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Analysis of Adaptive Threshold Value using Weighted Global and Local Approach Method for Herbs Leaves Image Data

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ABSTRACT

The recognition of the health benefits linked to integrating herbs as food constituents has gained substantial attention. Herbs possess the potential to amplify flavours without the adverse health consequences associated with other ingredients. This paper explores the integration of image analysis techniques, particularly edge detection and adaptive thresholding methods, to revolutionize plant identification and research, particularly in the context of herbal leaves. A novel Weighted Global and Local Approach is introduced, aiming to balance the extraction of broad image features with the preservation of intricate details, thereby enhancing segmentation precision. The integration of digital image processing into various domains underscores its importance, with image segmentation as a foundational aspect, aiding in the extraction of relevant information from images. Edge detection techniques, particularly the Canny edge detector, are pivotal in this process due to their capacity to enhance signal-to-noise ratios, resist noise, and remove noise through smoothing methods. The proposed method is intended to dynamically change threshold values by combining global and local features, resulting in accurate segmentation that captures both broad and fine-grained aspects of herbal leaves. Experimental results suggest that the method outperforms existing approaches, highlighting its potential for botanical research, medicinal plant identification, and image analysis applications.

Keywords:
Image analysis; Edge detection; Adaptive threshold; Modified Canny method; Weighted global and local; Herbal leaves images

1. Introduction

The recognition of health benefits associated with the incorporation of herbs as food ingredients has gained prominence in recent times. Herbs possess the potential to enhance flavours without the detrimental health impacts associated with other ingredients. For example, using stevia syrup and spices can produce excellent cuisine while eliminating unnecessary salt and sugar [1].The identification of various types of herbs is required for the preservation of diverse plant species and

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protective measures [2]. Nowadays, many research employ plants to generate innovations for a more affluent existence, such as [3-8],which use fruit peel extract, psidium guajava, harumanis mango, pandan leaf, hibiscus leaves, and hastata leaves. Botany and herbal studies have seen widespread use of image analysis tools, notably for precise segmentation of plant components such as leaves, stems, and flowers. This segmentation is critical for species identification, disease diagnosis, and growth monitoring, as herbal leaves have distinct visual characteristics that necessitate precise segmentation procedures. Quantifying leaf features such as area, shape, and texture help us better understand plant physiology and biochemistry.

In recent years, the convergence of computer vision and image analysis has greatly computerised the identification of medicinal plants based on leaf patterns. These discoveries may have impacts for pharmaceutical research and traditional medical practices. In this context, computer vision has developed as a major research field, with the goal of mimicking human-like visual analysis processes while increasing efficiency. The application of digital image processing in a variety of fields, including law, engineering, medical, and agriculture, emphasises its importance [9-12]. Among these applications, image segmentation remains critical, allowing for the extraction of relevant information from images. Traditional image segmentation techniques, such as thresholding, region-based methods, and edge-based approaches, provide a solid understanding of segmentation concepts [1]. Edge detection algorithms, such as Canny, Prewitt, Robert, and Sobel, are particularly useful in finding object boundaries in pictures, creating the basis for successful segmentation [9].

Image preprocessing is an important preliminary step for improving image quality before using it in machine learning models. Enhanced image quality allows for more accurate feature extraction, which is critical for applications such as plant species classification using leaf images [13]. In this context, Canny edge detection has gained recognition due to its ability to recognise edges even in noisy situations. However, the typical Canny algorithm encounters difficulties in responding to a variety of image features, prompting the development of enhanced and adaptive variants [14,15]. These adaptive thresholding methods, such as the Niblack, Sauvola, and Bradley-Roth methods, have shown effective in dealing with non-uniform lighting circumstances and complex patterns. A novel Weighted Global and Local Approach has emerged, seeking to strike a balance between capturing broader image features and preserving finer details, thereby enhancing segmentation accuracy, especially in complex scenarios [2].

The integration of image analysis techniques, particularly edge detection and adaptive thresholding methods, has transformed plant identification and research. These technologies enable accurate species classification, disease detection, and growth monitoring. While challenges persist, advancements in computer vision and image processing hold significant promise for enhancing agricultural practices, pharmaceutical research, and herbal studies.

