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LEAN-AGRIBOT USING ARTIFICIAL INTELLIGENCE: REVIEW

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Abstract— **The study targeted mainly the agricultural community. We studied the farmers various issues to look into the various aspects of pesticide, insecticides use in agriculture and its impact on the environment and human health. This paper describes the effective farming as well as a promising solution to the farmers by artificial intelligence technique. Intelligent farming is the practice of modern technologies such as sensors, robotics, and data analysis for shifting from tedious operations to continuously automated processes. Every year farmer experiences large losses due to pest infestation in crop & this in turn affect his lifestyle. These losses are basically due to, improper management of pesticides imbalanced pH of soil and discontinuous monitoring of farm. Uncontrolled spraying of pesticides, harmful insects and imbalanced pH of soil, reduces product of farmer both in quality and quantity. The A.I. and four-leg technology have the potential to solve these problems efficiently. This quad leg robot perform the functions like (a)Testing of soil pH by providing the proper solution depending upon the nature alkaline or acidic ,(b)Spraying of pesticides in proper proportion and (c)Targeting insecticide solution by PIR thermal sensing(if insects detect on crop) .This quad leg robot perform these functions by following the line of crops. The robot actually walks on farm in such a manner by following the crop line and performing the functions walking over the crops. This A.I. robot gives the solution on improving the soil productivity and improves the proper growth of plant.**

Keywords— **Intelligent farming, Robotics, Sensors, four-leg robot, Soil pH, Pesticide, Insecticide.**

I. INTRODUCTION

Lean-Agribot is a promising solution for digital farming and for handling the problems of workforce shortage and declining profitability. These technology are enhancing crop production and improving real-time management, soil productivity, (helps to improve crop monitoring system) crop health, reduce human health hazard. The relationship between extent of pesticide use and signs and symptoms of illnesses due to exposure was assessed in a cross-sectional survey of 631 farmers (537men and 94 women) in South India. Responses to questionnaires showed that 433 farmers (68.6%) sprayed pesticides themselves and were thus directly exposed. More than 75% used moderately or highly hazardous pesticides; 88% used no protection while handling pesticides. About 50% of sprayers mixed different brands. Retailers were the source of information about pesticides for 56%. The farmers reported excessive, sweating (36.5%), burning/itching of eyes (35.7%), and excessive salivation (14.1%) all more prevalent among sprayers. Among men, excessive sweating and eye and throat problems were significantly associated with exposure. There is a need to raise farmers' and authorities' awareness of the need to use protective gear when handling pesticides. To overcome on this problem we have designed a four-leg robot [1]. We are proposing a model which having the tendency for an effective farming. The proposed design is characterized by a simple, modular design, and easy interfacing capabilities. The proposed robot is "able to traverse rough terrain while carrying additional payloads". Such payloads can include, (a) Battery unit, (b) pesticide & insecticide tanks (it can also contains the solution for acidic or alkaline test by pH sensor if required), (c) pH sensor (on front right side leg), etc. The design parameters for Agribot i.e. quad leg robot is given in following table.

Table 1 Design parameters of Agribot (four leg robot)

Sr.no	Description	Design value	Symbol
1	Body height	4ft	H
2	Body width	2.8ft	W
3	Lengths l0 l1 l2	3ft 0.82ft 3ft(each leg)	l0 l1 l2

Where, lo=total length of body, l1=linkage length, l2=leg length, H=total height of body, W=total width of body.

For making easy farming with high accuracy (Poka-yoke technique), we designed a four leg robot having the above design parameters with easy handling. This robot is embedded with artificial intelligent technique with the help of arduino microcontroller. This Agribot has the payload capacity up to 25 kg. That means this agricultural robot has the capacity to walk and performs the functions on field with payload up to 25 kg. the payloads which we are installing with this Agribot is enlisted (a)Battery unit,(b)pesticide tank(10L capacity),(c)insecticide tank(5L capacity),(d)pH sensor(which actually attached with right leg of the robot).(e) The separate tanks for alkaline or acidic solution depending upon the nature of soil.

Table 2 Classification of tanks according to their operation

Sr. no.	**Classified tanks**	**Solutions used**	**Operations performed by the solutions**
1	Tank A	White vinegar solution(for acidic soil)	It will balance the pH up to >6.5
2	Tank B	Baking soda solution(for alkaline soil)	It will balance the pH up to <7.5
3	Tank C	Insecticide solution	It will target to the insects helps to improve crops health
4	Tank D	Pesticide solution	It will give the nutrition for the proper growth of crops


Fig.(a)crop line for dry beans


Fig.(b)crop line for cotton


Fig.(c)crop line for tomato

Fig. 3 crop line followed by robot. (a)crop line for dry beans, (b)crop line for cotton. (c) crop line for tomato.

