Selection of Color Space for Image Segmentation in Pest Detection

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***Abstract*--Image segmentation is the process of partitioning an image into multiple segments, so as to change the representation of an image into something that is more meaningful and easier to analyze. 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 analysis is very important and image segmentation is one of the desirable steps to distinguish the pest from rest of part of an image. Color image segmentation is desirable than gray scale image segmentation. This work suggests Entropy based thresholding 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 with the results of Fuzzy c-mean method.**

Index Terms: - greenhouse, image segmentation, pest detection

I. INTRODUCTION

The goal of image segmentation is to cluster pixels into salient image regions, i.e., regions corresponding to individual surfaces, objects, or natural parts of objects. Segmentation could be used for object recognition, boundary estimation within motion or stereo systems, image compression, image editing etc.

Pest detection is a major challenge in horticulture. Traditionally, counting is done manually and this is very time-consuming and expensive process. Image segmentation is one of the desirable steps in image analysis which is required for pest detection.

The greenhouse whiteflies(*Trialeurodes vaporariorum* Westwood) are the primary whitefly pests of greenhouse crops. They are sucking insects that secrete a white wax at certain stages of their life cycle. Compared to other pests of ornamentals, whiteflies have a long life cycle. The most obvious whitefly feeding damage symptoms are stem blanching, chlorotic spots, leaf yellowing and shedding, and at high population levels plant death.We can monitor whiteflypopulation levels by trapping winged adults on sticky cards and inspecting leaves.

Main goal of this project is the detection of bioagressors. Greenhouses are partly isolated from outside environment and highly controlled good test sites for innovative methodologies in crop protection. A strong demand now exists in many countries for non-chemical control methods for pests or diseases. Greenhouses are considered as biophysical systems with inputs, outputs and control process loops.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.

For the pest detection, image segmentation is one of the most important steps which enable the machine or computer to count the number of pests. Different segmentation algorithms can be used to achieve the aim.

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 basic idea of pest detection in greenhouse crop is taken from [5] and [6].In [7], 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. Basic theory for segmentation is taken from [8], [9], [10] and [11]. Fuzzy c-mean segmentation method has studied from [12], [13] and [14] for comparison purpose.

II. ENTROPY BASED HISTOGRAM THRESHOLDING ALGORITHM

A. 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]

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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

The RGB color space is widely used throughout computer graphics red, green and blue are three primary additive colors.

A system that is designed using the RGB color space can take advantage of a large number of existing software routines.

- YUV Color Space

The YUV color space is used in European TV transmissions. The U and V components convey the color information it also able to reduce the inter dependencies of the RGB components. The basic equations to convert between RGB and YUV are:

$$Y = 0.299R + 0.587G + 0.114B$$
$$U = -0.147R - 0.289G + 0.437B$$
$$V = 0.615R - 0.515G - 0.100B \qquad (1)$$

- YIQ Color space

This space is similar to YUV space and is used in American TV systems. The Y signal represents the elimination intensity while I and Q jointly describe the hue and saturation. The basic equations to convert between RGB and YIQ are:

$$Y = 0.299R + 0.587G + 0.114\mathrm{B}$$
$$I = 0.596R - 0.274G - 0.322B$$
$$Q = 0.211R - 0.253G - 0.312B \qquad (2)$$

- HSI Color Space

The HSI color space is compatible to the human perception. Hue gives color information; Saturation reflects the color purity and the brightness is denoted by Intensity. The basic equations to convert between RGB and HSI are:

$$H = arctan(\sqrt{3} \ * (G - B)/(2 * R - G - B))$$
$$I = (R + G + B)/3$$
$$S = (1 - \min(R, G, B)/I \qquad (3)$$

- $I_1I_2I_3$ Color Space

The basic equations to convert between RGB and $I_1I_2I_3$ are:

$$I_1 = 0.333R + 0.333G + 0.333B$$
$$I_2 = 0.500R + 0.500G - 0.500B$$
$$I_3 = -0.250R + 0.500G - 0.250B \qquad (4)$$

- HSV Color Space

The HSV color space is similar to the HSI space where the Value (V) component is given by an alternative transformation as the maximum of RGB component.

$$H = arctan(\sqrt{3} \ * (G - B)/(2 * R - G - B))$$
$$1 - 3 * \min(R, G, B)/(R + G + B)$$
$$\max(R, G, B) \qquad (5)$$

- 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.

