Combined Approach of Image Enhancement and Wavelet Feature Extraction for Plant Leaf Classification

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Abstract: Complete environment system depends on various plants. Plants help to maintain ecological system by controlling pollution and providing oxygen etc. but due to inappropriate information about plant may lead to decreasing the number of plant species resulting in imbalance in ecological system. Hence an automated system is required for botanists to categorize plants for maintains the database for further researches. In this field, computer vision techniques have proven significant techniques. For plant classification, an automated system is presented using improved pre-processing (by improving image enhancement or filtering scheme). Furthermore, wavelet feature and local features are also combine for feature vector formulation. Finally, a comparative classification study is presented where KNN, Neural Network and SVM classifiers are implemented. experimental study shows that SVM provides better classification performance and further performance can be improved by using combined feature extraction model.

Keywords: plant leaf recognition; classification; image enhancement; image filtering; wavelet.

Introduction

Ecological system and environment of earth are dependent on surrounding atmosphere. For maintaining the healthy atmosphere, plants are key component and plays crucial role. On other hand, various plants provide support to medical application, help to meet daily life requirements such as food, timber, clothing etc. According to WHO (World Health Organization), most of the African and Asian population dependent on the natural medication system. Natural medical systems are very popular due to its significant healing nature, affordable and safety to human health. These plants carry significant information which can help to improve the development of human society. For availing all these advantages, identification of plants becomes a crucial and important task for researchers [1].

During last decade, worldwide pollution has grown drastically which causes various serious issues related to nature such as global warming. To overcome this issue of global warming various plants are present in natural system which can help to reduce it but due to inappropriate information about advantages of plant the plant classes are getting to be distinctly uncommon and a significant number of them are going to vanished. Hence there is a need to recognize and classify the plants based on their category which can help botanists for managing database for further research in this field. In this field of plant recognition and classification, various techniques have been presented which are based on the computer vision systems. Recently, significant amount of work has been presented in this field where computer vision techniques are utilized for plant leaf recognition. These techniques work in a flow where image acquisition, pre-processing, feature extraction and classification is performed. Each stage plays an important role to provide better classification performance for plant leaf detection. Hu et al. [3] presented a new approach for plant leaf identification by considering contour-based shape descriptor features. This technique is capable to extract the feature where image is invariant, rotated or scaled. Complete features are stored in a distance matrix. In next stage, feature selection is presented by applying dimension reduction methodology. This technique aimed on providing better classification in a limited time constraint using shape descriptor features. Similarly, Almeida et al. [4] presented a classification approach for plant leaf species identification using unsupervised learning scheme. For obtaining the better classification performance, a new model is developed for similarity measurement unlike conventional approach. Generally, conventional models use pairwise distance measurement for approximation. Furthermore, it was also suggested that image fusion also can improve the classification performance [8]. Belongie et al. [5] discussed about shape extraction and object matching for real-time application scenarios. This objective is obtained by applying two-fold strategy where object shape estimation and align transforms are applied. During this process, a shape context is inserted which helps to analyze object shape at each point. Belhumeur et al. [6] developed a scheme for plant species classification for real-time application and implemented it in Smithsonian Institution National Museum of Natural History to help botanists. This model is developed using an interface where three leaf datasets are considered. Each dataset is labeled and verified by US National Herbarium's botanists. Saitoh et al. [7] presented a classification and recognition system for wild flowers. This work uses two sets of images where single set contains closer angle acquired images. Furthermore, clustering technique is implemented for segmentation and feature analysis. Piecewise linear discriminant function is used for classification by extraction 10 linear features. However, still these classification approaches suffer from various issues which can degrade classification performance for the plant recognition system.

Issues and challenges

Conventional techniques for plant identification purely depend on computer vision applications. In some of scenarios computer vision system fails to generate promising results for recognition and classification. Noise in original image is a well-known issue in this field. During image acquisition, unwanted signals may contaminate input image quality which may lead to degraded performance for classification. These issues are addressed by developing image denoising or filtering schemes such as median filter, wavelet filters etc. Another issue depends on efficient feature extraction model where shape descriptor, texture features etc. are extracted but image scaling, orientation and rotation effect feature extraction performance. Hence an efficient approach is required for image feature extraction for varied acquisition conditions. Finally, classification performance is a challenging task which is mainly dependent on the pre-processing and feature extraction techniques. However, efficient improved classification performance may lead to improved classification accuracy such as multiclass classifiers.

