ArmBot: A Computer Vision-based Disease Detection and Precision Pesticide Spraying Robot

A PROJECT REPORT

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BONAFIDE CERTIFICATE

This is to certify that the project work entitled "**DISEASE DETECTION AND PESTICIDE SPRAYING ROBOT**" is bonafide record of the work carried out by

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SIGNATURE

Project Viva-voce held on________________________

Examiner-I **Examiner-II**

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ABSTRACT

Keywords: Agricultural robots , Crop monitoring robot , Image processing, Disease identification and Pesticide delivery

India is mainly an agricultural country. In India, agriculture contributes about 16% of total GDP and 10% of total exports. Agriculture is the backbone of Indian economy and we depend on agricultural outputs for our food requirements. However, there is an urgent need to mechanize/automate the agricultural operations so that wastage of labor force is avoided and farming is made convenient and efficient. One of the major challenges faced by the farmers is to regularly monitor the crops for diseases from early stage to mature harvest stage which involves identification and monitoring of plant diseases and spraying of pesticides. It is very difficult to monitor the plant diseases manually and requires expertise in the detection of plant diseases.

Therefore an automated system consisting of disease detection and pesticide application in plants is required. ARMBOT (a prototype) is a ground-based agricultural robot that overcomes these challenges. It provides a small, portable and reliable platform to automatically survey farmland, detect diseases with the help of image processing techniques as well as to spray the pesticide. Image processing gives a fast, automatic and accurate solution to the user. A pesticide spraying system has been developed for the control of the diseases. The ARMBOT is tested in the field condition and assessment of its performance is carried out successfully.

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ABBREVIATIONS

GDP	Gross Domestic Product
NSSO	National Sample Survey Office
PCM	Precision Crop Management
CMV	Cucumber Mosaic Virus
IR	Infrared sensor
DC	Direct Current
PWM	Pulse Width Modulation
OpenCV	Open Computer Vision
RGB	Red Green Blue
HSV	Hue Saturation Value
LS	Left Sensor
RS	Right Sensor

CHAPTER 1

INTRODUCTION

1.1 AN OVERVIEW OF AGRICULTURE IN INDIA

India is an agricultural country where agriculture, is undoubtedly the largest (70%) livelihood provider in India. Industries in India mainly depend upon agricultural sector for their raw materials. Emphasis on modern agricultural practices and provision of agricultural subsidies, irrigation infrastructure and gradual investments in technological development are the major factors that contribute for growth in agriculture.

Indian agriculture has been transforming rapidly for the past two decades. New avenues for agricultural modernisation have been opened up by policies of globalisation and liberalisation which in turn lead to commercialisation and diversification, and also aided in various technological and institutional innovations owing to investments made by corporate entities.

Agriculture sector contributes towards 50% of the total workforce making it the largest employer in India .Agriculture also has a pivotal role in food security apart from economy and employment. According to (NSSO, 2013) more than half of the income of an average indian is spent on food security.

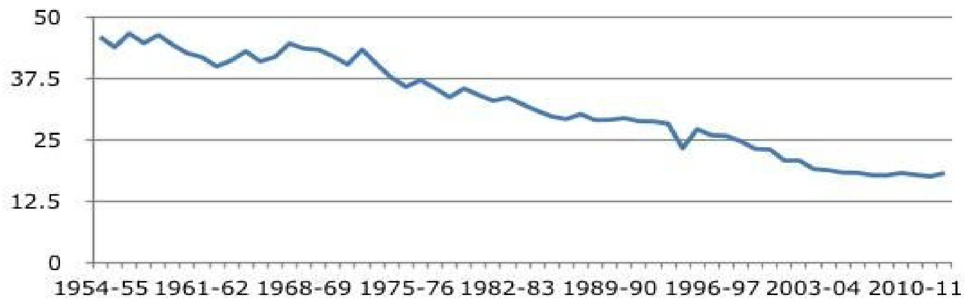


Fig.1.1 Contribution of agriculture sector to total GDP of India(1954-2012)

The contribution of agriculture sector for India in total GDP has been falling over the years irrespective of the growth rate of agriculture in food security that has been fluctuating continuously. As shown in Fig 1.1 [1] , at the time of Independence agriculture contributed almost 50% which is half of the total GDP has declined to 18% in the recent years which was more than 45% in 1954-55.

1.2 WHY AUTOMATION IN AGRICULTURE?

Monitoring the health of the crops and disease identification in plants play a vital role in successful cultivation of crops. [2] The quality and quantity of agricultural outputs drastically reduce due to diseases in crops. Earlier, an expertise person of that field would monitor and analyse the plant disease and spray adequate amount at the required areas manually. However this method involves a large amount of work force and excessive processing time. [3] For better management of crops Precision Crop Management (PCM) is well adopted in several developed countries that improves the yield of crop and optimizes the use of pesticides and chemicals that aids in reducing the cost and pollution. For greater accuracy, resolution and timeliness of PCM application and other remote sensing applications image processing solutions are well suited. Automated monitoring and disease detection can facilitate timely control of diseases in crops which in turn can lead to increased yield, improvement in the crop quality and reduction in the pesticides that need to be sprayed. There may be other advantages like reduced costs in production, reduction in exposure to pesticides for workers and inspectors working in the farm and increased sustainability

1.3 GREENHOUSE FARMING

The present agricultural scenario is a mix of outstanding achievements and missed opportunities. If India has to emerge as an economic power in the world, our agricultural productivity should equal those countries, which are currently rated as economic power of the world. We need a new and automated technology which can improve the productivity, profitability, sustainability of our major farming systems. One such technology is the greenhouse technology. Although it is centuries old, it is new to India

Growing plants and producing targeted outputs is both an art and science. About 95% of plants,either food crops or cash crops are grown in the open field. Since time immemorial, man has learnt how to grow plants under natural environmental conditions. In some of the temperate regions where the climatic conditions are extremely adverse where growing crops is difficult, man has developed methods of growing some high value crop continuously which is called as Greenhouse Technology. Greenhouse Technology is the technique of providing favourable environment conditions to the crops. It is rather used to protect the plants from the adverse climatic conditions such as wind, cold, precipitation, excessive radiation, extreme temperature, insects and diseases. It is an vital importance to create an ideal microclimate around the plants to obtain the required results. This is possible by erecting a greenhouse / glass house, where the ideal environmental conditions are created and one can grow any plant in any place in the house at any time by providing suitable environmental conditions with minimum labour. Greenhouses,as shown in Fig 1.2, are framed or inflated structures covered with transparent or translucent material to grow crops under partial or fully controlled environmental conditions to get optimum growth and productivity.

Fig 1.2 Greenhouse at SASTRA

1.3.1 Advantages Of Greenhouse Technology

1. Good distribution of light inside the greenhouse. The greenhouse covers have the ability to distribute the sun rays over the entire surface.

2. Energy efficiency takes advantage of the environmental conditions, such as optimizing the heat inside the greenhouse.
3. Control of microclimate. You can adjust the temperature, humidity, lighting,etc.
4. Protection against diseases, pests and other vermin which are dangerous for the crops.
5. Excellent ventilation.
6. Optimum sealing against rain and air so that required amount can be reached.
7. Increased production.
8. Production off-season.
9. Ability to grow all the year. You can get more than one crop cycle per year and different species of plants.

1.4 ABOUT SPINACH CROP

Spinach belongs to family of "Amaranthaceae" and a native of central and western Asia. It is a perennial vegetable and been cultivated throughout the world. Spinach is also known as "Palak" in Hindi. It is a rich source of iron, vitamin and antioxidants. It has many health benefits such as helps to increase immunity, good for digestion, also good for skin, hair, eyes and for brain health. It has anti-cancer and anti-ageing property. Andhra Pradesh, Telangana, Kerala, Tamil Nadu, Uttar Pradesh, Karnataka, Maharashtra, West Bengal and Gujarat are leading producing states of spinach in India.

1.5 WHY SPINACH FOR GREENHOUSE CULTIVATION?

Spinach is the quintessential leafy green which forms a basis for classic greenhouse crop. It must stay watered and the farmer must avoid extreme temperature shifts by monitoring the crop, but spinach can be cut from several times in a season and provides a dependable off-season income.Spinach can tolerate cold weather relatively well. However, young plants may need the protection of thick mulch in winter. Apart from thinning, spinach does not require any special care. Even working around the ground roots is necessary because its roots are shallow and any cultivation can easily damage them. Instead, apply mulch instead to suppress weeds and keep the soil moist.

1.6 COMMON DISEASES IN SPINACH

1.6.1 Stemphylium Leaf Spot

Fig 1.3 Stemphylium leaf spot

1.6.1.1 Disease symptoms-

1. Initial stage: Small (0.1 to 0.2 inch diameter),circular to oval, gray-green leaf spots.
2. Final stage: Leaf spots enlarge, remain circular to oval in shape, and turn brownish in color as shown in fig 1.3. Older spots coalesce, dry up, and become papery in texture.
3. Leaves showing disease symptoms: Visual signs of fungal growth are generally absent from the spots; hence this symptoms is readily differentiated from foliar diseases in which purple growth (downy mildew), green spores (Cladosporium leaf spot), or acervuli (anthracnose) develop within circular lesions. Overall, symptoms resemble the brownish and circular spots.