The Agribot will follow the crop line by sensing each and every crop within line. End of first line is can be identify by sensing last crop (from the same crop line) with PIR (Passive Infrared sensor) thermal sensor. After identifying by thermal sensing the robot will change its path by means the robot will follow the next line and cycle repeats until all crops won't get targeted successfully. As we designed this Agribot with height of 3.5ft., the robot will performs all the functions which are suitable according to its design. that means this Agribot will target all types of crop species which are preferable to the robot design. All the robot operations, sensor working, and including of four leg robot motion has been operated by arduino microcontroller by giving the set of instruction.by giving proper commands to the respective operations, robot successfully performs all tasks automatically by itself. This technique is known as A.I. (Artificial Intelligence) technique.as we know that to perform all operations successfully we have to give necessary commands to two separate arduino hardware. That is why we have explain the algorithms for perfect working. While detailed studying of this article we observed that, this designed agribot has tendency to reduce agricultural wastes. That wastes are of three types (3M): (i) MURI (ii) MURA (iii) MUDA

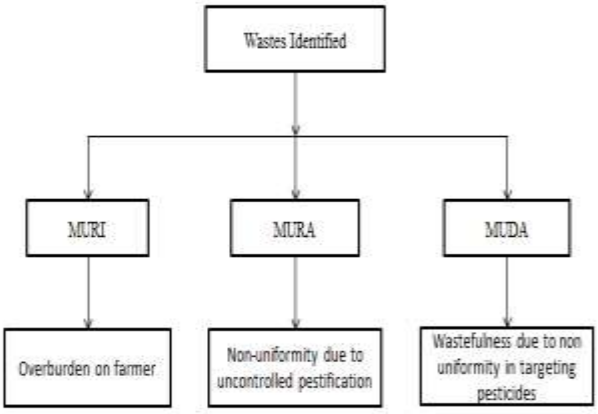

Fig.4 wastes identified in agricultural field

(i)MURI: Mura means overburden. We know that in primitive farming, farmers have to spray pesticides, insecticides solution manually. Some of the chemicals used in pesticides solution are health hazardous and can cause to make serious disease. They also work in farm without wearing any safety precautionary measures.

Fig.5overburden on farmers while doing work on field

The above figure shows the overburdens on farmer. To overcome this issue and to eliminate farmers' overburden, we have proposed a four leg Agribot. This will give the effective farming as well as a healthy atmosphere for crops.

(ii)MURA: Mura means non-uniformity in sense of agricultural field we can say it as over-pestification on crops. we can clear with the following images:

Fig.6 white fungus appears on tomato crop due to over-pestification.

The above figure shows that how mura waste affects on the agriculture field. Excessive spraying of pesticide leads to mura waste. The agribot has the tendency to eliminate such kind of waste with proper technique.

(iii)MUDA: Muda concept defines the wastefulness due to non- uniformity in targeting pesticides. As we know that, in some developing country farmers still use improper method to handle pesticide/insecticides. Farmer still targeting the pesticide in uncontrolled way, it means handling pesticides manually results in improper pestification. Some times by targeting pesticides manually and due to poor techniques, in some portion pesticides targeted excessively. While in some portion the farmer target pesticides below the requirement level or by mistake he left some portion. So by detailed study we identified such waste in agriculture field, and we also provide solution to eliminate such kind of waste in sense of Agribot. The fig(5) shows the non- uniformity in spraying the pesticides and can cause to formation of muda waste.

I.I PRIMITIVE FARMING

The farmers mixed the different pesticides in a vessel with water or they poured them directly into the spraying can and then mixed them in the spraying can itself. Due to lack of knowledge, unavailability of tools and techniques to handle pesticides/insecticides it leads serious illness to the farmers.as the farmer targeting pesticide/insecticide manually, farmer directly comes in contact with such hazardous chemicals (pesticides/insecticides chemicals)and they may get serious issues with their health[2].The following figure shows the primitive farming method.

Fig.7 spraying pesticides by manually without personal protection.

The Food and Agriculture Organization recommends that WHO categories Ia (extremely hazardous) and Ib (highly hazardous) pesticides should not be used Farmers sometimes return to the fields for work less than 24 hours after the application of pesticides. The continuation of pesticide spraying and other farming activities concurrently in the field can lead to direct exposure to pesticides, as they may still be dispersed in air. Hence, to eliminate the agricultural wastes (i.e.3M) and by considering the farmers' problem while spraying of chemicals, we have designed the "Lean-Agribot" [5].

II. PROPOSED METHODOLOGY

To eliminate the wastes (i.e. muda, mura, muri) in agricultural field as well as to make effective farming, we have proposed a new concept of "Agribot" with A.I. technique. For balancing the robot as well as to work all operations efficiently, we have divided this Agribot in two sections with two arduino hardware panels,(A)Arduino microcontroller for robot (by means of driving 12servomotors),(B)Arduino microcontroller (for performing all operations sequentially).