In order to address these issues, here an improved model of pre-processing and feature extraction is presented. Pre-processing stage includes image smoothing, image enhancement etc. whereas feature extraction is carried out by applying wavelet transformation. Classification is carried out using SVM (Support Vector Machine) classifier. Rest of the article is organized as follows: section II presents proposed approach for plant recognition and classification, Section III provides experimental study and a comparative analysis for varied classifiers. Finally, section V gives concluding remarks of proposed plant recognition approach.

Proposed Model

This work mainly concentrates on plant leaf recognition and classification using computer vision application. To obtain this objective, an improved approach for image pre-processing is combined with wavelet based feature extraction technique. A complete overview of plant recognition architecture is given in figure 1.

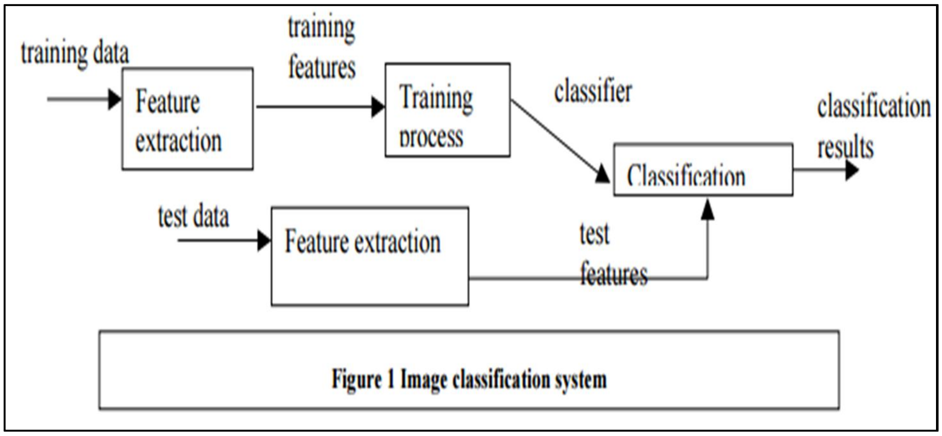


Figure 1. Plant Recognition system

This architecture follows a general process for image classification system as discussed in previous section. It is also analyzed that image pre-processing plays important role for classification, hence here we develop image denoising or image filtering model for maximizing the classification performance. This technique is discussed in next sub-section where input image is considered for processing and denoised image is obtained as the outcome.

Image denosing

This section presents image denoising model for plant leaf recognition systems. It is considered that plant leaf images are multivariate in nature which arises complexity during image denoising technique. Let us consider that input plant leaf image is denoted by $\mathbb{I}$ which can be expressed in the form of function such as:

$$f(x): \mathcal{D} \rightarrow \mathcal{S} = \{s_{min}, s_{min+1}, \dots, s_{max}\} \quad (1)$$

Where computation space is in discrete form denoted by $\mathcal{D}$ and considered domain definition is presented by f.Input images contain three different channels red, green and blue which are denoted by $\mathcal{S}$. In order to process this image further, original image is transformed into grayscale image where varied intensities of each pixel are analyzed. Let us assume that, at any point x, background noise is added to the original image which is expressed as:

$$f(x) = f_b(x) + n(x) \quad (2)$$

Background pixels are denoted by $f_b(x)$ at x point, added noise is denoted by $n(x)$. It can be defined in the form of function which is given as