4. Survival and spread: Fungus survives in seeds and infected seeds are the source of primary inoculums. Secondary infection occurs by means of conidia.

5. Favourable conditions: High humidity and moisture conditions favour the development of disease.

1.6.2 Cladosporium Leaf Spot

Produced by the fungus Cladosporium variabile. Usually, this disease appears only in the protected areas, but in the favorable years can appear in the field. The fungus attacks the leaves and can produce significant losses (75-100%). On the top of the leaves appear irregular spots as shown in fig 1.4 [4]. Gradually, the disease evolves, and on the lower side of the leaves, under the spots, appears a grey-violet fluff. The affected tissue dries and falls of the plant. The appearance of the disease is favored by the high temperatures, high atmospheric humidity and the lack of ventilation.

Fig 1.4 Cladosporium leaf spot

1.6.2.1 Measures to prevent and combat -

1. Elimination of the affected plants
2. Solarium ventilation
3. Avoiding sprinkling watering

1.6.3 Cucumber Mosaic Virus

Cucumber mosaic virus in spinach attacks most of the vegetables, including spinach. The leaves of the attacked plants shows yellowish spots of irregular shape as shown in fig 1.5 [4].The affected tissue doesn't develop uniformly. This leads to deformation of the leaves. In the advanced stages of the disease, the edges of the leaves turn yellow and after that brown. The plant gradually dries and dies. During the vegetation period, the virus is transmitted through aphids. Through the year the virus survives on the infected seed.

Fig 1.5 Cucumber mosaic virus

1.6.3.1 Measures to prevent and combat -

1. Usage of healthy and certified seed
2. Removal and destruction from culture of the plants which shows the symptoms of the disease
3. Usage of insecticides to keep under control the aphids.

1.6.4 Mycosis

Downy mildew is produced by the fungus Peronospora spinaciae. On the top of the leaves appear yellow spots as shown in fig 1.6 [4]. On the lower part of the leaves, under the spots, forms a grey-purple fluff. In wet and cool weather, the spots expand and cover the entire leaf. The attacked tissue becomes crumbly and detach of the plant. The onset of the disease is favored by the temperatures under 24 degrees Celsius and high humidity.

Fig 1.6 Mycosis

1.6.4.1 Measures to prevent and combat -

1. Correct crop rotation (spinach can return to the same field after 3 years)

2. Usage of healthy seeds
3. Treatments with Polyram DF, Ridomil, Merpan, Captan, Aliette

1.6.5 Anthracnose

Anthracnose produced by the fungus Colletotrichum spinaciae. On the attacked leaves appears some yellow or white spots as shown in fig 1.7 [4] . It the environmental conditions are favorable, The spots unify and cover the surface of the leaves. The leaves becomes brown and gradually falls of the plant. If the temperatures and the humidity are high, the disease can destroy the whole crop. In the winter, the fungus lives on the vegetable debris of the surface of the soil.

Fig 1.7 Anthracnose

1.6.5.1Measures to prevent and combat -

1. Correct crop rotation (spinach can return to the same field after 1-2 years)
2. Removal of vegetal remains after harvesting

3. Usage of healthy seeds

1.7 IMAGE PROCESSING TECHNIQUES

1.7.1 Image Acquisition

1. Capturing the image using a digital camera and storing in digital media and retrieving it at any time possible for openCV python operations.
2. The image captured is generally in the form of an RGB Model. Some other models like HSV, HSI, CMYK can also be used for analysis of the image.

1.7.2 Pre-Processing

1. It is the processing of the image to provide enhanced information about the infected region in the leaf.
2. Common techniques used are **resizing** and **filtering.**
3. The images that are captured by the digital camera are generally of high resolution. For openCV operations this high resolution image is scaled to standard resolution image that can be processed in python .
4. To reduce the noise and enhance the quality of the image, the unwanted regions of the image are removed by **filtering.**

1.7.3 Image Analysis

1. Segmentation, Feature Extraction and various measurements concerned with the image.
2. Segmentation:

The main purpose of segmentation is to separate the background from the disease affected region. Segmentation can be done using different methods like thresholding.

1.7.3.1 Thresholding:

The Pixels in the image are divided into 2 groups. This is done by calculating the threshold value. Based on the threshold value, all the pixels in the diseased region are labelled as 1(white) and those in the remaining region are labelled as 0(black).

CHAPTER 2

REVIEW OF LITERATURE

Major production and economic losses in agricultural industry worldwide are caused due to diseases in plants. Detection of diseases in plants and regular monitoring of health is critical for sustainable agriculture. [5] A sample of the infected crop is sent to the laboratory for molecular analysis to predict the type and severity of the disease if the farmer is unable to identify the symptoms of the disease which is time consuming. **Sindhuja sankaran** *et al.,* developed a ground-based sensor system to assist in monitoring health and diseases in plants under field conditions. These technologies include spectroscopic and imaging-based, and volatile profiling-based plant disease detection methods. Various sensing techniques such as colour, Near InfraRed (NIR), multispectral and hyperspectral cameras have been done for disease identification without interfacing it with mobile robot. [6] **Noa Schor** *et al.,* presented a robotic detection system for two major threats of bell pepper plants: powdery mildew (PM) and Tomato spotted wilt virus (TSWV) by developing an integrated disease detection system and algorithms. [7] **K.R.Aravind** *et al.,* designed a line following mobile robot for disease identification in a greenhouse with vision sensors for navigation across the field. An open source software known as Virtual Robot Experimental Platform (V-REP) was used for simulation of the robot. Processing of images for identification of disease and its representation in a Graphical User Interface (GUI) has been done using an algorithm in MATLAB R2011B which interacts with V-REP tool through socket communication and finally Texture based analysis has been done to identify the diseased crops among the healthy crops in the simulated field setup. There are very few studies on robot integrated with the disease

identification system. [8] Horticultural crops that are grown through greenhouse based cultivation are also prone to pest and diseases which may be lethal in some cases. [9] The evolution of the autonomous mobile robotics technology in recent time and need for precision in agriculture has resulted in increased study on its application in agricultural operations. An automated monitoring of crop will be of significant benefit to the farmers as the continuous monitoring task by human is tedious and classification of disease by farmer is difficult. Different crops exhibit chaotic physical characteristics in terms of height, canopy size, etc. making the agricultural environment highly unstructured. [10] Studies with respect to the application of the robot with disease identification system are very limited. Identification of disease in crops using visible range image by image processing in is quite a difficult task. [11] **Pilli** *et al.,* (2014) has developed a robot for identification of diseases in an outdoor environment in groundnut and cotton crops at its early stages. Neural network technique is employed to identify the magnesium deficiency in cotton and yellow spot in groundnut.[12]**Paul Boissard** et al., developed an automatic pest recognition system using k-means clustering in combination with a correspondence filter for early pest detection in greenhouse plant.[13]**Shantanu Phadika** *et al.,* worked on pattern recognition techniques to identify the infected part of the leaf . [14] **Zulkifli Bin Husin** *et al.,* performed image processing in MATLAB Digital camera was used for acquisition of image is done by a digital camera while LABVIEW software is used for GUI.

CHAPTER 3

SCOPE OF THE PRESENT WORK

In this project, we have developed a simple disease monitoring robot that analyses the status of the crop and sprays the pesticide accordingly. It can monitor small horticultural crops in the nursery using a USB camera connected to the pc. For navigation, the robot uses simple line follower with IR sensors for detecting the line in the greenhouse. The robot is tested in an experimental field where the crops are placed at a fixed locations along the path of the robot . The physical dimension of the crop has to be taken into consideration in order to design the robot for its application in different crop varieties. Many other crops such as radish, onion etc. can be monitored in the earlier stage of their growth by the robotic prototype that we have developed especially in greenhouse nurseries.This robot continuously monitors the growth of the crops for site-specific application of pesticides once the infected region has been detected and analyzed. In most of the cases the crops that are infected with a disease exhibit visible symptoms. Thus we have developed a monitoring system that consists of a conventional camera that can capture the visible image of the crop and further analysis can be done by using an image processing software. A conceptual design of the crop monitoring robot has been done as shown in Fig. 3.1. The design has been done using PRO-E software. The physical design is such that the robot passes through each crop in the field. The robot has two supporting wheels in the rear side with two motor-driven wheels in the front as shown in Fig 3.2.

3.1 Scope of present work is limited to the following constraints

1. The robot can only be used if there is a path that is supportive for following a fixed line and surface of the track should be plain.
2. The plant height should be at a particular level because the height of focus cannot be altered by the proposed design.
3. The light intensity at which image processing process is done should not be varying

By considering the above constraints, the proposed project can be done in a greenhouse whose path between crops should be sufficient for our robot movement. The process should be done at a particular time of the day to compensate light variation or it can be used during night with constant light from an external source .

