Computing (2018) 100:1189–1201
https://doi.org/10.1007/s00607-018-0638-1

Computer vision based technique for identification and quantification of powdery mildew disease in cherry leaves

Namita Sengar[1] · **Malay Kishore Dutta**[1] · **Carlos M. Travieso**[2]

Received: 29 January 2018 / Accepted: 15 June 2018 / Published online: 28 June 2018

Abstract
There are different reasons like pests, weeds, and diseases which are responsible for the loss of crop production. Identification and detection of different plant diseases is a difficult task in a large crop field and it also requires an expert manpower. In this paper, the proposed method uses adaptive intensity based thresholding for automatic segmentation of powdery mildew disease which makes this method invariant to image quality and noise. After the segmentation of powdery mildew disease from leaf images, the affected area is quantified which makes this method efficient for grading the level of disease infection. The proposed method is tested on the comprehensive dataset of leaf images of cherry crops, which achieved good accuracy of 99%. The experimental results indicate that proposed method for segmentation of powdery mildew disease affected area from leaf image of cherry crops is convincing and computationally cheap.

Keywords Image processing · Powdery mildew · Cherry · Disease quantification

Mathematics Subject Classification 68-04 Explicit machine computation and programs (not the theory of computation or programming)

✉ Malay Kishore Dutta
malaykishoredutta@gmail.com

Namita Sengar
sengarnamita35@gmail.com

Carlos M. Travieso
carlos.travieso@ulpgc.es

1 Department of Electronics and Communication Engineering, Amity University, Noida, India

2 Signals and Communication Department, IDeTIC, University of Las Palmas de Gran Canaria, Las Palmas de Gran Canaria, Spain

1 Introduction

Plant diseases are one of the main reasons which cause a major economic loss in agriculture, which is about 33 billion dollars/year only from plant pathogens [1]. In India pests, weeds and plant diseases are the major reasons for loss of 15–25% of the potential crop production [2]. The cause of these plant diseases and their damage is fungal infections, viral infections, bacterial infection and infestations by insects. Infection causes a significant agronomic impact on different parts of the plant [3]. Pathogens can also be spread through ornamental plants, which act as a host for this infection.

Infectious plants are common, which encourages us to work on a system for early disease detection. This kind of system is proposed in this work which can aid in decreasing losses caused by plant diseases discussed above [4]. Identification, prevention and treatment of disease is the basic and most important pattern to follow for safety and improvement in quality of crops [5].

Visual inspection is the first and the most prominent method to identify leaf infection, but it has a drawback that it relies on expert manpower and number of costly devices [6]. Another system includes diagnosis of leaf infection using chemical methods which is destructive and requires a lot of experiments. Chemical methods are not suitable for real time diagnosis of plant diseases. For real time diagnosis image processing provides a non-destructive method for detection of diseases in plants by using different discriminatory features between healthy and unhealthy plants.

To study in detail about these discriminatory features in plants analysis of different parts of the crops is the best route map. There are many chemical, biochemical and microbiological methods, which are expensive, tedious, destructive, time consuming and labor-intensive, which needs experts. These methods are widespread for crop quality assessment but due to their expert needs and cost many non-invasive, fast and low cost measurement methods are being developed for continuous determination of crop quality [7]. Bai et al. proposed a method for detection of disease in cucumber by using neighbourhood grayscale information and fuzzy clustering segmentation for disease segmentation in cucumber leaf [8]. Wang et al. uses different type of neural network to differentiate between wheat stripe rust and wheat leaf rust and also differentiate grape powdery mildew and grape downy mildew using color based features [9]. Sena Jr et al. proposed a method which aims to discriminate between maize plants affected by fall armyworm from healthy plants using image processing [10]. Zhang et al. aims for segmenting and classifying lesions in citrus leaves, which is divided in two parts, the first part separates disease spots from the rest of the part of leaf which is done by using threshold, second part performs classification for discrimination between true lesions on leaf [11]. Khirade and Patil [12] presented artificial intelligence based technique for detection of plant disease from leaf images. Xu et al. [13] presented an interesting method for detection of nitrogen and potassium deficiencies in tomato crops. In this work, texture features were extracted from Fourier transform and wavelet domain using difference operators. Features selected by genetic algorithm were subjected to k-nearest neighbour classifier for final identification. Camargo and Smith [14] developed an image processing based algorithm for identification the visual symptoms of plant diseases from colored leaf images. Weizheng et al. [15] designed an algorithm for quantification of lesions in soybean leaves. Many leaf diseases such as powdery mildew, downy mildew, leaf scorch can be found in plants. The powdery mildew on leaf surface covers the area of leaf which serves as an obstacle in process of photosynthesis. There might be delay and improper judgement in the disease detection of plant leaves which might lead to lower productive crop quality and crop failures. Therefore an automated system is required to detect the disease so that proper measures could be taken before hand [16, 17].