B. 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

$$Image = \{I_{ij}\} \qquad (6)$$

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

$$H_r = \{h_r^k\} \qquad (7)$$

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,

$$E_r = -\sum \bar{h}_r^k \, log_2(\bar{h}_r^k),$$
$$\bar{h}_r^k = \frac{h_r^k}{\sum_{\forall k} h_r^k} \qquad (8)$$

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:

$$E = max_c\{E_c\} \qquad (9)$$

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

$$k_f = \{1, \ldots, \tau\}, k_b = \{\tau + 1, \ldots, \hat{k}\} \qquad (10)$$

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

$$H_f^\tau = -\sum_{f\in k_f} h_E^f log_2(h_E^f) \quad (11)$$

$$H_b^\tau = -\sum_{b\in k_b} h_E^b log_2(h_E^b) \quad (12)$$

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

$$\tau^* = max_\tau\{(H_f^\tau + H_b^\tau) - |H_f^\tau - H_b^\tau|\} \quad (13)$$

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

$$F = \{I_{ij}^{kf}\}, B = \{I_{ij}^{kb}\} \quad (14)$$

Where, $\{I_{ij}^{kf}\}$ 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 byk^b.

III. EXPERIMENTAL STUDY

Six test images of pest infected leavesare used in the experiment to verify the segmentation results of the method, namely 'Entropy Based Thresholding'. Some images contain single whitefly, whereas some contain multiple whiteflies. For each test image two steps are carried out as follows:-

A. Entropy Based Thresholding Algorithm

1. Information Content

The entropies for each color component are calculated using (15), which is given in Table I and Table II for Test Image 1 and Test Image 2, respectively. The subscripts, E_1 stands for the entropy contained in the R space in RGB images. Similarly, E_1 stands for the entropy contained in the H space in HSV images.

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 1, 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.1 and Fig.2. 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 and Test Image 3, whiteflies are segmented very well. In Test Image 4, pests are segmented along with veins of a leaf. Leaf veins are counted as white pixels, thus, adding some noise in the segmentation result. In Test Image 5, whiteflies are closely connected, so segmentation is little bit complex. The segmentation result is not satisfactory for Test Image 6.

Table I
Entropy of Different Color Spaces- Test Image 1

Color Space	E_1	E_2	E_3
RGB	0.0808	0.0808	0.0808
HSV	1.6682	**2.7105**	0.0808
YIQ	0.0808	0.2419	0.0808
YUV	0.0808	0.1614	0.1614
$I_1I_2I_3$	0.0808	0.1614	0.1614
HSI	0.1614	1.6696	0.2419

Table II
Entropy of Different Color Spaces- Test Image 2

Color Space	E_1	E_2	E_3
RGB	0.0808	0.0808	0.0808
HSV	2.0342	**2.7880**	0.0808
YIQ	0.0808	0.1614	0.1614
YUV	0.0808	0.1614	0.1614
$I_1I_2I_3$	0.0808	0.1614	0.1614
HSI	0.2419	0.0808	0.1614

B. Fuzzy c-mean Segmentation Algorithm

Fuzzy c-means is the method of clustering which allows one piece of data to belong to two or more clusters. It is one of the standard methods for segmentation. [13]

In Fig. 3, the Test Image 3 and Test Image 5 are given. Results of segmentation are given in the same figure. In 3-class fuzzy c-means algorithm, two levels of threshold are defined. Segmentation is better in any of the level. In both the results, the Level 2 gives the better segmentation result.

Fuzzy c-mean algorithm is little time consuming and gives segmentation result with more noise. Thus, for pest detection application, it is not actually suitable.

IV. CONCLUSION

The goal is detection of pests in the greenhouse crops. The paper focuses on the Entropy based Segmentation for detecting the pests.The suggestedmethod 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. Entropy based segmentation is desirable than simple thresholding. The given method is also better than Fuzzy c-means method because it gives less noisy results and faster than that of FCM. The motivating results are obtained. The suggested method is verified for pest infected leaves.