3.2 Future Scope:

1. By improving the structural design the robot can be tested in real time farming at rough terrains.

2.By using advanced sensors and cameras ,the robot can be made to form its own path at given conditions like lane tracing in self driving vehicles

3.By training it with a lot of data from real time farmers with varying climatic conditions, the efficiency can be improved further for using it throughout the day.

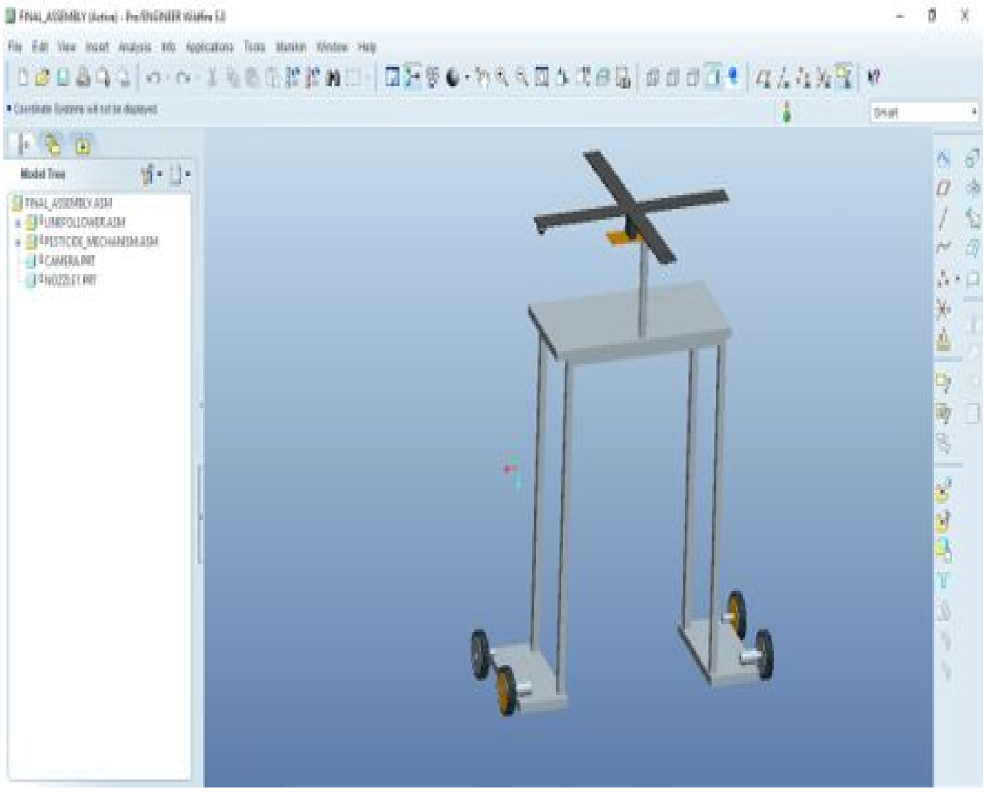


Fig 3.1 Pro-E Design of the robot

Fig 3.2 Crop monitoring robot tested in real time

CHAPTER 4

EXPERIMENTAL PROCEDURES

The experimental field consisting of spinach crops equally spaced at a certain distance along each row in the greenhouse. Multiple crops with varying textures have been included for identifying the diseased crops from the healthy ones that are placed randomly in the field. Each column is separated by a fixed distance, as each crop requires minimum lateral spacing and for the purpose of stable turning of robot. Further, each crop requires specific spacing to minimize the competition for nutrients, to obtain maximum energy from light source and for maximum canopy size. Each crop varying in height from 10 cm to 30 cm is placed across the field. The crops located at a specific position is notified by a white perpendicular line to ensure the robot's halt and process the health of the crop. The line is placed at 10 cm from the crops along the direction of motion of the robot.

4.1 Components Required

4.1.1 Components for line following robot:

Line follower robot senses white line on a black sheet by using IR sensor and then sends the signal to arduino, then arduino drives the motor according to sensors output. The components for line following robot are discussed below:

1. Arduino
2. DC motors - 2
3. Wheels -4

4. L293D Motor driver - 1
5. IR sensors - 2
6. Connecting wires
7. 12-V battery

4.1.1.1 Arduino:

A microcontroller is used to control the whole process of line following as well as pesticide spraying that is ARDUINO. Arduino is an open source software. Arduino boards are equipped with sets of digital and analog input/output pins that may be interfaced to various expansion boards and other circuits.

4.1.1.2 DC motors:

Two geared motors are used at the front side of the line follower robot. The DC motors are of 150 RPM high torque motors that can be used for carrying more loads. Motors are connected to the front wheels, when signal is obtained from Arduino motors will rotate which in turn rotate wheels and thus robot will move forward.

4.1.1.3 Wheels:

Four wheels are used as to obtain balance and sustain heavy loads, in which two are placed as front wheels and two as rear. Front wheels are connected to dc motor and rear wheels are placed as dead wheels which will rotate when front wheels are rotating, thus robot will move forward with four wheels. The wheels are selected in such a way that they can move on the rough terrains as well.

4.1.1.4 L293D Motor Driver:

L293D motor driver is an IC chip which is used to control motors in robots. It has an interface between Arduino and motors.It has two channels for driving two motors. L293D is a 16-pin IC. Arduino can only supply 5 volts but to run a motor 12 volts is required which can be obtained from a motor driver.

4.1.1.5 IR Sensors:

IR sensor is an electronic instrument which is used to sense certain characteristics of the surroundings by emitting or detecting infrared radiation.

4.1.2 Components for rotating and spraying mechanism

A servo motor is used to rotate the upper mechanism that consists of a camera at one end and nozzle at the other. Through this mechanism the robot captures image from the camera.Once the disease is detected the servo activates the mechanism such that the nozzle comes in place of the camera and the pesticide is sprayed on the crop.

Components used are:

1 Hylam sheet

2. Servo motor, servo motor clamp
3. Camera
4. L293D motor driver
5. Pipe
6. Submersible pump
7. 12-v Battery
8. Connecting wires

4.1.2.1 Hylam sheet:

Hylam sheet is used as it is of less weight and servo motor can rotate this sheet. This sheet can also sustain weights of camera which is used to send the video captures for disease detection and pipe with nozzle with carries pesticide.

4.1.2.2 Servo motor:

A servo motor is a rotary actuator or linear actuator that allows for precise control of angular or linear position. It consists of a suitable motor coupled to a sensor for position feedback. A high torque servo motor is used as it need to rotate plus shaped hylam sheet.

4.1.2.3 Submersible pump:

A submersible pump is placed inside the pesticide bottle, it absorbs water and spray through a pump attached to it. The specification of pump is 12-volts.

4.1.2.4 Camera:

A USB camera that is connected to the pc/laptop is placed on one of the extension of the robot facing downwards to capture the image of the leaf which is later analysed by image processing

4.2 Connections for crop monitoring robot

4.2.1 Connections for line following robot:

A line follower robot is an autonomous robot which moves forward by following either black or white line. In this line follower we used two IR sensors which can detect white or black colour and gives its output to the arduino which in turn provides input to the dc motors connected to the wheels. The block diagram is shown in figure 4.1.

IR sensor is having three pins(ground, OUT, VCC) of which ground and VCC are connected to ground and VCC of arduino respectively. OUT is connected to the PWM pin in arduino board.

L293D acts as an intermediate between DC motors and arduino as arduino can provide only 5V but to run a DC motor we require 12V. OUT pins are connected to the positive and negative terminals of DC motor. IN pins are connected to the PWM pins in arduino. The GND and power supply pins are connected to the corresponding pins in arduino.12v and GND pins are connected to the 12v battery.

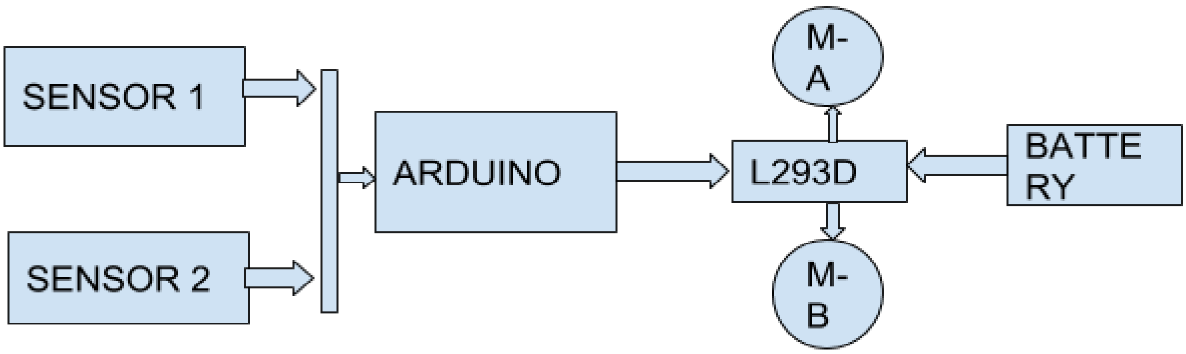


Fig 4.1 Block diagram of line follower

4.2.2 Connections for the spraying mechanism:

This mechanism is designed in such a way that a plus shaped mechanism is placed on the servo motor on which one side camera is placed and on the other side a nozzle for pesticide spraying is placed.For nozzle to spray pesticide, a submersible pump is placed inside the pesticide bottle which sucks the pesticides in the bottle and flows through a pipe and sprays at the diseased area.

