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Variable Rate Spraying System with Estimating Canopy Volume for Orchard Trees

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Abstract - *Automatic pesticide spraying requires precise calculation of canopy size of trees. It is challenging due to complicated growth structures and sizes of plants. In growing seasons, we found trees have different shapes and sizes. So we need to assess this changing things about tree like heights, widths, diameter and total canopy volume of tree. In this study, Ultrasonic sensor based automated system developed for calculation of tree canopy volume and spraying to targeted plant with proportion to canopy volume of respective plant. The system includes ultrasonic sensor, controller, lead screw slider, proxy sensor and spraying mechanism. Geometrical characteristics of tree are obtained using ultrasonic sensor and proxy sensor. Hence, the ultrasonic sensor and proxy sensor provides 2D array of tree. After measurement of this parameters, we can calculate tree canopy volume by using canopy volume formula and also spray pesticides proportional to the canopy volume on targeted tree. Experiment were conducted for 2 samples of plants which having different shapes and sizes. Results showed no significant difference between ultrasonically and manually measured tree canopy volumes which were 6 to 7%. Liquid pesticide savings were more in comparison to a conventional application were recorded for 2 samples of plants.*

Key Words: ***Ultrasonic sensor, Proxy Sensor, Canopy volume, Pesticide spraying.***

1. INTRODUCTION

Canopy volume is refers to the canopy cover which is visible by our eyes. Actually it is the space occupied by different organs of plant like leaves and branches. In growing seasons, this organs changes its shapes and sizes. The geometrical characteristics of tree are depends on this organs, and also canopy volume of plant. This canopy volume parameter is useful to define plant growth as well as productivity of plant. And hence they can be indicators for tree biomass and growth assessment, crop forecasting, water utilization assessment, health evaluation, and long-term fertility monitoring. Thus, there are large amount of agricultural applications insecticide treatments, watering to plants, fertilization, and crop training which depend largely on the structural and geometric characteristics of the above-ground organs of plants. So here need is to Develop automated equipped system with potential of finding canopy characteristics to bring down environmental contamination and production costs.

Some of the applications like Automatic pesticide sprayers require precise calculation of canopy size. As canopy volume changes, the requirement of pesticide doses will changes. Thus each and every tree has different requirement of pesticide which depends on respective tree canopy volume. It is important to calculate canopy volume to advance spray application efficiency as well as reduce the atmospheric pollution.

Important factor about plant is it must have saved from attacks of insects and various diseases. Farmers mainly uses large amount of pesticide treatment or chemical application for higher production. But excessive use of chemicals causes effect on fruits and soil productivity which pollute the environment. Thus it is harmful for human health. Spraying pesticide is also causes harm to human body through air because of this chemicals. Hence it is important to develop system which calculate parameters of tree like height, width and diameter of plant and find the canopy volume so we can decide how much amount of pesticide application requires to the specific plant which can give proper solution to our many problems.

2. Materials and methods

2.1 Materials

The system made up of vertical slider with DC motors. Ultrasonic sensor are mounted on this moving slider. Vertical slider move ultrasonic sensor up and down with the help of push button. Travelled distance of ultrasonic sensor to detect tree canopy can be measured using proxy sensor. Hence proxy sensor gives the instantaneous value of height of ultrasonic sensor, when sensor will move from the bottom of tree to the top of tree. Simultaneously, Ultrasonic sensor measures the distances of

the tree from the slider unit. We can check maximum diameter of plant with help of controller by using this various distances measured by ultrasonic sensor. Proxy sensor also provides height of tree where maximum diameter occurs. In this way, the ultrasonic sensor and proxy sensor provides 2D array of tree. By using this measured parameters of tree, controller calculate tree canopy volume by using canopy volume formula. Then it will displayed on LCD. After calculating tree canopy, controller head to work on spraying mechanism thus gives command for spraying pesticides on targeted tree. According to measured canopy volume, the required amount of pesticides is applied to each tree. Hence the same slide is comes downward with spraying which proportional to canopy volume and stops at the ground level.