The main contribution of this work is the automated segmentation of powdery mildew disease affected area from leaf image of cherry using adaptive intensity based method. The thresholding parameters for gray level slicing are calculated using local features of leaf image which makes the proposed system fully automatic and invariant under different environmental conditions. Prior to segmentation of powdery mildew disease affected area, background and other noises were segmented for accurate segmentation. Another significant contribution of proposed method that it also quantized the ratio of disease affected area to healthy leaf area. The proposed method includes segmentation of powdery mildew disease segmentation using adaptive intensity based thresholding which is computationally cheap for real time applications.

In the remaining portion of the paper we will be discussing about, a detailed description of the proposed method and techniques used (Sect. 1.1 to Sect. 1.3), experimental results are explained according to the experimentation process used (Sect. 2) and last is the conclusion derived from all the results (Sect. 3).

1.1 Proposed method

The proposed method is divided in 2 segments: Firstly, segmentation of disease effected area, Secondly, quantification of infected area. Initially shadow and another noise is removed from background using ‘a’ channel of lab converted image then disease area is segmented using intensity based thresholding from the same channel.

Figure 1 shows the block diagram of proposed method for detection and quantization of powdery mildew disease in cherry leaves. To analyse disease affected area, quantization of is performed by using ratio of disease area to healthy area (Figs. 2, 3).

1.2 Region of interest (ROI) segmentation

Method proposed in this paper takes the leaf area as the region of interest (ROI) but it also contains some background noise. An input image used for ROI segmentation is the coloured image of cherry leaf samples. The true colour RGB image is converted into Lab colour space model, which has three dimensions. The three dimensions are, L for lightness and ***a*** for green–red and ***b*** for the blue-yellow color opponents. Algorithm 1 explains the steps of the proposed method of ROI segmentation and powdery disease segmentation from the sample images.

