Improving the quality of handwritten image segmentation using k-means clustering algorithms with spatial filters

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ABSTRACT

One of the ways to predict human characters is by using handwritten patterns. Graphologists have analyzed handwriting to determine a writer's personality by considering several parameters: writing slopes, spacing, inclination, and writing size. The results of the analysis have been widely used as a reference for psychologists to assess an individual's personality. Moreover, researchers have applied techniques to identify human characters using image processing techniques. However, different styles of handwriting require more research to develop. The process of separating objects from backgrounds needs a segmentation process. This research improves the quality of handwritten image segmentation using k-means clustering algorithms with the spatial filter. This spatial filter consisted of the median and mean filters. This research created various k values to gain the best segmentation results. The results showed that the median filter with a kernel size of 3×3 and the k value = 2 was the best segmentation result because the value of silhouette coefficient was the highest compared to the value of filter type and other k values which reach 99.22%.

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1. INTRODUCTION

Handwriting is the result of human work that has unique characteristic that differs from each other. Graphology experts [1] or graphologists analyze human characters and personalities by observing handwriting patterns visually or directly [2]. An individual's behaviour is the reflection of his/her personality. Changes or fluctuations in behaviour or emotions may be seen while examining one's handwriting. Such changes in moods can be encountered from an individual's handwriting as well. Generally, graphologists predict human characters by considering handwriting characteristics and investigating writing pressures, letter spacing, slope with the baseline parameters, the letter-slant, height of the T-bar, and width of margins. The results of this analysis have been utilized in psychology, education, criminology, and medicine [3], [4]. Identification of such behavioural traits are possible using graphology and applications in several domains for handwriting-based personality have been explored [5]. The improvement of the accuracy requires an information technology that can help graphologists interpret handwritten images by using image processing techniques [6]. One of the important steps in image processing is the segmentation process that aims to separate backgrounds from objects. Human handwriting has different styles and shapes. The quality of handwritten images crucially determines the nature of one's personality; thus, good quality of an image is necessary [7].

Segmentation is a step to partition an image into different regions by creating boundaries that separate areas. At the same time, one of the most frequently used steps is pixel zoning of an image [8]. Image segmentation aims to divide an image into segments with similar features or attributes [9]. Edge-based segmentation techniques can identify essential things, namely corners, edges, points, and lines in the image. However, in some cases, there are pixel categorization errors in the edge-based segmentation category. Therefore, one of the edge detection techniques is the segmentation method [10]. Many studies have considered k-means to maximize the efficiency of the algorithm [11]. This algorithm performs unattended clustering in favor of their inherent distance from each other, which classifies the input data points into several categories [12]. Where the iterative algorithm minimizes the number of geometric distances between the centroid cluster and each object. This research improved the quality of handwritten image segmentation using k-means clustering algorithms with the spatial filter. The k-means algorithm is used for image segmentation. The image has been changed to a grayscale image then facilitates cluster extraction. To measure the performance of the segmentation results, the silhouette coefficient was calculated [13]. In the K-mean clustering algorithm: divide the image into K groups and add points [14]. The silhouette coefficient method is a measurement method that combines cohesion with separation to determine the quality of clusters. Image segmentation is done by using the k-means clustering method. It is one of the algorithms to classify some cluster regions by considering certain characteristics [15]. The Efficient image segmentation and implementation of k-means clustering is urgently needed [16].

