Abstract— Farmer needs alternatives for weed control due to the desire to reduce chemicals used in farming. However, conventional mechanical cultivation cannot selectively remove weeds and there are no selective herbicides for some weed situation. Since hand labor is costly, an automated weed control system could be feasible. A robotic weed control system can also reduce or eliminate the need for chemicals. Many attempts have been made to develop efficient algorithms for recognition and classification. Currently research is going on for developing new machine vision algorithms for automatic recognition and classification of many divers object groups. In this paper an algorithm is developed for automatic spray control system. The algorithm is based on erosion followed by dilation segmentation algorithm. This algorithm can detect weeds and also classify it. Currently the algorithm is tested on two types of weeds i.e. broad and narrow. The developed algorithm has been tested on these two types of weeds in the lab, which gives a very reliable performance. The algorithm is applied on 240 images stored in a database in the lab, of which 100 images were taken from broad leaf weeds and 100 were taken from narrow leaf weeds, and the remaining 40 were taken from no or little weeds. The result showed over 89% results

Keywords-component; real-time weed recognition; weed detection; image processing; Ranandom Transform; image classifier; weed segmentation.

I. INTRODUCTION

The machine vision based approach uses shape, texture, color and location based features individually or jointly to discriminate between weed and crop. The studies report varied results for these features and their combinations [10]. An imaging sensor is a key component of almost any weed detection and classification system and methods of using them are various. Individual plant classification has been successfully demonstrated with either spectral [25] or color imaging [6]. The spatial resolutions of spectral systems are typically not adequate for accurate individual plant or leaf detection. Then again, color-imaging methods with higher spatial resolution do not offer the important additional information the spectral data provides [26].

Weed control is a critical farm operation and can significantly affect crop yield. Herbicides play an important role in weed control but their use is under criticism due to perceived excessive use and potentially harmful effects. Several studies suggest that patch spraying considerably reduces herbicide use. Manual scouting for patch spraying consumes considerable resources and is not a feasible option for most farm operations [24]. Many researchers with varied success have investigated Patch spraying using remote sensing and machine vision. Machine vision systems are suitable for plant scale herbicide application whereas remote sensing can be employed on plot basis. Both of these systems essentially require image acquisition and image processing. Image size ranges in the order of megabytes, thus processing takes 0.34s to 7s depending on image resolution, crop and weed type, algorithm used and hardware configurations [23, 19].

The first step in identifying weeds within an image involves classifying the pixels [22]. The purpose of segmenting the image into plant and background pixels is to detect the amount of plant material within a specific area [22]. If the amount of plant material reaches a specific threshold, that area is targeted for herbicidal spray application [22]. The spray threshold is limited by the fraction of background pixels that are misclassified as plant material. If the spray threshold is set too close to the background misclassification rate, then herbicide will be wasted spraying background. Therefore, a larger misclassification rate limits the smallest plant that can be detected without targeting the background for spray [22].

A system that could make use of the spatial distribution information in real-time and apply only the necessary amounts of herbicide to the weed-infested area would be much more efficient and minimize environmental damage. Therefore, a high spatial resolution, real-time weed infestation detection system seems to be the solution for site-specific weed management.

II. RELATED WORK

For weed detection a lot of accurate methods have been developed, such as wavelet transform to discriminate between crop and weed in perspective agronomic images, [13] spectral reflectance of plants with artificial neural networks [15], such as principal component analysis. Other researchers have investigated texture features [12] or
biological morphology such as leaf shape recognition [13]. So in real time for the identification/Classification of crop rows in images, a lot of fast methods have been implemented [14], some of them are based on Hough Transform [16], some of them are based on Fourier Transform [17], some are based on Kalman filtering [18] or linear regression [19]. The Hough Transform is usually implemented for automatic guidance in crop fields [20, 21]. Consequently there are now various vision systems available on autonomous weed control robots for mechanical weed removal.

