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Study of Venation of leaf using Image Processing

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***Abstract*— In this work, various edge detection techniques have been implemented on an image of a leaf taken under different light conditions to study the venation pattern of that leaf. The efficiency and the accuracy of these techniques in detection of the veins have been compared and analyzed. Edge detection operators such as Sobel and Canny edge detectors have also been implemented in the leaf image to identify the difference between the two. Step edges and ridge edges have been found out by taking the Gaussian and the first and second order derivative of the Gaussian of the image. The experimental result showed that canny edge detectors have been more accurate and can detect the veins more precisely with more details as compared to other techniques.**

Keywords*— *Gradient, first order derivative, second order derivative, Gaussian of an image, Step edges.

INTRODUCTION

Plant is one of the most important forms of life on earth. Plant recognition is very demanding in biology and agriculture as new plant discovery and the computerization of the management of plant species become more popular. The focus of computerized living plant recognition is on stable feature's extraction of plants. The information of leaf veins, therefore, play an important role in identifying living plants. Another advantage of vein feature extraction is that a botanical interpretation of leaves needs the data to be in a form that allows comparisons between different tree leaves [11].

There are basically two types of Venations: Reticulate venation and Parallel Venation. Reticulate venation are the ones in which the veins and veinlets of the plants are distributed forming a network. Parallel venation are the ones in which the veins of the plants run parallel to each other. A plant leaf is a complex light-scattering object characterized by the fact that the contribution of the flux of radiation reflected from the surface of the leaf and the contribution of the flux of radiation scattered by the interleaf structure elements to the total flux of radiation reflected from the leaf depend heavily on the wavelength of radiation incident on this leaf as well as on the conditions of its illumination and observation [12-14]. Laboratory experiments and remote investigations performed under natural conditions showed that the reflection properties of vegetation and of individual plant leaves are dependent not only on a number of biometric parameters, but also on the conditions of their illumination and observation [13]. In the general case the process of interaction of optical radiation with vegetation is described with the help of complex models having a great number of input parameters [14], the most important of which are the optical characteristics of individual phytoelements and the angular dependences of these characteristics.

The essential and the most important tool for identifying the venations of leaves is Image processing. In imaging science, image processing is any 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. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. For identifying the venation of leaves, various image segmentation and edge detection algorithms were being used in the past by the researchers. In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments. 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. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as colour, intensity, or texture. Due to the importance of image segmentation a number of algorithms have been proposed but based on the image that is inputted the algorithm should be chosen to get the best results. In [1] the author gives a study of the various algorithms that are available for colour images, text and gray scale images. Point-based or *pixel-based segmentation* is conceptually the simplest approach used for segmentation.

Edge based segmentation is only possible if all objects show the same gray value or if we apply different thresholds for each objects. An *edge based segmentation* approach can be used to avoid a bias in the size of the segmented object without using a complex thresholding scheme. Edge-based segmentation is based on the fact that the position of an edge is given by an extreme of the first-order derivative or a zero crossing in the second-order derivative.

Model-Based Segmentation can be applied if we know the exact shape of the objects contained in the image. Edge detection is the name for a set of mathematical methods which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. The points at which image brightness changes sharply are typically organized into a set of curved line segments termed *edges*. Various edge detection algorithms are being used for detecting the edges of an object. However the selection of the algorithms depends on the type of images as well as the area of interest related to the image. An edge has both magnitude and direction. The direction is used to identify the next possible edge point. Finally, all the edge points are linked together to form an object boundary. In an ideal scenario, all edges are connected and we get a perfect boundary, but this is seldom the case due to various reasons such as difference in illumination, partially visible objects, texture variation, inefficiency of the edge detection operator etc. To resolve these issues, there has been a number of edge detection operators defined throughout the history of Image Processing. However, no one of them is a panacea for Edge Detection. All the edge detection methods are based upon the description of 'changes of continuous functions using derivatives' given by calculus. Simply put, all operators are gradient operators [15].