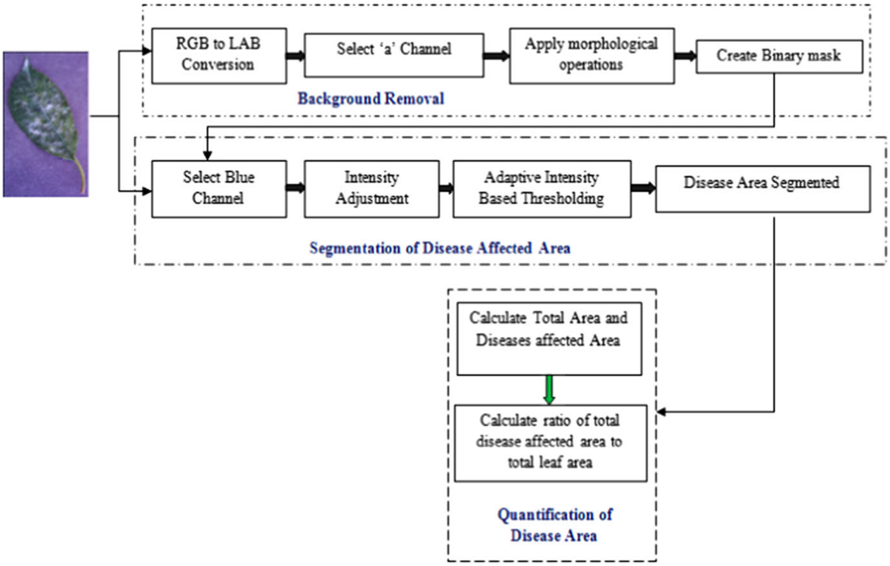


Fig. 1 Block diagram of proposed powdery mildew disease detection method

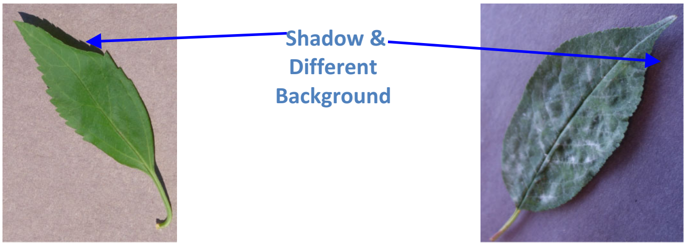
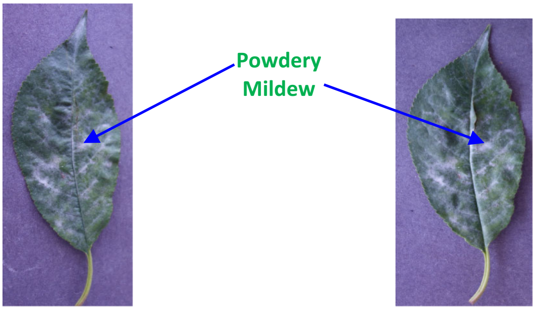


Fig. 2 Two sample images of healthy leaf and powdery mildew disease affected area of cherry leaf

Fig. 3 Two sample images of powdery mildew disease affected leaf of cherry



Algorithm 1: ROI (leaf) - Segmentation of disease area and quantification

Step 1: *Load the RGB colour image I_{RGB} of the leaf sample.*
Step2: *To create binary mask to remove background noise, RGB image I_{RGB} is converted into LAB*
Color image is transformed into Lab color space as follows:

$$L = \begin{cases} 116\left(\frac{y}{y_n}^{\frac{1}{3}}\right) - 16 & if\ \frac{y}{y_n} > 0.008856 \\ 903.2\left(\frac{y}{y_n}\right) & if\ \frac{y}{y_n} \le 0.008856 \end{cases}$$

$$a = 500 \times \left(f\left(\frac{x}{x_n}\right) - f\left(\frac{y}{y_n}\right)\right)$$

$$b = 200 \times \left(f\left(\frac{y}{y_n}\right) - f\left(\frac{z}{z_n}\right)\right)$$

In Lab color space, L is lightness, a and b for the color opponents green–red and blue–yellow. x_n y_n and z_n the XYZ tristimulus values. The values are:

$$x_n = 95.047$$
$$y_n = 100.000$$
$$z_n = 108.883$$

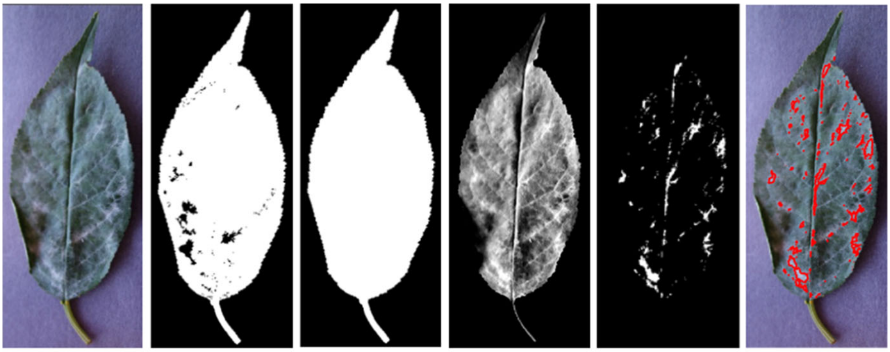
*(*The subscript n means "normalized value")*

CIE XYZ (Tristimulus values) is a device invariant color representation. It serves as a standard reference against which many other color spaces are defined.