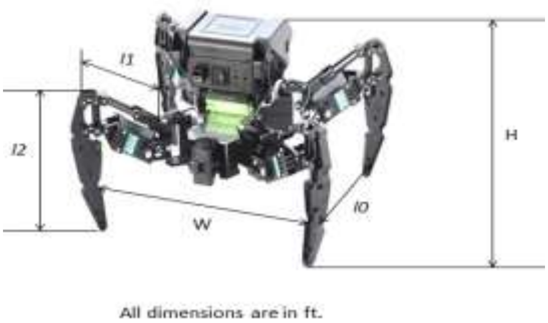

Fig. 8 Proposed "Lean-Agriot" with twelve degrees of freedom

The above four leg insect robot with twelve degrees of freedom we have chosen for working effectively on rough surface [6]. As we know that the agricultural surfaces are very irregular and rough, it is very difficult to walk/run the robot on such difficult surface. Many robots are designed before to perform on field, but the main problem which we understand that the robot with wheel arrangements doesn't perform in field properly. Sometimes what happens, the wheels trapped in soil due moisture-ness present in soil. Considering this problem, we designed a robot having it's four leg with sharpened the lower edges (as shown in fig.8).This robot has the tendency to walk on field very effectively without any failure. This robot is named as "Lean-Agribot", as this robot is eliminating 3M wastes in agricultural field as well as performing all operations like spraying, testing, identifying problems (by insect detection over crops) with the help of A.I. technique. To be more specific, the four leg robot, have 12 Degrees of Freedom (DOFs), respectively, with 3 servomotors (DOFs) per leg. We are using total 12 servomotors to walk robot effectively. The design parameter of Agribot is mentioned in figure.1.The robot has capacity to bear the payload up to 25kg.The payload contains the following items:

1) One shoot-multiple operations

We designed the robot in such a way that, we fixed four tanks with different solutions. All these tanks are fixed above its bed with separate pump mechanism. All these tanks have provided different operations. The following fig. shows the detailed about this mechanism.

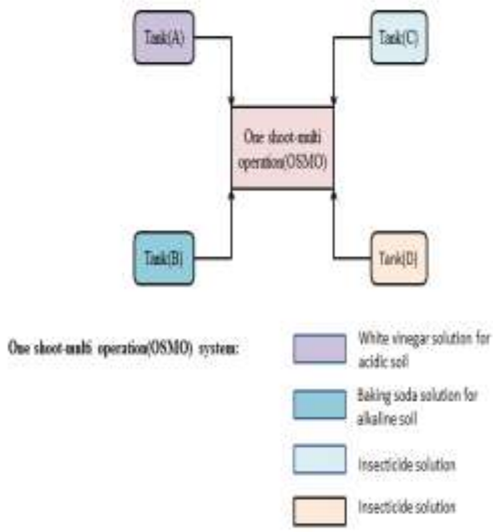

Fig. 9 One shoot-multi operation (osmo) system

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2) Pump
The diaphragm pesticide pump used to pump/extract the solution from tank. Each tank has provided separate pump mechanism [3].

Fig. 10 DC diaphragm pesticide pump

The diaphragm pesticide pump is more suitable for the tanks to extract/pump the solution. This DC operating pump has specification of 12v,130psi with 6L/min water high pressure pump.

3) Nozzle design (Diaphragm check valve)
The size of the spray droplet can have a direct influence on the efficacy of the chemical applied, so selecting the proper nozzle type to control spray droplet size is an important management decision. The following diagram shows the auto-flow adjustment nozzle for spraying/targeting solution.

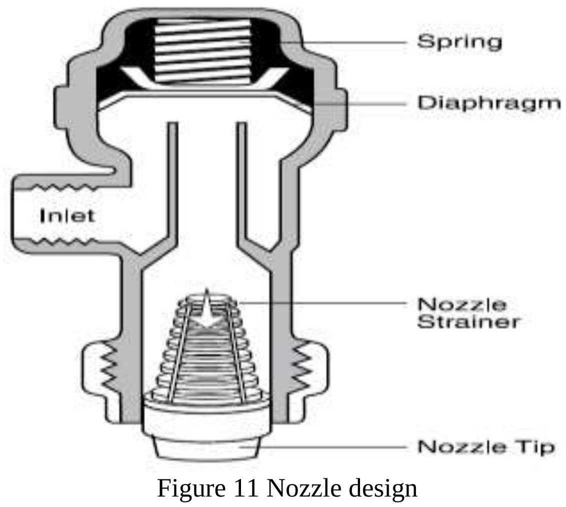

Figure 11 Nozzle design

Design of the nozzle affects the droplet size and is a useful feature for certain applications. Large droplets are less prone to drift, but small droplets may be more desirable for better coverage. Pressure affects droplet size – higher pressures produce smaller droplets. Check valves allow the nozzles to be changed without material leaking from the boom. We have selected this design because it has diaphragm valve which can adjust the rate of flow of solution. Only one nozzle (one shoot-multiple operations) we have provided for spraying solutions. This nozzle is adjusted in such a manner that, it is located at the center of below bed size. With the help of arduino support system, the solution from respective tank will be spray/target accurately on crops.