The block diagram is shown in Fig 4.2.

L293D motor driver is used as the intermediate connection between the pump and the arduino.Positive and negative pins of pump are connected to the OUT pins of the motor driver. IN pins of motor driver are connected to the arduino pins.12v and GND pins of motor driver are connected to the 12v battery for power supply.

A high torque motor of 8kgf is used as it need to bear the weight of camera and nozzle.Three pins of the servo motor 5v,GND and signal pins are connected to 5v,GND and PWM pins respectively.

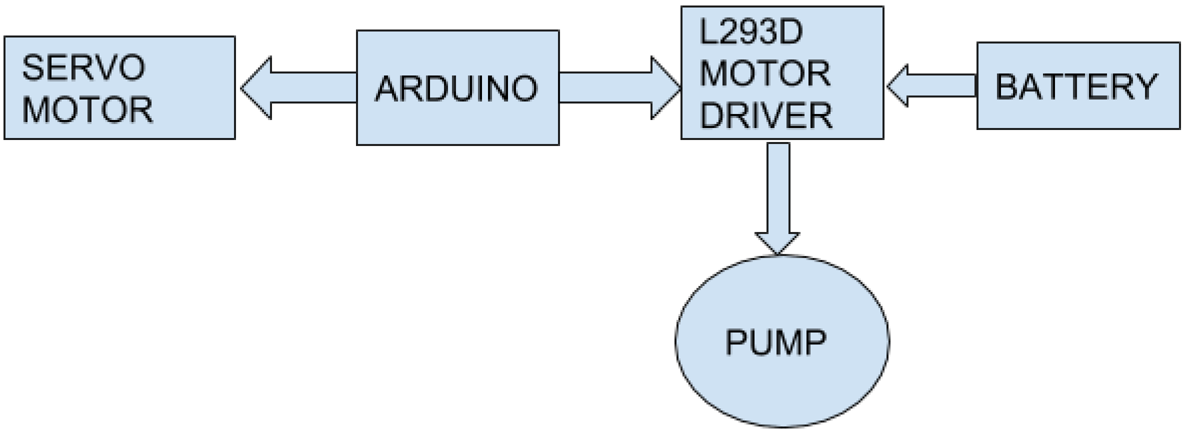


Fig 4.2 Block diagram of the spraying mechanism

4.3 PROPOSED METHODOLOGY

The experimental operation can be split up in to

1. Forward movement

2. Halt

3. Image capturing

4. Pesticide spraying

4. Resume movement

5. Turn movement at end of row

4.3.1 Navigation of crop monitoring robot

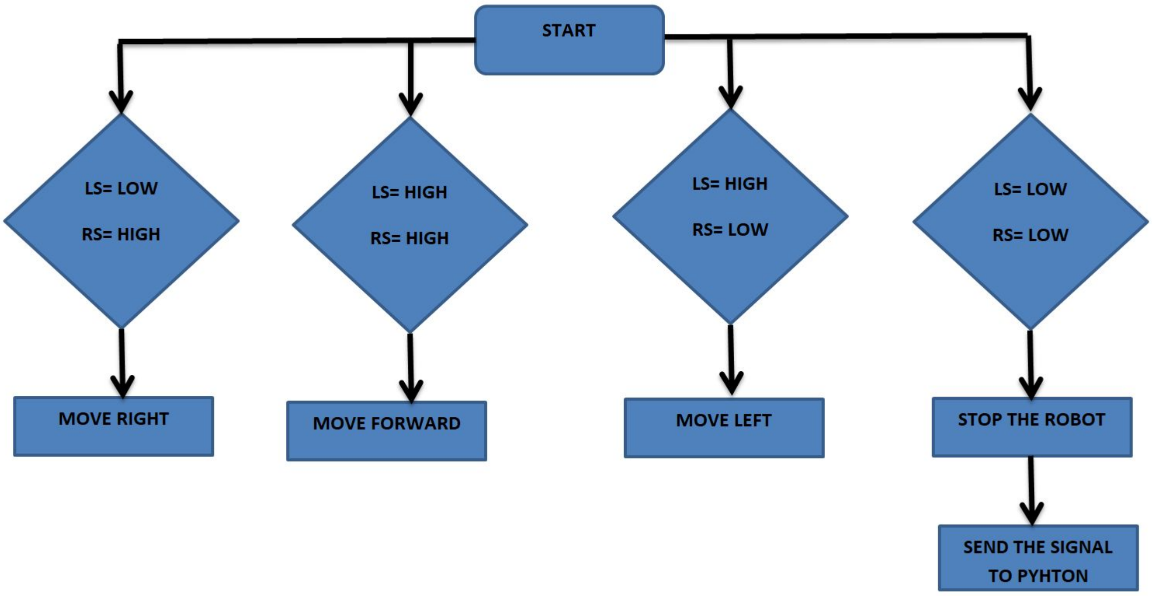


Fig 4.3 Flow chart for navigation

Robot navigated by line follower will make the strategy of navigation to be simple in greenhouse and more focus can be given to image processing for identification of crop status and diseases. The flow chart for navigation strategy of the robot is shown above in Fig 4.3. When the robot moves forward, both the sensors wait for the line to be detected. For example, if the IR Sensor 1 in the above image detects the black line, it means that there is a right curve (or turn) ahead.Arduino UNO detects this change and sends signal to motor driver accordingly. In order to turn right, the motor on the right side of the robot is slowed down using PWM, while the motor on the left side is run at normal speed. Similarly, when the IR Sensor 2 detects the black line first, it means that there is a left curve ahead and the robot has to turn left. For the robot to turn left, the motor on the left side of the robot is slowed down (or can be stopped completely or can be rotated in opposite direction) and the motor on the right side is run at normal speed.Arduino

UNO continuously monitors the data from both the sensors and turns the robot as per the line detected by them.

4.3.2 Disease identification by image processing

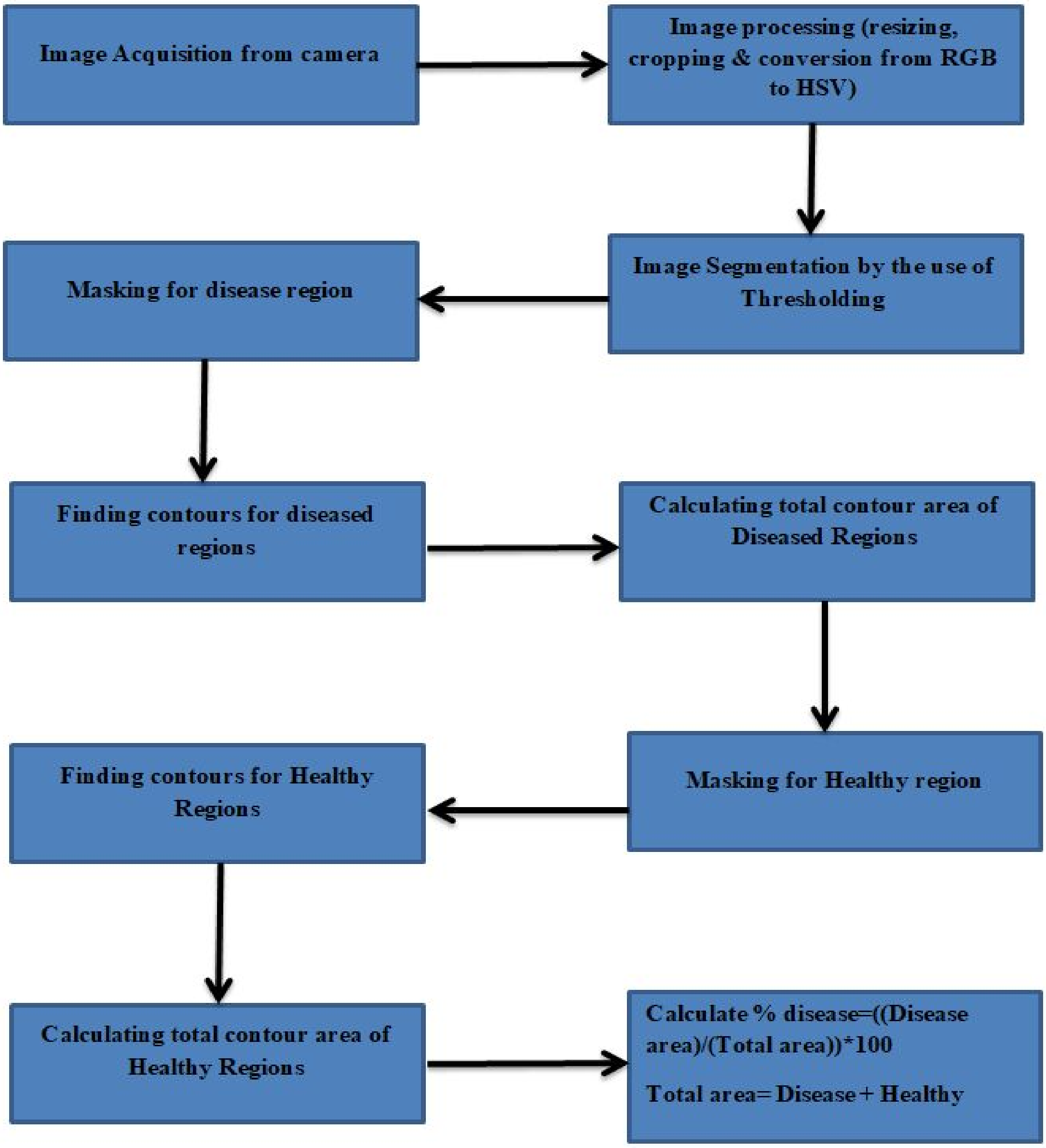


Fig 4.5 Image processing flow chart

Steps followed as shown in Fig 4.5

- ➢ Import all the necessary libraries that are used for image processing
- ➢ Set the upper and lower limit **boundaries** of the required colour that needs to be identified after processing the image

