Weed Detection and Removal based on Image Processing

Rincy Johnson, Thomas Mohan, Sara Paul

Abstract*: Agriculture, although known as the backbone of the Indian economy, is facing crisis in terms of production. One of the major issues in the agriculture sector is the growth of weeds among the crops. They compete with the desired plants for various resources and hence their growth must be inhibited. At present weeds are removed either manually, which is a time consuming and labour intensive task, or herbicides are being sprayed uniformly all over the field to keep them under check. Spraying of herbicide is very inefficient as the chemical contributes less to weed control and cause contamination of the environment. The main objective of this work is a weed control system that differentiates the weed from crops and restricts weed growth alone by the precise removal of the weed. This is implemented by capturing the images of the field at regular intervals and processing them with a Raspberry Pi board by making use of an image processing algorithm to differentiate the desired plants from the weeds. This is based on various features like colour and size of the crop and weed. Once the weeds are identified and located correctly through image processing, a signal is transmitted from the Raspberry Pi board to turn on the weed cutting system. The selective activation of the weed removal system helps in the precise removal of the weeds and this provides a better environment for the desired plants to grow well.

Index Terms: Agriculture, Crop, Image Processing, Raspberry Pi, Weed Detection, Weed Removal.

I. INTRODUCTION

With a world population of 7.7 billion which is still increasing, there is a demand for increased food production all around the globe. Agriculture holds an important role in this regard. It is, therefore, necessary to ensure that the cultivation methods used are advanced and the best; and they produce maximum yield. Technology oriented cost-effective strategies are a good option. The implementation of scientific methods in the field of agriculture can bring great changes to the productivity of crops. They can give better yield with reduced human labour. Having a lot of factors to be considered, from tilling of the soil to the packaging of processed food items, each domain requires detailed study and analysis. This work focuses on the area of weed management.

Weeds are the unnecessary plants growing among a set of cultivated crops that compete with the desired plants for resources like light, water, space and nutrients. The weeds may take up the essentials supplied for crop growth. Such a situation can cause considerable decline or delay in the yield. Hence there is a requirement to inhibit the weed growth as much as possible. Also, the growth rates of the weeds are likely to be higher than the crops. This is because the weed's root or seed is already present in the soil waiting for the ambient growth conditions to shoot up. This calls for repeated and periodic weed removal. This is a time consuming and labour intensive task when manually performed. An automated weed removal system is a solution to these problems.

Here the identification and removal of weeds are performed through image processing. The system focuses on reducing human labour as well as the time required to identify and remove the weeds without adversely affecting the crop. The weed management system performs image acquisition from the field. Image processing is then performed in the Raspberry Pi board using Open source Computer Vision which is a library of pre-written functions. An appropriate algorithm for weed detection is developed for this. Based on the results, the activation of the weed removal mechanism is controlled. The entire system is set up on a moving robot.

II. RELATED WORKS

The automatic weed detection and smart herbicide sprayer robot developed in [1] uses an image processing algorithm to process the images captured by the Raspberry Pi Camera at regular intervals and upon identifying the weeds, an arrangement is made to spray the herbicide directly and only on the weeds. The algorithm mainly uses an Erosion and Dilation approach to detect weeds. Once the weeds are identified, a signal is sent from Raspberry Pi to the motor driver IC controlling the water pump motors to spray the chemicals over the weeds. In [2], Ajinkya Paikekari *et.al.* implemented weed removal by spraying herbicides only in the areas where weed is present. The system detects and separates out the weed affected area from the crop plants in an image taken from the fields by using MATLAB to implement image processing. The algorithm loads the image from the source and performs colour segmentation and edge detection to obtain the desired features to detect the weed affected area from the image. To filter the image are divided into blocks of a certain size. If the edge frequency is greater than a threshold value then detects the block as weed block and all the pixels in that block are converted to white pixels. Thus, weed blocks are total white blocks and other blocks remain unchanged.
The system implementation of an image processing technique for weed detection and removal is introduced in [3]. It involves simple edge detection techniques using various filters like the Gaussian filter and Laplacian filter. Finally, feature extraction results are obtained using ORB algorithm. The RGB image taken is processed for detecting the weeds. After certain steps, an output image is obtained where the

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weeds are separated from the crop. In paper [4], Amir H. Kargar B *et.al.* developed a weed detection and classification method that can be applied for autonomous weed control robots. The plants are classified into crops and weeds by a machine vision algorithm. Image acquisition is done by any types of digital cameras such as normal webcams. The acquired images are processed in the LabVIEW environment to find locations of weeds in the image. Finally, herbicides are sprayed on desired spots. The paper [5] utilizes a picture handling calculation to take pictures of the manor columns at consistent interims and after recognizing the weeds in the captured image, a flag is signalled from Raspberry Pi to the motor driver IC governing the water pump motors to shower the weed killer chemical specifically and just on the weeds. The herbicide is put away in a compartment fitted with water pump engines joined to shower spouts.

