Leaf Disease Grading by Machine Vision and Fuzzy Logic

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Abstract- present paper introduces an innovative approach to automatically grade the disease on plant leaves. The system effectively inculcates Information and Communication Technology (ICT) in agriculture and hence contributes to Precision Agriculture. Presently, plant pathologists mainly rely on naked eye prediction and a disease scoring scale to grade the disease. This manual grading is not only time consuming but also not feasible. Hence the current paper proposes an image processing based approach to automatically grade the disease spread on plant leaves by employing Fuzzy Logic. The results are proved to be accurate and satisfactory in contrast with manual grading.

Keywords- color image segmentation, disease spot extraction, percent-infection, fuzzy logic, disease grade.

INTRODUCTION

The sole area that serves the food needs of the entire human race is the Agriculture sector. It has played a key role in the development of human civilization. Plants exist everywhere we live, as well as places without us. Plant disease is one of the crucial causes that reduces quantity and degrades quality of the agricultural products. Plant Pathology is the scientific study of plant diseases caused by pathogens (infectious diseases) and environmental conditions (physiological factors). It involves the study of pathogen identification, disease etiology, disease cycles, economic impact, plant disease epidemiology, plant disease resistance, pathosystem genetics and management of plant diseases. Disease is impairment to the normal state of the plant that modifies or interrupts its vital functions such as photosynthesis, transpiration, pollination, fertilization, germination etc. Plant diseases have turned into a nightmare as it can cause significant reduction in both quality and quantity of agricultural products [2].

Information and Communication Technology (ICT) application is going to be implemented as a solution in improving the status of the agriculture sector [3]. Due to the manifestation and developments in the fields of sensor networks, robotics, GPS technology, communication systems etc, *precision agriculture* started emerging [10]. The objectives of precision agriculture are profit maximization, agricultural input rationalization and environmental damage reduction by adjusting the agricultural practices to the site demands.

In the area of disease management, grade of the disease is determined to provide an accurate and precision treatment advisory.

EXISTING SYSTEM: MANUAL GRADING

Presently the plant pathologists mainly rely on the naked eye prediction and a disease scoring scale to grade the disease on leaves. There are some problems associated with this manual grading.

Diseases are inevitable in plants. When a plant gets affected by the disease, a treatment advisory is required to cure the

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disease. Chemical pesticides are commonly used to cure the diseases. But, excessive use of pesticides for plant disease treatment increases costs and raises the danger of toxic residue levels on agricultural products. As pesticides are among the highest components in the production costs of field crops and have been identified as a major contributor to groundwater contamination; their use must be minimized. This requires that the disease must be identified accurately along with the stage in which the disease is; so that only a proper quantity of pesticide can be used for the treatment rather than blindly spraying.

Presently, the plant pathologists rely on disease scoring scale to grade the disease. This is shown in Table 1.

Table I: Disease Scoring Scale for Leaves

Percent Infection	Disease Grade
0	0
Up to 1	1
1 – 10	2
10 – 20	3
20 – 40	4
40 – 100	5

From the table 1, it is observed that the grade of the disease is assigned based on the percent-infection i.e., if the infection percent is about 5 then the grade is 2. The problem here is that even if the percent-infection is 2 or 9 the grade remains 2 only.

Presently, percent-infection is calculated based on grid paper analysis. This method is time consuming and burden of repetitive tasks. Since human intervention is involved, it is prone to errors also.

Hence, now the time has come to overcome these problems. This can be achieved by inculcating machine vision into the agriculture to get the accurate grade of the disease. With this motto the present paper proposes an automatic and accurate disease grading system for plant leaves which can be of great useful for the agronomists.

METHODOLOGY

The proposed methodology aims to model a promising disease grading system for plant leaves. For the experimentation purpose, pomegranate leaves are considered. The flow chart of the methodology is presented in the annexure 1 in the appendix. The system is divided into the following steps: (1) Image acquisition (2) Image Pre-processing (3) Color image segmentation (4) Calculating A_T and A_D (5) Disease grading by Fuzzy Logic.