Edge detection methods play a pivotal role in image analysis, with the Canny edge detector regarded as one of the most reliable options due to its capacity to enhance signal local ratios, resist noise in challenging environments, and effectively remove noise through smoothing techniques. Despite its merits, the Canny edge detection algorithm presents challenges, such as extended computation time, making real-time response difficult to achieve. To address these issues, the current study focuses on plant identification through leaf analysis, employing an enhanced image enhancement approach that encompasses contrast stretching followed by Canny edge detection. Notably, Canny edge detection has been instrumental in creating databases for plant identification, with its edge filtering and optimization techniques contributing to its popularity in retrieving image characteristics [2].

Edge detection approaches make substantial contributions to plant identification databases, notably in the context of leaf analysis [2]. Canny edge detection stands out as a popular method due to its robust properties. It has a high signal-to-noise ratio, precise edge positioning accuracy, a low error rate in edge detection, and a low mean square error [15]. However, several issues remain, such as the algorithm's sensitivity to noise, which might cause the loss of weak edge information when filtering out noise, limiting its adaptability. The conventional Canny edge detection algorithm is widely used in practical engineering applications. However, several features of the algorithm require improvement. Specifically, the algorithm's reliance on a first-order finite difference within a 2x2 adjacent region to calculate image gradients can limit its effectiveness [14].

Using Canny introduced by [16] high threshold values and low threshold values are determined manually which requires more thorough empirical examination. This empirical examination requires many experiments to be conducted to determine the appropriate threshold values. However, for more challenging applications, the threshold values often change according to different lighting and natural scenery factors for different images.

Therefore, a threshold value capable of adapting to image feature changes is essential to obtain satisfactory edge detection results in many cases [17]. This adaptive capability is necessary because images have variable scenery and lighting properties for each image. To overcome this threshold value problem many studies use [18] method so that threshold values can be adaptively generated [19]. However, overall, these studies only assessed the global image of the threshold value selection process. Furthermore, when images become complex, different local regions will require very different threshold values to obtain the actual edge [20].

Furthermore, the classic Canny algorithm's set threshold value approach might lead to the loss of local feature edge information, particularly in cases with a lot of edge information, such as photos of rice pests and diseases [14,21]. This demonstrates the algorithm's drawback in adjusting to complicated settings, calling into doubt its applicability for such contexts. In response to these issues, adaptive thresholding approaches have emerged as reliable solutions capable of dealing with complex image situations. The Weighted Global and Local Approach, as proposed in this context, is a novel improvement in adaptive thresholding. By combining global and local information, this method seeks to find a compromise between capturing broad image features and conserving finer details, hence improving image segmentation accuracy, particularly in scenarios with complex patterns and various colours [2].

To increase image processing clarity and accuracy, this work employs the Canny image enhancement method, which replaces the typical Canny operator's picture gradient with gravitational field intensity. Furthermore, the system uses an adaptive threshold selection mechanism based on standard deviation. Despite algorithmic enhancements, the proposed Canny algorithm has a lower execution time than the most recent cutting-edge implementations [14]. This study presents a unique approach that uses contrast stretching prior to Canny edge detection to overcome the drawbacks of standard Canny edge detection.

This unique approach decreases the formation of false edges and produces a smoother vein structure within plant leaves, improving the efficiency of plant identification [2] .To boost accuracy, the Canny edge detection algorithm has been upgraded by incorporating DCT transform, coefficient, and reversals to substitute the Gaussian function for denoising. However, the algorithm's tolerance to mild moisture and sensitivity to specific image conditions, particularly when using a Gaussian filter, highlight the need for additional study into alternative image processing methods [22]. Another research project provides an enhanced Canny edge detection technique. This improved approach uses enhanced filtering techniques to denoise images and calculates gradient amplitude using a four-direction gradient template. Furthermore, image block processing combined with the maximum inter-class variance technique (Otsu) improves the accuracy of edge information recognition in complex backgrounds [15]. In response to this issue, the use of adaptive thresholding approaches has gained popularity. These approaches dynamically modify threshold values based on the image's local features, allowing for the distinguishing of regions of differing brightness. Among these, the Weighted Global and Local Approach stands out as a potential option, exploiting both an image's overall context and the smaller features of local regions.

