Comparative Performance Evaluation of XYZ Plane Based Segmentation and Entropy Based Segmentation for Pest detection

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Abstract

Image segmentation is the process of partitioning an image into multiple segments. The purpose of segmentation is to decompose the image into parts that are meaningful with respect to a particular application. In modern crop status management in greenhouse, instead of doing manually, crop status is monitored using cameras with some automation. One of the major problems in the greenhouse crop production is the presence of pests. An accurate and timely monitoring of pests population is the basic requirement. In the pest detection, image segmentation is one of the desirable steps to distinguish the pest from rest of part of an image. This work suggests two methods, namely 'Segmentation using XYZ plane' and 'Entropy based histogram thresholding'. In the first method, XYZ color plane followed by thresholding is used instead of RGB space to overcome with some major problems in segmentation. The second method is given in which the maximum information content is used to decide the segmentation rule. Results are dependent upon a color space selection. The suggested segmentation algorithm is applied for images of pest infected leaves. Results are compared.

Keywords: *greenhouse, image segmentation, pest detection, color plane.*

1. Introduction

The purpose of image segmentation is to decompose the image into parts that are meaningful with respect to a particular application. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics.

Pest detection is a major challenge in horticulture. Traditionally, counting is done manually and this is very time-consuming and expensive process. Results may not be accurate most of the times as human gets fatigue. Thus, machine vision is the best way to get accurate results. Image segmentation is one of the desirable steps in image analysis which is required for pest detection.

The greenhouse whiteflies (*Trialeurodes vaporariorum* Westwood) are significant pests in greenhouse crops worldwide. Whitefly adults are tiny white insects about 1.0 mm long. They are often described as moth-like in appearance, but they have piercing, sucking mouthparts. Whitefly may be present in greenhouses year round, but the population is worst in summer, especially when it is hot and dry, or sunny as per growers report. Thus, though controlling whiteflies is easier in winter, chemical control is less effective in the summer. Adult whitefly also has the potential to cause crop losses indirectly by transmitting plant viruses. We can monitor whitefly population levels by trapping winged adults on sticky cards and inspecting leaves.

Main goal of this project is the detection of bioagressors. The adult whiteflies can usually be found towards the top of the plant on younger leaves. It is very beneficial to take photographs of these adult whiteflies. Whitefly management is a rapidly changing scene. For crop protection, it is necessary to obtain the accurate information about the status of the plants. Thus, pest detection is very much necessary to take decision about the treatments.

One of the most important problems in color image analysis for pest detection is the segmentation. In this paper, we consider color uniformity as a relevant criterion to partition an image into significant regions. For this purpose, the color of each pixel is initially represented in the RGB color space where the color component levels of the corresponding pixel are namely red (*R*), green (*G*) and blue (*B*). Other color spaces can be used and the performance of an image segmentation procedure is known dependent upon the choice of the color space. In this paper, we propose methods to describe image segmentation based on choice of color spaces.

The review [1] related to color image segmentation helps to understand various techniques, methods, themes, approaches and controversies that are to be applied for color image segmentation. Different image segmentation techniques have been surveyed through [2], [3] and [4]. The

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basic idea of pest detection in greenhouse crop is taken from [5] and [6]. In [7] and [8], XYZ color space is studied well. These papers include the advantages and use of XYZ color space. Basic theory for segmentation is taken from [9], [10], [11] and [12]. Different types of segmentation methods have been surveyed. In [13], Entropy Based Histogram Thresholding Algorithm is explained for color image segmentation for aerial images. The aim is to detect the whiteflies on the infected leaves. In [14], color space and its relation with image segmentation is described.

2. Segmentation Using XYZ Color Plane

The segmentation based on XYZ plane with the background is described below:-

2.1 Basic Idea

'Color' is a property that distinguishes among different kinds of light. It is defined wholly in terms of human perception. A color is usually specified using three co-ordinates, or parameters. These parameters describe the position of the color within the color space being used. A 'color space' is a method by which we can specify, create and visualize color. Generally, a color space is a geometrical representation of colors in a space. The characteristics generally used to distinguish one color from another are *brightness, hue and saturation*. The hue and saturation are together called as *Chromaticity.* The amount of red, green and blue needed to form any particular color are called the *Tristimulus values*.