(1) Image acquisition

The digitization and storage of an image is referred as the image acquisition. In any image processing applications, the work always starts with image acquisition. In the current work, the images of diseased samples of pomegranate leaves are captured using Nikon Coolpix L20 digital camera having 10 megapixels of resolution and 3.6x optical zoom, maintaining an equal distance of 16 cm to the object. All the images are then saved in the same format i.e., JPEG. For the purpose of image acquisition, authors have visited and captured images from several pomegranate farms in the places of Hagaribommanahalli, Bellary district and Kaladhagi, Bagalkot district of Karnataka, India.

(2) Image Pre-processing

Image processing is a form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image.

Digital image processing is the use of computer algorithms to perform image processing on digital images [5]. Preprocessing uses the techniques such as image resize, filtering, segmentation,

cropping, contrast enhancement, angle correction, morphological operations etc. In the contemporary exertion, image resize and filtering are performed as a part of pre-processing.

Initially, captured images are resized to a fixed resolution so as to utilize the storage capacity or to reduce the computational burden in the later processing. Noise is inevitable during image acquisition or transmission. Noise would disturb the segmentation and the feature extraction of disease spots. So they must be removed or weakened before any further image analysis by applying an appropriate image filtering operation. In the present work, authors have considered Gaussian filter to filter out the input images.

(3) Color image segmentation

Image segmentation refers to the process of partitioning the digital image into its constituent regions or objects so as to change the representation of the image into something that is more meaningful and easier to analyze. The level to which the partitioning is carried depends on the problem being solved i.e. segmentation should stop when the objects of interest in an application have been isolated [5]. In the current work, the very purpose of segmentation is to identify regions in the image that are likely to qualify as diseased regions. There are various techniques for image segmentation such as clustering methods, compression-based methods, histogram-based methods, region growing methods etc. *K-means clustering* method has been used in the present work to carry out segmentation. K-Means Clustering is a method of cluster analysis which aims to partition *n* observations into *k* mutually exclusive clusters in which each observation belongs to the cluster with the nearest mean. Following are the steps in K-means clustering.

Step1: Read Image
Step2: Convert Image from RGB Color Space to L*a*b* Color Space: This

conversion enables to quantify the visual differences present in the RGB image.

Step 3: Classify the Colors in 'a*b*' Space Using K-Means Clustering. K-means clustering treats each object as having a location in space. K-means finds partitions such that objects within each cluster are as close to each other as possible, and as far from objects in other clusters as possible. Since the color information exists in the 'a*b*' space, the objects of interest are the pixels with 'a*' and 'b*' values. The output of *k-means* is the set [cluster_index cluster_center].

Step 4: Label Every Pixel in the Image Using the Results from K-means: For every object in the input image, k-means returns an index corresponding to a cluster and labels every pixel in the image with its cluster_index.

Step 5: Create Images that Segment the original image by Color: This step will result in k number of images each of which is a segment of the original image that are partitioned by color.

When the segmentation is completed, one of the clusters contains the diseased spots being extracted. This image is saved and considered for calculating A_D

(4) Calculating A_T and A_D

In image processing terminology area of a binary image is the total number of *on* pixels in the image [18]. Hence, the original resized image is converted to binary image such that the pixels corresponding to the leaf image are *on.* From this image total leaf area (A_T) is calculated. Similarly, the output image from color image segmentation, containing the disease spots, is used to calculate total disease area (A_D).

(5) Disease grading by Fuzzy Logic

Once A_T and A_D are known, the percent-infection (PI) is calculated by applying the formula (1).

$PI = (A_D / A_T) * 100$ . . . (1)

Now that, the Grade of the disease has to be determined from PI. Fuzzy Logic has been employed for this purpose.

Fuzzy Logic (FL) –

FL, which was first introduced by Lotfi Zadeh (1965), is used to handle uncertainty, ambiguity and vagueness. It provides a means of translating qualitative and imprecise information into quantitative (linguistic) terms [4]. Fuzzy set theory and fuzzy logic provide powerful tools to represent and process human knowledge in the form of fuzzy IF-THEN rules.

Over the past few decades, *fuzzy logic* has been used in a wide range of problem domains. The areas of applications are very wide: process control, management and decision making, operations research, pattern recognition and classification. In the lack of precise mathematical model which will describe behavior of the system, Fuzzy Logic is a good "weapon" to solve the problem: it allows using *logic if-then rules* to describe the system's behavior.