Step 3: *Select "a" channel image*
Step 4: *Apply morphological operations hole filling and erosion with structuring element of shape 'disk' with size 5 to remove the unwanted noise*
Step 5: *Apply binary mask to "a" channel image*
Step 6: *Select blue channel image (I_b)*
***Step** 7: Apply intensity based thresholding to segment disease area by using following threshold*
Th=maximum intensity(I_b)-0.15(maximum intensity(I_b))*
Step 8: *Calculate ratio of disease effected area to healthy area*

In this proposed method Lab color space model removes the background noise which contains shadow and uneven background. From this image obtained from Lab color space model channel 'a' is selected. Channel 'a' contains less background noise and covers prominent leaf area. To create binary mask of actual leaf area some morphological operations like holes filling and erosion is applied which helps provide a perfect mask of leaf area. Then, blue channel image is selected for segmentation of disease area as in blue channel area affect of powdery mildew disease is more prominent from other channel images. Adaptive intensity based thresholding is used to segment the disease affected area which depends on local parameters of image, which make this different from any other type of noise in image and is invariant to image quality.

Binary mask of ROI is created by using 'a' channel image and disease area is segmented using blue channel image as explained in Algorithm 1, shown in Fig. 4.



(a) (b) (c) (d) (e) (f)

Fig. 4 **a** Original image, **b** ‘a’ channel image, **c** binary mask of ROI, **d** blue channel image, **e** segmented disease area and **f** boundary of segmented disease area

Figure 4 represent the step wise result of proposed algorithm in which Fig. 4a shows the original cherry leaf image affected with powdery mildew disease, Fig. 4b shows the ‘a’ channel image of Lab color space model and Fig. 4c shows the mask of original leaf image which have uniform background. Figure 4e represents the segmented disease area take out from blue channel image (extracted from RGB image of leaf) shown in Fig. 4d. Figure 4f enlightens the disease area, found in Fig. 4e, on the disease effected leaf.

1.3 Quantification of disease effected area

After the segmentation of powdery mildew diseases in cherry leaf image, disease affected area is quantified for final decision. The ratio of disease affected area and total area of leaf is calculated to quantify that how much area of leaf is affected by powdery mildew disease. Total area of leaf does not include background area of leaf. For powdery mildew disease leaf, this area should be high and for healthy leaf it should be approx to zero. Before quantification of disease area, powdery mildew disease includes:

(a) Background and shadow removal: From Lab color space module ‘a’ channel is used to remove the unwanted noise as different background or shadow.
(b) Segmentation of disease affected area: Powdery mildew affected area is segmented in cherry leaf images by using adaptive intensity based thresholding.

Disease affected area ratio in leaf is calculated as follows

$$\text{Disease affected Area ratio} = \frac{\text{Disease affected Area}}{\text{Total Area}}$$

This parameter is used to make final decision whether input leaf is healthy or still disease affected and gives a quantitative parameter for decision support.