The RGB color space is a primary additive color space. It is possible to match any color by mixing appropriate amounts of three primary colors. The RGB color space has a major drawback that, the tristimulus values and chromaticity coordinates can be negative, because it is not possible to match all the colors by additive mixture with a real primary space. The XYZ color space was developed by CIE as an alternative to RGB. One of the characteristics of this system is that the tristimulus values *X*, *Y*, and *Z*, are always positive for all real color stimuli.

Several reasons for the adoption of imaginary primaries:-
1. It was necessary to devise *X*, *Y*, and *Z* such that they would be positive for all possible real stimuli.
2. The coefficients were chosen such that the *Y* tristimulus value was directly proportional to the luminance of the additive mixture.

In this space, *X*, *Y* and *Z* primaries are not physically realizable but they have been defined so that all the color stimuli are expressed by positive tristimulus values.

2.2 Segmentation

As specified earlier, the XYZ color space is very useful for segmentation using simple thresholding. The algorithm for the method 'segmentation using XYZ plane' is shown in Fig. 1. The algorithm steps are described as follows:-
Step 1: Take input RGB image.
Primary image is generally is in RGB format. Thus, camera captured image is considered.
Step 2: Convert RGB color space to XYZ color Space.
As specified earlier, due to some drawbacks of RGB color space, the RGB image is converted to XYZ color space image. The basic transformation is given as follows-

$$\begin{aligned} X &= 0.607R + 0.174\,G + 0.200B \\ Y &= 0.299R + 0.587G + 0.114B \\ Z &= 0.000R + 0.066G + 1.116B \end{aligned} \tag{1}$$

Step 3: Take Z-plane.
It was observed that the Z-plane is more suitable for segmentation than the other two planes. Thus, Z-plane is considered separately for further processing.
Step 4: Apply Thresholding.
The Simple thresholding is applied on the Z-plane image which, in turn give a segmented image which is in binary form..
Step 5: Apply Median filter. (If necessary)
The segmented image may contain some noise which is similar to salt and pepper noise. Thus, if necessary, the median filtering is done.
Step 6: Apply erosion. (If necessary)
If the segmented image is used for further use, such as counting, erosion is very useful to separate out the pests from each other. Thus, if necessary, the erosion is applied.

In this way, the segmentation is done using transformation from RGB to XYZ color space.

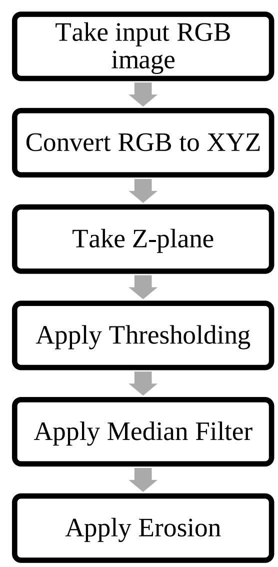

Fig. 1 Algorithm for Segmentation Using XYZ Plane

3. Entropy Based Histogram Thresholding Algorithm

3.1 Basic Idea

Color image segmentation using entropy based thresholding is dependent on the 'information content' measured by entropy which is used to select the color space domain such that it is the largest among other color spaces under test. The aim is to allocate an individual pixel into its corresponding segment by maximizing the total information and minimizing the difference between the information contained in foreground or background surface. [7] Primary image is taken from the camera which is generally, in RGB format. Other color spaces are obtained through appropriate transform operations.

- RGB Color Space
- YUV Color Space
- YIQ Color space
- HSI Color Space
- $I_1I_2I_3$ Color Space
- HSV Color Space
- Effect on Segmentation Quality

Different color spaces are used because each space indicate different amount of information in an image. Thus, best suitable color space component is selected for segmentation.

3.2 Entropy Based Thresholding

Image segmentation is done depending on entropy calculation of each color space component. The image is segmented as foreground and background based on segmenting criteria.

1. Entropy Calculation

Entropy or information content of each color space component is obtained from probability distribution. Let the color image in RGB format be given by

$$Image = \{I_{ij}\} \tag{2}$$

Where, $I_{ij} = \{R_{ij}, G_{ij}B_{ij}\}$, for $i = 1, \ldots\ldots, v$, $j = 1, \ldots, u$, denotes the color magnitude of a pixel located in image's ij location. Subscripts u, v are the width and the height of the image.

For each color component, histogram is obtained as

$$H_r = \{h_r^k\} \tag{3}$$

Where, r is subscript for R component and $k = 1, \ldots, \hat{k}$ is bin index. Here the number of bins is chosen for sufficient resolution and ease of computation.