The primary objective of this journal paper is to present a comprehensive analysis of the Adaptive Threshold Value using the Weighted Global and Local Approach for herbal leaves image data. The proposed method seeks to strike a balance between capturing the holistic structure of herbal leaves and preserving their intrinsic details. By adapting threshold values to the distinct characteristics of different leaf areas, this approach aims to enhance accuracy and robustness in segmentation.

This research intends to go deep into the theoretical basis of adaptive thresholding and its practical impacts in the context of herbal leaves. The paper will present a detailed review of the Weighted Global and Local Approach, clarifying its underlying mechanics and emphasising its potential advantages over traditional methods. To empirically demonstrate its efficacy, a thoroughly collected library of herbal leaf images will be used for a thorough performance evaluation. The search for local threshold values that can be applied to different domains will be discussed. That is, with a fixed division strategy of images being used fully to analyse local and global images. This process aims to obtain local regional values for the image. To obtain robust edge images, relevant local features must be considered while determining threshold values [23]. The fixed division method was first introduced in Abdullah *et al.,* [24]'s local threshold value feature search experiments. In Gaur [25] employed this method by dividing the image into 3x3 fixed division blocks in the image division, and Meng *et al.,* [26] used 8x8 fixed division blocks in their study.

The paper's structure is organized as follows: Section 2 offers a detailed explanation of the proposed Adaptive Threshold Value using the Weighted Global and Local Approach, elaborating on its algorithmic intricacies. Section 3 outlines the experimental setup, dataset, and performance metrics used for evaluating the method's accuracy and adaptability. Section 4 presents the results and discussions, shedding light on the comparative analysis with existing approaches. Finally, Section 5 concludes the paper by summarizing the findings and outlining potential directions for future research.

2. Proposed Adaptive Threshold Value using Weighted Global and Local Approach

This study will focus on processing phase. Here, edge detection method will be implemented. First the comparison between the method that gives more valuable will be used then analysis of image qualitatively and quantitatively will be conducted. The following subtopics discussed the process for the proposed method.

2.1 Algorithmic Overview

Detail of the modification of Canny method will be discussed in this section. As mentioned previously that the drawback of Canny method was the selection of threshold values. This paper proposed, the adaptive threshold value using the weighted global and local approach is designed to address the challenges posed by complex and varied images, such as herbal leaves with intricate vein patterns and diverse coloration. This method seeks to achieve accurate segmentation by dynamically adjusting threshold values by using Otsu method [18] based on both global and local image characteristics.

Here, the analysis involve is to determine the more significance statistical value between the maximum and the minimum value and to determine the significance approach between the global or local approach. Other than that, the role of the weighted fusion added will be analysed also. In this study to overcome this threshold value problem the method of [18] so that the threshold value adaptively will be used. Pseudocode below shows the whole process of proposed approach begin with the step of generation of threshold values from the original image pre-processor.

Adaptive Threshold Value using Weighted Global and Local Approach
Input: Herb leaves image data from [27]. Output: Edge image obtained; Start 1. Image pre-processing; 2. Threshold value search using the proposed method.: For each weight $n = 1,2,3,\ldots,10$ do: a. Adaptive threshold values using global and local approaches; b. Analysis of the maximum value and minimum threshold value of each selected resolution 3. Selection of the best edge from the highest F-measure value. Stop.

2.2 Global Component

The global component of the algorithm aims to capture the broader context of the image. It computes a global threshold value by analysing the overall intensity distribution of the image. This threshold serves as a starting point for segmentation, aiding in the differentiation between foreground and background. In this study, the image spatial features from global and local approach will be analysed. The grey level features will be used to get the are high threshold value (H_t) and low threshold value (L_t).