4.3.2.1 Image acquisition

1. In order to capture the real time images , call a function named video capture to get access to **live streaming**
2. Use structural elements in python called **kernel** that form unit matrices of a specified size which are used to approximate the colours to be identified
3. Set the font to display it on the final image if required
4. Set a loop to process each and every pixel in the image within a fixed frame. The loop terminates after processing the whole image
5. Call a function known 'imread' to read the image from the camera and assign it to a variable

4.3.2.2 Image preprocessing

1. **Resize** the image according to the required resolution
2. Crop the image to the required coordinates in order to eliminate the background disturbances and process only the necessary part
3. The image obtained is in the form of RGB format. Convert it into **HSV model** using 'cvtcolor' function and display the converted image that is later used for segmentation

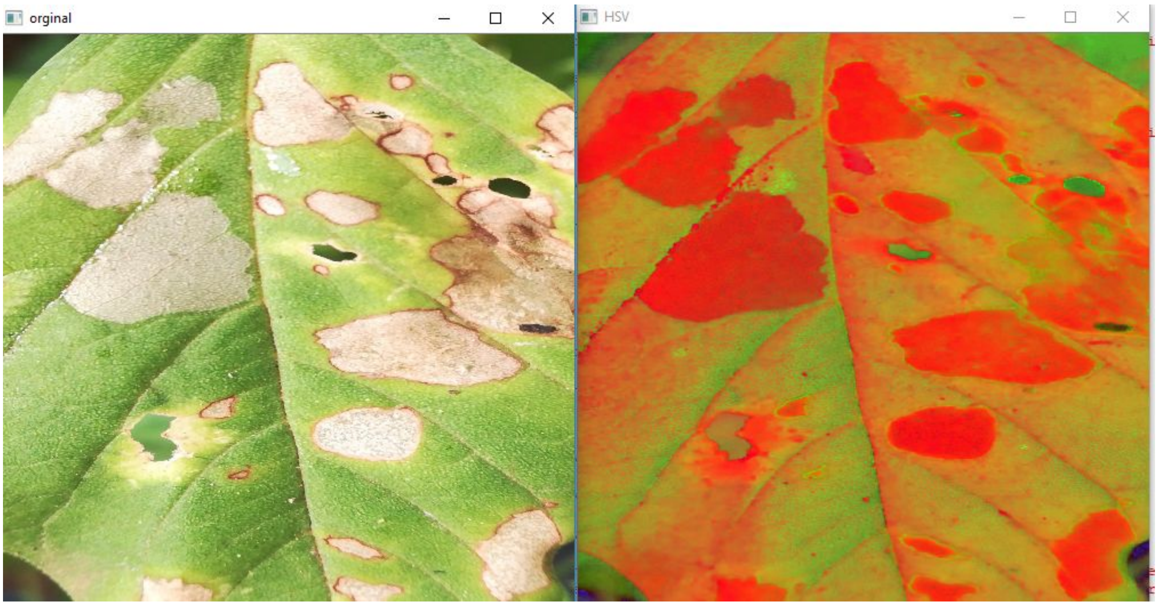


Fig 4.6 Original and HSV images of an input sample leaf

4.3.2.3 Image Segmentation

1. Masking the required colour – use ‘inrange’ function to **threshold** the range of values that are given as arguments in the function
2. Apply morphological transformations within the desired range to filter the image and reduce background disturbances and other noise effects
3. Display the transformed image after **filtering**
4. The contours are found out and drawn around the masked image within the desired range by calling the functions ‘find contours’ and ‘draw contours’
5. Arguments passed in draw contours function include the image, count of the contours , the number of contours to be drawn and the thickness of contour
6. Calculate the desired contour area of the regions that need to be segmented

7. The sum of all the contour areas is calculated based on the count of the contours. The final contour area is found out and the masked image is displayed.
8. The process is repeated for other regions of the image that need to be **approximated by contours**
9. The desired result is obtained by a few math calculations based on contour areas

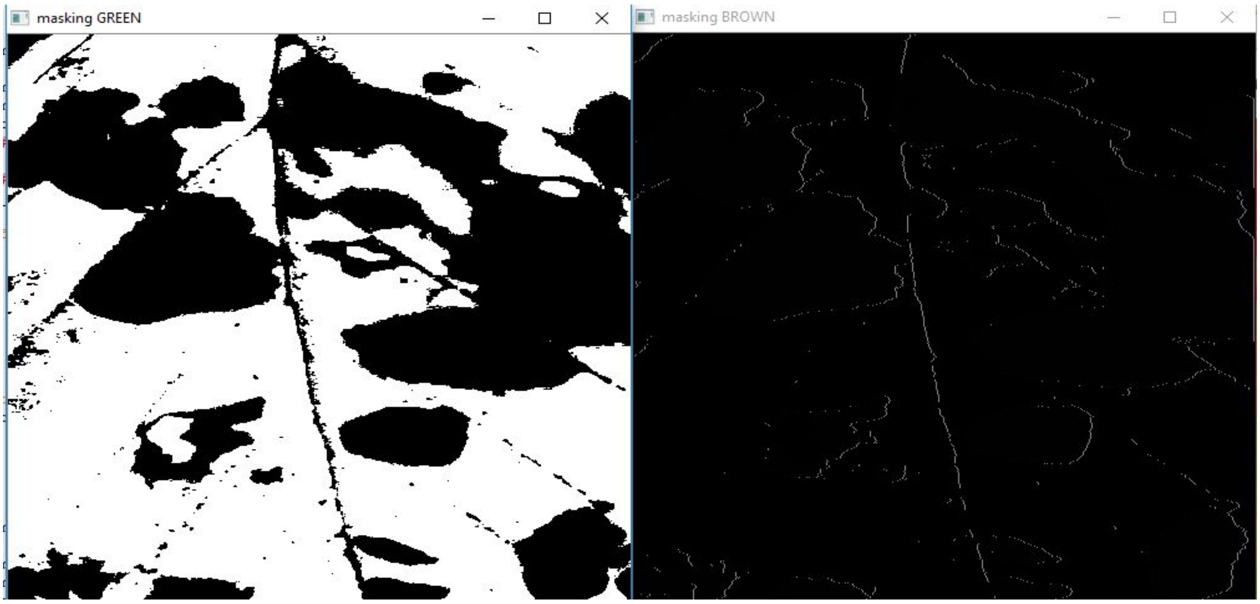


Fig 4.7 Masked regions of healthy and infected regions of an input sample leaf

4.3.2.4 Image Recognition

1. Finally the required image is obtained that differentiates the desired regions of the crops in order to determine the health of the crop based on those regions

2. The disease percentage is calculated based on contour areas.
3. The final contour area is reset to original values for processing a new image