The paper [6] presents a detailed review of the methods used for detecting the weed from among the crop by using image processing. The paper describes different classification techniques like SVM, NN, DA and methods like Otsu's, 2G-R-B which are used to differentiate weeds and crops. In paper [7], the image processing algorithm for crop and weed detection and management uses energy, entropy, inertia, local homogeneity, contrast and morphological size based features. A Cartesian robot manipulator locates the weed position on real field by calculating the coordinates and selectively sprays the herbicides. In [8], the weed and crop colour images are acquired through the digital camera. Excess green-grey transformations are performed to easy and fasten processing for the segmentation stage. Background and plants of the image are separated according to the grey index. Extraction of weed and crop from the segmented image is done by area thresholding.

III. PROPOSED SYSTEM

This work aims at the development of a system for automated weed detection and removal based on image processing. The block diagram of the proposed system is shown below. It consists of an image processing unit, and a weed cutting and movement mechanism. Both the processing unit and the weed cutter are placed on the moving platform.

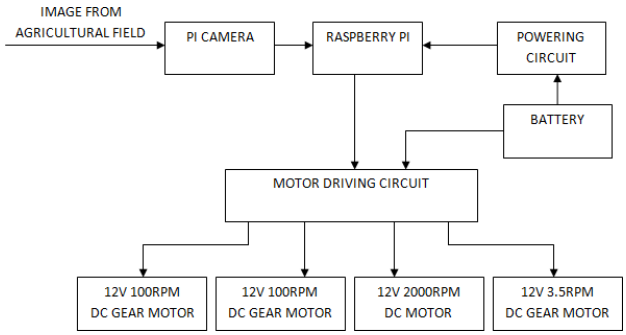

Figure 1: Block Diagram of the Weed Detection and Removal System

The project takes into consideration the following assumptions. In the agricultural field where the plants are grown and the system is being operated, the crops are cultivated in rows. The next assumption is that during the initial stages of cultivation, weed removal is performed manually. Hence the crops are supposed to be larger than the weeds growing among them.

A. Processing Unit

Raspberry Pi is the processing unit in this system. The Pi Camera is connected to the Raspberry Pi board to capture the images of the cultivation and the images are processed by the Raspberry Pi board. The Raspberry Pi processor along with the Pi Camera is set up on a four-wheeled moving robot that moves through the space between the rows of crops. The Raspberry Pi board supports the stand-alone operation. It is powered with a 5V supplied from the powering circuit. The Pi Camera captures the image of the crop from sides. The captured image is stored in the memory card inside the Raspberry Pi unit and is immediately processed by the Raspberry Pi. The images are processed to determine whether weeds are present in between the cultivated crop. The processing involves various stages. Initially pre-processing is carried out. This includes image smoothening, colour space conversion, thresholding, erosion and dilation. The dilated image is a binary image in which the plant regions alone are white in colour. This is further processed to obtain the contours of the plant regions. The contour coordinates are then found and bounding rectangles are drawn. The object areas inside the rectangles are categorized as weeds and crops based on their size and position. Thus the weeds are detected separately. The weed co-ordinates are analyzed and aligned with the position of the weed cutter.

B. Weed Removal and Movement Mechanism

This includes the four-wheeled robot moving through the field on which the processing unit is also set up. The whole mechanism stops moving at required intervals. And in this duration the image is captured, image processing is performed; the decision regarding the activation of the weed cutter is made and is executed. If weeds are detected through image processing and co-ordinate alignment is performed, then the motor controlling the rack and pinion mechanism is activated to extend the weed cutter to the exact location. The weed cutting blade attached to the high-speed motor at the end of the rack and pinion arrangement is activated then so as to cut the weed and after the removal of the weed, the rack moves back to its position and the robot moves forward. If weeds are not identified then the robot simply moves forward without activating the rack and pinion mechanism and the weed cutting blade. The process of capturing the image of the field, processing it and deciding whether or not to turn on the weed cutter and the movement of the robot further is continued to cover the entire length of crop row.