$$f_p(x) = f_s(x) + f_{noise}(x) \quad (3)$$

Image structure is denoted by $f_s(x)$ and noise function is presented by $f_{noise}(x)$. Prior to image denoising general parameters such as grayscale conversion, edge detection and image smoothing are applied. For noise consideration, impulse model is applied here. To obtain image denoising performance, median filtering is applied. During pre-processing stage, noise generation model is implemented where artificial noise is generated in spikes form. These spikes are random in nature and gets generated during image acquisition. For noise generation, a specific amount of image pixels contaminated by selecting random values in the range of 0 to 255. This noise model can be represented as:

$$\mathbb{I}_n(i,j) = \begin{cases} \mathbb{I}(i,j) \; x \geq prob \\ \left(\mathbb{I}_r(i,j), \mathbb{I}_g(i,j), z\right) \; y < \frac{1}{3} \;\; x < prob \\ (\mathbb{I}_r(i,j), z, \mathbb{I}_b(i,j), z)) \; \frac{1}{3} \leq y < \frac{2}{3} \;\; x < prob \\ \left(z, \mathbb{I}_g(i,j), \mathbb{I}_b(i,j)\right) \frac{2}{3} \leq y \;\; x < prob \end{cases} \quad (4)$$

Where $prob$ denotes the noise probability in input image, $\mathbb{I}_r$ denotes red channel of the image, $\mathbb{I}_g$ denotes green channel and blue channel is denoted by $\mathbb{I}_b$. According to image size, x varies from 0 to 255 and noise probability varies from 0 to 1.

Improved Image Enhancement

In this work, a novel approach for image enhancement is presented for image filtering purpose. This technique is based on the entropy maximization approach which helps to improve the image quality for further processing. This objective is achieved by increasing the quantization resolution of each pixel for given image. Hence, pixel intensity amplitude estimation is a main task which improves image quality. This technique aims on the low-pass filtering and edge preserving nature by estimating continuous luminance for given input image. for any given input image luminance is modeled as expressed in Eq. (5).

$$\mathbb{I}(x,y) = \sum_{(i,j)\in S(x,y)} \alpha_{i,j} I(x+i, y+j) + \eta \quad (5)$$

Where $\alpha_{i,j}$ denotes image model parameters, pixel location is denoted by (x,y), $S(x,y)$ denotes neighbourhood location of processing pixels and η is the model fitting error. For noise estimation, least mean square estimation is developed which is expressed as:

$$\underset{\alpha}{argmin} \sum_{(x,y)\in S(x,y)} \left|\left|J(x,y) - \sum_{(i,j)\in S(x,y)} \alpha_{i,j} I(x+i, y+j)\right|\right|_2^2 \quad (6)$$

This model helps to minimize the error and performs image reconstruction of image. This can be expressed as

$$\underset{I}{min} ||I - AI||_2^2 + \lambda ||I - J||_2^2 \quad (7)$$

However, this model is not final restored model of image. for further improvement to this model, gray level transformation $T(.)$is applied. Let us consider that input image consists K number of gray level with a probability of P for reconstructed image. hence histogram equalization transform can be implemented as:

$$k = T(i) = K \int_0^i P(t)dt \quad (8)$$

During this process, tone-preserving is a key issue which is addressed here by applying discrete optimization model. For each restored image patch, luminance ratios are quantized into uniform bins. At this stage, gray level vectors are presented as $s = (s_1, s_2, \ldots, s_{K-1})$. Image enhancement model can be formulated by using proposed entropy maximization using an optimization problem given as:

$$\min_{s} \sum_{k=0}^{K-1} -P[s_k, s_{k+1}] \log P[s_k, s_{k+1}] \quad s.t.\ s_{k+1} - s_k \leq \tau\ \forall_k \tag{8}$$

τ denotes noise distortion parameter for given image.