In this global approach the high threshold value (H_t) and low threshold value (L_t) will be obtained from the image directly representing as H_{Global} and L_{Global} (refer Eq. (2)).

$$\text{Global image} = P_{Global} \tag{1}$$

$$H_{Global} \text{ and} \in P_{Global} \tag{2}$$

$$L_{Global} = \frac{1}{2} H_{Global} \in P_{Global} \tag{3}$$

2.3 Local Component

The local component of the algorithm considers the intricate details present in different regions of the image. It involves dividing the image into smaller, often referred to as windows or patches. For each of these subregions, a localized threshold value is calculated based on the statistical properties of the histogram of greyscale value within that region. This localized threshold adapts to the specific characteristics of each subregion, accommodating variations in coloration, texture, and lighting conditions.

For local image approach to find the spatial values, original image will be partitioned into 2 × 2 (4 parts) which labelled as P_1, P_2, P_3 and P_4 or formulate as Eq. (4)

$$\text{Local image} = P_t \text{ where } t = 1,2,3,4 \quad (4)$$

Then on each part, threshold value generated by Canny will be used for analysing which are high threshold value (H_{Local}) and low threshold value (L_{Local}).

$$H_{Local} \in P_t \quad (5)$$

$$L_{Locall} = \frac{1}{2} H_{Local} \in P_t \quad (6)$$

The method of this local image analysis is depicted in Figure 1.

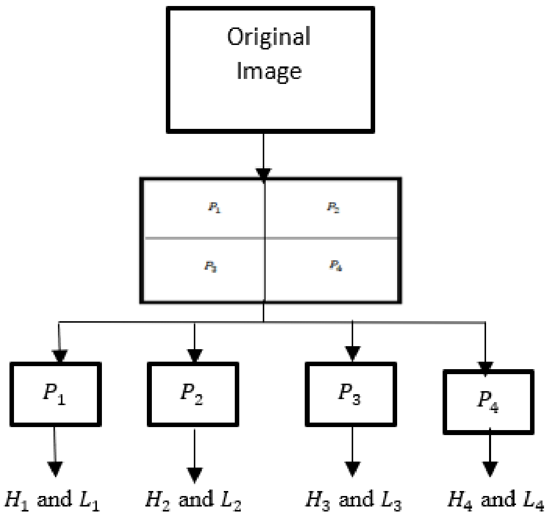


Fig. 1. Proposed process to analyse the local image (2 × 2 (4 parts))

2.4 Weighted Fusion

The key innovation of the proposed approach lies in the fusion of the global and local components. The localized threshold values are combined with the global threshold using a weighted average or a similar fusion mechanism where weight $n = 1,2,3,\dots,10$.

For global component, the high threshold (H_{Global}) and low threshold (L_{Global}) from Eq. (2) will be calculated combined with the weight to become weighted high threshold (WH_{Global}) and weighted low threshold (WL_{Global}) as follows:

$$WH_{Global} = \frac{1}{n} \times H_{Global} \quad (6)$$

$$WL_{Global} = \frac{1}{n} \times L_{Global} \quad (7)$$

Then, for the local component, the high threshold (H_{Local}) and low threshold (L_{Local}) from Eq. (4) will be calculated combined with the weight to become weighted high threshold (WH_{Local}) and weighted low threshold (WL_{Local}) . The statistical measures for each of the resolution level at maximum and minimum are defined for P_1, P_2, P_3 and P_4 will be

$$WH_{Local} = \frac{1}{n}(\arg max\, H_{Local}) \tag{8}$$

$$WL_{Local} = \frac{1}{n}(\arg max\, L_{Local}) \tag{9}$$

$$WH_{Local} = \frac{1}{n}(\arg min\, H_{Local}) \tag{10}$$

$$WL_{Local} = \frac{1}{n}(\arg min\, L_{Local}) \tag{11}$$

The Adaptive Threshold Value using the Weighted Global and Local Approach represents a holistic and dynamic method for segmenting complex images, particularly herbal leaves. By blending the global context with localized information, this approach leverages the strengths of both components to achieve accurate and robust segmentation. The threshold values ensure a balanced segmentation that captures both the broader structure and the finer details of herbal leaves. The subsequent sections will delve into the practical implementation and empirical evaluation of this method using curated herbal leaves image data.