IV. IMPLEMENTATION

A. Work Flow

Weed detection and removal are based on image processing. The field image is captured and processed by the Raspberry Pi. If weeds are not detected, the robot moves forward and captures the next image. If weeds are detected in the image their coordinates are checked to find if the weeds are in the

centre and aligned with the position of the weed cutting blade. The robot moves till the coordinates get aligned. Once it gets aligned, the rack and pinion arrangement is activated; taking the weed cutter to the weed's location and then the weed cutter is activated. Then pinions are rotated in the reverse direction and rack comes back to its position. These steps are repeated for the entire length of the row. The workflow of the system is shown in the figure below.

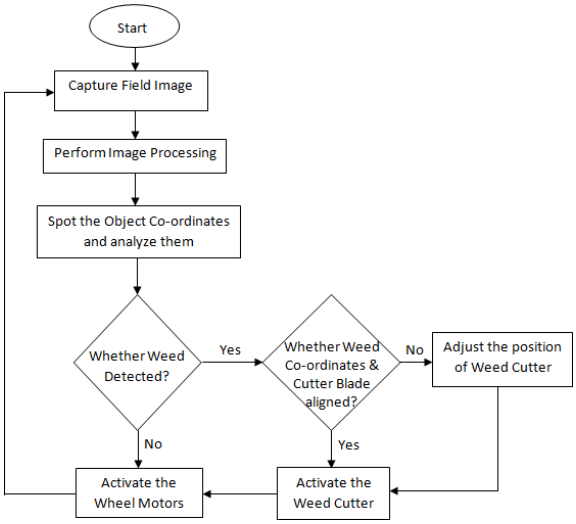

Figure 2: Work Flow

B. Image Processing Algorithm

The field image captured is processed by the Raspberry Pi board. The image passes through various stages of processing. Initially, image pre-processing is performed to suppress unwanted distortions and to enhance some image features important for further processing.

Step 1:	Image pre-processing
Step 2:	Find contours of entire plant region
Step 3:	Obtain co-ordinates of plant region from contour values
Step 4:	Bound the contours using rectangles and number them
Step 5:	Consider each bounded area and analyze the co-ordinate values to determine size
Step 6:	Classify contours on lower half with smaller size as weeds and those on upper half and larger size as crops
Step 7:	Check if there is enough space between the co-ordinates of classified weed and crop
Step 8:	Confirm the presence of weed when criteria in step 6 & 7 are met
Step 9:	Use the confirmed weed's co-ordinates for alignment of weed cutter

Figure 3: Image Processing Algorithm

The pre-processing stages include blurring, colour space conversion, masking within a range, erosion and dilation. From the dilated image, contours of the entire plant region are obtained and this gives the corresponding coordinate values. These values are then used to draw rectangles bounding the contour areas and numbering is given as well. From the coordinate values of bounding rectangles, the sizes of the plants are obtained. Bigger ones are the crop and smaller ones are weeds as per the assumptions considered. Once plants are classified as weeds and crops, the space between the weed and crop is checked to ensure that the activation of weed cutter will not damage the crop. The positions of the detected weeds are then checked to align them with the position of weed cutter by moving the robot. After aligning the positions, the signal for activation of the weed cutter is given. The whole process repeats over the entire length of the row where the crops are cultivated. An overview of the image processing algorithm is shown in Fig.3.

C. Hardware Setup

The entire system is mounted on a four-wheeled robot. The structure comprises of an aluminium chassis of dimensions 190mm*105mm*40mm and wheels of diameter 7cm and width 4cm. 12V 100RPM DC geared motors are attached to the wheels of the robot to control the movement. The motors on each side of the chassis are connected in parallel to ensure uniform motion of wheels.