Gradient edge detectors are those which describe edges by means of partial derivatives. A change in the image function can be described by a gradient that points in the direction of the largest growth of the image function. They are of three types:

1. Operators performing derivatives by using differences. Eg: Sobel

2. Operators based on the zero crossings of the second derivatives. Eg: Canny edge detector.

3. Operators that match the image function to a known parametric model of the edges.

PREVIOUS WORKS

A lot of Research has been done in the past on Venation of leaves and various types of Image Segmentation Algorithms have been used for the above purpose. In [1], the author gives a study of the various algorithms that are available for color images, text and gray scale images. The seed region growing algorithm proposed by Adams and Bischof, Metmert and Jackway [2] described the dependency relationship between pixels in the seed growth. The first order of dependence occurs when the number of pixels has the same difference ratio as their vicinity. The second order of dependence occurs when a pixels has the same difference ratio as their vicinity. The original algorithm for segmentation of gray scale image was developed by Rosenfeld-pfaltz [3] described a two pass 'sequential algorithm' for the segmentation of binary images. The key feature of the Rosenfeld-pfaltz algorithm is that the image is raster-scanned, first the forward direction, from top left to bottom right, then backwards. During the forward pass, each pixel is located a region label, based *on* information *scanned* through; the regions so demarcated may have pixels with more than one label therein. During the backwards pass, a unique label is assigned to each pixel. Hence this classic algorithm *can* be described as a two pass algorithm. The watershed algorithm is more representative in the application of mathematical morphology theory for image segmentation. Watershed algorithm is a region based segmentation techniques image that uses image morphology. But the result of Watershed algorithm is an over segmented image. However in [4], the problem of undesirable over segmentation results produced by the watershed algorithm, when used directly with raw data images was solved. In this paper a combination of *K-means clustering and Watershed* techniques then region merging and edge detection procedures were used. The clustering method was applied to obtain an image of different intensity regions based on minimum distance to examine each pixel in the image and then to assign it to one of the image clusters. Then a *watershed transformation technique* worked on the gradient of that image was employed to reduce the over segmentation of the *watershed algorithm*. But the result is over segmentation image if we use the *watershed algorithm* with the gradient of raw data image without clustering method above. To get rid over segmentation, merging method based on *mean gray values and edge strengths* (T1, T2) were used. The *watershed algorithm* can segment image into several homogeneous regions which have the same or similar gray levels [4]. For applying the *watershed transform* an advanced, fast, and an accurate algorithm proposed by Vincent [5] was used. From this algorithm: A marker image included zero marker values of watershed line pixels was obtained. In the proposed method, the segmentation regions and their boundaries were defined well and all of the boundaries are accurately located at the true edge [4]. And if k-means is first taken and then DIS with 25% of mean DIS is done, then it has been seen that all the edges of the images were shown. So we don't need to use Watershed technique [4].The disadvantages of the techniques used in [4] depend mainly on k-means results, where if the clustering procedure is not implemented correctly, the results are incorrect. The segmentation methods that are based on discontinuity property of pixels are considered as boundary or edges based techniques and that are based on similarity or homogeneity are region based techniques. In [6], a two-level approach for image segmentation based on region and edge integration. Edges are first detected in the original image using a combination of operators for intensity gradient and texture discontinuities. To preserve the spatial coherence of the edges and their surrounding image regions, the detected edges are vectorized into connected line segments which serve as the basis for a constrained Delaunay triangulation. Segmentation is first performed on the triangulation using graph cuts. Finally, the obtained segmentation on the triangulation is projected onto the original image and region boundaries are refined to achieve pixel accuracy. Region based methods can also be categorized into local region growing and top down global region partitioning, such as graph-theoretic optimal grouping algorithms [7,8]. Global region partitioning uses statistics obtained from all the pixels in an entire image. They do not reflect the local characteristics available at a specific pixel. On the other hand, local region growing or edge detection offer accurate boundary localization, but usually do not have sufficient global knowledge to perform the task well. This two level approach for image segmentation based on region and edge integration cleanly separates the foreground from the background. This method favours segmentation that pass through more detected edges in the original image. In [11], the popular and efficient Fast ICA algorithm is applied to patches of leaf images to learn a set of linear basis functions or features for the images and then the basis functions are used as the pattern map for vein extraction. A gray-scale image is transformed into a pattern map (feature map) in which the leaf, edge, background and other pixels are classified into different classes by pattern matching. Compared with conventional mathematics-based templates such as Harr transform [16] and Gabor functions [17], the proposed method is based on the statistics of images. High accuracy of vein detection can be achieved, and it is free of the influences of illumination and there is no need to pre processing. For image processing application, a perceptual system is exposed to a series of small image patches, taken from one or more large images. The pixel gray-scale intensity (or contrast) in an image, or in practice, a small image patch is an observation, x_i. Each image patch has been considered as a linear superposition of some features or basis vectors a_{ij} that are constant for an image.