4) Batteries (LFP-Lithium Ion Phosphate)
The most important factor is power source. To perform robot effectively, we have chosen LFP battery source. LFP is known as more stable chemistry, which means the temperature threshold for thermal runaway (or fire) is higher than that of NCM (Lithium Nickel Manganese Cobalt) and NCA (Lithium nickel cobalt aluminum). LFP batteries provide the best thermal and chemical stability, which results in superior safety over NMC/NCA batteries. The LFP battery is still preferred because of its low energy density. LFP uses Lithium-phosphate (12V) as cathode material. The power source has been categorized in two sections, from (figure. 13) power source to hardware support system of four legs by means of driving12 servomotors and (B) power source to hardware support system of controlling operations. The following figure shows the cycle life for LFP battery.

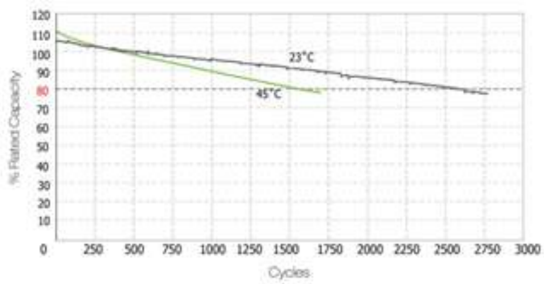

Fig. 12 Cycle life for LFP battery

III. CONSTRUCTION

The overall working of Agribot is divided into two categories, i.e., part (A) Arduino microcontroller(for four leg robot) and (B) Arduino microcontroller(for performing the operations) hardware system First part includes hardware system support to the four leg robot mechanism and second hardware part includes system support for performing the functions on field. Due to this seperative characteristic of the model, this model separates from other robotics models which are already exists. The first part with details explained below:

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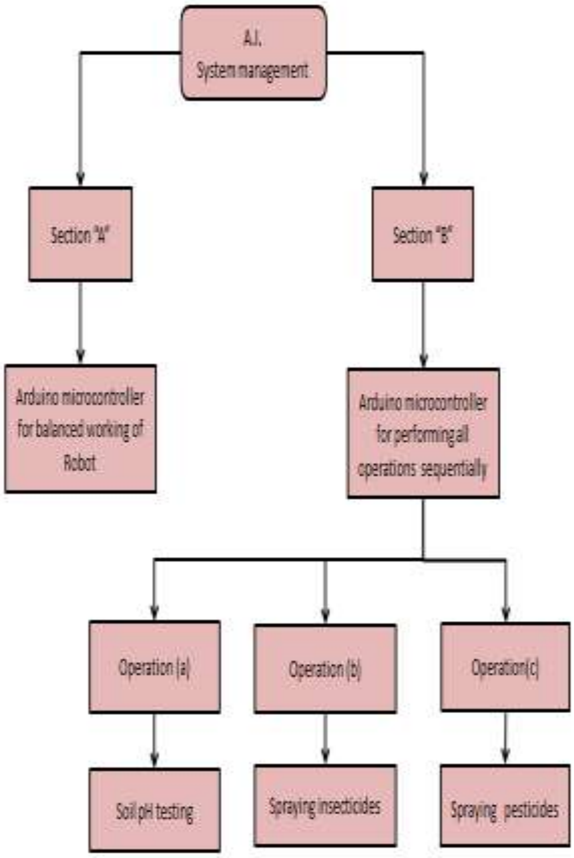

Fig. 13 Classification of Agribot

Part (A)

To validate the different configurations of the CPGs we have performed hardware implementation on dedicated hardware, such as arduino (Microcontroller). And FPGA board for high and low level implementation, respectively. The arduino board used in this work is the Bot-Board arduino (Fig.14(a)), which is based on Atom Microcontrollers for Lynx motion robots. It has an onboard speaker, three buttons and LEDs, a Sony PS2 controller port, a reset button, logic and servo power inputs, an I/O bus with 20 pins and power and ground, and a 5v dc 1.5 amp regulator. Also, up to 18 servos can be plugged in directly.

Fig. 14 (a) BotBoarduino-(Lynx motion)

In order to have better hardware conditions for Agribot, we also considered the implementation on FPGA board, such as more resources to implement complex designs, a hardware design language (HDL), low power consumption, reconfigurability, hardware parallelism, and very high processing speed. Specifically, in this work we use Spartan 6XEM6310-LX45 board. This specific board has two more advantages: on one hand the dimensions, only7.5cm*5cm (highly suitable for our robots), and on the other hand a graphical interface for friendly interaction between the PC and the FPGA.

Fig. 14 (b) Servo controllers SSC32

A SSC-32 servo controller (Fig.14(c)) is used to handle servomotors in the robot. This is a servo controller with 32channels of 1uS resolution servo control and a bidirectional communication.

Fig. 14 (c) FPGA (field programmable gate array)

To connect and control the servos through the FPGA, we also use a breakout board (BRK6110), which allows us an easy connection to high-density connectors on the XEM6110-LX45 by routing all signals to four 40-pin 2-mm headers. The high density connectors for mating to the XEM are pre-installed on the BRK6110 [1].