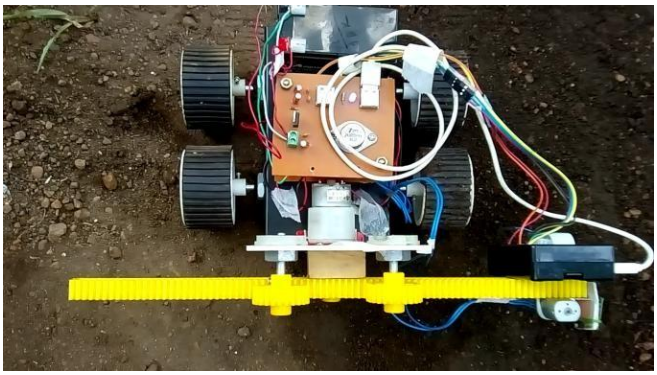

Figure 4: Image of the Hardware Setup

The weed cutter movement mechanism is implemented using a rack and pinion arrangement. A base is required to fix the pinions. This is fabricated by performing laser cutting on an acrylic sheet of 3mm thickness. Holes are cut by measuring the diameter of the motor shaft. The pinions are placed on one side of the acrylic sheet, the DC motor and dummy motors are connected to the pinions from behind the sheet. The weed cutter is moved from the base position to the crop row upon identifying weed as a result of image processing. To implement this movement rack and pinion arrangement is made use of. The weed cutter is fixed on one end of the rack. The rack and pinion arrangement consists of three pinions and one rack. One of the pinions is placed on one side of the rack and is connected to a 12V 3.5RPM DC geared motor for controlling the movement by receiving input from the Raspberry Pi board. Two other pinions are placed on the other side of the rack and are attached to dummy motors to synchronize with the rack movement. The field image is captured by Raspberry Pi using Pi Camera. The images are stored in the 16GB memory card inserted in the board. The Pi Camera and Raspberry Pi board are fixed on one end of the rack and pinion mechanism. The Raspberry Pi board is placed inside the black case seen in the figure. The Raspberry Pi board is powered from the powering circuit via USB 21 cable. Pi Camera is connected to the camera port of Raspberry Pi via a ribbon cable of length 15cm. Raspberry Pi board is powered from the powering circuit fabricated which gives a 5V power through the USB port with an input of 12V. The weed cutter is a blade attached

on the shaft of a high-speed DC motor. This high-speed motor is fixed on one end of the rack and pinion movement mechanism. When the weed cutting motor is activated by the signal from Raspberry Pi board, the blade attached to the motor shaft rotates at very high speed causing the weed in the region to be cut off. As of now wire tie and single-stranded wire are used as blades. Sharper and strong blades can chop the weeds better.

V. RESULTS

A row of Spinach is cultivated for experimental purpose. Plants are grown by keeping a minimum distance of 15 cm between them. The vehicle is also kept at an approximate distance of about 12cm from the crop row. Image capturing is performed by connecting Pi Camera to the Raspberry Pi board. A sample of the image captured from the field is shown in Fig.5. The image contains both the plant and weed.

Figure 5: Field Image Captured

The captured image then goes through different stages of processing to detect the presence of weed. The outputs of the various processing stages like blurring, colour space conversion, thresholding, erosion and dilation are shown in the following figures. Fig.6 is the blurred version of the captured image. The high-frequency components in the image are removed. The image is smoothed and details are reduced.

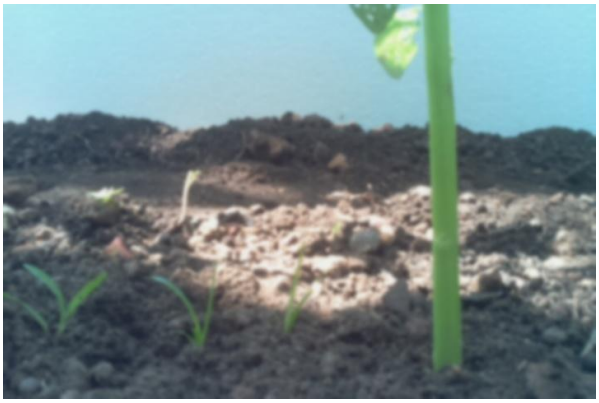

Figure 6: Blurred Image

The BGR to HSV converted image is shown in Fig.7. This generates an image in which the colours in the image are enhanced. The plant regions including both the crop and weed are distinct in the image.

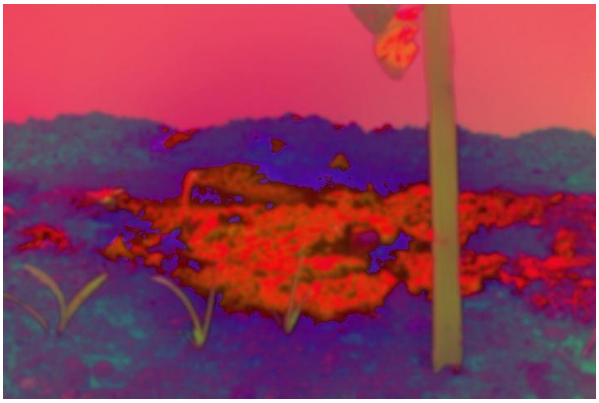

Figure 7: Image after Colour Space Conversion

Fig.8 is the result of thresholding. This gives a binarized image corresponding to the upper and lower ranges of green colour obtained in the field image. The plant areas alone are white in colour in the image.