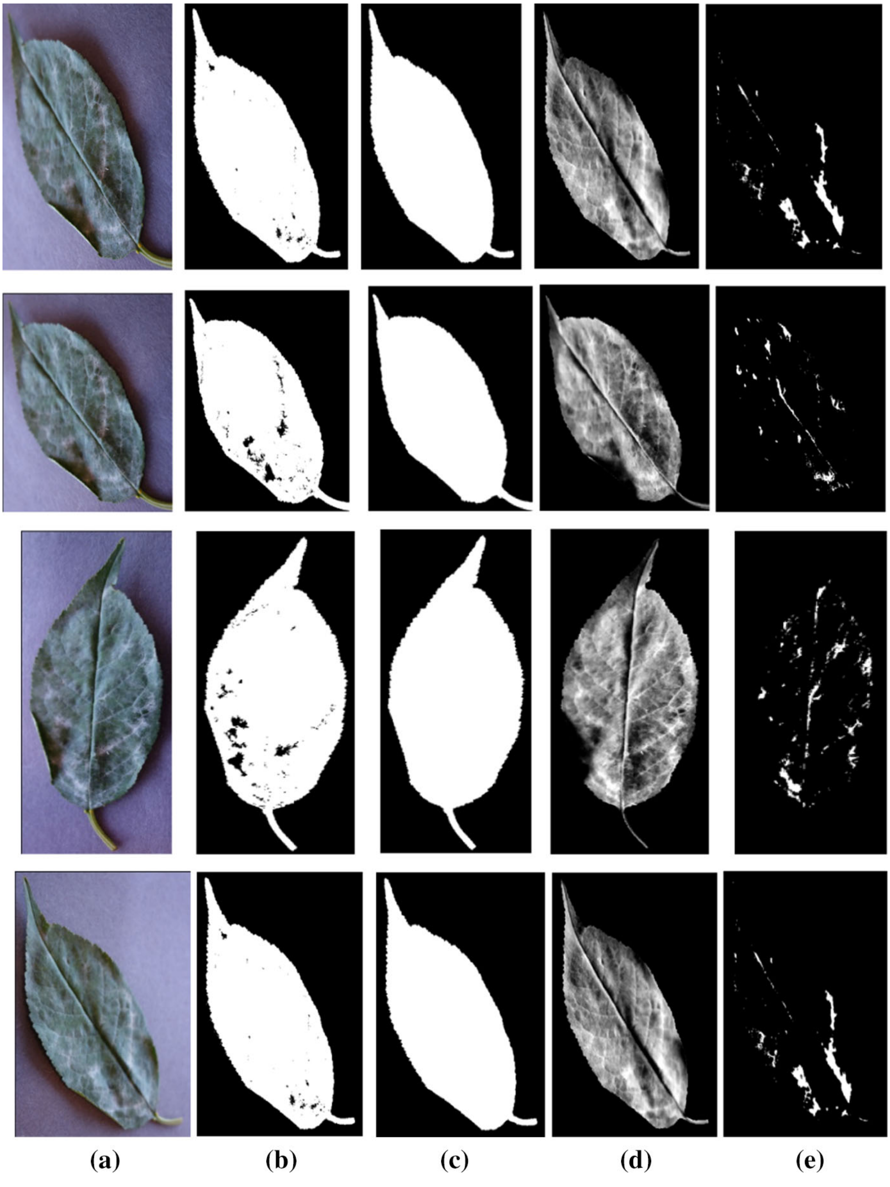


Fig. 5 Powdery mildew disease affected area **a** original image, **b** 'a' channel image, **c** binary mask of ROI, **d** blue channel image and **e** segmented disease area

2 Results and discussion

The proposed image processing based method for detection of powdery mildew disease in cherry crops is tested on leaf images of cherry crops obtained from plant village database associated with Land Grant Universities in the USA [14]. Sony DSC