Block diagram shows our desired work related to project. This system consists of Vertical lead screw slider unit with ultrasonic sensor, push button, Proxy sensor, ATMEGA32 microcontroller, LCD display, DC motor and spraying mechanism.

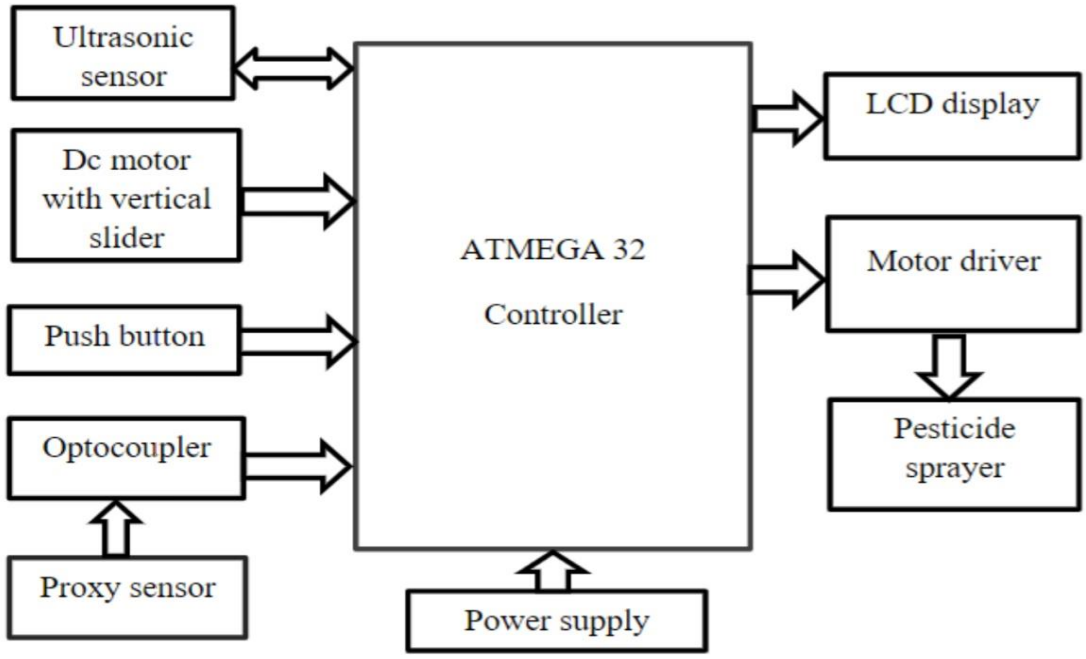


Fig 1. Block Diagram of Variable Rate Spraying System for Orchard Trees

2.2 Methodology:

1. Ultrasonic sensor is mounted on moving lead screw slider which has height of 1m. DC motor will used for moving the ultrasonic sensor in two directions up and down. It will move at a controlled speed for scan the tree profile. The speed was adjusted by changing the motor speed and duration of pulse signal.

2. The push button is used in which 4 keys are provided to move the slide up, slide down, start canopy measurement and stop measurement.

3. Set the slide to the bottom of tree using yellow key. Set the trees centre distance from system is 60 cm.

4. Press the green key and Start the measurement.

5. As we know ultrasonic sensor is used for measuring distance between the slider and tree. Actually this sensor used to measure distances to the detected object. When we apply 10µs trigger pulse, it starts transmitting sound waves of frequency of 40 kHz which are larger than range of human hearing. It strikes on object and bounce back to the receiver of sensor. After measuring travelled time of waves and speed of sound waves, we can calculate distance to the target. After that we give

instruction to slider with the help of push button to move upward from bottom. And take different measurements of distances between slider and tree. By using this distances between slider and tree, we can calculate diameter of tree.