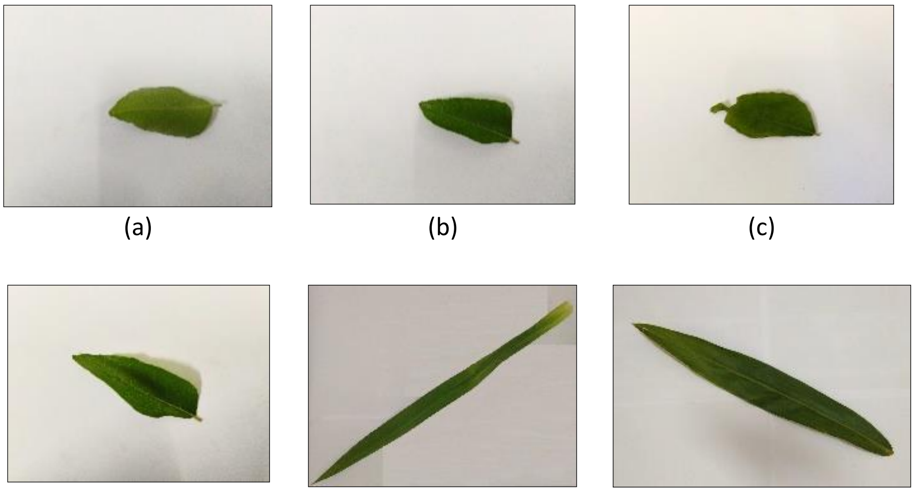
Furthermore, for each P_t the values of H_t and L_t will be used to generate an edge result image. Finally, the collected data will be compared to the ground truth image to determine the measurement value.

3. Experimental Setup and Performance Evaluation

To test the accuracy and adaptability of the proposed Adaptive Threshold Value that use the Weighted Global and Local Approach, a detailed experimental setup was created using MATLAB. This setup included selecting an appropriate dataset, preprocessing processes, implementing the algorithm, and applying performance measures.

3.1 Dataset

For this study, a diverse dataset of herbal leaves images was carefully curated. The dataset comprises images captured under varying lighting conditions, with different species, textures, and colorations of herbal leaves. This diversity ensures that the method's performance is rigorously tested across a range of scenarios commonly encountered in herbal research. Here, the leaves of herbal plants grown in Malaysia from [27] will be used. In this data set the ground truth edge image provided for evaluation phase. There are 180 leaf photos total, including Murraya Koenigii, Curcuma Longa, Citrofortunella Microcarpa, Pandanus Amaryllifolius, and other species. Figure 2 depicts an example of an image from the data set; these six images will be used in the analysis section.



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

Fig. 2. Example of image from the data set and these six images will be used in analysis part. a) image 001, b) image 002, c) image 016, d) image 023, e) image 136 and f) image 169

3.2 Preprocessing

Preprocessing of the dataset involved standardization, noise reduction, and enhancement techniques. Here, the RGB image processed to split the channel between red, green, and blue. Then the green channel had been chosen to enhance the image. After that the image had been sharpen by using contrast and histogram equalisation method. These steps aimed to mitigate inconsistencies arising from lighting variations and noise, ensuring that the algorithm's performance is influenced primarily by its segmentation capabilities rather than the quality of input images.

3.3 Performance Measurement

To quantitatively assess the accuracy and adaptability of the method F-measure were employed:

$$\text{F-measure} = \frac{2\times\text{recall}\times\text{precision}}{\text{recall}+\text{precision}} \tag{12}$$