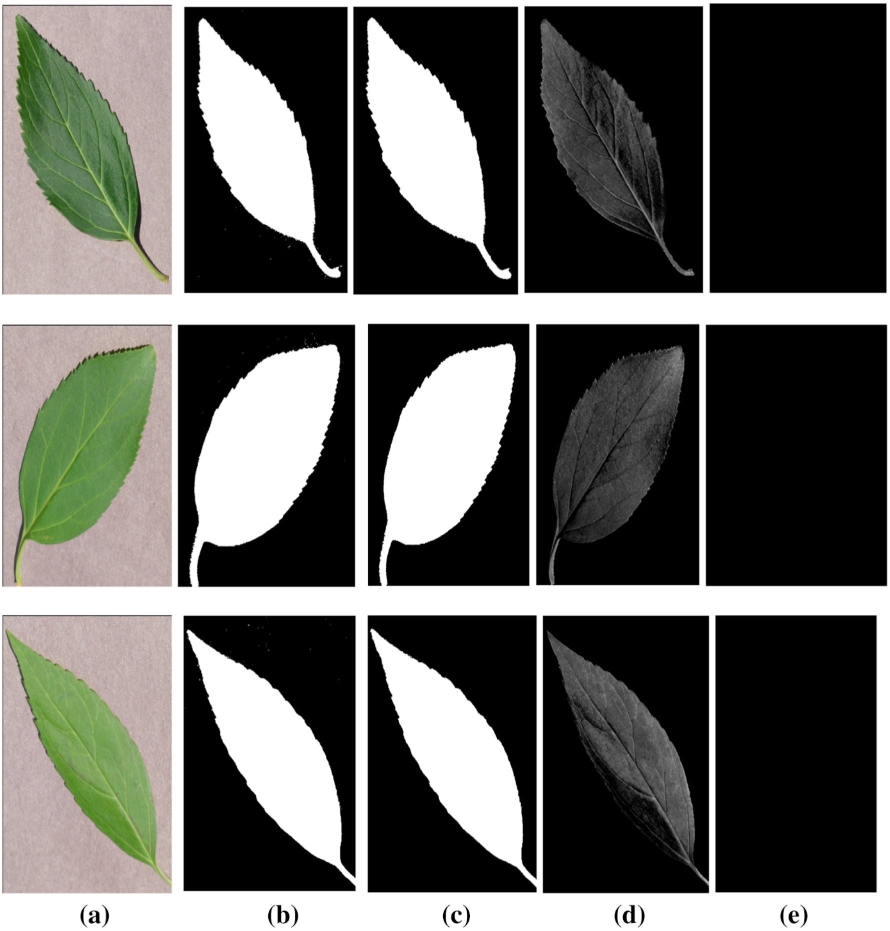


Fig. 6 Powdery mildew disease affected area **a** original image, **b** ‘a’ channel image, **c** binary mask of ROI, **d** blue channel image and **e** segmented disease area

- Rx100/13 20.2 megapixels’ camera was used to capture leaf images of different resolutions in JPEG format. The performance of proposed imaging method of disease identification is tested on 50 healthy leaves and 50 powdery mildew diseases affected leaves of cherry crops. Figure 5 shows results of segmentation for identification of powdery mildew disease from leaf image of cherry. It can be seen in the Fig. 5 that powdery mildew leaves are correctly segmented from disease affected leaves for identification of the disease.

Figures 5 and 6 represent the stepwise result for affected leaves and healthy leaves. As shown for healthy cherry leaves nothing is detected while for disease affected leaves, disease area is segmented.

Table 1 shows the performance of proposed method in terms of quantization of disease area. For healthy leaves ratio is almost zero while for powdery mildew disease affected leaves ratio is more than zero.

Table 1 Result of proposed method in terms of disease area (for 25 samples of each category)

Samples	Total area	Disease affected area	Ratio
Powdery mildew disease affected cherry leaves			
Sample 1	194,942	12,701	0.0652
Sample 2	256,011	8531	0.0333
Sample 3	127,751	5131	0.0402
Sample 4	173,255	7956	0.0459
Sample 5	198,672	11,696	0.0589
Sample 6	147,899	7589	0.0513
Sample 7	116,788	10,577	0.0905
Sample 8	184,667	11,790	0.0638
Sample 9	149,478	4687	0.0313
Sample 10	117,378	5886	0.0501
Sample 11	159,579	6958	0.0436
Sample 12	126,438	5972	0.0472
Sample 13	116,594	6846	0.0587
Sample 14	156,386	4978	0.0318
Sample 15	184,838	6948	0.0375
Sample 16	115,853	7968	0.0687
Sample 17	166,731	9586	0.0574
Sample 18	163,786	6958	0.0421
Sample 19	116,788	7166	0.0613
Sample 20	138,581	4768	0.0344
Sample 21	157,472	8326	0.0528
Sample 22	176,881	7375	0.0416
Sample 23	115,888	4879	0.0421
Sample 24	159,065	6238	0.0392
Sample 25	158,973	6852	0.0431
Healthy cherry leaves			
Sample 1	133,287	0	0
Sample 2	122,728	0	0
Sample 3	124,591	1	0.000000802
Sample 4	139,692	0	0
Sample 5	154,517	0	0
Sample 6	128,864	3	0.000023
Sample 7	125,678	0	0
Sample 8	153,727	0	0
Sample 9	158,947	0	0
Sample 10	128,946	0	0
Sample 11	149,858	0	0

Table 1 continued

Samples	Total area	Disease affected area	Ratio
Sample 12	157,368	0	0
Sample 13	126,471	0	0
Sample 14	116,874	0	0
Sample 15	126,389	0	0
Sample 16	127,378	0	0
Sample 17	137,367	0	0
Sample 18	148,959	0	0
Sample 19	138,953	0	0
Sample 20	112,795	0	0
Sample 21	168,999	0	0
Sample 22	157,992	0	0
Sample 23	138,378	0	0
Sample 24	163,789	0	0
Sample 25	137,277	0	0