The S are stochastic coefficients, different from patch to patch. In a neuron scientific interpretation, the variables s_i $(i=1\ldots n)$ model the responses of simple cells, and the columns of A are closely related to their receptive fields. The basis functions form the columns of the constant matrix, A. The weighting of this linear combination is given by a vector, S. Each component of this vector has its own associated basis function, and represents an underlying “cause” of the image. The goal of a perceptive system is to linearly transform the images, X, with a matrix of filters, W, so that the resulting vector $Y=WX$ *recovers* the underlying causes, S, possibly permuted or rescaled. FastICA is an efficient and popular algorithm for independent component analysis invented by Aapo Hyvärinen [18]. Hyvarinen and his co-workers have introduced a family of fixed-point algorithms. The members of this family are differentiated firstly by the algorithmic approach and secondly by the contrast function used. The key to all the variations is to find independent components by separately maximising the negentropy of each mixture [18]. There are mainly two algorithmic approaches, the symmetric approach and deflation approach, in the fixed-point algorithm class. The symmetric approach uses a modified rule for the update of the unmixing matrix W that enables simultaneous separation of all independent components, whereas the deflation approach updates the columns of W individually, finding the independent components once at a time. In [11], the training set consisted of randomly generated 50,000 12x12 pixel patches from 12 sub-images, taken from 21 kinds of tree leaf images. The training set was considered as the observation data in the ICA model. It has been seen in [11] that the results using the Fast ICA algorithm for the whole leaves are not so good but it is comparable to the results by using Prewitt edge detection operator. Prewitt edge detection operator is a powerful feature detection algorithm used in computer vision. The performance of Fast ICA algorithm is not better than those of Prewitt because Fast ICA is a linear technique and was originally developed for the blind signal separation problem. The experimental results in [11] demonstrated that ICA performs well in vein extraction.

MATERIALS AND METHOD

A 14.1 Megapixel Sony digital Camera was used to capture images of leaf under different light conditions. Pictures have been taken under normal daylight & flashlight conditions which were then considered as the source images for the experiment. Images collected were analysed using Matlab codes for different operators.

At first, the normal daylight image was taken as input in Matlab and it was resized to smaller size for better and smooth detection. The RGB image was converted to grayscale image for further processing of the image. The initial size of the image was 588 by 1139 pixels. The Sobel mask was implemented in the image to get the structure of the veins. The intensity edges are detected using the first and second order derivatives of Gaussian. 2D Gaussian function of the image was detected using the formula

$$G_\sigma(x,y) = \left(\frac{1}{\sqrt{2\pi\sigma}}\right)\exp[-\frac{x^2 + y^2}{2\sigma^2}]$$

Where σ =the spreads of the blob of the Gaussian function.

The first order derivative of the image in x direction is given by the expression

$$\frac{\partial}{\partial x}G_\sigma(x,y) = \frac{-x}{2\pi\sigma^4}\left(\frac{1}{\sqrt{2\pi\sigma}}\right)exp[-\frac{x^2 + y^2}{2\sigma^2}]$$

And the second order derivative of the image in y direction is given by

$$\frac{\partial}{\partial y}G_\sigma(x,y) = \frac{-y}{2\pi\sigma^4}\left(\frac{1}{\sqrt{2\pi\sigma}}\right)exp[-\frac{x^2 + y^2}{2\sigma^2}]$$

The tensor product between the Gaussian of the image and its first order derivative gives the step edges of the grayscale image of the leaf. The same image is being processed using the canny edge detection algorithm [9] and its veins have been detected by the same. The subsequent images i.e. the dark light image (with flash) and the back portion of the leaf under normal light conditions were also processed using the same techniques to get the details of the structure of the veins.