A lot of research on image segmentation uses techniques from conventional and based learning methods, where the k-means algorithm is one of the simplest to generate an exciting region [17], [18]. The followings are some previous research investigating the processing of handwritten images. Brodowska examined handwritten image segmentation and employed several approaches, such as holistic, classic, recognition-based segmentation, and mixed approaches. The approaches were selected depending on the types of alphabets and characters read [19]. Nath and Rastogi [20] developed some stages in optical character recognition (OCR). The segmentation was done using the explicit and implicit approaches. Meanwhile, the classification is done by varying some features. Choudhary *et al.* [21] observed a handwritten image segmentation using an object or region selection-based approach that meets the criteria of width above the limit values. The extraction was performed on each character. Meanwhile, words with different sizes were considered as the background that made noise. Choudhary *et al*. [22] also developed a new technique for vertical segmentation in which the segmentation was performed per pixel after the characters had been depleted to get the character sizes. This technique improved the quality of word segmentation on handwritten images; thus, the problems in the open character segmentation were minimized. Rani and Kumar [23] studied character segmentation. The unfixed size of handwritten characters caused problems in the segmentation. Phukan and Borah [24] developed a system to recognize characters and vary processing stages. Features were extracted using a feature of moments. The introduction process employed several approaches, such as template matching, statistical techniques, structural techniques, and neural networks. Choudhary reviewed a segmentation to automatically recognize the handwriting on a static surface. Moreover, Choudhary reviewed some segmentation approaches: explicit, implicit, and holistic approaches. He also compared the results of previous research that investigated word segmentation [25]. Dave [26] conducted a study using several methods for text segmentation on images. This research assisted people to read texts on images based on the segmentation area in computer vision. The first step was conducting the segmentation based on the retrieval information. Then, factors that affected the segmentation process were varied. The next step was developing segmentation levels. The last step was reviewing the employed techniques, advantages, and disadvantages of each technique to provide suggestions to develop the next method. Bal and Saha [27] elaborated a system to identify human characters by using the image segmentation and a rule-based system method on the slope, baseline, and writing thickness. Durga and Deepu [28] evolved a technique to recognize handwriting using convolution neural network algorithms on the letters i and t and produced 90% of accuracy. Jindal and Ghosh [29] developed the segmentation of words and characters in ancient handwritten Devanagari and Maithili documents using horizontal zoning and the accuracy obtained 97.39%.

In summary, handwritten image segmentation plays a crucial role in improving the accuracy of handwriting-based personality analysis. Researchers have employed various techniques, including the k-means clustering algorithm, to segment handwritten images and enhance the quality of the analysis. This field continues to evolve with advancements in image processing and machine learning techniques.

2. METHOD

This study employed data in the form of scanned images of handwriting obtained from graphologists. The image processing started with reading image files of handwriting. The type of these image files was grayscale. Then, the locations of the handwriting were cropped manually. The next step was improving the quality of the images using the spatial filter. The following step was the segmentation using the k-means clustering algorithm to separate the handwriting objects from the backgrounds. The last step was the evaluation to determine the performance of the segmentation results. The flow diagram of the image processing is presented in Figure 1.

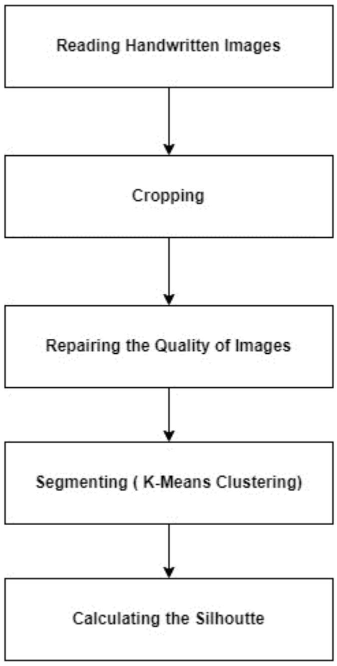

Figure 1. Flow diagram of the image processing

3. RESULTS AND DISCUSSION

3.1. Reading handwriting images

The input data used in this image processing study consisted of handwritten images that had been cropped and converted to grayscale. An example of the input image is visualized in Figure 2, providing a clear representation of the initial data used for the segmentation analysis. Grayscale images are particularly suitable for various image processing tasks, including clustering and segmentation, as they simplify the data representation while retaining essential visual information, allowing for effective analysis and segmentation.

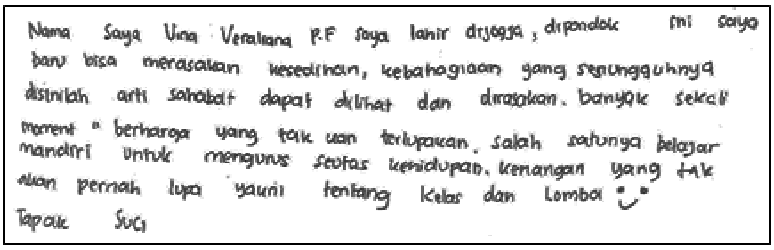

Figure 2. Input images

3.2. Improving the quality of images

The quality of the images was enhanced through the application of spatial filters, specifically median and mean filters. These filters are instrumental in reducing noise and enhancing image clarity. Figure 3 displays the image that has undergone quality enhancement using a 3×3 median filter. This filtered image showcases the effectiveness of the filter in reducing noise and improving the overall visual quality, which is crucial for achieving more accurate and reliable segmentation results in subsequent analysis. Further segmentation involved the process of delineating and separating the objects from the background within the images. This step is critical for isolating and identifying the specific elements oregions of interest, which is often a fundamental objective in image processing and analysis.