From the literature survey, it has been proved that fuzzy logic can be inculcated effectively and efficiently in the agriculture domain covering a wide range of precision agriculture applications such as texture analysis, agriculture produce grading, effective use of herbicide sprayers in disease control etc. Hence, in the present work Fuzzy Logic (FL) is used for the purpose of disease grading.

RESULTS AND ANALYSIS
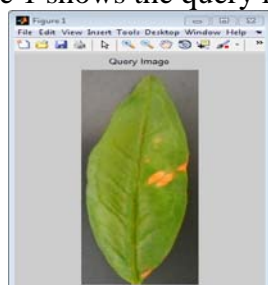### (1) Image acquisition

Figure 1 shows the query image.

Fig1. Query Image

(2) Image Pre-processing
A. Resize

The image is resized to a resolution of [200 250]. Figure 2 shows the result of resizing for the sample query image.
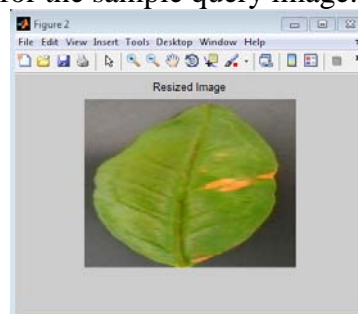

Fig2. Resized image

A. Filtering

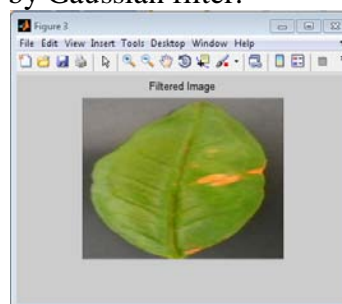Figure 3 shows the image that has been filtered by Gaussian filter.

Fig3. Gaussian Filtered Image

(3) Color image segmentation

K-means segmentation algorithm requires users to select the value 'k'. The correct choice of k is often ambiguous. Increasing k will always reduce the amount of error in the resulting clustering, to the extreme case of zero error if each data point is considered its own cluster (i.e., when k equals the number of data points, n). Intuitively then, the optimal choice of k will strike a balance between maximum compression of the data using a single cluster, and maximum accuracy by assigning each data point to its own cluster.

After some trial and error method, for the current work, value of K is chosen as 10 and the corresponding results are shown in Annexure 2 in the appendix where the figure (a) shows the L*a*b converted image. Figure (b) shows the image labeled by cluster index. Figures (c) through (l) shows segmentation results.

From these figures, it can be seen that the cluster 3 contains the disease spots being extracted and the same is displayed in Figure 4.
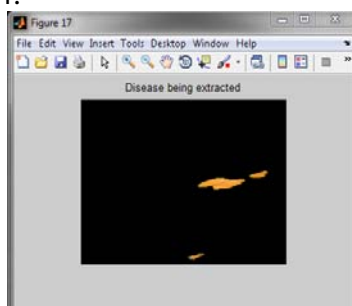

Fig4. Disease portion extracted

(4) Calculating A_T and A_D

Total Leaf Area (A_T)
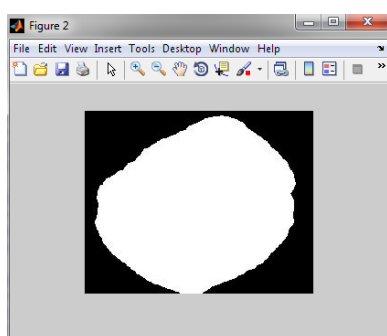
Figure 5 shows the binary image of the original resized image.

