying pesticides and harvesting. Currently, the spraying is done by manually climbing the tree along with a hosepipe and spraying the pesticides at high pressure. Manual climbing is a hazardous task and many people have lost their lives because of doing it in an improper way, with no safety gear and knowledge. With labor being scarce in contemporary agriculture it has become very difficult to protect the crop from pests and prune during harvest time. Hence automation is the best solution to eliminate human intervention and save time and money. This paper presents the design concept of a Semi - Autonomous tree climbing and pesticide spraying robot which can be manually controlled, set up and run by at most two people and is farmer friendly. There have been many attempts and designs for this type of robot, but most of them try to mimic the human action of tree climbing and have failed to be practically useful. This design, unlike the formers ones, does not mimic the human action. Instead, it uses a single wheel driven by a high torque geared motor for movement and spring based gripping arms around the tree trunk which adjust according to the varying diameter of the trunk. The robot chassis, which uses aluminium extrusions, is made rigid and lightweight.

A brief overview of the robot's operation is explained as follows. This robot is designed to be used along with the conventional petrol engine based pesticide pump as carrying a pressurized pesticide tank while ascending will increase the payload and reduce the efficiency of the robot. Hence the pump is set to work on the ground while its high-pressure output is delivered up to the robot through a thin hose pipe. To note, this robot should be used with a few practical methods already in practice. The pesticide outlet from the pump is also controlled by a foot switch which energizes a solenoid valve at the pump outlet. The climbing, valve, and the servo unit are all controlled by a wired/RF remote controller from the ground. The design of the servo controlled nozzle is explained later in this article. The farmer looks for the pest infected parts of the tree's crown and sprays the pesticide wherever required by controlling the direction of the nozzle.

Many designs have been done to achieve this task efficiently. The design [3] by Rajat Mittal et al. tries to mimic the human action of climbing a tree, which has too many moving sections in the unit and can unnecessarily load the system. Instead, the proposed design uses a single motor to climb hence minimizes the number of moving units. In the perspective of the operation, the prototype [1] by Shwetha B et al. can only spray one tree at a time. But by using Servo motors with a Laser guide to control nozzle direction; this robot can spray up to 6 trees around the robot which are within a range.

This article is organized into Chassis Design, Climbing and Spraying Unit, Control of the robot with Transmitter and Receiver sections.

II. CHASSIS DESIGN

The chassis basically has a T-Shaped design completely built from aluminium extrusions chosen for their light weight and rigidity in construction. The gripping arms are also made of aluminium and are equipped with high load springs. Centre of the T-Frame houses the driving motor and wheel for climbing and also the servo mechanism for spraying. The gripping arms are provided with wheels at their ends and also a tail wheel.

Wheels used will be hard nylon serrated wheels to provide enough friction for climbing. Suitable arrangements for wiring and circuitry can be easily made as extrusions have a lot of usable empty volume inside. The housings for driving, spraying and control unit are built upon this frame.

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The design of the T-Frame is shown below, all dimensions are in mm.

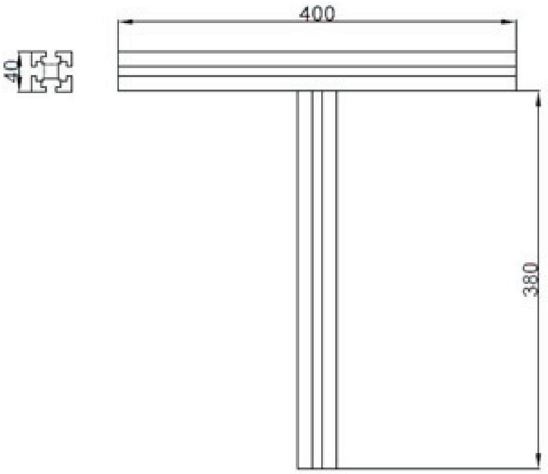

Fig. 2- T frame

II. CLIMBING MECHANISM

The climbing unit comprises of a high torque geared DC motor and two spring loaded gripping arms. The torque required by the motor is determined in the calculations later in the article. Only one driving motor is chosen to avoid instability, lower power consumption, reduce weight and it eliminates the challenge of achieving synchronization between different motors. The proposed design is symmetric to account for good balance while ascending the tree.