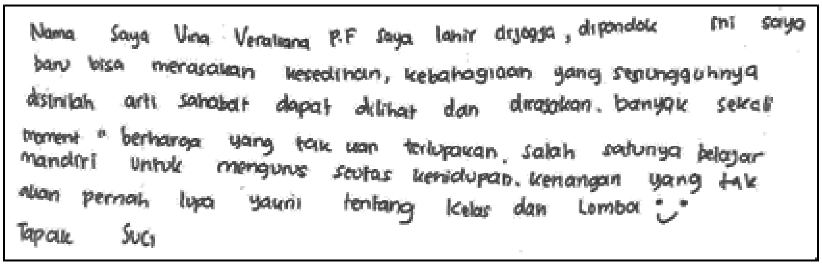

Figure 3. The image resulted from improving its quality

3.3. Segmentation

Segmentation was done using k-means clustering algorithms and varying the k value. The displays of binary images with various k values resulted from the segmentation are shown in Figures 4 to 7. K-means is a clustering algorithm used in data analysis and image processing. By setting the parameter k=2, this algorithm attempts to separate elements in handwriting into two groups based on similarity of attributes or features. The segmentation result using k-means with k=2 will divide the elements in handwriting into two different groups, often referred to as 'cluster 1' and 'cluster 2' or 'group 1' and 'group 2'.

When using k-means with k=3, the algorithm will aim to divide the elements in handwriting into three groups based on their attribute or feature similarities. The segmentation result will yield three distinct clusters, often labeled as 'cluster 1,' 'cluster 2,' and 'cluster 3' or 'group 1,' 'group 2,' and 'group 3.' This level of segmentation can be valuable in scenarios where you need finer-grained separation of elements within handwritten text, such as distinguishing between letters, numbers, and special characters.

With k=4 in k-means, the algorithm will work to separate elements in handwriting into four distinct groups, each characterized by similarities in their attributes or features. The segmentation outcome will present four separate clusters, typically identified as 'cluster 1,' 'cluster 2,' 'cluster 3,' and 'cluster 4' or 'group 1,' 'group 2,' 'group 3,' and 'group 4.' This increased level of segmentation can be advantageous when dealing with handwritten documents containing a variety of characters or symbols, enhancing the ability to differentiate between different types of content.

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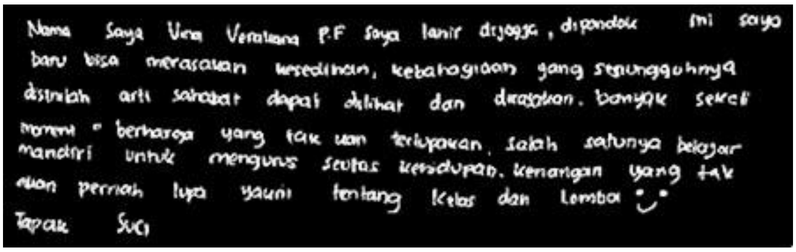