Fig5. Binary version of the query image

From this figure, the value of total leaf area is:

Total leaf area (T_A) = 30468 pixels

Total Disease Area (A_D)

Figure 6 shows the binary image of the disease portion.
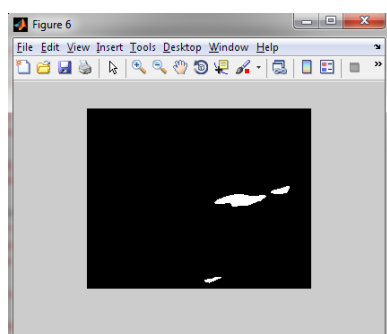
Fig6. Binary version of the disease portion

From this figure, the value of total disease area is:

Total leaf area (T_D) = 682 pixels

(5) Disease grading by Fuzzy Logic

From (1), Percent-infection is given by

$$PI = (A_D / A_T) * 100$$
$$= (682 / 30468) * 100$$
$$= 2.238414 \%$$

A Fuzzy Inference System (FIS) is developed for disease grading by referring to the disease scoring scale in Table I. For the FIS for disease grading, input variable is Percent Infection and output variable is Grade. Triangular membership functions are used to define the variables and six fuzzy rules are set to grade the disease. Figure 7 shows the result of grading. Also, the Percent-Infection and the corresponding Disease Grade will be displayed in a separate text file.
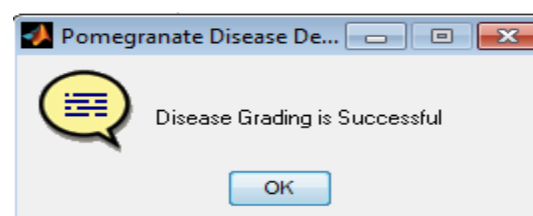
Percent-Infection= 2.238414%
Disease Grade = 1.500000e+000

Fig7. Result of Disease Grading

From the result, it can be observed that the accurate values of percent-infection and disease grade are obtained with which a proper treatment advisory can be given thereby eliminating eh above said problems.
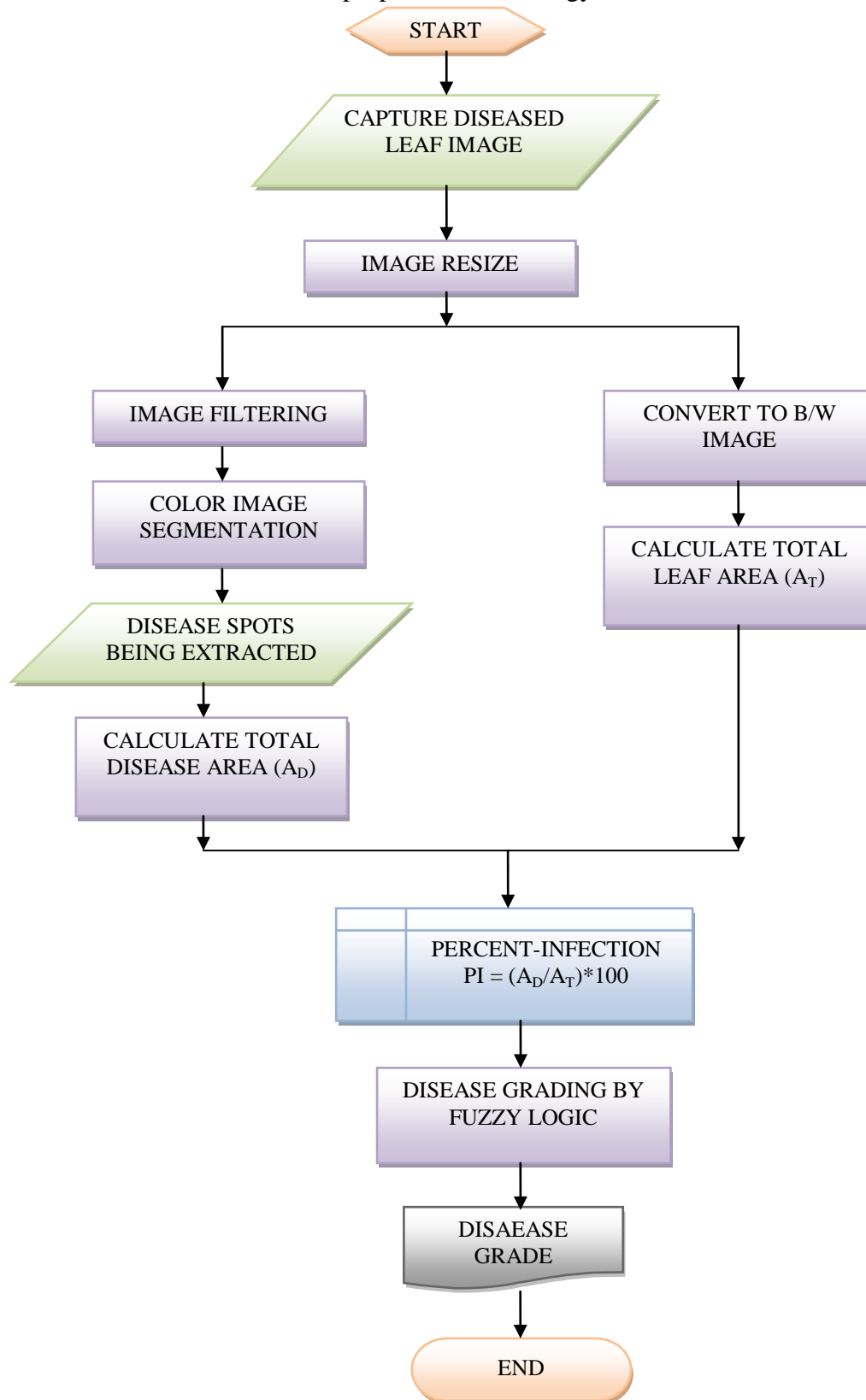
CONCLUSION