F-measure score is the harmonic mean of precision and recall, offering a comprehensive assessment of segmentation quality that considers both false positives (TP) and false negatives (FN). The value is in range [0,1] then it indicates that the higher the value obtained symbolizes the closer the resultant image to the reference image. Where recall is

$$\text{recall} = \frac{TP}{TP+FN} \tag{13}$$

and precision is

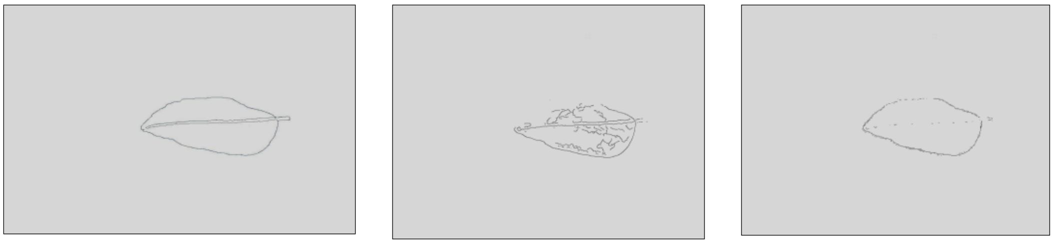
$$\text{precision} = \frac{TP}{TP+FP} \tag{14}$$

TP, FP and FN denote the true positive, false positive and false negatives values respectively. Precision measures the proportion of correctly segmented foreground pixels among all the pixels classified as foreground, while recall measures the proportion of correctly segmented foreground pixels among all the ground truth foreground pixels. A balanced trade-off between precision and recall indicates the method's effectiveness.

The experimental setup devised for evaluating the Adaptive Threshold Value using the Weighted Global and Local Approach encompasses a diverse dataset, meticulous preprocessing, algorithm implementation, and a range of performance metrics. This setup ensures a comprehensive assessment of the method's accuracy and adaptability across various herbal leaves images, shedding light on its potential contributions to the field of botanical image analysis. The subsequent section will present and discuss the empirical results, highlighting the method's strengths and areas for further improvement.

4. Results and Discussion

The study began by finding the best edge detection method for the leaf image used. The previous studies stated the two most frequently used image detection methods are the Canny and Sobel methods. Before conducting further process these two standard edge detection methods will be compared to investigate which method will be selected. Figure 3 shows example the edge from 1 image generated from provided from the data set, edge image generated from these Canny and Sobel methods. It shows that Canny method gives more detail image than Sobel method qualitatively.



(a) (b) (c)

Fig. 3. Edge image from (a) ground truth (b) Canny Method and (c) Sobel method

From the F-measure value from Table 1 shows that the Canny method gives the higher value than Sobel Method which indicates that Canny Method is close to the ground truth image provided.

Table 1
F-Measure Value Obtained From standard Canny and Sobel Method

Image	Canny	Sobel
001	0.1618	0.1212

Furthermore 6 images from the dataset had been chosen for further process. Table 2 shows the detail of F-measure obtained. From the quantitative results obtained, it can be observed that Canny method outperform the Sobel method but for image 016 the Sobel method is seen to outperform the canny method.

Table 2
Comparison on F-measure obtained from the 6 images by using Canny and Sobel method

Image	Canny	Sobel
001	0.1618	0.1212
002	0.2051	0.1776
016	0.1617	0.2162
023	0.1191	0.0596
136	0.0777	0.0458
169	0.232	0.1774

However, when viewed qualitatively it can be seen that the fringe image resulting from Figure 4 is approximately the same as the result of image 001 in Figure 3 i.e., the edges resulting from the Canny method are more detailed than the Sobel method. The study, therefore, continued with a focus on the modified Canny method.

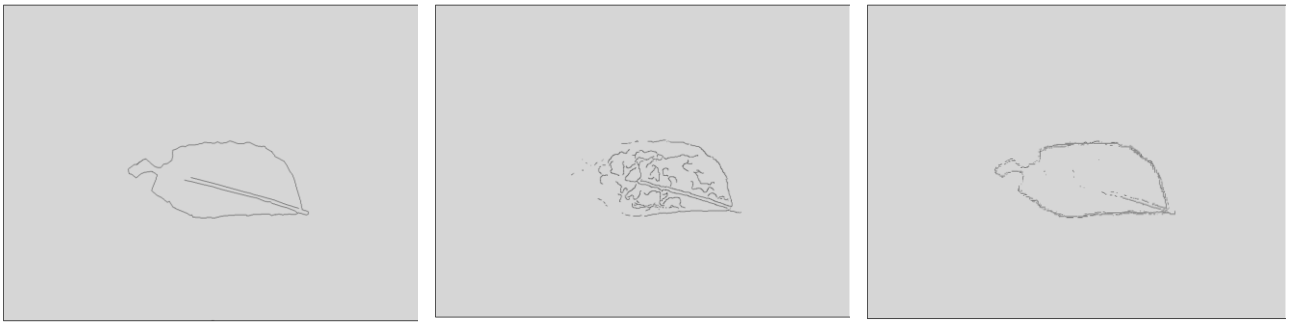

(a) (b) (c)