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Fig. 14 (d) Breakout board BRK6110

Part (B)
The second part of hardware includes the proper functioning of all operations with the help of arduino-uno microcontroller.
The operations performed by microcontroller with proper Algorithm sequence are:
(A) Soil pH detection
(B) Intelligent spraying of insecticides
(C) Continuous spraying of pesticides.
All these operations performed by A.I. techniques and are considered by identifying the farmers' issues on farming. All operations are explained below:

A) Soil pH detection
To increase the soil productivity and for proper growth of crops, it is very essential to measure the pH value of soil. For getting the precision value of soil pH, a pH Meter using Soil PH Sensor and Arduino for the measurement of **Soil** pH**.** Soils can be naturally acidic or alkaline & can be measured by testing their pH value. Soil pH is a measure of the acidity or alkalinity of the soil. In chemistry, pH is a scale used to specify how **acidic** or **basic** nature of soil. Acidic solutions have a lower pH, while basic solutions have a higher pH. Thus pH **sensor** has the ability to determine the pH of any solution, i.e., it tells whether the substance is acidic, basic or neutral in nature. By knowing the pH, we can monitor the soil quality in Agricultural Farm [4].

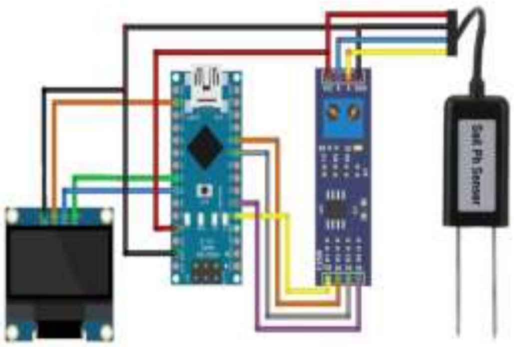


Fig. 15 Soil pH interfacing module

However, soil is considered a natural medium for plant growth & development. Much research is going on to determine the internal factors of farmers' crop production failure. One of the factors is the balance of nature in unstable or unfertile soil that inhibits plant growth and plant root development. The pH is the acidity **or** basicity of material measured on a scale between (0to14**)**. The pH value lesser than 7 is considered **acidic** and greater than 7 is considered **basic.** If the pH scale is 7 then the material is neutral**.** The most ideal soil conditions for the growth & developmen of plants are neutral soil. However, some types of plants are still tolerant of soils with slightly acidic pH with a maximum pH of 5. The sensor works perfectly with **Modbus** RS485 and the result is highly impressive. Modbus is RS485 is a serial data transmission protocol defines communication between a host (master) and devices (slaves) that allows querying of device configuration and monitoring. Most soils have pH values between **3.5** and **10**. In higher rainfall areas the natural pH of soils typically ranges from 5 to 7, while in drier areas the range is 6.5 to 9. Soils can be classified according to their pH value.
The following table shows the pH range and the solution used for balancing the proper pH of soil:

Table 3 Classification of soil pH and remedy for balancing range.

Sr.no.	**Nature of soil**	**pH range**	**Solution used for balancing soil pH**
1	Acidic	>6.5	White vinegar with water(tank A)
2	Neutral	6.5-7.5	Balanced pH
3	Alkaline	<7.5	Baking soda with water(tank B)

The above table shows the classification of soil pH with solution to make soil balance. If soil test comes acidic(>6.5)then the pump extract from the tank "A" which contains White vinegar solution, or sensor detects alkaline soil the pump extract the solution from tank "B". Actually this operation is performed by the soil EC sensor .we have designed robot in such a manner that the EC sensor can work with coordination of four leg movements. The EC sensor is fixed with right leg of robot, in such a manner that the leg movement and sensor can work with coordination. After the 50 cycles, the robot will stop on actual field and the sensor attached to the right leg activates and starts getting the results from soil. Here, the number cycles defines the advancing of the robot one step ahead. It means when four leg take movement simultaneously with balanced coordination effect,

then the robot will considered to be as one cycle ahead. As the robot designed with four leg coordination effect we have given the momentary term cycles instead of using steps. At this stage the robot will in stable position and it will not move forward until it won't get the proper results.

As result comes and display on screen, Arduino decides to spray mode and target according to the output given by EC sensor. To perform this operation effectively, we have made the proper algorithm steps to determine the accurate results.