The combined gross weight of the robot covering the frame, gripping Arms, driving motor and the spraying system is calculated to be about 3 kg as per the solid modeling of the design. The total weight including the rubber pipe for supplying the pesticide (considered the Payload) is about 7 kg. The torque required by the motor is calculated as follows.

$$Tw = TTE \times R \times RF \quad (1)$$

where:
Tw = wheel torque (Nm)
TTE = total tractive effort (N)
R= radius of the wheel/tire (m)
RF = resistance factor

$$TTE = RR + GR + F \quad (2)$$

where:
TTE = total tractive effort (N)
RR = force necessary to overcome rolling resistance (N)
GR = force required to climb a grade (N)
F = force required to accelerate to final velocity (N)

The values required for the above equations are calculated as follows, using:

Co-efficient of friction (μ) of wood a = 0.1
Radius of Wheel(R) = 40mm
Weight of Vehicle (W_{gv}) = 7 kg
Angle of inclination (α) = 90 °
Maximum vehicle speed (V_{max}) = 0.125 m/s
Resistance factor = 1.1, Time to attain V_{max} (T_a) = 1s
(i) RR = $W_{gv} \times \mu$ = 0.7 kg
(ii) GR = $W_{gv} \times \sin(\alpha)$ = 7 kg
(iii) F = $W_{gv} \times [V_{max} / [9.8 \times T_a]]$ = 0.089 kg

Substituting the above values in Eq (2)
TTE = 7.78kg

Hence from (1), Tw = 3.35 Nm

Fig. 3 - Top view of the robot (emphasizing on the self- adjusting spring grippers)

Considering a factor of safety of 2, the maximum torque required from the motor is 6 Nm. The motor chosen is of 30 Rpm, with Load Current of 7.5A and provides a rated torque of 8 Nm.

The springs are chosen by selective method or trial and error method such that it has a firm grip around the tree and does not load the system while climbing.

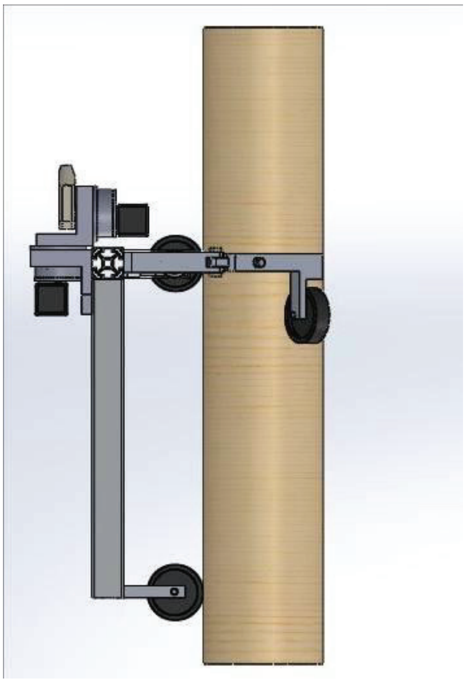

Fig. 4. Side view of the robot

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The robot should climb a height of 10 meters, stall at that point and spray the pesticides to the fruit bearing parts around the crown of the tree. Hence, as far as the gripping arms are concerned, they are designed to adjust their proximity with the varying diameter of the tree trunk as it climbs. As shown in fig.4, there is a free rotating wheel at the end of each gripper arm which acts as a firm gripper at the same time easing the movement of the robot.

III. SPRAYING UNIT

The spraying unit consists of two servo motors that control the direction of the nozzle at right angles to each other to provide two axes of rotation. They are mounted using L brackets and one servo will have its shaft directly coupled to the nozzle. A low power laser is also mounted on the nozzle to act as a guide while spraying the pesticides.

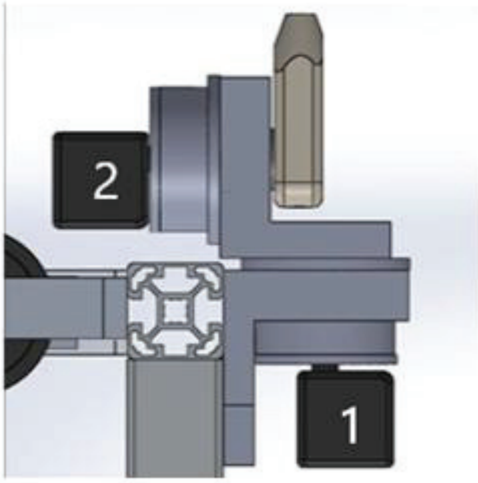

Fig. 5. Side view of the spraying unit with servo motors and nozzle

Servo motors used will be of half rotation, capable of rotating 180 degrees. The combined solid angle the two servos can cover is a quadrant as shown in fig.6.