Figure 4. The result of binary image segmentation with the k value = 2

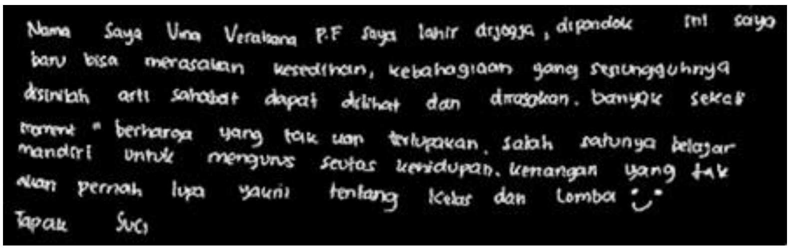

Figure 5. The result of binary image segmentation with the k value = 3

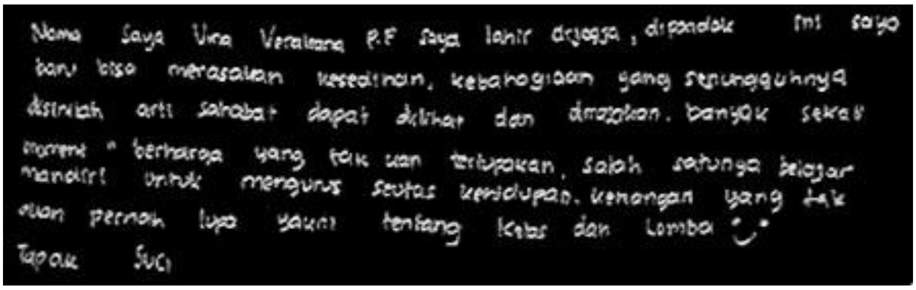

Figure 6. The result of binary image segmentation with the k value = 4

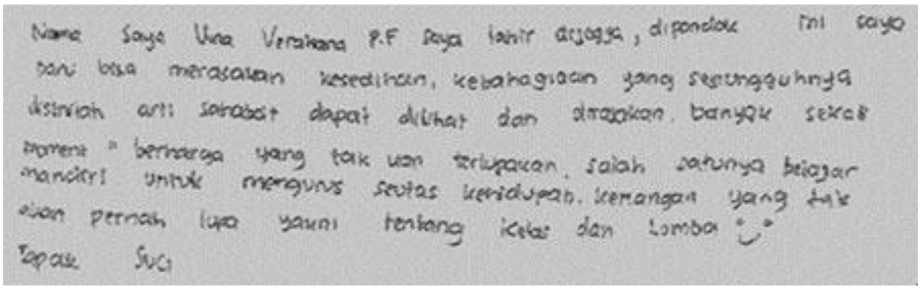

Figure 7. The result of binary image segmentation with the k value = 5

3.4. Calculating the silhouette coefficient

The silhouette coefficients of several images resulted from the segmentation without filters arsummarized in Table 1. The silhouette coefficient serves as a metric for assessing the similarity of objects within clusters and the dissimilarity between objects in different clusters. Ranging from -1 to 1, positive values indicate better similarity within clusters, negative values imply less ideal separation, and values near 0 denote cluster overlap. When applied to segmentation with different k values, such as k=2, k=3, k=4, and k=5, the silhouette coefficient offers insights into the quality of cluster separation for specific data or images. In essence, for k=2, it gauges the effectiveness of dividing data into two clusters, while for k=3, it evaluates the separation of three clusters, and so on. Comparing these silhouette coefficient values aids in determining the optimal number of clusters for segmentation within a given context.

Table 1. Silhouette coefficients of images resulted from the segmentation without filters

No	Names of images	Silhouette coefficients			
		k = 2	k = 3	k = 4	k = 5
1	text 01.jpg	0.9860	0.9702	0.9707	0.9605
2	text 02.jpg	0.9867	0.9870	0.9865	0.9842
3	text 03.jpg	0.9806	0.9751	0.9759	0.9736
4	text 04.jpg	0.9921	0.9793	0.9876	0.9778
5	text 05.jpg	0.9849	0.9771	0.9812	0.9727

Silhouette coefficients, presented in Tables 2 and 3, offer valuable insights into image segmentation. In Table 2, the coefficients are derived from segmenting images using a 3×3 median filter, providing evaluations for k=2, k=3, k=4, and k=5. The silhouette coefficient acts as a crucial metric, assessing both the similarity within clusters and the distinctions between objects in different clusters. Its range, from -1 to 1, signifies positive values for stronger intra-cluster similarity, negative values for less-than-optimal separation, and values near 0 for cluster overlap. Essentially, it quantifies the efficacy of dividing data into two clusters at k=2, extending to the assessment of three, four, or five clusters' performance as k increases. Table 3, on the other hand, showcases silhouette coefficients for images segmented using a 5×5 median filter, again across the same range of k values. It's important to note that the choice of a 3×3 or 5×5 median filter can lead to differing segmentation characteristics, underscoring the significance of silhouette coefficient comparisons in determining the most suitable clustering approach for specific contexts and filter size.