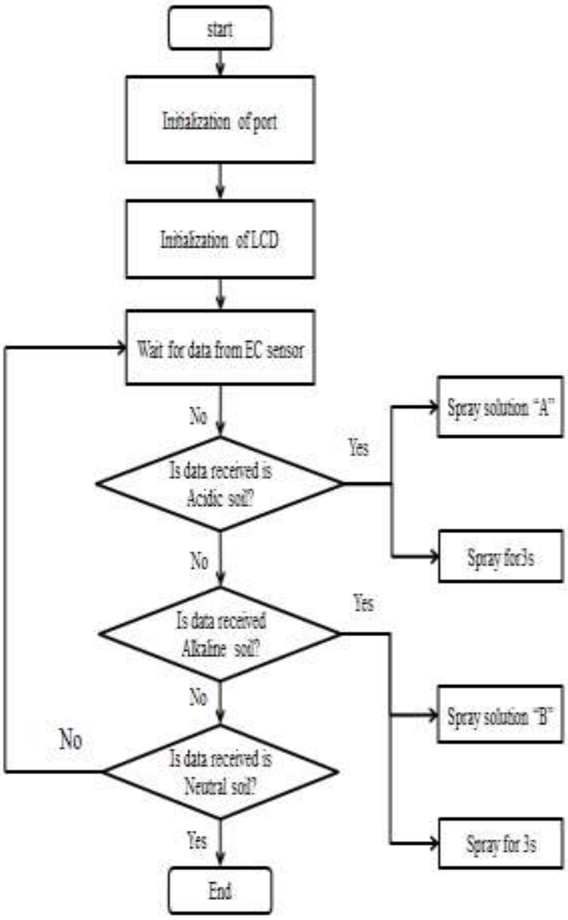


Fig. 15 (b) Algorithm steps for soil pH testing

Need of soil pH testing:

(1) Soil pH affect amount of nutrients and **chemicals** that are soluble in soil water.

(2) The development of strongly acidic soils can results in poor plant growth as a result of Aluminum and Manganese toxicity or calcium and magnesium deficiency.

(3) Alkaline soils may have problems with deficiencies of

Proof: The above Figures gives the proof of fungus over crop due to impact of soil pH affecting on crop health.

Fig. 16 (c) Proof of uncontrolled pH affecting on crops health.

B) Spraying of Insecticide solution

A separate pesticide tank separate nozzle and pump has been provided for extraction of solution from the tank, to this lean-agribot. The mechanism used for identifying the crop health i.e. detection of insecticides on the crop leaves, the PIR(Passive Infrared Sensor)thermal sensor is we used here.by thermal imaging sensed by PIR ,the robot can easily detect the target(insects presents over leaves).By giving proper set of instructions by arduino-uno microcontroller, the will detect the target efficiently and by giving proper command the pump will activate and insecticide solution can be spray from nozzle for 3 sec to the identified target. The working principle for the PIR sensor could be clearer with (fig.16 (a))

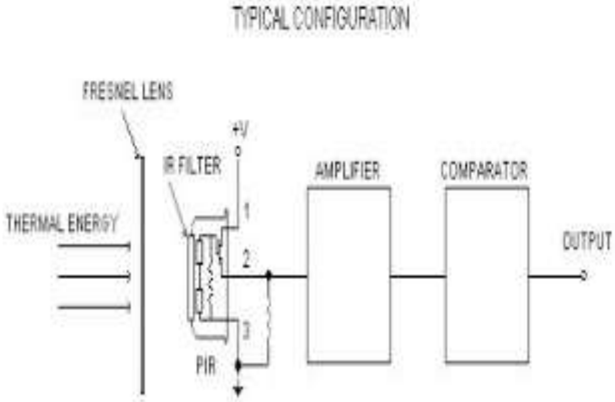


Fig. 16 (a) working mechanism for PIR sensor

The PIR sensor has beneficial characteristic is that, it can sense any insect by their movements. PIR also helps robot to identify crop line. By mean if crop line exists or not can be identified by this PIR sensor. PIR motion sensors can detect moving objects even in dark with great accuracy. PIR sensors can detect the motion of objects without coming in contact with them. They are very easy to install and do not require much wiring. Considering this major application, we have selected this sensor. Identification of insects over crops/crop leaves for proper health of crops, this operation is very necessary to maintain crop health. To perform the above operation with accuracy we have provided the algorithms which will give the proper directions to follow the operation successfully. The insecticides spray conditionally i.e., timer is set and only for 5second the pump will spray solution. After targeting of insecticide solution, the robot will move to next operation. Below instructions are being triggerd with the help of PIR sensor:

1) PIR Thermal sensing toe each crop
2) PIR will sense an insect
3) Arduino will give set of instructions
4) Spraying of insecticide solution