6. Algorithm used for calculating diameter of tree which is used to find canopy volume of tree shown in fig (2) below:

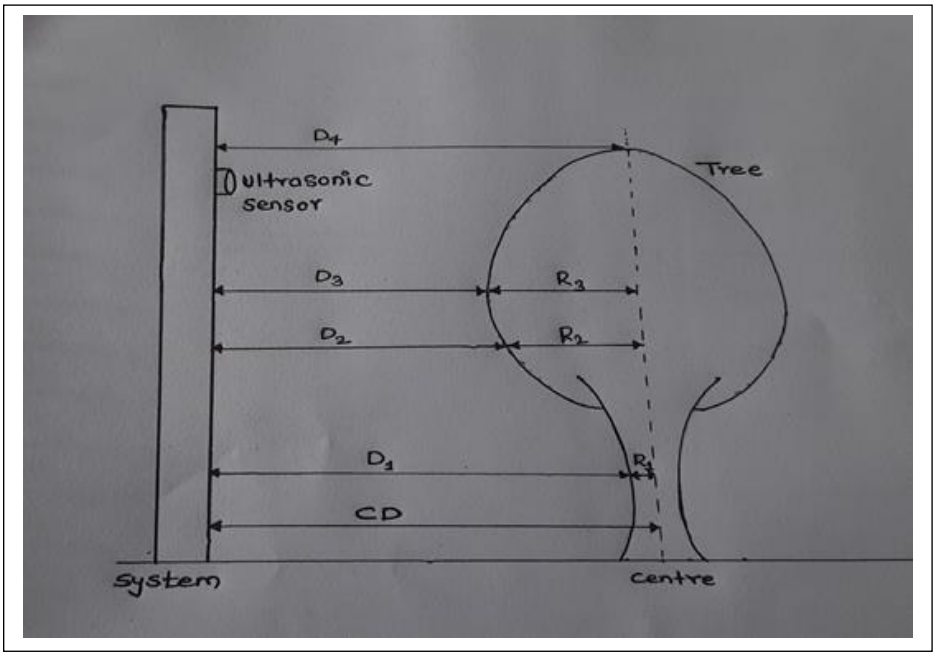


Fig 2. Schematic view of Tree for calculating Distances and Diameter

CD = Centre distance (it is measured between slider and centre of tree)

CD = D1 + R1

Where, D1 measured by ultrasonic sensor

R2 = CD – D2

Where, D2 measured by ultrasonic sensor

R3 = CD – D3

Where, D3 measured by ultrasonic sensor

In this way, controller compares all the values of radius of tree and taken maximum value and calculate maximum diameter.

Diameter of Tree= 2 * (Maximum Radius of Tree)

7. Proxy sensor will measure the instantaneous value of height of ultrasonic sensor, at the time when ultrasonic sensor moves upward from the bottom of tree. Actually here proxy sensor connected at bottom of slider and which detect motor rotations. After each rotation of motor, the ultrasonic sensor moves upward with 1.76mm height. For every rotation proxy sensor will gives high output. In this way, controller will calculate heights of tree with help of output of proxy sensor. So the first maximum

value of ultrasonic sensor gives us the value of H_{TR} which is height of trunk. Proxy sensor also calculate height of the tree from ground level and the height from ground to the point where the maximum canopy diameter occurs.

8. Press the Blue key at the Top of tree. After measurement completed system will calculate the canopy volume by using Albrigo's Prolate spheroid formula:

By Albrigo's Formula,

$$CV = \frac{\pi D^2}{4}\left(\frac{2(H_T - H_C)}{3} + (H_C - H_{TR})\right)$$

Where,

CV = canopy volume (m^3)

H_T = overall canopy height above ground

D = canopy diameter of tree

H_C = height to the point of maximum canopy diameter (m)

H_{TR} = height from ground to the canopy trunk

9. After calculating canopy volume, controller display the value on LCD and gives command to slide comes downward with spraying pesticide and stops at the ground level. The amount of spraying is proportional to the canopy volume of tree.