RESULTS

Various images of the leaf that were taken by the camera were being analyzed in Matlab for the detection of veins. Basically three images were being taken as the source of input. These images were being then processed using the Sobel mask, Canny edge detectors for the detection of edges. Also the ridge edges are detected using the first order derivative of the Gaussian. The initial size of the leaf under normal light conditions was 588 by 1139 pixel which was then resized to 471 by 971 pixels for fast Matlab computation. The leaf under flash light was initially 1744 by 4320 pixels and it was resized to 524 by 1296 pixels. Similarly the image of the back side of the leaf under normal light conditions was reduced to 549 by 1342 pixels from the initial size of 1829 by 4473 pixels. The results of these operators for the various images of leaf under different light conditions are shown in the figures.

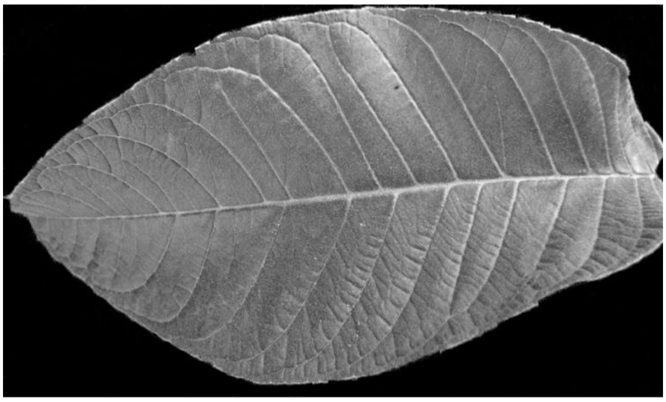

Fig1 (a) Grayscale image of the leaf under normal light condition

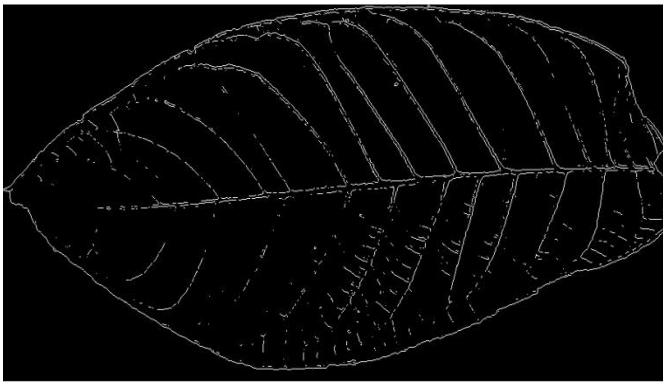

Fig1 (b) Output of Sobel operator of the leaf under normal light condition

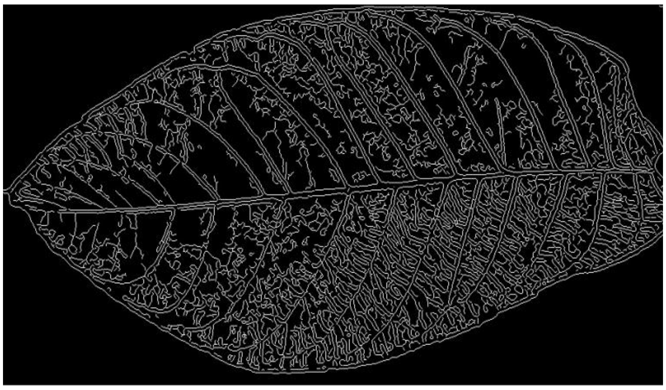

Fig1 (c) Output of Canny Edge detector of the leaf under normal light condition

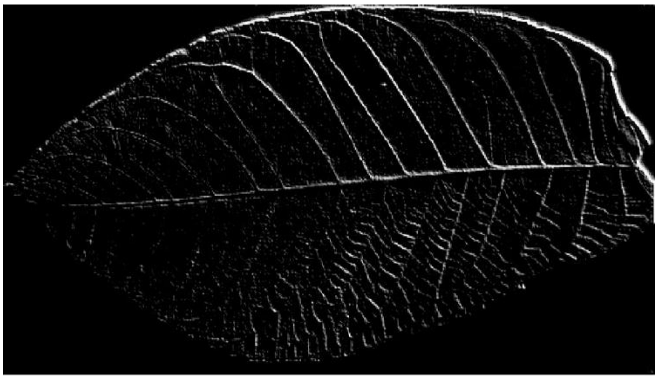

Fig1 (d) Step Edges of the leaf under normal light condition

Fig 2(a) Grayscale image of the Leaf under flash light

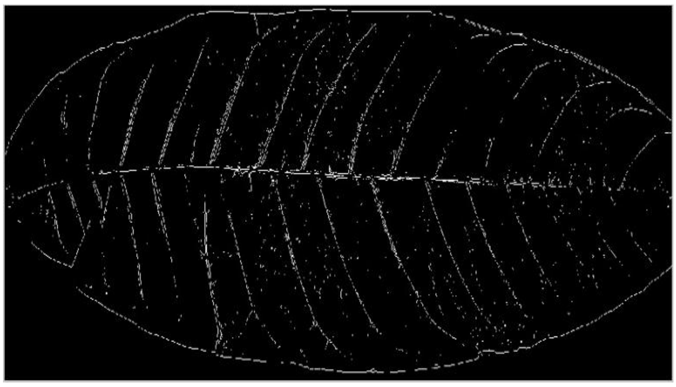

Fig 2(b) Sobel operator output of the Leaf under flash light

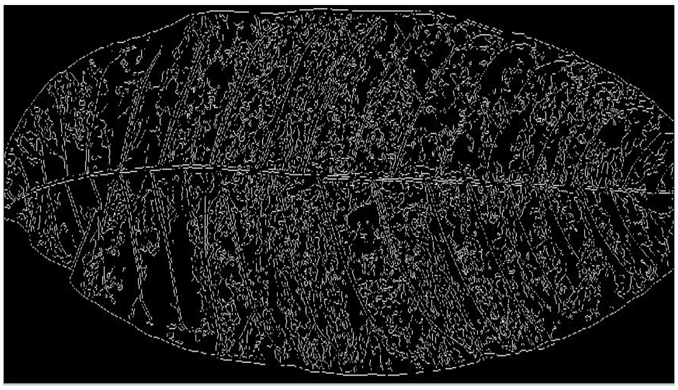

Fig 2(c) Output of Canny Edge detector of the leaf under flash light

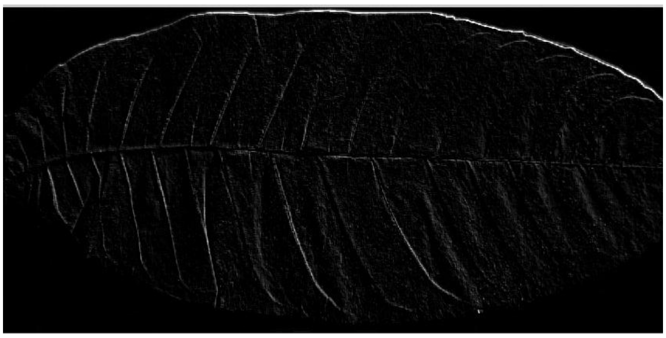

Fig2 (d) Step Edges of the leaf under flash light