Fig. 4. Edge image 016 from (a) ground truth (b) Canny Method and (c) Sobel method

Next F-measure of global and local image using weighed fusion values will be generated as graph in Figure 5 and Figure 6 below. It can be seen from the results that the maximum value of the local approach dominates the overall result compared to the minimum value of the local approach(refer arrow shown in the graph). Therefore, the study was continued using maximum values from the local image to be compared with the global approach. For image 001 with F-measure value is 0.2115 for maximum local approach seems to outperform others and for image 169 with F-measure value is 0.3737 for global approach is the highest among others.

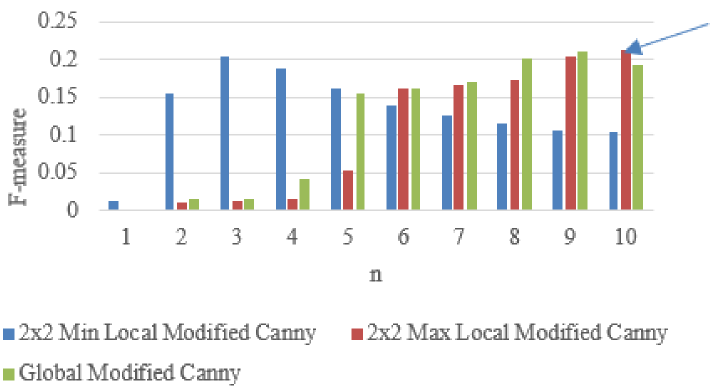


Fig. 5. The resulting F-measure graph from image 001

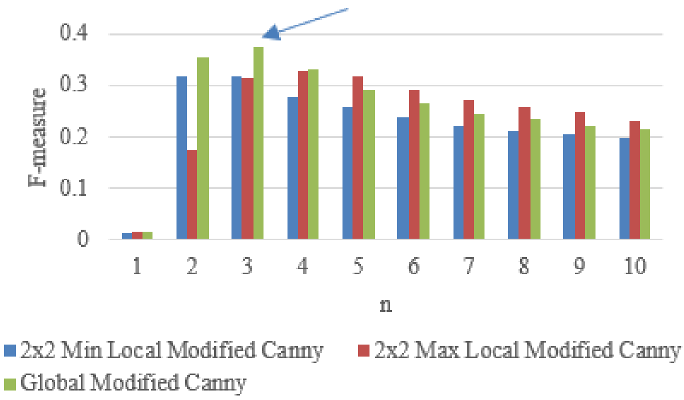


Fig. 6. The resulting F-measure graph from image 169

Then, the comparison results for all six images used in this proposed modified Canny method using the maximum approach on image local and image global are displayed in graph Figure 7. The graph shows that the is similar pattern for the highest F-Measure values from each image by using these two approaches. This is significant explaining that each edge resulting from the Canny method for different leaf images has the same ability for each edge.

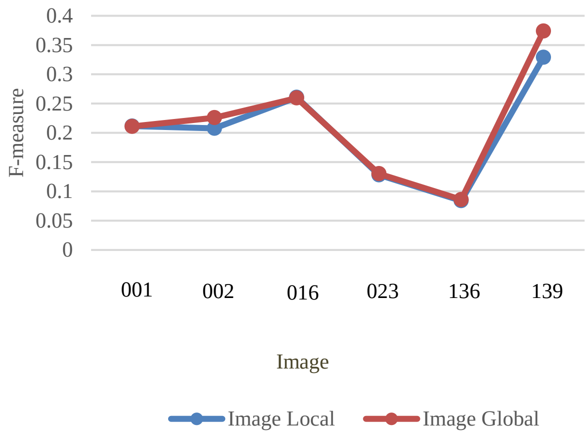


Fig. 7. Graph of the highest F-measure obtained for each image from local and global approach

Then Table 3 shows the comparison table for original Canny method, local approach of original Canny method [27], proposed method using maximum local approach and proposed method using global approach. The results shows that the proposed method outperform the original Canny method and previous study. For these 6 images, can be seen that the global image more dominant than maximum local image approach. The proposed adaptive threshold value is quite convincing by adding the weight on selecting the H_t and L_t on generating the edge image.