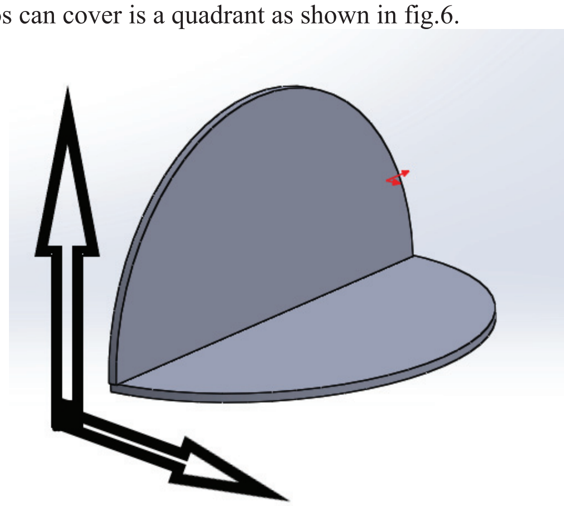

Fig. 6. Spatial cover of the nozzle

Input to the nozzle will be from the pesticide pump which will be kept on a rigid trolley on the ground. The control of the supply is by using a footswitch which the operator should press to open the valve outlet to the robot. This arrangement of pumping from the ground is done so as to reduce the weight and for convenience.

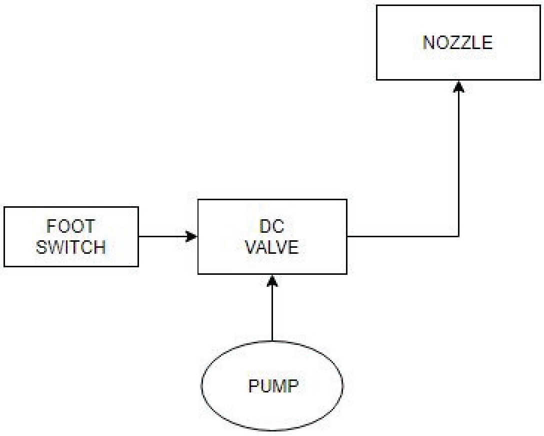

Fig. 7. Block diagram of the spraying layout

The servos will be controlled from a joystick in the RF remote controller. The laser guides the approximate spray region on the tree and the operator can control the nozzle direction and the outlet valve with its help. The operator can press the footswitch and spray only when the nozzle is pointed to the disease affected regions on the tree by not facing the pesticides. The servos chosen are waterproof for safety and protect the inner shaft.

IV. TRANSMITTER

The transmitter section in the RF remote controller consists of the microcontroller Atmega32 as the main CPU. It has a 32kb programmable flash memory, 2Kb SRAM and 32 programmable I/O lines with 4PWM channels. The joystick and control buttons are for the servo motors and the driving motor. Atmega32 is programmed such that the input from the joystick will be converted into an effective angle for both the servos to rotate and two control buttons are used to rotate the main motor in Clockwise or Anti-Clockwise directions to Ascend or Descend the tree respectively. The microcontroller then sends the signal to the encoder HT12E which encodes the signal and transmits through the RF Transmitter to the robot. A 9V battery acts as the power supply for the transmitter and the range of the remote control is about 30 meters.