Wavelet Feature Exxtraction

After applying efficient pre-processing steps, wavelet feature extraction model is implemented. Wavelet feature extraction model helps to obtain frequency domain feature parameters by decomposing image into multiple sub bands. A general architecture of wavelet feature extraction model is presented in figure 2 where input image is decomposed into two bands known as low and high band decomposition. Feature extraction process is presented as follows:

Input: Plant leaf category image **Output**: feature vector and decomposed image
Step 1: initialize decomposition step for each image Step 2: for $i = 1$ to total number of images Step 3: Scaling coefficient computation Step 4: detailed coefficient computation Step 5: end for // step 2 Step 6: updated coefficient for each image and vector formulation

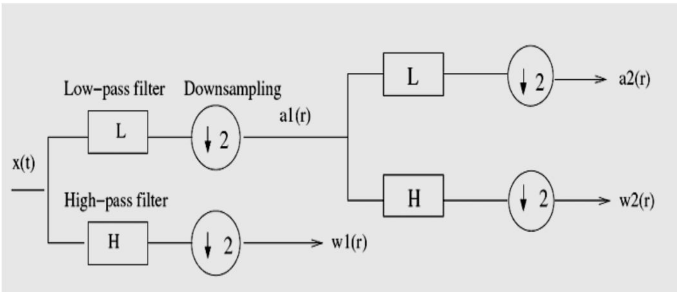


Figure 2. Wavelet feature extraction decomposition stage

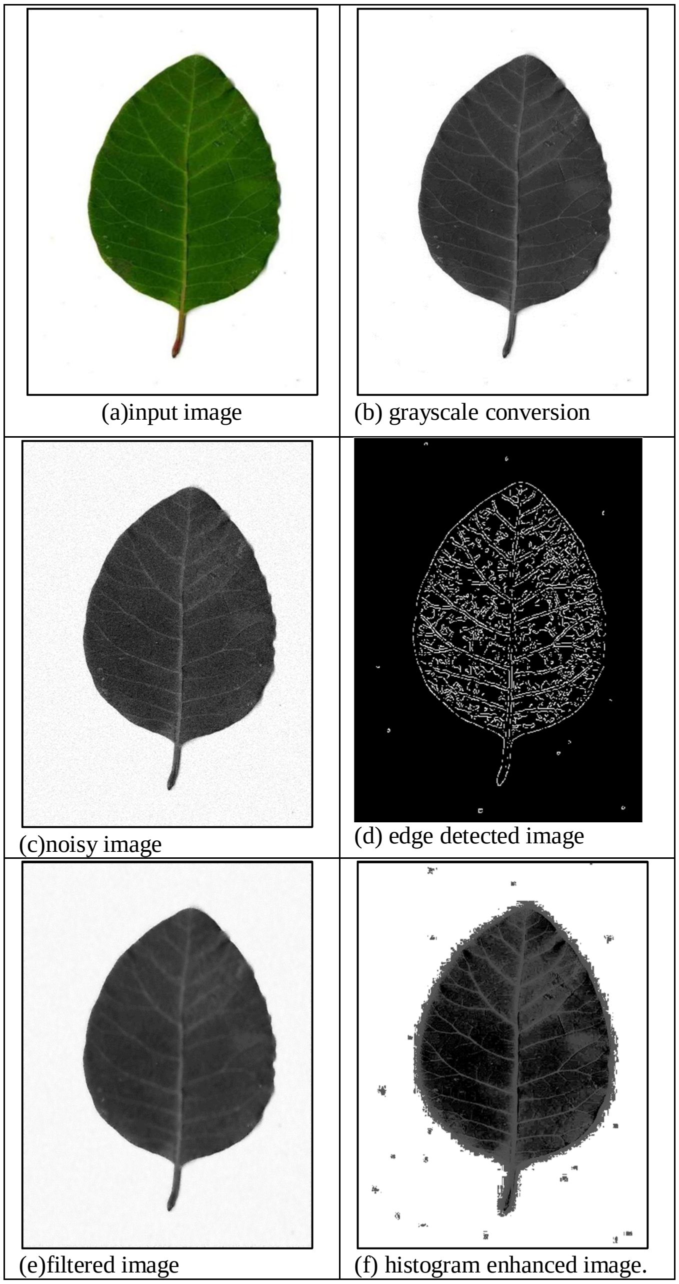
Experimental Study

This section provides extensive experimental study for plant leaf recognition and classification. Proposed approach is implemented using MATLAB tool on windows operating system with i5 intel processor with 8 GB RAM. For experimental study, various species are considered here. Table 1 shows total species and considered number of leaf for each category. Total number of training images are 237 and testing is applied for 65 images.