Table 2 Performance of proposed imaging method for identification of powdery mildew disease from leaf image of cherry crops

Total number of sample images		Correctly identified by proposed method	Sensitivity (%)	Specificity (%)	Accuracy (%)
Healthy leaves	50	49	100	98	99
Disease affected leaves	50	50			

Table 2 represent the result of the proposed imaging method achieved 99% accuracy with 100% sensitivity and 98% specificity which are encouraging and convincing as well for automated identification of powdery mildew disease from cherry leaves.

Table 3 shows the computational time required for segmentation of powdery mildew from healthy/disease affected leaf images. The algorithms were implemented in MATLAB R2012b (Math Works) software using CPU@ 2.3 GHz, 4 GB RAM, 32-bit operating system. It can be clearly seen in Table 3 that proposed automated imaging method is computationally cheap and can be used for real time applications. The results indicate that the proposed method gives good result for powdery mildew disease identification.

Table 4 represent the comparison of existing algorithm for plant disease detection with proposed algorithm. It shows that the proposed algorithm has competitive results in terms of accuracy and it also contains quantization of disease effected area.

Table 3 Computation time required by proposed algorithm for powdery mildew disease detection

Hardware: CPU@ 2.3 GHz, 4 Gb RAM, 32 bit operating system

Sample leaf image	Healthy/disease affected leaf	Computational time (in s)
Image 1	Healthy leaf	1.05478
Image 2	Healthy leaf	1.14789
Image 3	Healthy leaf	1.03799
Image 4	Healthy leaf	1.07989
Image 5	Healthy leaf	1.14669
Image 6	Healthy leaf	1.26888
Image 7	Healthy leaf	1.00659
Image 8	Healthy leaf	1.03667
Image 9	Healthy leaf	1.15677
Image 10	Healthy leaf	1.04377
Image 11	Healthy leaf	1.15676
Image 12	Healthy leaf	1.02356
Image 13	Disease affected leaf	1.00035
Image 14	Disease affected leaf	1.00255
Image 15	Disease affected leaf	1.15668
Image 16	Disease affected leaf	1.15677
Image 17	Disease affected leaf	1.14588
Image 18	Disease affected leaf	1.00255
Image 19	Disease affected leaf	1.23561
Image 20	Disease affected leaf	1.26898
Image 21	Disease affected Leaf	1.05678
Image 22	Disease affected leaf	1.14567
Image 23	Disease affected leaf	1.25789
Image 24	Disease affected leaf	1.15789

3 Conclusion

For optimum use of pesticide and to minimize loss of crops, identification of crop diseases plays an important role. The proposed work presents an imaging method for automated identification and quantification of powdery mildew disease from leaf image of cherry crops. Adaptive intensity based method was used for segmentation of disease affected area from leaf images. Thresholding parameters were calculated from local features of leaf image to make the proposed system fully automatic and invariant under environmental conditions. Prior to segmentation of from leaf, thresholding and morphological operations were applied on selected suitable channel of input color image for background and noise removal. The experimental results indicated that proposed method is efficient and computationally less costly, which is

Table 4 Table of comparison between method proposed with previously reported methods

Research papers	Crop	Method used	Dataset used	Result
Wang et al. [8]	Detection of spot diseases from cucumber leaf images	Fuzzy clustering segmentation method based on neighborhood grayscale information	129 cucumber disease images	Average segmentation error 0.12%
Garcia et al. [18]	Identification of multiple plant diseases	Colour transformations, colour histograms and a pairwise-based classification system	Local Dataset of 82 different disorders distributed over 12 plant species	Max accuracy: 76%
Kim et al. [19]	Classification of Grapefruit peel disease	Color texture feature analysis	Local dataset of 39 images	Accuracy—96%
Camargo and Smith [14]	Identification of nitrogen and potassium deficient tomatoes	Color and texture features of leaves	80 samples per class were collected for training and testing	Accuracy –95%
Proposed method	Identification and quantification of disease area in cherry leaves	Noise removal, disease area detection using intensity based thresholding and quantization of disease effected area	100 images	Accuracy—99%

suitable for real time application of identification of powdery mildew disease in cherry crop.