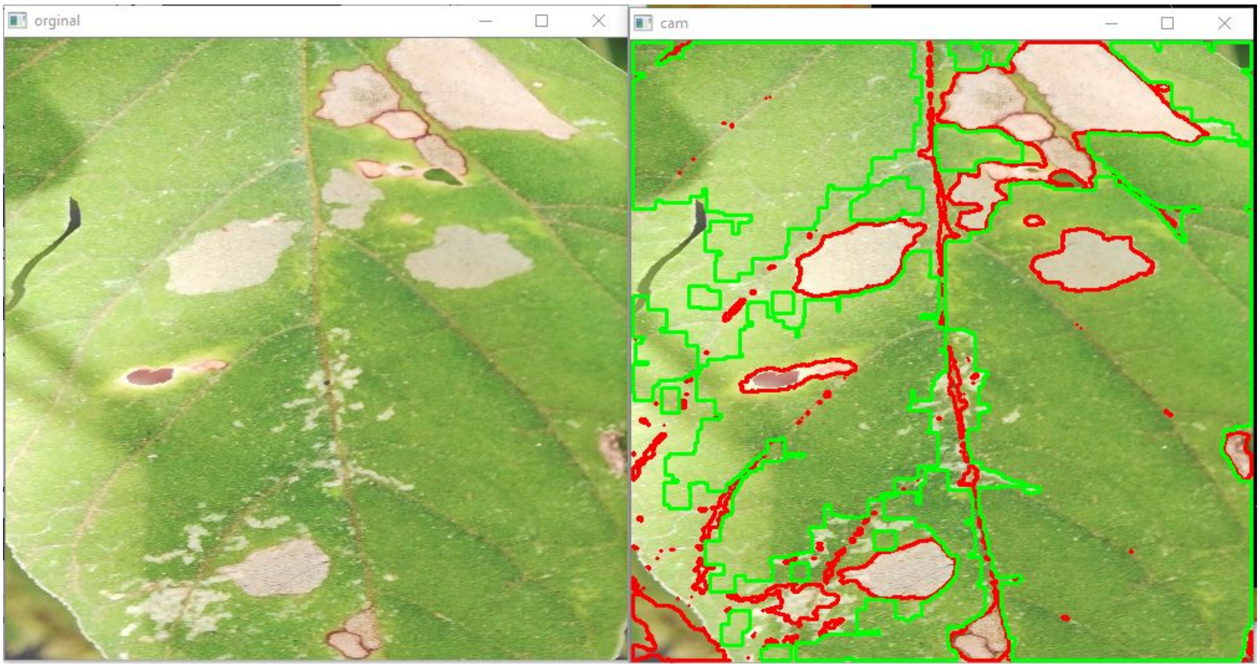


Fig 4.8 Input and output image of a sample leaf (before and after image processing)

4.3.3 Complete flow chart of robotic system

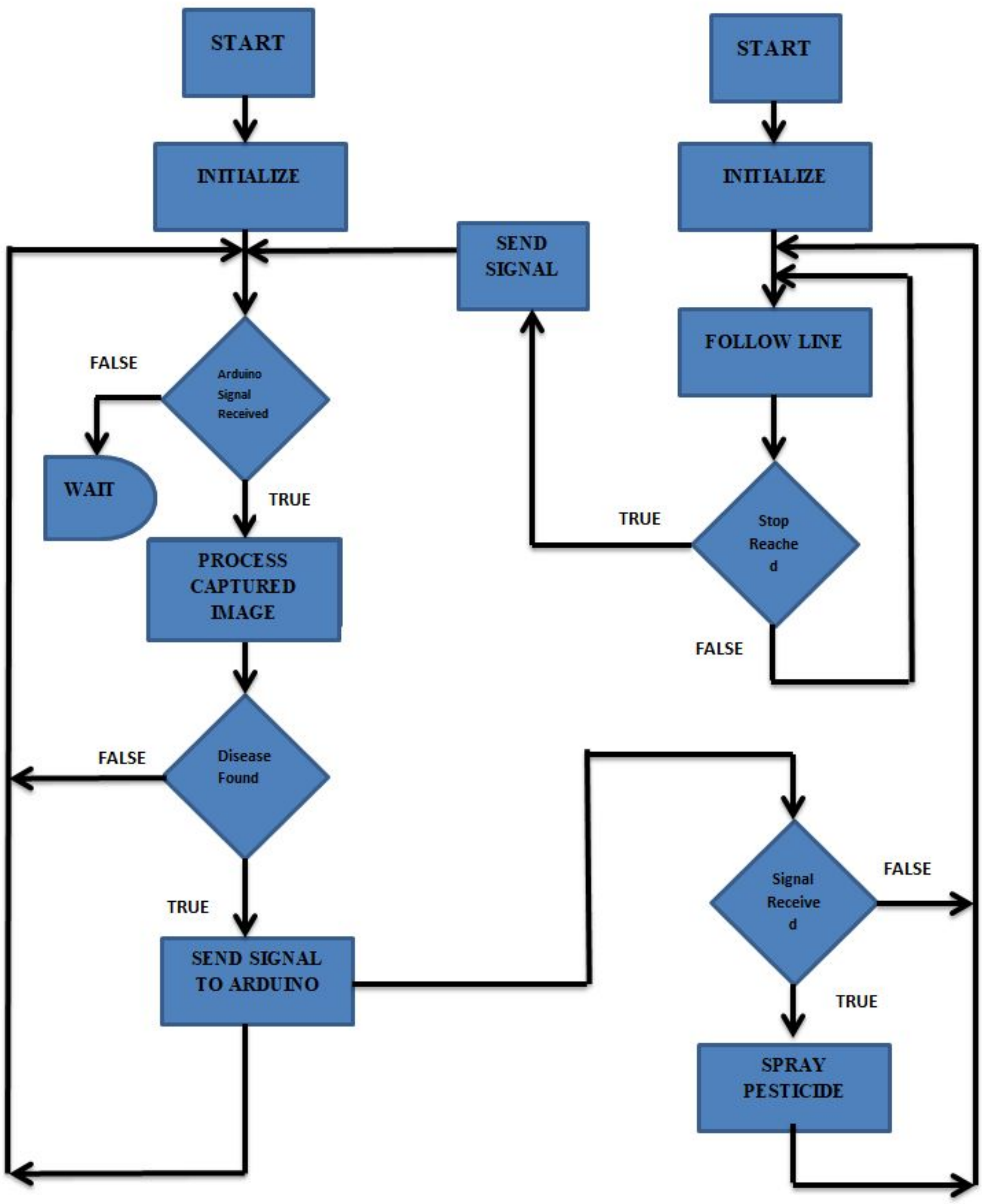


Fig 4.4 Total process flow chart

Above flow chart, as shown in Fig 4.4 describes the overall process of the robot.Once the robotic system is started, the setup is initialised , the robot follows a fixed path until it halts at a certain distance on detecting a black strip along the whitepath. The robot now sends a signal to the processor to process the code for image processing through serial communication. A digital image captured by the camera is processed simultaneously and identifies the infected region in the crop and calculate the disease percentage in the crop.A signal is sent to the arduino once the value obtained is above the threshold limit. The servo attached to the robot is activated and turns the upper setup of the robot at an angle of 90 such that nozzle comes in place of the camera. A submersible pump placed in the pesticide bottles in now activated to spray the required pesticide accordingly and the servo is now activated again to return the setup to its original position.The above process is repeated once again until the end of the path.

CHAPTER 5

RESULTS AND DISCUSSION

The steps of image processing are carried out in python openCV on input samples. All the samples of leaves and crops are given as input data where the images are processed and the healthy region of the crop is separated from the infected region and the values of corresponding regions are shown as output in terms of **total contour area** surrounded by that particular region. The percentage of the region that has been infected is found out. The crop is said to be healthy if the percentage of infected region is greater than a threshold value (taken as 5%) , thereby determining the status of the crop and later corresponding pesticides are applied.

Experimental results (SET -1)

leaf	healthy region (contour area in pixels)	infected region (contour area in pixels)	disease %	status
1	173346	33145	16.05	diseased
2	230243	400	0.17	healthy
3	176783	496	0.27	healthy
4	110921	49410	30.81	diseased
5	191583	4343	2.22	healthy
6	131520	86918	39.79	diseased
7	115964	47111	28.89	diseased
8	238084	2791	1.16	healthy
9	231745	7476	3.13	healthy
10	97185	22845	19.03	diseased