Fig 1(b) shows that the implementation of Sobel operation on the grayscale image of the leaf detected the hard edges of the leaf. However the Sobel operator can detect the boundary of the leaf very accurately and all the pixels along the border were detected. Fig 1(c) shows that canny edge detector is very much efficient and more accurate in determining the edges of the leaf. It detected both the hard and soft edges of the leaf. More details regarding the veins of the leaf can be obtained from this detector. The Tensor product between the Gaussian and the first derivative of the Gaussian gave the Step edges of the leaf. It showed only those edges whose intensity changes abruptly from one value to other. Fig2 (a) shows the leaf under flash light conditions. The top half of the leaf is more illuminated because of the effect of the flash of the camera. This area is having more number of brighter pixels as compared to the other part of the leaf. Due to the presence of brighter pixels, the sobel operator can't fully detect the veins in that particular region as seen in fig 2(b). However the canny detector can determine the veins and sub veins of the leaf more accurately irrespective of the effect of flash light. The detection of step edges is also affected by the presence of brighter pixels. Since there is no abrupt change of intensity in that particular region, so the step edges are not present in that region and hence it has not been detected by the program. Fig 3 shows the images of the back side of the leaf under normal light conditions. The Sobel operator detected the boundary of the leaf very well in this case. However it could not detect all the hard edges of the leaf vein. Canny detector detected all the hard and soft edges of the veins of the leaf as seen in fig 3(c). The step edges of the back side of the leaf was being detected with the highest accuracy as it involves a very sharp change in pixel value between the primary vein and the secondary veins of the leaf.