In agriculture, imaging devices provide useful information to detect in-field heterogeneities. Depending on what we want to see (a leaf, a plant) and to allow the features to be visualized, remote sensors can be embedded in different vehicles such as tractors, agricultural engines [2], aircraft [3, 2] or satellites. For sustainable agriculture, particular attention must be paid to herbicide treatments as they are the major agricultural pollutants and site-specific spraying of weeds in crop fields could avoid considerable use of herbicides. Consequently, many researchers have developed different vision systems [5] to highlight weed plants in crops and to map the weeds in real-time for site-specific spraying of infested areas [7, 8]. These systems can be based on optical sensors (photodiodes), which can be used for the classification/discrimination between plants (narrow plants and broad plants) from their reflection spectra. The best known are Weed seeker, and Spray vision [8]; however, these systems cannot discriminate between crop and weeds. More recently [9, 10], have developed a robot, with two vision systems guided by crop rows, which aims to mechanically remove weeds in the inter row. However, this detection method is devoted to crops sown by drilling methods such as salad or sugar beet [11]. An off-line approach has been also investigated where data are acquired in one pass and analyzed at the office. In a second pass, the weed mapping is used to control an agricultural engine in the crop field. As an example, [12] developed a multispectral imaging system embedded in a small aircraft, which over-flew a sunflower field crop. This discriminated between crop and inter-row weeds with spatial image processing based on Gabor filtering, which detected crop rows by their frequency. However, weeds within the crop row were not recognized.

The purpose of this paper is to develop an algorithm for real time that is not an autonomous robot but to investigate a real time machine vision system. The system contains a CCD camera mounted in front of the tractor at an angle of 45 degree at a distance of 4 meter long from the earth, which is used for the classification of two types of weeds (broad and narrow) by using the proposed image processing technique Erosion followed by Dilation.

III. OBJECTIVES

Since in practice there are only two types of herbicides used: for broad leaves weed and narrow leaves weed (grass). The objective of this paper is to:

- Develop a real time sensor that are capable of recognizing the presence and type of weeds and apply their right type of herbicides.

IV. MATERIALS AND METHOD

A. Hardware Design

The initial design of the machine-vision-controlled sprayer included camera vision system is shown in Figure 3. Images are taken with the help of camera before being processed by the system. The resolution of an image is 240 by 320 pixels. The camera is positioned at four meter and at a angle of 45 degree from the ground in front of the sprayer boom. This is because; the long narrow area in front of the sprayer could be captured with higher resolution without increasing the image size. The software is developed in Matlab. A Graphical User Interface (GUI) is developed that shows the Original image, processed image and the result of the proposed algorithm.

B. RGB to Grayscale

In the start of the image preprocessing operation the input image is decomposed into red, green and blue components to create a binary image using the following transformation.

If \( G > R \) and \( G > B \) and \( G > 150 \) then
\[
PIMG = 1
\]
Else
\[
PIMG = 0
\]
End if

Where R, G and B are the red, green and blue components and PIMG is the processed binary image. The resulting binary image will have weeds in bright pixels and background in dark pixels.

C. Methodology

One of the simplest uses of erosion is for eliminating irrelevant or hidden details (in term of size) from a binary image. i.e. The color images are converted to gray scale and then to binary image for easy and fast processing. An image segmentation step is conducted to divide the image into two classes i.e. plant and background (soil). The binary image A of the plant class is eroded by a structuring element i.e. To erode an image we move a structuring element (morphological filter/mask) of size 3x3 pixel by pixel upon the given image, so in this way we remove the unnecessary details from an image for fast processing

\[
A \ominus B = \{ z \mid (B)_{z} \cap A^{c} \neq \emptyset \}
\]

This equation indicates that the erosion of A by B is the set of all points z such that B, translated by z, is contained in A. Set B is commonly referred to as the structuring elements as well as in other morphological Operations.

The MATLAB code of erosion is as
\[
B = \text{strel} (\text{shape}, \text{parameter})
\]
‘strel’ is a morphological structuring element. The shape used here is ‘diamond’ and parameter is ‘eye (5)’

\[ A = \text{imerode} (A, B) \]

Here A is the input image and B is structuring element.

After eroding the image A, the dilation segmentation algorithm is applied, which has its own 3x3 structuring element, due to which it will dilate the required image. A dilated by the structuring element of dilation of B, which is defined as

\[ A \oplus B = U_{b \in B} A_b \]

Whose MATLAB code is given as:

```matlab
se = strel ((shape, se, PACKOPT)
d = imdilate (A, se)
```

strel is a morphological structuring element. The shape used here is ‘ball’ and the PACKOPT means here ‘same or full’. Basically Erosion shrinks the image but the Dilation expands a set (objects). So dilation and erosion satisfy the duality property, which is defined as

\[ A \ominus B = (A^C \ominus B)^C \]

Figure. 3 shows the Flow Chart of a Real-Time Specific Weed Recognition System, which was developed to recognize the broad and narrow weed classification [27]. The algorithm was based on erosion followed by dilation segmentation algorithm.