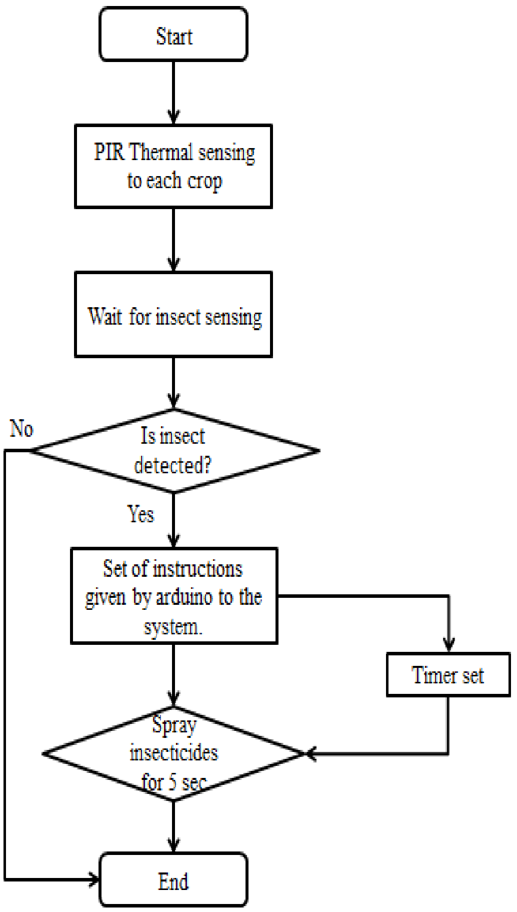


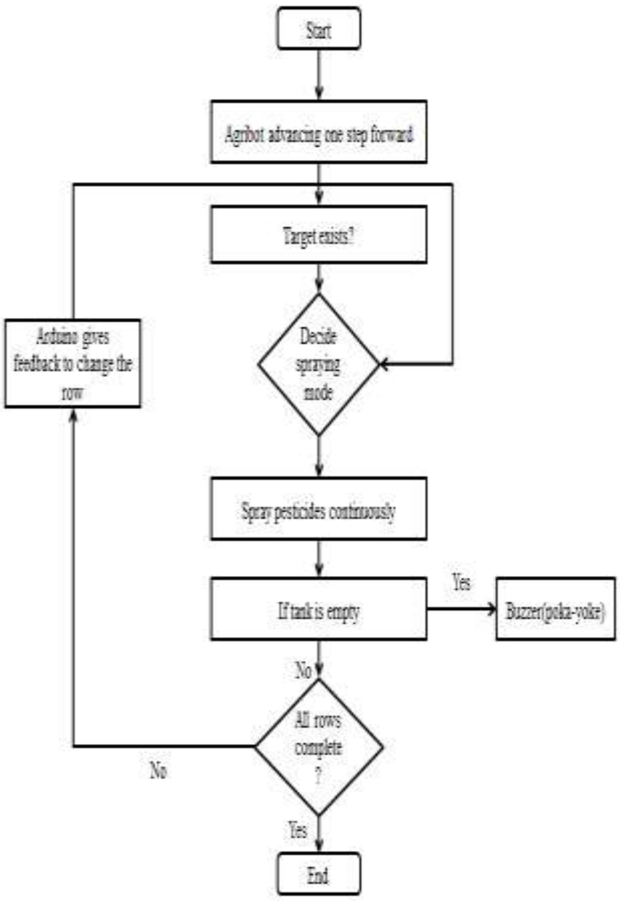
Fig. 16 (b) algorithm steps for spraying of Insecticides

The program will run sequentially as provided in above algorithm. The PIR sensor starts sensing to each crop, if insect detected the arduino gives proper command to spray proper solution for timer set 5second.

C) Spraying of Pesticide

Fig.17 algorithm steps for spraying of pesticides

The third important operation is pestification. As we know that, for proper growth of crops and to eliminate the various plant disease Spraying of pesticides with proper proportion is necessary. As the agribot starts working on field, it will spray the pesticide solution to each and every crops by continue spraying.it has the only limitation that we are providing pesticide tank of 10 Ltr capacity, as we designed the agribot for a payload capacity up to 25kg.Depending upon the overall farming size, we can adjust the pesticide tank by refilling it manually with safety precautions like use of gloves, masks, protective clothes, personal hygiene, appropriate footwear, head gear, etc. Here, the Agribot is doing lean work by using "Poka-yoke (mistake proofing)" Technique. The buzzer will activate for mistake proofing, that means the buzzer will indicate the tank has empty and need to refill the tank with solution manually. We are using the term poka-yoke, which defines the lean work done by robot. As buzzer activates the robot will stop advancing until the tank will not get refill. After the refilling of tank with solution, the robot will to its next cycle means robot will move forward. With the help of arduino programming it is possible to self-operate the robot according to operation need.



International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 7, Issue 5, ISSN No. 2455-2143, Pages 181-191
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This spraying technique is very much effective to work on field with high accuracy, and giving the satisfactory results to the farmers. To maintain all these functions properly, the basic need is to set proper algorithm steps. The algorithm steps for functioning of spraying pesticides shown below: The above algorithm gives the proper direction for controlling the functions successfully.

IV. PROCESS FLOW FOR AGRIBOT

This robot is designed to perform multi-oprations with high accuracy with proper hardware suport system.To bobtain high accuracy,it is very important toselect proper design of hardware support.To achieve this, we classified the Agribot into two hardware support sysytem so as to obtain proper coordination between robot mechanism as well as performing precise operations.The "Len-Agribot" is an evidence for lean work,By identifying and eliminating the agriculture wastes.The poka-yoke(lean task) also accurately performed by the Agribot to avoid mistakes while performing on field.The proper sequence of overall Agribot functions descibeb below with the help oh flowchart.