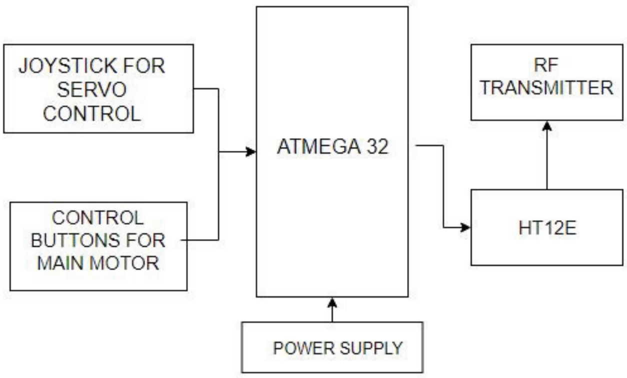

Fig. 8. Block diagram of the transmitter section

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V. RECEIVER AND CONTROL

This unit is completely mounted on the robot chassis except for the power supply. The power supply used is a 12V, 7.2Ah battery which is housed in a trolley on the ground to make it convenient to move around the plantation and is kept on the ground to reduce the weight of the robot. The required cables from the supply will be running to the robot till the top. A power distributor board is used to deliver the required power to the peripherals and motors of the robot. In the robot, an RF receiver module is used and is connected to the HT12D Decoder to decode the signal from the remote control. This is received by the microcontroller which controls the servos, and main motor. The motor rotates at a speed of 30rpm and the servos have an angle range of 0 to 180 degrees.

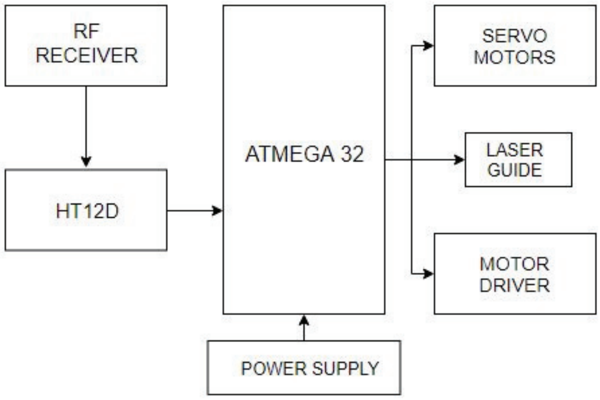

Fig. 9. Block diagram of the receiver section

A laser guide is also provided parallel with the nozzle which helps in aiming the nozzle while spraying. There is no specific motor speed control provided in the system which is not required for simple and user-friendly operation.

VII. RESULTS

This robot is designed to ascend with a motor of torque 8Nm and a suitable gearbox can also be coupled with it to increase the torque if required in the prototype with higher gear ratios. The loaded springs used in the arms should be manually calibrated by trial and error method with the conditions that

1. It provides sufficient gripping force for the robot
2. It doesn't load the system while ascending the tree.

The servo motors are 180-degree servos with 10kgcm torque enough to handle the spraying nozzle. To reduce the payload, the hose used to deliver the pesticide from the pump to the robot is a 12mm PU tube with 10 bar pressure handling capacity and is flexible for the servo rotations. The nozzle is of brass being non-corrosive as the main content in the pesticides used is copper sulfate. The spray range is about 5-8m and can cover surrounding trees within this range.

VIII. CONCLUSION

Automation and application of robotics are believed to be a great leap in agriculture. This design aims at a low cost, user friendly and efficient way of spraying pesticide increasing crop yield and reducing labor requirements. The climbing mechanism can also be applied to other tall and non-branched trees and even for pruning the fruit with cutting blades as designed by [2] P Soni Devang et al. The design can be further improved by mounting a camera on the nozzle and transmit the video data to the operator's controller with image processing features.AI can also be used to automatically spray the pesticide when affected areas are detected. This robot can be developed to be controlled by a smartphone via Bluetooth/Wi-Fi reducing the extra cost of the RC remote controller and is more accessible as smartphones have gained immense popularity even in rural areas. The proposed design though being a concept is done keeping many practical barriers in mind and to overcome them in simple and inexpensive ways.

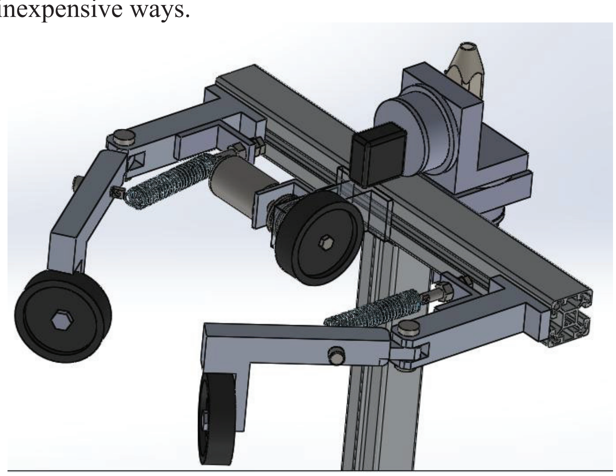

Fig. 10. An Isometric view of the proposed model

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