Table 1. Considered plant leaf images

Name of species	Considered samples for Training	Sample Image for Testing
Coggygria	54	10
Oleander	72	10
Opalus	17	10
Sativa	12	10
Serotina	14	10
Spinosa	11	5
Tobira	57	10

General pre-processing steps are applied here which includes grayscale conversion, edge detection, binary conversion and adding noise in original image data. Complete process is depicted in figure 3. Furthermore, adaptive image filtering and entropy maximization process is implemented for image enhancement. Feature extraction phase is completed using wavelet transform model. Figure 3(a) shows input original color image, 3(b) shows grayscale converted resampled image. In the next stage, noise is added to original grayscale converted image. after adding noise, edge detection scheme is applied to extract the main shape of input leaf image. This process is re-implemented after filtering stage to analyze the image quality. Finally, image histogram is computed and quality of image is enhanced by applying histogram equalization technique. Later, entropy maximization technique is implemented for image smoothing resulting in image quality improvement. According to computer vision based image classification stage, feature extraction is carried out using wavelet feature extraction.



(a)input image (b) grayscale conversion
(c)noisy image (d) edge detected image
(e)filtered image (f) histogram enhanced image.

Figure.3. image pre-processing stage

Wavelet feature extraction process is depicted in figure 4 where input image is decomposed in 4 sub bands. These bands are known as LL (Low-Low), LH (Low-High) and HL(High-Low). These bands contain complete information regarding image transformation hence considered as main feature vector for processing. To obtain decomposition, 'daubchies' wavelet decomposition model is applied. Along with wavelet feature extraction, other local feature extraction is also performed which includes contrast, correlation, Energy, homogeneity and entropy also computed. This combination of feature extraction helps to build a robust feature model. For considered sample image these features are presented in table 2.

Table 2. Local Feature Extraction

Feature name	**Computed Value**
Energy	0.49
Contrast	0.063
Correlation	1
Homogeneity	0.45
Entropy	11.28

Similarly, for this image, wavelet feature extraction process is also shown here.