References

1. Popp J, Pető K, Nagy J (2013) Pesticide productivity and food security. A review. Agron Sustain Dev 33:243–255
2. State of Indian Agriculture, Government of India. http://www.prsindia.org/administrator/uploads/general/1517552563~~State%20of%20Agriculture%20in%20India.pdf. Accessed 28 Mar 2018
3. López MM, Bertolini E, Olmos A, Caruso P, Gorris MT, Llop P, Penyalver R, Cambra M (2003) Innovative tools for detection of plant pathogenic viruses and bacteria. Int Microbiol 6:233–243
4. Sankaran S, Mishra A, Ehsani R, Davis C (2010) A review of advanced techniques for detecting plant diseases. Comput Electron Agric 72:1–13
5. Pertot I, Kuflik T, Gordon I, Freeman S, Elad Y (2012) Identificator: a web-based tool for visual plant disease identification, a proof of concept with a case study on strawberry. Comput Electron Agric 84:144–154
6. Bock CH, Poole GH, Parker PE, Gottwald TR (2010) Plant disease severity estimated visually, by digital photography and image analysis, and by hyperspectral imaging. Crit Rev Plant Sci 29:59–107
7. Bai JX, Li X, Fu Z, Lv X, Zhang L (2017) A fuzzy clustering segmentation method based on neighbourhood grayscale information for defining cucumber leaf spot disease images. Comput Electron Agric 136:157–165
8. Wang H, Li G, Ma Z, Li X (2012) Application of neural networks to image recognition of plant diseases. In: International conference on systems and informatics, Yantai, pp 2159–2164
9. Sena DG Jr, Pinto FAC, Queiroz DM, Viana PA (2003) Fall armyworm damaged maize plant identification using digital images. Biosyst Eng 85:449–454
10. Xu G, Zhang F, Shah SG, Ye Y, Mao H (2011) Use of leaf color images to identify nitrogen and potassium deficient tomatoes. Pattern Recognit Lett 2(32):1584–1590
11. Wiwart M, Fordonski G, Zuk-Golaszewska K, Suchowilska E (2009) Early diagnostics of macronutrient deficiencies in three legume species by color image analysis. Comput Electron Agric 65:125–132
12. Khirade SD, Patil AB (2015) Plant disease detection using image processing. In: IEEE international conference on computing communication control and automation, pp 768–771
13. Xu G, Zhang F, Shah SG, Ye Y, Mao H (2011) Use of leaf color images to identify nitrogen and potassium deficient tomatoes. Pattern Recognit Lett 32(11):1584–1590. https://doi.org/10.1016/j.patrec.2011.04.020
14. Camargo A, Smith JS (2009) An image-processing based algorithm to automatically identify plant disease visual symptoms, vol 17, no 1. Elsevier, Amsterdam, pp 9–21
15. Weizheng S, Yachun W, Zhanliang C, Hongda W (2008) Grading method of leaf spot disease based on image processing. In: 2008 international conference on computer science and software engineering. IEEE, Wuhan, pp 491–494
16. Zhou B, Xu J, Zhao J, Li A, Xia Q Research on cucumber downy mildew detection system based on SVM classification algorithm. In: 3rd international conference on material, mechanical and manufacturing engineering (IC3ME 2015)
17. Gupta V, Sengar N, Dutta MK, Travieso CM, Alonso JB (2017) Automated segmentation of powdery mildew disease from cherry leaves using image processing. In: 2017 international conference and workshop on bioinspired intelligence (IWOBI), Funchal, pp 1–4
18. Garcia J, Barbedo A, Koenigkan LV, Santos TT (2016) Identifying multiple plant diseases using digital image processing. Biosyst Eng 147:104–116
19. Kim DG, Burks TF, Qin J, Bulanon DM (2009) Classification of grapefruit peel diseases using color texture feature analysis. Int J Agric Biol Eng 2(3):41