The histogram is firstly normalized to give a probability distribution. The entropy or information content is then calculated for normalized histogram of each color space component. The entropy is given by,

$$E_r = -\sum \bar{h}_r^k \, log_2(\bar{h}_r^k),$$
$$\bar{h}_r^k = \frac{h_r^k}{\sum_{\forall k} h_r^k} \tag{4}$$

Where, $\bar{h}_r^k$ is the normalized histogram or the probability distribution of a given color space and E_r is entropy related to given color space.

The color space component with maximum entropy is selected among all. It given as:

$$E = max_c\{E_c\} \tag{5}$$

Where, c is the index for each color space component. The histogram related to this maximum entropy color component is used for segmentation.

2. Segmentation

The original histogram with maximum entropy is considered for thresholding to separate the image into foreground and background objects. Let the distribution H_E be selected. The condition to obtain candidate threshold is that the some of the entropies of the foreground and background objects is maximized and their difference is minimized. That is, balance between total maximum information content and individual maximum information is attempted to find as a segmentation design principle.

Let the candidate threshold be τ. The foreground and background objects are determined as a function of the variables

$$k_f = \{1, \ldots, \tau\}, k_b = \{\tau + 1, \ldots, \hat{k}\} \tag{6}$$

Where, k_f and k_b are the indices of foreground and background objects such that their pixel values in the selected color space fall within the range of the distribution that is to be segmented.

The threshold τ is further adjusted across the distribution, such that, $0 < \tau < \hat{k}$. Two entropies corresponding to foreground and background objects are calculated by

$$H_f^\tau = -\sum_{f \in k_f} h_E^f log_2(h_E^f) \tag{7}$$
$$H_b^\tau = -\sum_{b \in k_b} h_E^b log_2(h_E^b) \tag{8}$$

The segmenting threshold, τ^* is selected using (20),

$$\tau^* = max_\tau\{(H_f^\tau + H_b^\tau) - |H_f^\tau - H_b^\tau|\} \tag{9}$$

This segmenting threshold is then applied on the color space component having maximum entropy. Each pixel is compared with the segmenting threshold and final the segmenting pattern is obtained.

The received segmenting pattern is then applied to original RGB image to obtain foreground and background objects which are segmented as

$$F = \{I_{ij}^{k^f}\}, B = \{I_{ij}^{k^b}\} \tag{10}$$

Where, $\{I_{ij}^{k^f}\}$ are pixels such that their transformed space pixels fall within the foreground range of bins in the selected distribution of a color space. The background object B is selected as all other pixels indexed by k^b.

4. Experimental Study

Three test images of pest infected leaves are used in the experiment to verify the segmentation results of the methods, namely 'Segmentation Using XYZ Plane' and 'Entropy Based Thresholding'. Some images contain single whitefly, whereas some contain multiple whiteflies. Discussion on the results is done as follows:-

4.1 Segmentation Using XYZ Plane

The RGB Image is first converted to XYZ color space. Then, the Z-plane is considered separately. Z-plane images are shown in Fig. 2 (b), (e) and (h). This image is then thresholded and a binary segmented image is obtained. To get clear differentiation between the pests, further erosion is applied on segmented image, which gives the final segmented objects. These are shown in Fig. 2 (c), (f) and (i).
Test image 1 is clearly segmented. Test image 2 is segmented well with little bit noise. Test image 3 is also segmented very well.

4.2 Entropy Based Histogram Thresholding

1. Information Content

The entropies calculated are different for different color spaces as each space contain different information. In Test Image 1, the maximum entropy obtained is 2.7105 found in S space of HSV color space. In Test Image 2, the maximum entropy obtained is 2.7880 found in S space of HSV color space.

Maximum entropies are selected for remaining images similarly.

2. Segmentation

Results of segmentation are shown in Fig.3. In Test Image 1, single pest is segmented as foreground object and rest of the part is considered as a background. In Test Image 2, pests are segmented along with veins of a leaf. Leaf veins are counted as white pixels, thus, adding some noise in the segmentation result. The segmentation result is not satisfactory for Test Image 3.