Table 6.1 Disease percentage and status of experimental samples

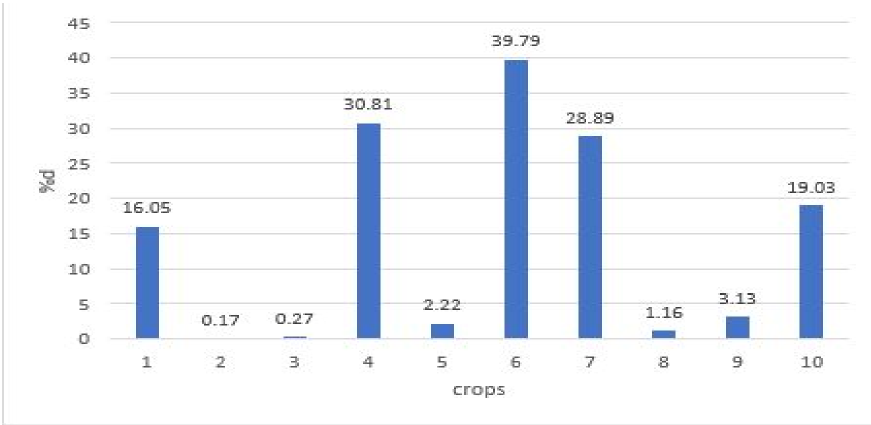


Fig 6.1 Bar chart of %d vs sample leaves

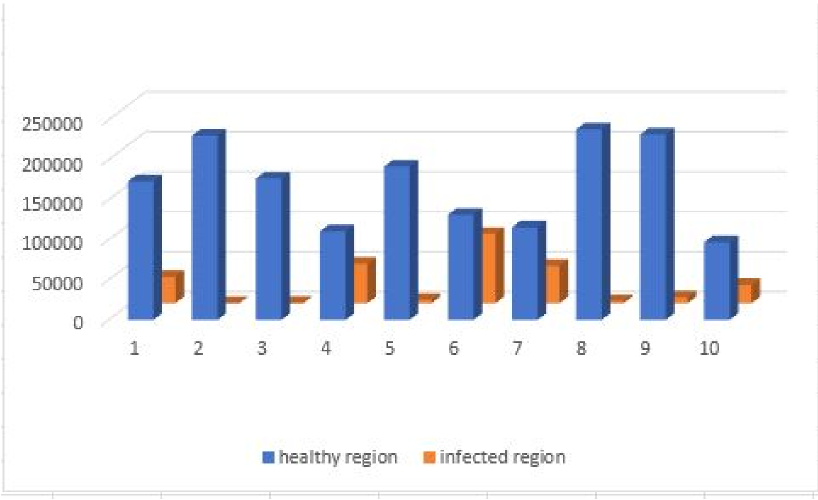
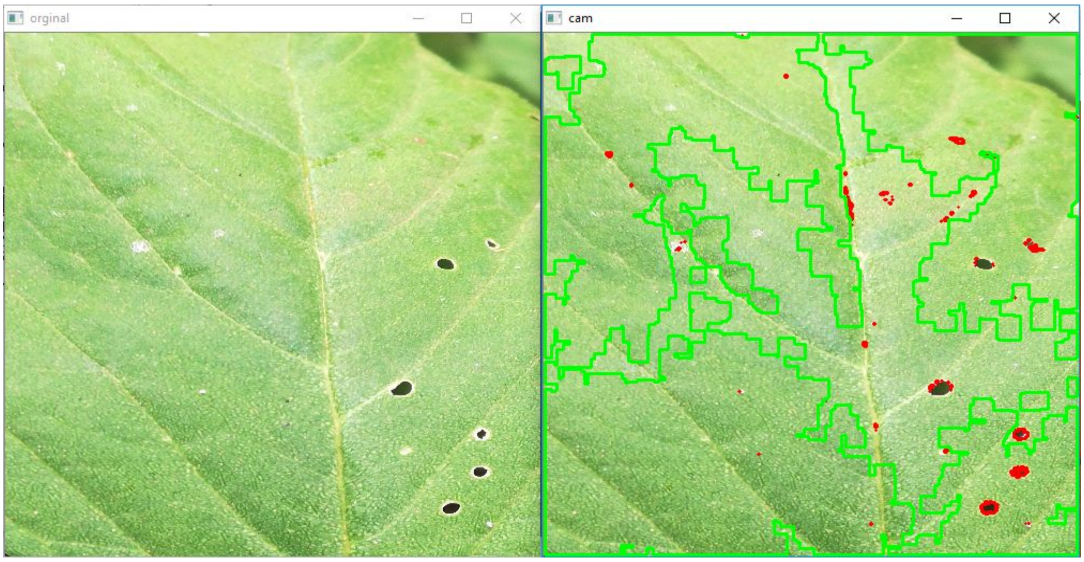


Fig 6.2 Bar chart of healthy and infected regions of the sample leaves

Input image Output image

Fig 6.3 Input and Output images of the sample leaf 6



Input image Output image

Fig 6.4 Input and Output images of Sample leaf 3

Fig 6.3 and Fig 6.4 show the input image and output images of the given samples. In the output image, the infected region is depicted by red contours and the healthy region is depicted by green contours.

Real time results (SET-2)

Crop	healthy region (contour area in pixels)	infected region (contour area in pixels)	disease %	status
1	198349.5	12547.5	5.949	diseased
2	239638.5	6116	2.488	healthy
3	155047.5	44133.5	22.157	diseased
4	222330	44497.5	16.676	diseased
5	154607.5	53525.5	25.716	diseased
6	134612	51222	27.563	diseased
7	226447	11010.5	4.6368	healthy
8	208913.5	11181	5.08	diseased
9	209777	20769	9.008	diseased
10	246152	1983.5	0.799	healthy

Table 6.2 Disease percentage and status of real time samples

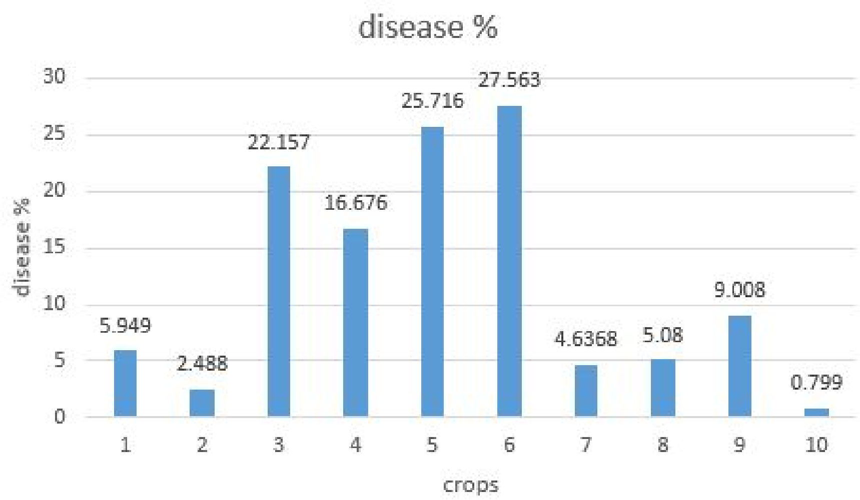


Fig 6.5 Bar chart of %d vs sample crops

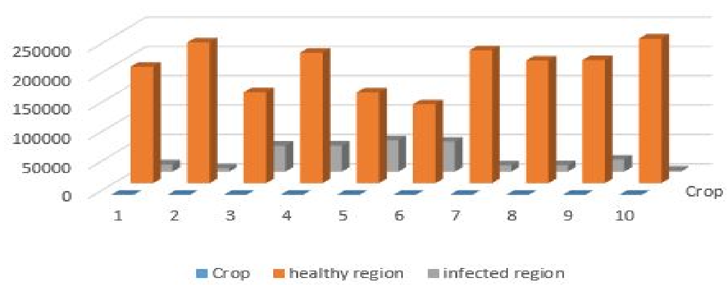
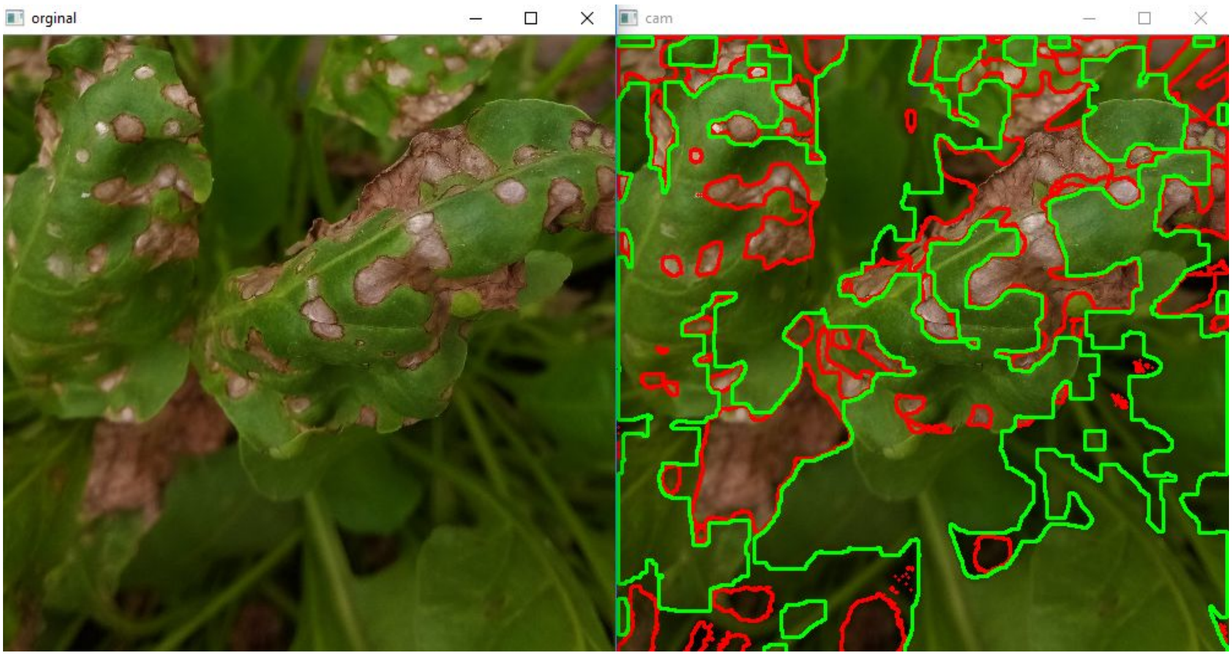
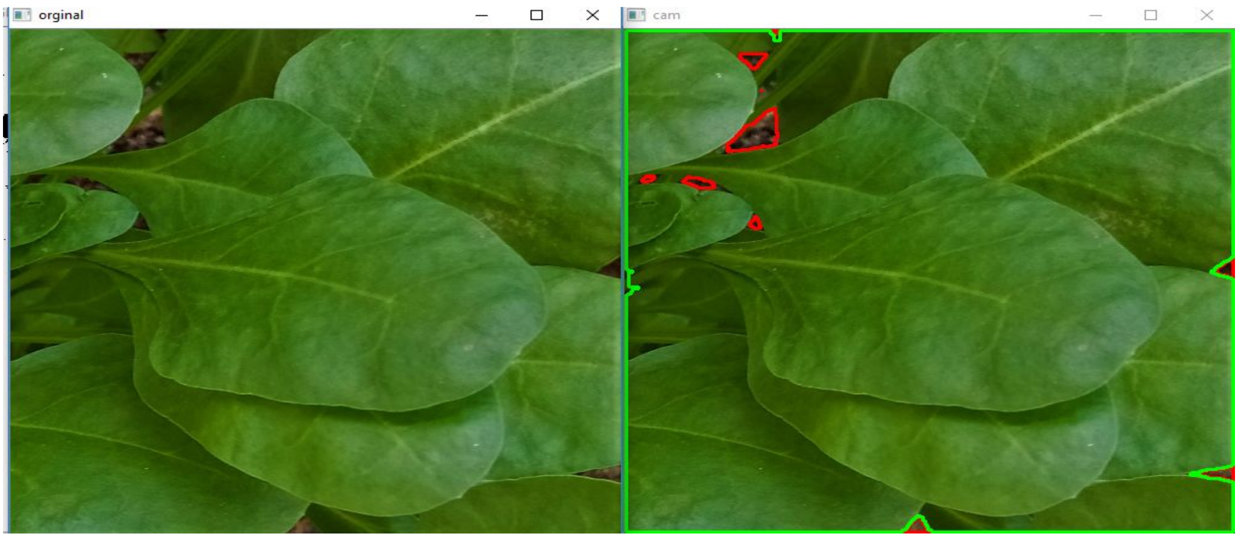