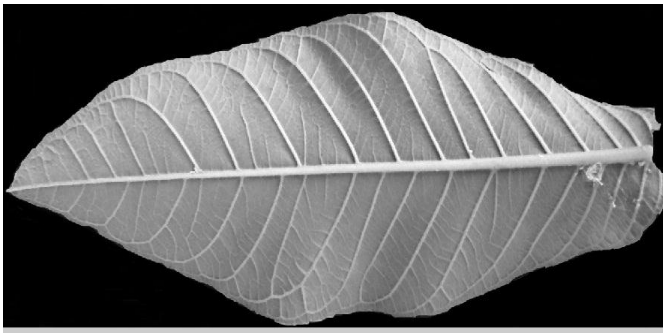

Fig3 (a) Grayscale image of the back side of the leaf under normal light condition

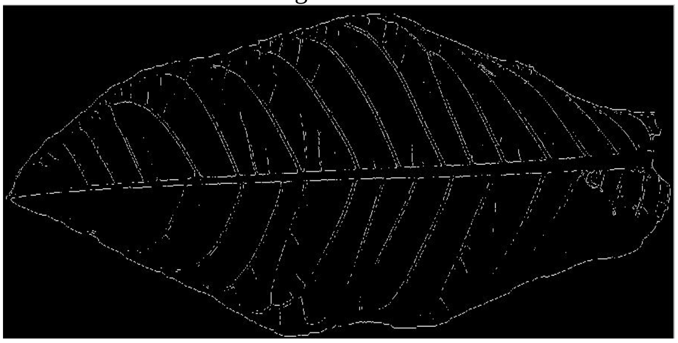

Fig3 (b) Output of Sobel operator of the back side of the leaf under normal light condition

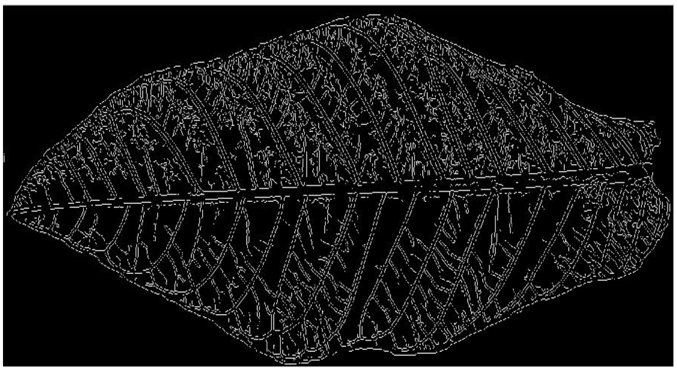

Fig3 (c) Output of Canny Edge detector of the back side of the leaf under normal light condition

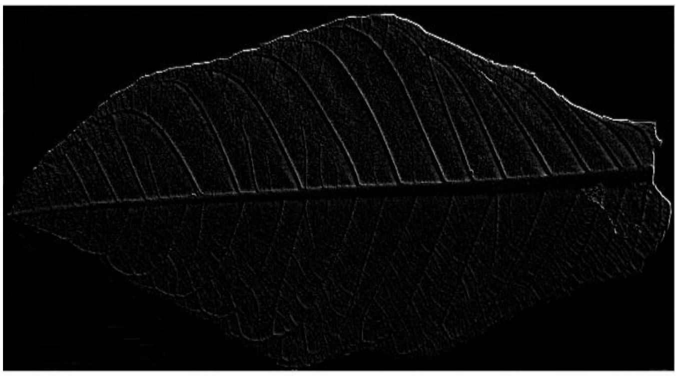

Fig 3(d) Step Edges of the back side of the leaf under normal light condition

CONCLUSION

The images of the leaf under normal light and flash light conditions have been analyzed using Matlab codes for various edge detection operators. With the results obtained from the experiment, it can be stated that the canny edge detectors works very well under both the light conditions of the leaf. Both the primary and secondary veins of the leaf are being well detected by this edge detector. However Sobel edge detector works very well in boundary detection of the leaf under all the light conditions. Step edges are detected very well during all the conditions whenever there is a sharp change of intensity of pixels in the leaf. This work can be further enhanced for color image processing of the leaf giving more emphasis on the RGB components of the leaf for detecting the venations of the leaf.

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