5. Conclusion

The goal is detection of pests in the greenhouse crops. The paper focuses on two methods, namely 'Segmentation using XYZ plane' and 'Entropy based Segmentation' for detecting the pests. As lot of color spaces exist for different applications and several definitions for a same color space, it is difficult to select one for a color image analysis application. The CIE XYZ color space is the most common way to describe the color of light. The CIE XYZ color space is selected in order to overcome the problems of the RGB primary space. The second suggested method is used for segmentation of color images. The study of selection of the color space for deciding a segmentation threshold has been presented. Different color space component carry different amount of information. This information is obtained by calculating entropy of individual color space component. The segmentation result has been obtained by applying threshold on single color space. Both the methods give well results for segmentation. But the Entropy based method gives color segmented image, whereas the segmentation using XYZ plane gives binary segmented image. But in Segmentation using XYZ plane method, the total noise gets removed. Thus, as per the requirement, both the methods can be well executed. The suggested method is verified for pest infected leaves.

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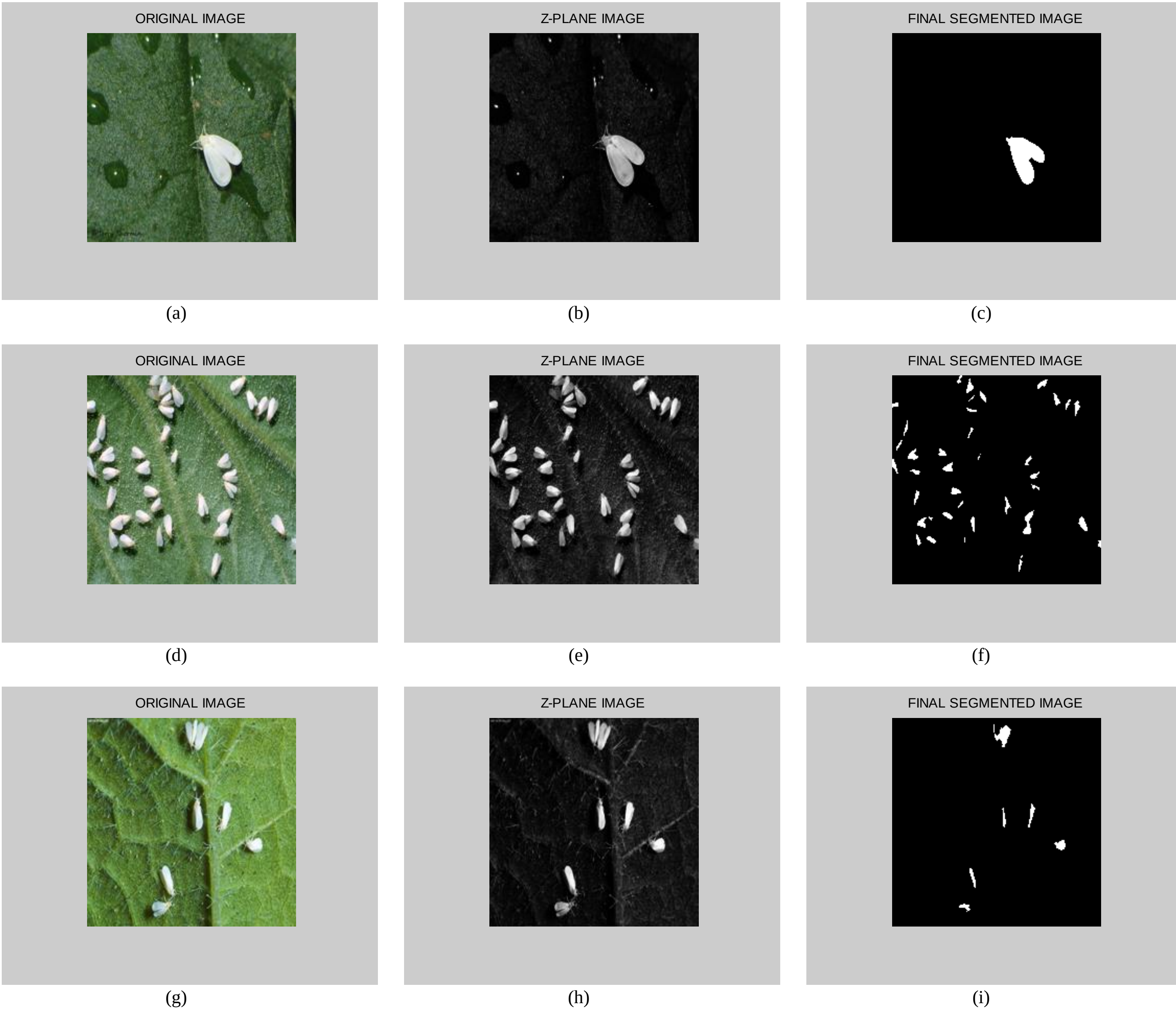