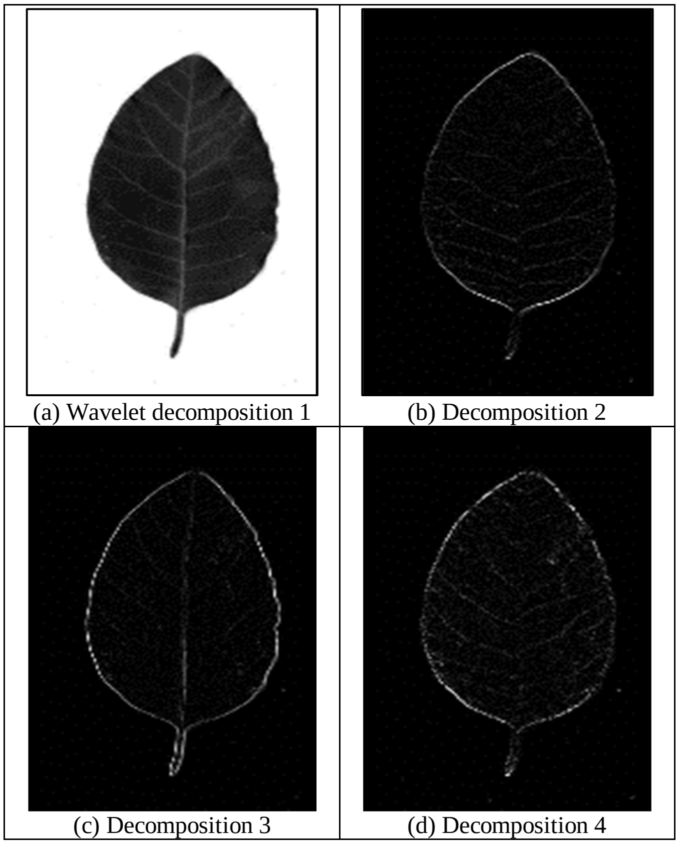


Figure.4. Wavelet Decomposition stage

Finally, a classification study is carried out where two experimental scenarios are created for same image database. In first experimental study, combination of image enhancement, wavelet and local feature extraction is not presented whereas second test scenario feature vector is considered by combining improved image pre-processing and wavelet feature extraction. Three different classifiers are considered for classification performance analysis. these classifiers are KNN, Neural Network and SVM (Support Vector Machine). Classification performance is computed by considering standard conventional performance measurement metrics i.e. True Positive Rate, False Positive Rate, Precision, Recall and classification accuracy for all three classifiers.

First of all, performance is measured for test case 1 where feature vector is not considered in a combined form.

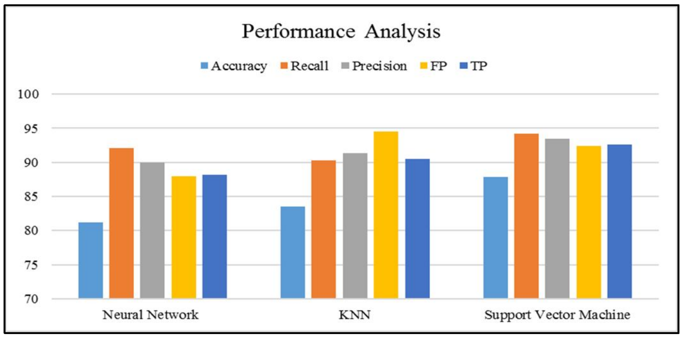


Figure.5. Performance analysis for test case 1

Table 3. Test case 1 performance measurement

Classifier Name	TPR	FP	Precision	Recall	Accuracy
Neural Network	88.22	87.93	90.01	92.13	81.22
KNN	90.50	94.55	91.38	90.24	83.57
Support Vector Machine	92.61	92.37	93.44	94.21	87.81

Similarly, test case 2 is considered for performance measurement where features are combined using improved pre-processing and wavelet feature extraction model. This performance measurement is presented in table 3. A graphical representation for case 1 is given in figure 5.

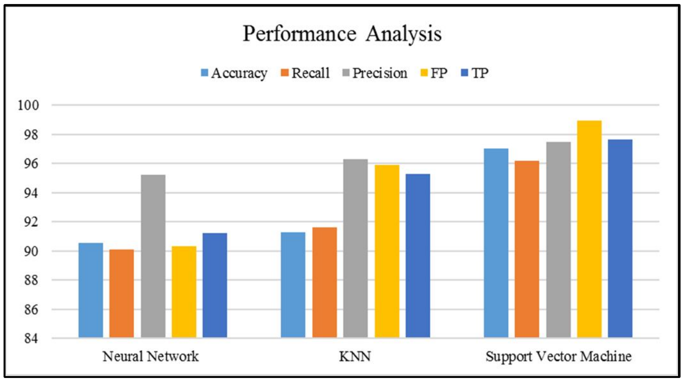


Figure 6. Performance comparison

Table 3. Test case 2 performance measurement

Classifier Name	TPR	FP	Precision	Recall	Accuracy
Neural Network	91.20	90.34	95.21	90.10	90.52
KNN	95.27	95.88	96.27	91.61	91.28
Support Vector Machine	97.63	98.97	97.49	96.16	97.04

This study shows that proposed combined feature extraction model provides better classification performance when compared with conventional feature extraction model. For this case also a graphical representation is given in figure 6.

Overall evaluation shows that support vector machine provides better classification performance using conventional techniques of feature extraction. For further improvement in classification performance, here a combined feature extraction model is presented which shows significant improvement in classification accuracy. Hence this combined model can be utilized for real-time application for plant recognition and classification.

Conclusion

This work presents an automated process for plant leaf identification and classification using computer vision schemes. To carry out this work, an improved image enhancement model is developed which provides better performance for image filtering. Wavelet transform approach is utilized for feature extraction analysis. experimental study is resented for three different classifiers. Analysis shows that proposed combination of feature module provides significant performance with SVM classification technique.

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