Table 3
Comparison table of F-measure values obtained from Original Canny Method, Previous Study and Proposed Method

			Proposed Method	
Image	Canny Method	Local approach original Canny method [27]	Maximum local approach	Global approach
001	0.1618	0.2035	0.2115	0.2109
002	0.2051	0.2187	0.2076	0.2258
016	0.1617	0.2523	0.2605	0.2594
023	0.1191	0.123	0.1281	0.1302
136	0.0777	0.0802	0.084	0.0859
169	0.232	0.2841	0.329	0.3737

In term of adaptive threshold values generated using this proposed method, as seen in Table 4 shows that the highest threshold (H_t) values are in range $[0.05, 0.2]$ and the lowest threshold (L_t) values are in range $[0.003, 0.05]$. As known that the threshold values are in range $[0, 1]$ so can be seen that the threshold values generation from the proposed method are at left side (< 0.5) of the histogram of grey level value which near to the white area.

Table 4
Threshold values obtained for the Highest F-measure values

	Maximum local approach			Global approach		
Image	F-measure	L_t value	H_t value	F-measure	L_t value	H_t value
001	0.2115	0.0333	0.0667	0.2109	0.0037	0.0658
002	0.2076	0.0416	0.0831	0.2258	0.006	0.0846
016	0.2605	0.0659	0.1318	0.2594	0.0189	0.151
023	0.1281	0.0377	0.0755	0.1302	0.0057	0.0796
136	0.084	0.065	0.1301	0.0859	0.029	0.1739
169	0.329	0.077	0.1539	0.3737	0.029	0.1739

The study encompassed experimentation with the remaining 180 images in the dataset, revealing a clear predominance of the global image over the maximum local image approach in the context of the proposed method. In comparison to the traditional Canny method, the newly introduced approach consistently outperformed the conventional Canny method in terms of performance. The empirical results and comparative analysis highlight the promising potential of the proposed Adaptive Threshold Value using the Weighted Global and Local Approach. The method's ability to adapt to varying conditions and accurately capture complex leaf structures suggests its applicability in various botanical and herbal research domains. The balanced fusion of global and local information sets it apart from traditional thresholding techniques, offering a holistic solution for herbal leaves image data.

5. Conclusions

In this paper embarked on an exploration of the Adaptive Threshold Value using the Weighted Global and Local Approach for herbal leaves image data segmentation. The primary goal was to address the challenges posed by complex leaf structures, varying lighting conditions, and intricate vein patterns. Through an in-depth analysis, we demonstrated that the proposed approach offers a comprehensive solution that balances global context with localized details.

The experimental results showcased the method's accuracy and adaptability across diverse scenarios, outperforming traditional global thresholding methods. The weighted fusion of global and local threshold values showcased a harmonious blend that effectively captured both broad leaf structures and finer details, such as vain patterns and colour variations. This approach holds significant promise for applications in botanical research, medicinal plant identification, and beyond.

The Adaptive Threshold Value using the Weighted Global and Local Approach offers a promising advancement in image segmentation for herbal leaves data. The method's ability to adapt to diverse conditions while preserving details sets it apart from traditional approaches. The empirical results demonstrate its potential to contribute significantly to botanical research, medicinal plant identification, and various image analysis applications. As the field of image analysis continues to evolve, this approach stands as a testament to the ongoing quest for precision, adaptability, and innovation in understanding the intricate world of herbal leaves. For further exploration, incorporating a multi-scale approach could enhance the method's ability to handle leaves with varying sizes and structures, ensuring accurate segmentation across different leaf types.

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