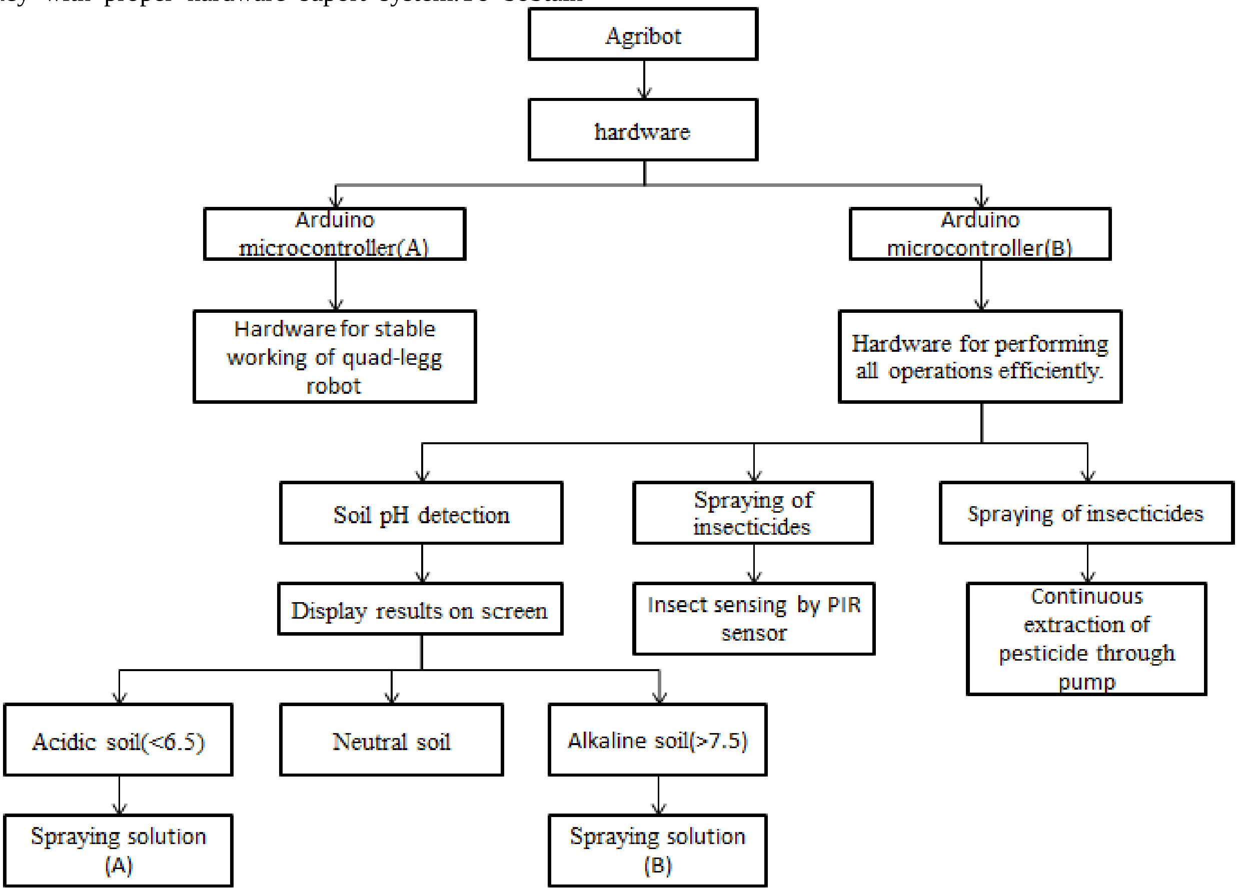

Fig. 18 Lean-Agribot working process flow

The above fig. shows working process flow of Lean-Agribot. All operations and how they actually carried out with the help of hardware support system, is explained in above (fig.18) neatly.

V. CONCLUSION

After detailed study of agricultural wastes and serious issues in agricultural field, we have made a robot (inspired from insects' biological structure) having four legs. Lean-Agribot is designed to eliminate the agricultural 3M wastes (muri, mura, muda) as well as to solve the serious issues relating to farmers' health. Based on the result obtained from the algorithms, a decision can be taken as which type of solution should be sprayed. Pesticides being used in agricultural tracts are released into the environment and come into human contact directly or indirectly. Farmers' are exposed to pesticides found in environmental media (soil, water, air, and food) by different routes of exposure such as inhalation, ingestion, and dermal contact. Exposure to pesticides results in acute and chronic health problems, ranging from temporary acute effects such as irritation of the eyes and excessive salivation to chronic diseases such as cancer and reproductive and developmental disorders. Automatic spraying system has been successfully design to reduce human work. A biologically inspired embedded system for four leg robot locomotion has been presented. This robot has tendency to work with all operations effectively on filed.

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