As it is realized throughout this paper, an approach to automatically grade the disease on plant leaves is very much essential in the present scenario. The Grading System built by Machine Vision and Fuzzy Logic is very useful for grading the disease. This kind of expert system is going to help pathologists as it overcomes almost all the disadvantages of manual grading in terms of complexity and time. The observed results through experiments are found to be accurate and satisfactory.
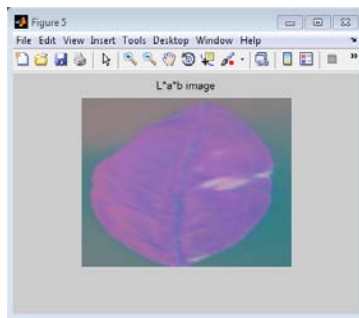
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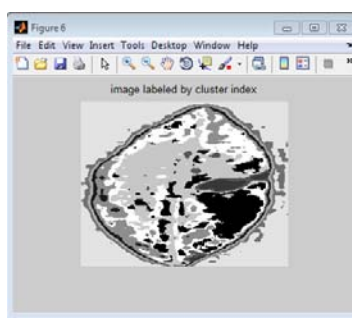
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APPENDIX

Annexure 1: Flow chart of the proposed methodology

```
                          START
                            │
                            ▼
              CAPTURE DISEASED LEAF IMAGE
                            │
                            ▼
                      IMAGE RESIZE
                 ┌──────────┴──────────┐
                 ▼                     ▼
          IMAGE FILTERING       CONVERT TO B/W
                 │                  IMAGE
                 ▼                     │
          COLOR IMAGE                  ▼
          SEGMENTATION          CALCULATE TOTAL
                 │              LEAF AREA (A_T)
                 ▼                     │
          DISEASE SPOTS                │
          BEING EXTRACTED              │
                 │                     │
                 ▼                     │
          CALCULATE TOTAL              │
          DISEASE AREA (A_D)           │
                 └──────────┬──────────┘
                            ▼
                  PERCENT-INFECTION
                  PI = (A_D/A_T)*100
                            │
                            ▼
                  DISEASE GRADING BY
                     FUZZY LOGIC
                            │
                            ▼
                     DISAEASE
                      GRADE
                            │
                            ▼
                         END
```