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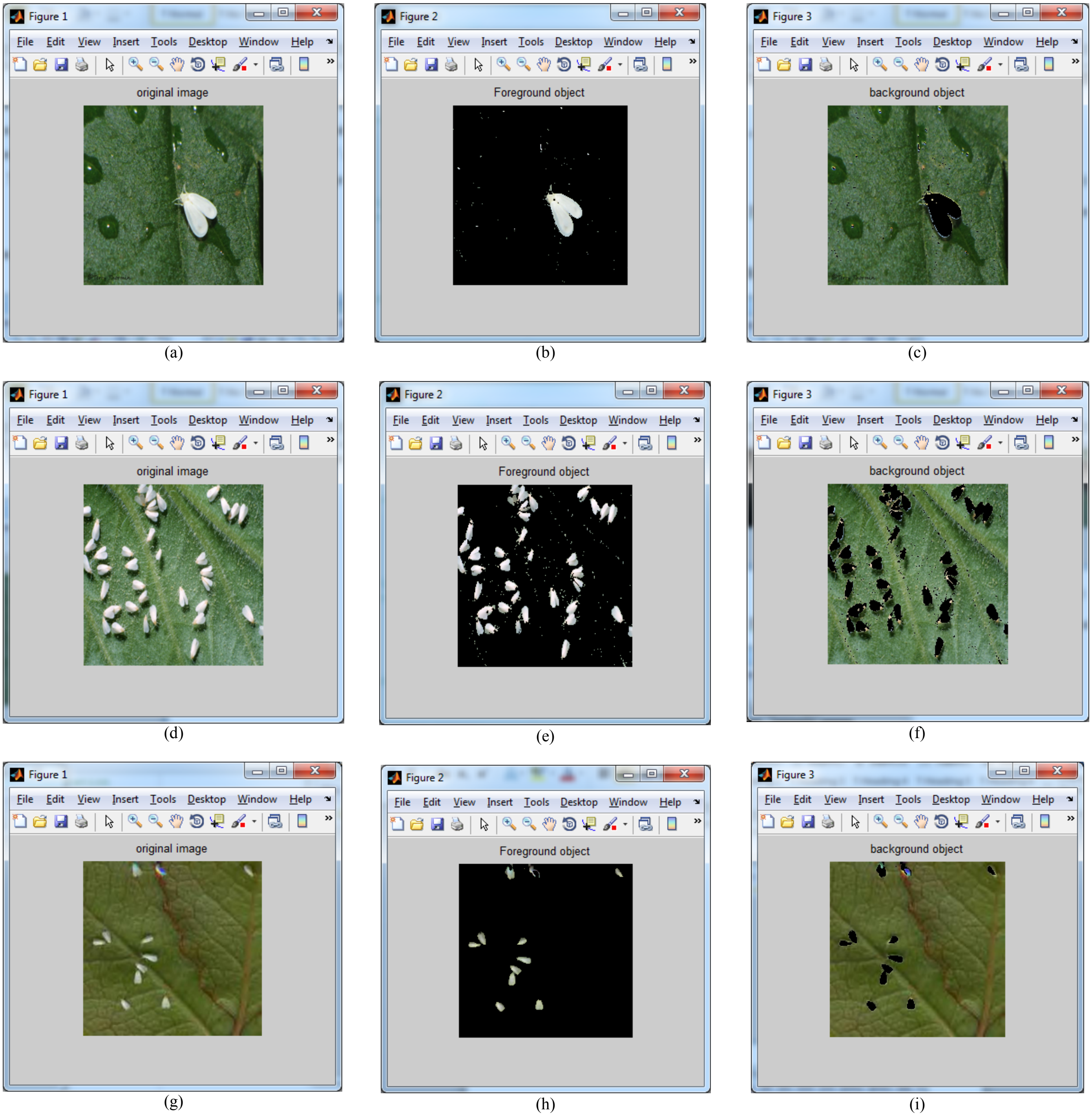

Fig.1 Segmentation Results of pest infected leaves: (a), (d) and (g) - Test Image 1, Test Image 2 and Test Image 3
(b), (e) and (h) - Foreground Objects
(c), (f) and (i) - Background Objects