The pseudo-code used for the proposed algorithm is given as

1. [Image taken by CCD camera]
2. [CPU receives the image]
3. [Apply the proposed algorithm and recognize the image]
4. [Decision box ON or OFF the dc pump according to the decision of the CPU]
5. [DC pump will apply the right type of herbicides]

The pseudo-code is shown in the form of a flowchart shown in Figure 1 that how it is working internally. First the CCD camera captures the image and then forwards it to CPU, then the CPU process the image by using the morphological filter (Structuring element) which is the filter of Erosion to remove the unnecessary information from the image as shown figure 4, and the dilation is to be applied. Basically erosion removes the unnecessary details and to makes the image shrink, and then dilation expands that image after removing the hidden details. The CPU takes the decision on the bases of the summation of the pixels of the image as shown in figure 4. The simple equation for the summation of the pixels is given as:

\[
\text{Sum} = \sum_{i=0}^{M} \sum_{j=0}^{N} (i + j) \quad \text{(1)}
\]

The Matlab Code used, to find out the summation of pixels.

```
Sum = sum (sum (Eroded Image));
```

To determine the pixels of the image, the image is scanned morphologically and the calculating results are to be stored in the form of tables, the process is known as raster scanning as shown bellow.
Matlab Code to create lookup Tables:
% set up a look up table T1 to find Junctions.
lut = makelut (@junction, 3);
junctions = applylut (b, lut);
[rj, cj] = find (junctions);
% set up a look up table T2 to find Endings.
lut = makelut (@ending, 3);
ends = applylut (b, lut);
[re, ce] = find (ends);

To test whether the center pixel within a 3x3 neighborhood is a junction / ending in LT1 / LT2, the center pixel must be set and the number of transitions/crossings between 0 and 1 as one traverse the perimeter of the 3x3 region must be 6 or 8 for junction and 2 for ending. Pixels in the 3x3 region are numbered as follows
\[
\begin{pmatrix}
1 & 4 & 7 \\
2 & 5 & 8 \\
3 & 6 & 9
\end{pmatrix}
\]

Now the intensities of the resultant image are added and compared with the selected threshold value (T) for classification of weeds into broad and narrow.

V. RESULTS AND DISCUSSION

Fig.4. Show the classification images of broad and narrow weeds. These images are processed by the proposed algorithm (Erosion followed by Dilation). The algorithms gave reliable accuracy to detect the presence or absence of weed cover. For areas where weeds are detected, results show over 89% classification accuracy over 240 sample images within which 100 samples from broad weeds, 100 samples from narrow weeds and the remaining 40 from no or little weeds. The percentage of each class as shown in the Table 1

<table>
<thead>
<tr>
<th>Weeds Type</th>
<th>Results found correct %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broad Weeds</td>
<td>82%</td>
</tr>
<tr>
<td>Narrow Weeds</td>
<td>85%</td>
</tr>
<tr>
<td>No or Little Weeds</td>
<td>100%</td>
</tr>
</tbody>
</table>

In the above table the percentage of each category has been determined by applying the proposed algorithm upon the database of 240 images (containing 100 samples of broad, 100 samples of narrow, 40 samples of no or little weed), from which we determined the percentage of each category by adding the pixels of all the processed database of images containing of 240 images of broad, narrow, and no or little images. The algorithm takes 320 ms to process an image.

VI. CONCLUSION

A weed detection/classification system is developed and tested in the lab for selective spraying of weeds using vision recognition system. In this paper, an algorithm based on Erosion followed by Dilation and is developed for weed classification and recognition. The system shows an effective and reliable classification of images captured using a video camera.

VIII. FUTURE WORK

In this paper weed image, which has one dominant weed species can be classified reasonably accurate in one environmental condition. But the case of different environment one weed classes cannot be accurately classified. The environmental parameters greatly affect the performance of currently developed weed classifier. i.e. Lighting conditions, wind, and other natural environment parameters degrade the performance of algorithm. Further research is needed to develop such classifier, which will perform Environmental adaptive weed recognition and classification and which will also detect natural environment parameters and classify weed images according to these parameters to enhance the result of weed classifiers.

REFERENCES


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Fig.4. Resultant Images of Weed Recognition Based on Erosion and Dilation Segmentation Algorithm

Narrow Leaf Image

Binary Image

Eroded Image

Dilated Image

Broad Leaf Image

Binary Image

Eroded Image

Dilated Image

Little Leaf Image

Binary Image

Eroded Image

Dilated Image

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