Where A_T = total leaf area, A_D = total disease area, $PI = (A_D/A_T)*100$
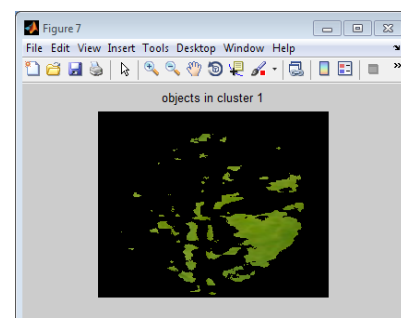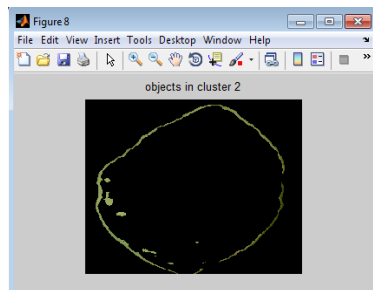
Annexure 2: Segmentation results for the Query image
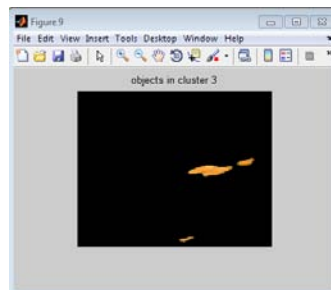

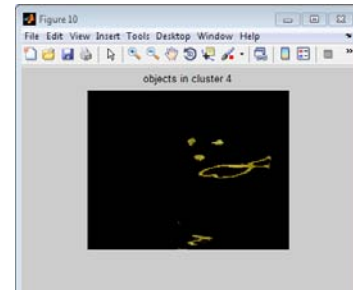(a) LAB image

(b) Cluster index Image
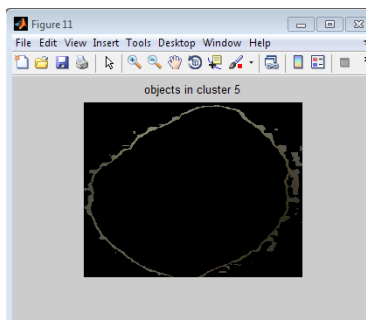
(c) Objects in Cluster 1
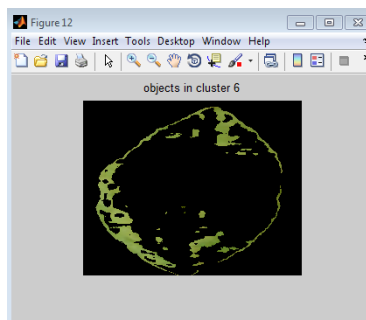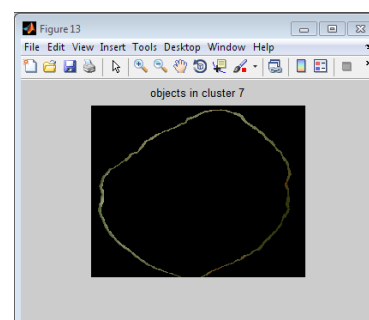
(d) Objects in Cluster 2

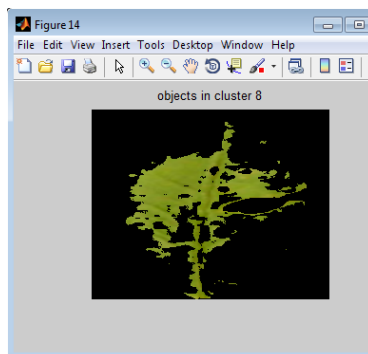(e) Objects in Cluster 3

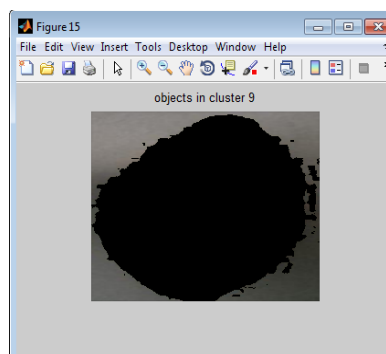(f) Objects in Cluster 4

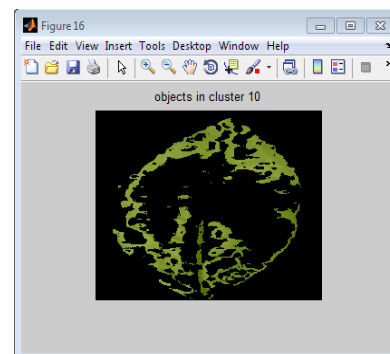(g) Objects in Cluster 5

(h) Objects in Cluster 6

(i) Objects in Cluster 7

(j) Objects in Cluster 8

(k) Objects in Cluster 9

(l) Objects in Cluster 10