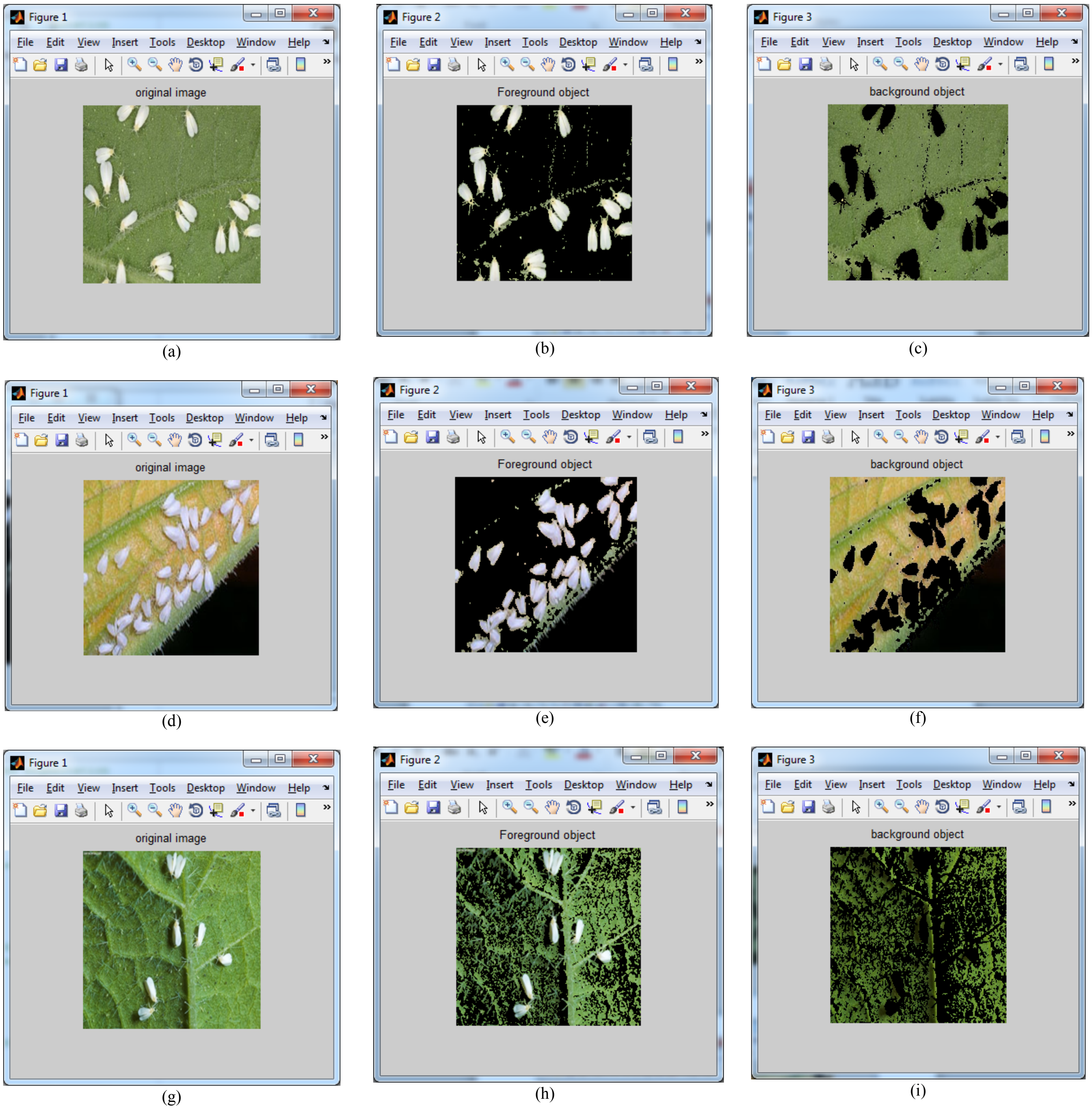

Fig.2 Segmentation Results of pest infected leaves: (a), (d) and (g) - Test Image 4, Test Image 5 and Test Image 6
(b), (e) and (h) - Foreground Objects
(c), (f) and (i) - Background Objects