RESULTS

Table 1. Measurements of First Tree Sample:

No.	Distances measured by ultrasonic sensor	Radius of Tree belongs to each distance (Radius= CD - Distance)	Diameters (DIA)
1	60	0	0
I	36	24	48
3	27	33	66
4	26	34	68
5	28	32	64
6	27	33	66
7	29	31	62
8	30	30	60
9	46	14	28
10	47	13	26

Table 2. Measurements of Second Tree Sample:

No.	Distances measured by ultrasonic sensor	Radius of Tree belongs to each distance (Radius= CD - Distance)	Diameters (DIA)
1	57	3	6

I	56	4	8
3	46	14	28
4	49	11	22
5	55	5	10
6	51	9	18
7	50	10	20
8	38	22	44
9	41	19	38
10	39	21	42

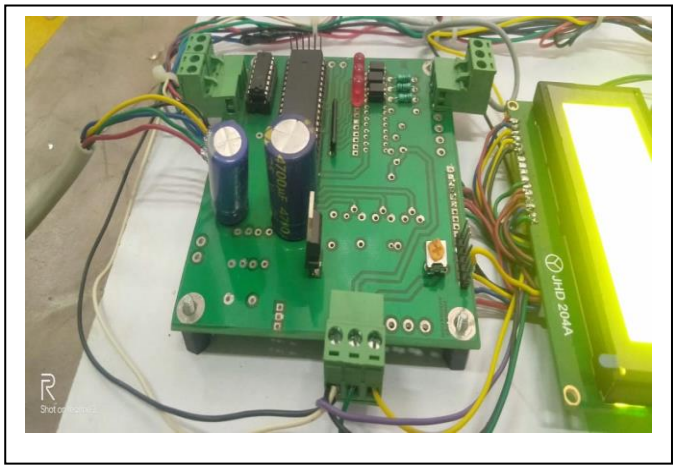
Table 3. The change of measured geometrical characteristics of tree with manual and ultrasonic sensor measurement:

No.	**Manual Measurement (m)**				**Ultrasonic Measurement (m)**			
	H_{TR}	**D**	**H_C**	**H_T**	**H_{TR}**	**D**	**H_C**	**H_T**
1.	0.36	0.70	0.53	0.88	0.37	0.68	0.54	0.86
2.	0.51	0.55	0.62	0.88	0.48	0.44	0.69	0.88

Table 4. The change of measured canopy volume with manual and ultrasonic measurement:

No.	**Manual Measurement (m^3)**	**Ultrasonic Measurement (m^3)**	**Spraying Rate (ml/sec)**
	Canopy Volume CV	**Canopy Volume CV**	
1.	0.15	0.14	31
2.	0.08	0.05	17

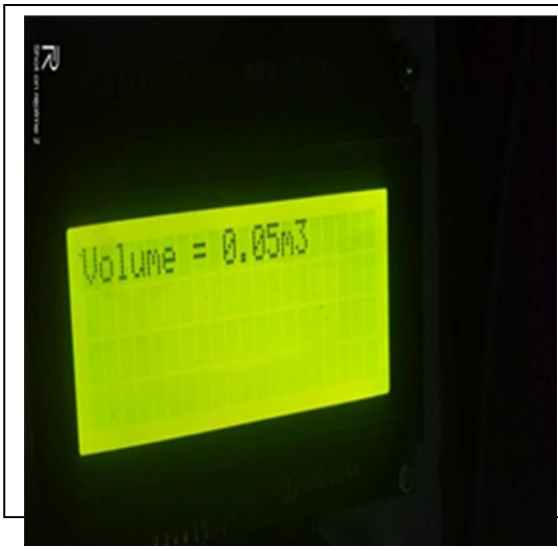
Variable Rate spraying System Views:




Shot on realme 2


Shot on realme 2


Volume = 0.14m3
spraying force = 31


Volume = 0.05m3

CONCLUSION

Ultrasonic technology can gives more accuracy and cost effective solution. This system gives less relative error between measured canopy and actual value of canopy volume which is 6 to 7%. Due to actual canopy volume measurement pesticide liquid saving is more in comparison to conventional application.

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