Silhouette coefficients of images segmented with a 5×5 median filter are shown in Table 3 for the same k values. It should be noted that using 3×3 and 5×5 median filters can produce different segmentation characteristics. The silhouette coefficient serves as an important metric for evaluating the extent to which objects in a cluster are similar to each other and how well the objects in a cluster are different from others. Silhouette coefficient values range from -1 to 1, with positive values indicating a better level of similarity within clusters, negative values indicating less than optimal separation, and values close to 0 indicating overlap between clusters. Thus, in essence, for the value k=2, this metric helps measure the effectiveness of dividing the data into two clusters, while for the values k=3, k=4, and k=5, it provides information about how well three, four, or the five clusters function in separating objects in the image.

Table 2 denote that the highest silhouette coefficients in each image were consistently observed in the segmentation with a 3×3 median filter and a k=2. These results highlight the superior clustering performance achieved with these specific settings, as indicated by the silhouette coefficients, which reflect better intra-cluster similarity and more distinct inter-cluster separation. This suggests that, for the analyzed images and segmentation task, utilizing a 3×3 median filter and selecting k=2 yielded the most optimal clustering outcome, underscoring the importance of these parameters in image segmentation.

Table 2. Silhouette coefficients of images resulted from the segmentation with median filter of 3×3

No	Names of images	Silhouette coefficients			
		k = 2	k = 3	k = 4	k = 5
1	text 01.jpg	0.9879	0.9741	0.9666	0.9696
2	text 02.jpg	0.9877	0.9840	0.9840	0.9801
3	text 03.jpg	0.9857	0.9754	0.9717	0.9715
4	text 04.jpg	0.9922	0.9854	0.9828	0.9784
5	text 05.jpg	0.9870	0.9748	0.9817	0.9778

Table 3. Silhouette coefficients of images resulted from the segmentation with median filter of 5×5

No	Names of images	Silhouette coefficients			
		k = 2	k = 3	k = 4	k = 5
1	text 01.jpg	0.9899	0.9764	0.9599	0.9620
2	text 02.jpg	0.9863	0.9840	0.9822	0.9798
3	text 03.jpg	0.9881	0.9681	0.9674	0.9641
4	text 04.jpg	0.9916	0.9814	0.9785	0.9863
5	text 05.jpg	0.9870	0.9794	0.9796	0.9780

The Silhouette coefficients for image segmentation using a 3×3 mean filter and different values of 'k' in k-means clustering are shown in Table 4. The best clustering result was obtained by using a 3×3 mean filter and selecting k=2, highlighting the significance of these parameters in image segmentation. Table 5 indicates that for the specific segmentation task using a 5×5 mean filter, the Silhouette coefficient for 'k' = 4 reached a value of 0.9744, which is notably higher than the Silhouette coefficients for other 'k' values. This observation strongly suggests that, for this particular set of images and the chosen segmentation method, 'k' = 4 is the most suitable choice for achieving the best separation of clusters. Selecting 'k' = 4 in this context appears to result in a superior segmentation quality, and it is likely the optimal choice for this image segmentation task.

Table 4. Silhouette coefficients of images resulted from the segmentation with a mean filter of 3×3

No	Names of images	Silhouette coefficients			
		k = 2	k = 3	k = 4	k = 5
1	text 01.jpg	0.9745	0.9686	0.9587	0.9499
2	text 02.jpg	0.9811	0.9772	0.9704	0.9772
3	text 03.jpg	0.9689	0.9600	0.9496	0.9580
4	text 04.jpg	0.9821	0.9779	0.9710	0.9614
5	text 05.jpg	0.9717	0.9694	0.9633	0.9662

Table 5. Silhouette coefficients of images resulted from the segmentation with a mean filter of 5×5

No	Names of images	Silhouette coefficients			
		k = 2	k = 3	k = 4	k = 5
1	text 01.jpg	0.9643	0.9584	0.9605	0.9486
2	text 02.jpg	0.9679	0.9622	0.9708	0.9630
3	text 03.jpg	0.9480	0.9494	0.9474	0.9364
4	text 04.jpg	0.9734	0.9740	0.9744	0.9727
5	text 05.jpg	0.9614	0.9570	0.9570	0.9566

4. CONCLUSION

This study investigated handwritten image segmentation using the k-means clustering algorithm. Meanwhile, the quality of images was improved using spatial filters. The most significant segmentation results were from the segmentation with a median filter of 3×3 and a k=2 which reach 99.22%. The results of this study are applicable as a reference to develop an analysis system of handwritten images to identify human characters. Further research can implement the gaussian filter to eliminate noise on handwritten images and the deep learning method to identify the characters of writers.

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