Fig.2 Segmentation Results of Method Using XYZ Plane:
(a), (d) and (g) - Test Image 1, Test Image 2 and Test Image 3
(b), (e) and (h) – Z-plane Image
(c), (f) and (i) – Final Segmented Image

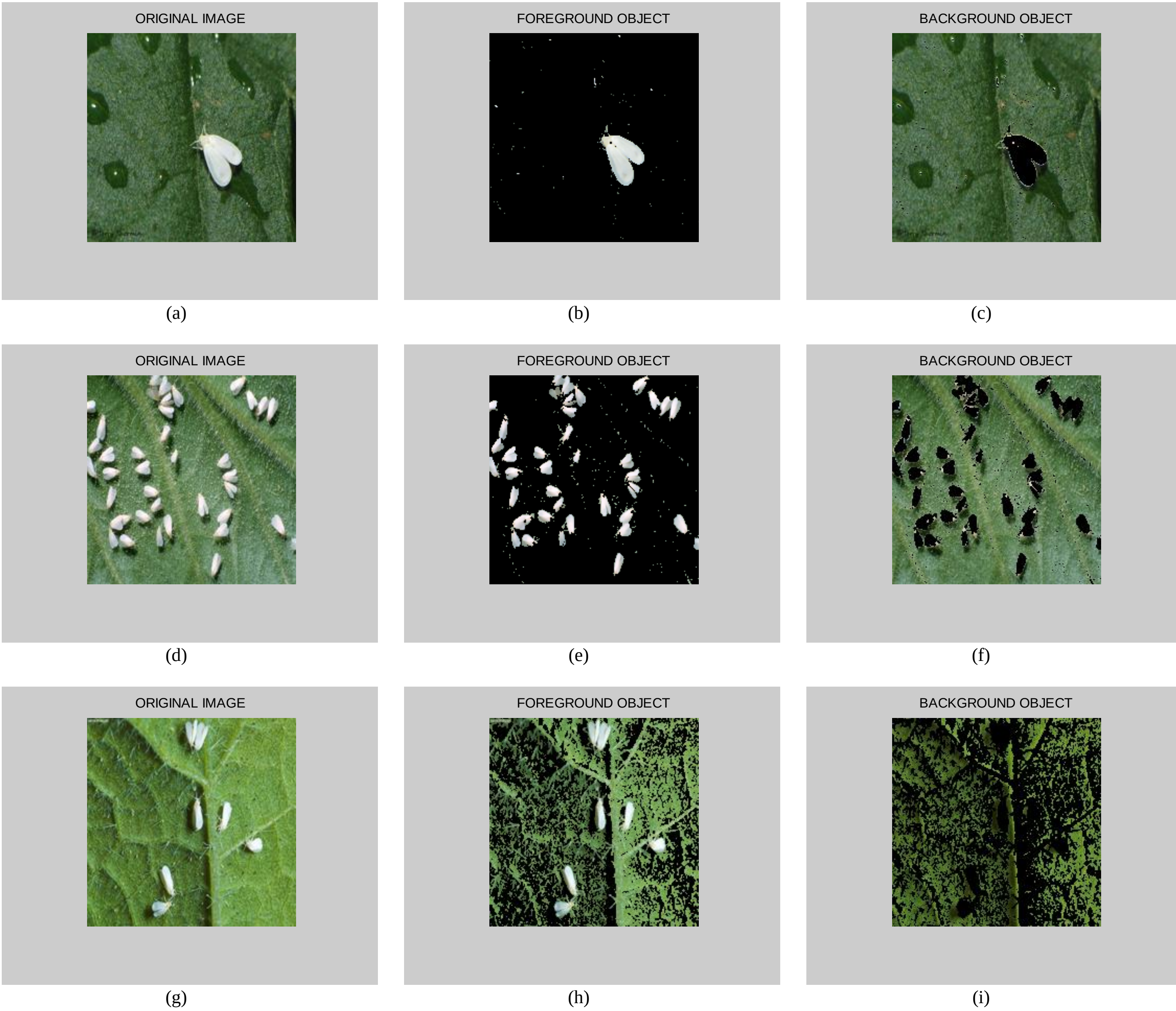

Fig.3 Segmentation Results of Entropy Based Histogram Thresholding
(a), (d) and (g) - Test Image 1, Test Image 2 and Test Image 3
(b), (e) and (h) - Foreground Objects
(c), (f) and (i) - Background Objects