Fig 6.6 Bar chart of healthy and infected regions of the crops



Input image Output image

Fig 6.7 Input and Output images of Sample crop taken in real time



Input image Output image

Fig 6.8 Input and Output images of Sample crop 10 taken in real time

CHAPTER 6

CONCLUSION

Green house based robotic system has been successfully developed and tested for the identification of diseased crop and pesticide application. An algorithm has been developed for processing the obtained image which will be the benchmark for the future work. The algorithm must also be tested for a wide variety of other patterns and colours of the given crop. Many other statistical parameters that are related to image features are required for determining the health status of crop in greenhouse as it will have more dynamic climatic conditions of the environment. Moreover the pesticide spraying mechanism can be further modified and developed for targeted pesticide delivery and precise application of the pesticides for enhanced productivity.There may be errors due to camera parameters (orientation ,resolution,etc) , varying features of the crop and other random errors. Further studies shall be carried out to evaluate the other disease identification parameters in order to categorize various diseases in real time and spray the required pesticides accordingly.

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2.Used as support for solving Python code related problems https://stackoverflow.com

3. decided to go with OpenCV, Why not MATLAB?

https://www.researchgate.net/post/Best_for_Image_Processing-Matlab_or_OpenCV

APPENDIX

IMAGE PROCESSING CODE:

```
import cv2

import numpy as np

import math

import time

import serial

ser = serial.Serial('COM6',9600)

#Initializing the RGB values for healthy and diseased

lb_green=np.array([33,80,40])

ub_green=np.array([102,255,255])

#Disease RGB values Got from A website named --> https://imagecolorpicker.com/

lb_brown=np.array([20,100,100])

ub_brown=np.array([30,255,255])

greenarea=0

brownarea=0

greentotal=0

browntotal=0


cam=cv2.VideoCapture(0)

kernelOpen=np.ones((15,15))
```

```
kernelClose=np.ones((30,30))


while True:

getval= ser.readline()

ret,img=cam.read()

#IMAGE PREPROCESSING

mg=cv2.resize(img,(500,500))

cv2.imshow("orginal",img)

imgHSV=cv2.cvtColor(img,cv2.COLOR_BGR2HSV)

 cv2.imshow("HSV",imgHSV)

#MASKING DISEASE

mask=cv2.inRange(imgHSV,lb_brown,ub_brown)

 maskOpen=cv2.morphologyEx(mask,cv2.MORPH_OPEN,kernelOpen)

maskClose=cv2.morphologyEx(maskOpen,cv2.MORPH_CLOSE,kernelClose)

 cv2.imshow("masking BROWN",maskClose)

_,cnt,hie=cv2.findContours(mask,cv2.RETR_EXTERNAL,cv2.CHAIN_APPROX_SIMPLE)


for i in range(len(cnt)):

x,y,w,h=cv2.boundingRect(cnt[i])

brownarea=cv2.contourArea(cnt[i])

        if(brownarea > 0):
```

```
                    cv2.drawContours(img,cnt,-1,(0,0,255),2)

                    browntotal=browntotal+brownarea

print browntotal,"DISEASE"

 cv2.imshow("masking BROWN",mask)

#MASKING GREEN

mask=cv2.inRange(imgHSV,lb_green,ub_green)

maskOpen=cv2.morphologyEx(mask,cv2.MORPH_OPEN,kernelOpen)

maskClose=cv2.morphologyEx(maskOpen,cv2.MORPH_CLOSE,kernelClose)

cv2.imshow("masking GREEN",maskClose)

_,cnt,hie=cv2.findContours(maskOpen,cv2.RETR_EXTERNAL,cv2.CHAIN_APPROX_NONE
)

  cv2.drawContours(img,cnt,-1,(0,255,0),2)

for i in range(len(cnt)):

          x,y,w,h=cv2.boundingRect(cnt[i])

          greenarea=cv2.contourArea(cnt[i])

          greentotal=greentotal+greenarea

      print greentotal,"GREEN"

      cv2.imshow("masking GREEN",mask)

      if(greentotal==0):

            greentotal=1

disease_percentage=(browntotal/(greentotal+browntotal))*100

 print "Disease percentage :",disease_percentage,"%"
```

```
 cv2.imshow("cam",img)

#RECOGNITION

if (disease_percentage>5):

        val="1"

        ser.write(val)

browntotal=0

greentotal=0

 cv2.waitKey(20)
```

ARDUINO CODE:

```
#define lmotorf 10

#define lmotorb 5

#define rmotorf 9

#define rmotorb 6

#include <Servo.h>

#define pumpf 12

#define pumpb 13

#define enable 8

Servo myservo;

int pos = 0,k;

char readvalue;
```

```
void setup()
{
  pinMode(lmotorf,OUTPUT);
  pinMode(lmotorb,OUTPUT);
  pinMode(rmotorf,OUTPUT);
  pinMode(rmotorb,OUTPUT);
  pinMode(enable,OUTPUT);
  pinMode(4,INPUT);
  pinMode(2,INPUT);
  myservo.attach(3);
  pinMode(pumpf,OUTPUT);
  pinMode(pumpb,OUTPUT);
  digitalWrite(enable,HIGH);
  Serial.begin(9600);
}

void loop()
{
  int lsensor=digitalRead(4);
  int rsensor=digitalRead(2);
    if((lsensor==HIGH)&&(rsensor==HIGH))
```

```
{
digitalWrite(lmotorf,HIGH);
digitalWrite(rmotorf,HIGH);
}
if((lsensor==HIGH)&&(rsensor==LOW))
{
digitalWrite(lmotorf,LOW);
digitalWrite(rmotorf,HIGH);
}
if((lsensor==LOW)&&(rsensor==HIGH))
{
digitalWrite(lmotorf,HIGH);
digitalWrite(rmotorf,LOW);
}
  if((lsensor==LOW)&&(rsensor==LOW))
 {
digitalWrite(lmotorf,LOW);
digitalWrite(rmotorf,LOW);
delay(200);
Serial.println("signal from arduino");
```

```
if (Serial.available())
{
  readvalue = Serial.read();
  if(readvalue='1')
  {
    myservo.write(k);
  for (pos = k; pos <= 180; pos += 1)
  {
  myservo.write(pos);
  delay(100);
  }
   digitalWrite(pumpf,HIGH);
   digitalWrite(pumpb,LOW);
   delay(2000);
   digitalWrite(pumpf,LOW);
   digitalWrite(pumpb,LOW);
for (pos = 180; pos >= k; pos -= 1)
{
  myservo.write(pos);
  delay(100);
}
```

```
 do
 {
 digitalWrite(lmotorf,HIGH);
 digitalWrite(rmotorf,HIGH);
 digitalWrite(lmotorb,LOW);
 digitalWrite(rmotorb,LOW);
   }while((lsensor== LOW)&&(rsensor== LOW));
  }
 else
 {
do
   {
    delay(3000);
   digitalWrite(lmotorf,HIGH);
   digitalWrite(rmotorf,HIGH);
   digitalWrite(lmotorb,LOW);
   digitalWrite(rmotorb,LOW);
   }while((lsensor==LOW)&&(rsensor==LOW));
  }
 }}}
```