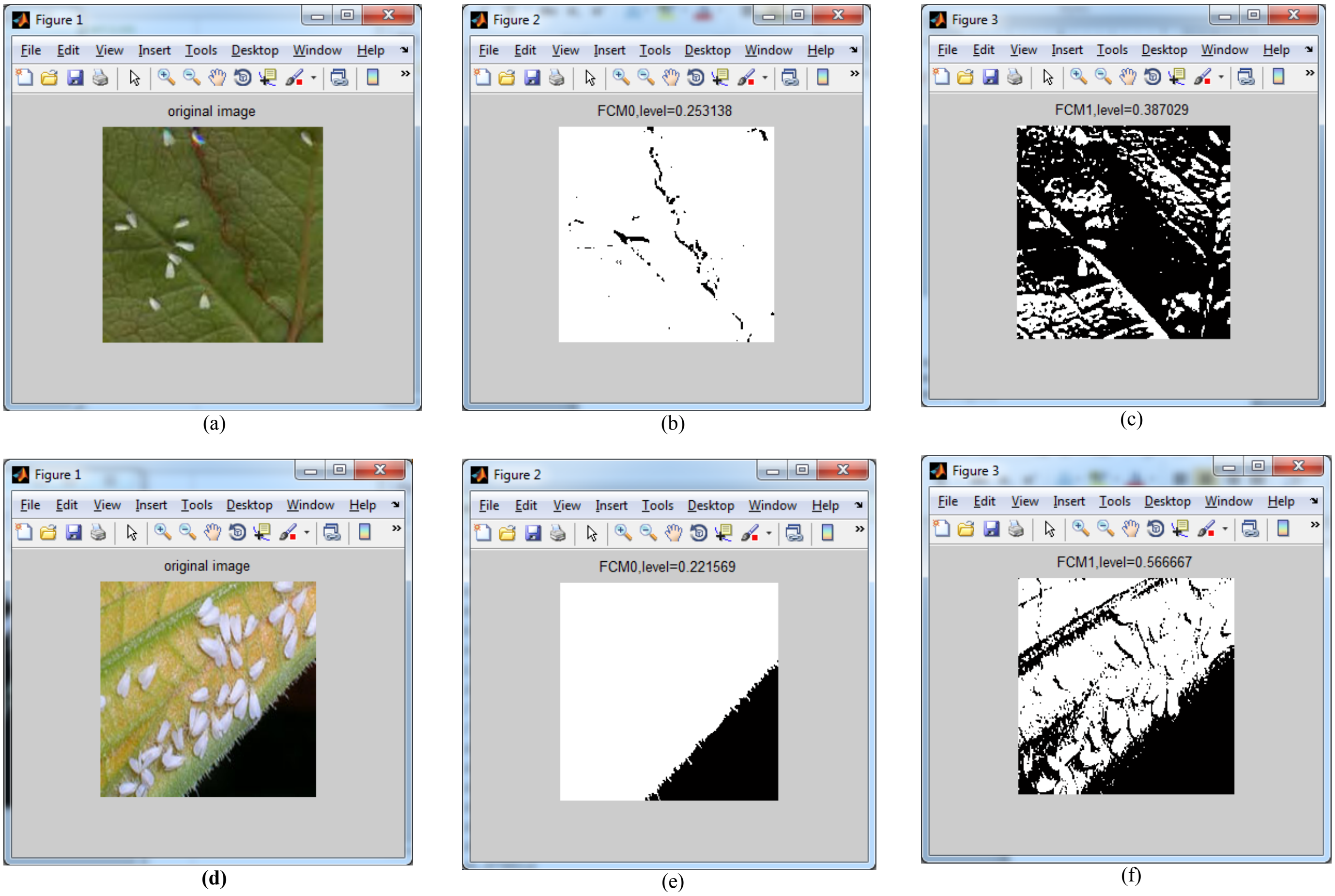

Fig.3 Segmentation Results of pest infected leaves: (a) and (d) - Test Image 3, Test Image 5
(b) and (e) -Level 0 segmented image
(c) and (f) -Level 1 segmented image