Figure 8: Thresholded Image

Eroded image is shown in Fig.9. Erosion diminishes the features of an image by eroding away the boundaries, thereby removing the small white noises.

Figure 9: Eroded Image

Fig.10 is the dilated image. Dilation is just the opposite of erosion and it accentuates the features. It increases the object area which is shrunk due to erosion.

Figure 10: Dilated Image

From the dilated image, contours which indicate the plant edges are identified and their co-ordinates are extracted. The snapshot of the array of contour coordinates corresponding to the detected contours is shown in Fig.11.

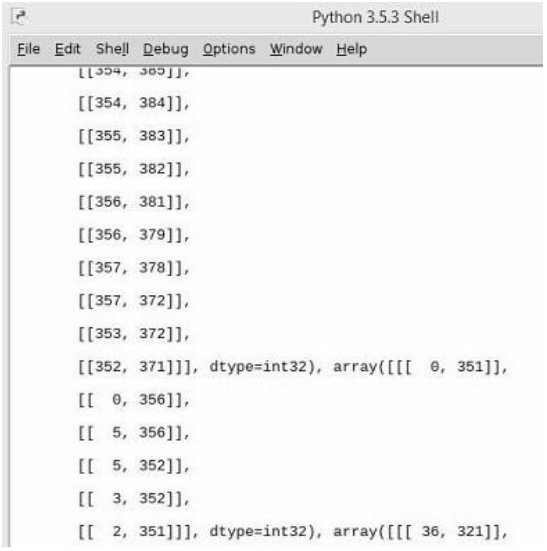

Figure 11: Arrays of Contour Coordinates

The final result of the various images processing stages is shown in Fig.12. The plant and weed portions can be seen bounded by rectangles in the image.

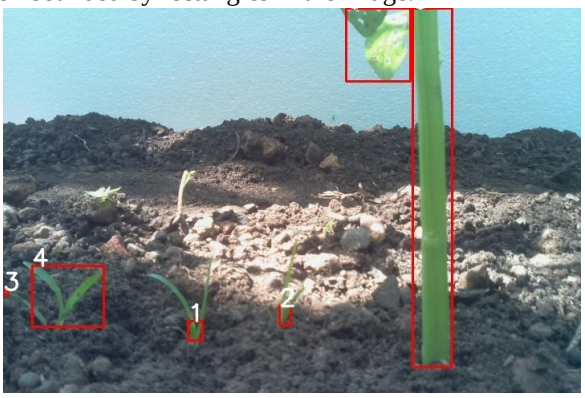

Figure 12: Image after Processing

Snapshot of identifying the positions of weeds are shown in Fig.13. The position and size of these rectangles are used to generate control signals for the movement of the motors in the system. When the object detected is within the coordinates marked as the centre region, the weed cutter is activated. When the weed coordinates are in the left or right regions, the vehicle is moved backward or forward as required and after this movement, the weed cutter is activated. Using this method weeds that are smaller in size and are at a minimum distance from the crop are removed successfully. Weeds closer to the crop are not removed as exception case is set not to harm the crop at any cost.

Figure 13: Coordinates of weeds

VI. CONCLUSION

Agriculture sector provides the basic ingredients to humanity and raw materials for industrialization. One of the many problems in the field of cultivation is the growth of weeds among the crops which takes in the water and nutrients required for the cultivated crop. Automatic weed detection and removal based on image processing addresses this issue. The entire system for weed management is set up on a four-wheeled robot. The system is deployed in the field where spinach is cultivated row-wise. The vehicle movement in the real field is achieved. The movement can be made better using bigger wheels for the vehicle. Colour images with required quality are obtained from the field using Pi Camera. Images are captured sideways, unlike the usual practice of taking the top view of plants. Image processing focuses on the plant size and colour rather than their shape and is done by the Raspberry Pi board. Weeds growing among the crops are detected successfully. The alignment of cutter and its activation based on the image processing result is also carried out efficiently. The weeds growing closer to the crop cannot be removed as the activation of the cutter at that point may cause the removal of the crop as well. This system helps the crop to gain the nutrients and water supplied to it and thus produces a better yield. The entire process is automated which reduces a lot of manual effort. The main advantage of this system is that weeds are identified and selectively removed, unlike the herbicide sprayers which also damage the crops.

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