

K-Means Clustering Segmentation on Water Microbial Image with Color and Texture Feature Extraction

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Abstract—Image segmentation is one of the analytical processes for digital image recognition, where this process divides the digital image into several unique regions based on homogeneous pixels. The process of homogeneous grouping images is based on several colour, texture and shape features. Colour in digital image processing is very important because colour has many information humans can easily understand. Colour has various features, combining colour intensity and grey (grayscale) and binary (black and white) values. However, the colour feature extraction process has many weaknesses. If the object used has a very small size and range area, the use of colour features needs to be combined with extraction, and the segmentation process can be maximized. This study uses colour and texture features in the extraction process. It uses bacterial objects (microbes) from water, with limited image quality and objects that tend to be difficult to identify. The colour space feature extraction process is combined with a Gabor filter so that the segmentation process produces high-quality accuracy. Good. The Gabor filter used in this study is combined with the L^*a^*b space vector to increase accuracy in the segmentation process. The results showed that the use of texture features resulted in an increase in accuracy of 17.5% by testing the cluster value of 1.2.

Keywords: K-Means Clustering; Gabor Filter; Segmentation; Feature Extraction

1. INTRODUCTION

Artikel To obtain in-depth information from the image, the digital image processing process must go through several processes; others are preprocessing, image segmentation, image analysis, and image interpretation [1][2]. Most digital images have elements of a combination of texture and color as the main feature of the image; combining these two features can produce images with the same color but have several identical textures from one image to another. Segmentation is the process of homogeneous grouping pixels based on texture, color, and shape features. [3] The results obtained from image segmentation are binary images where the desired object has a white color or a value of 1, while the background to be removed has a black color or a value of 0. Humans, as visual creatures, tend only to be able to distinguish motorcycle taxis based on their color. However, the object's texture has an essential role in determining the object's character. Characters in textures are spatially repeating patterns; in other cases, the texture features have a random aspect and different variations in terms of shape, color, and other supporting elements. Image segmentation methods include discontinuity detection, clustering, thresholding, region-based segmentation, watershed algorithm-based segmentation, and line detection using the hough transform.

Of the several methods, the researcher chose the clustering method, which has a high level of effectiveness and a relatively small level of complexity[4]. Because it has a trim level of complexity, the clustering method is widely used and applied to various digital image segmentation processes. Several extraction features from each pixel are implemented as input space vectors so that they can be analyzed using the clustering method. A preprocessing step is needed to perform feature extraction on each pixel. Vectors identical to pixels in a region will be grouped, while those that are different will be grouped with pixels corresponding to points in other regions. Each vector in an area can be obtained from the results of the clustering process by providing a pixel label corresponding to the group and its members. Texture feature extraction produces a description of an object related to the relevant parameters and properties of the object. This data can be used to group and assign objects to a class [5].

In this study, using a microbial water dataset consisting of 60 dataset samples, the segmentation process was carried out to determine the character of each microbial colony found in water. This study uses texture and color features, and these two features have separate properties from one another. The texture feature uses grayscale, while the color feature uses RGB color. Color is one of the features in the three-dimensional RGB (*Red, Green, Blue*) color space with the same frequency relationship as the light spectrum. RGB representation can obtain other colors by utilizing linear or non-linear transformation modes. The grouping of color types into four parts, among others: premier color (R, G, B), (Rf, Gf, Bf) (X, Y, Z), luminance color space (L^*a^*b), (L^*u^*v), (Y',U',V'), (Y', I',Q'), then the perceptual color space (H,S,I), (L,C,H), (H,L,S) and the independent axis color space. Image segmentation can be done with various existing methods. Several other well-known methods are often used, such as Wavelet, Region Growing, Mean Shift, and several other methods. Kmeans is used in this study as a group-based method that combines and performs the isolation process of subregions separately. The K-means algorithm has simplicity and good capacity in classifying extensive data. Besides that, Kmeans can limit the distance between data to clusters. In this research, segmentation is done by applying the texture and color extraction processes as the main features of the image. Measurement of segmentation using the hit per rate model, so that every 1 sample from the data set will take 1 type of image at random for quality testing and image analysis. The analysis is done by inputting images with excellent image quality from the segmentation results so that pattern recognition can be carried out optimally.

2. RESEARCH METHODOLOGY

This study used sample data of 60 digital images obtained from a manual photo process using a modified DSLR camera with a Genesis 445 microscope. Dataset collection was carried out in 2 stages, starting from photos with a depth of 150% depth and 670% depth to produce good image data.

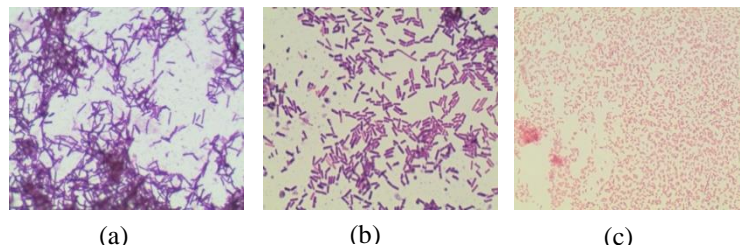


Figure 1. Sample of water microbial dataset: Clostridium (a), Proteus (b), Lactobacillus (c)

2.1 Water Microbe

The Microbes are a group of organisms that divide themselves and groups (colonies) to survive. Microbes are single-celled living things with prokaryotic characteristics, so they are challenging to detect. Bacteria develop and form different patterns between bacteria with each other, resulting in the form of colonies between bacteria that have their uniqueness [6][7]. Although they have different shapes, each bacterium is influenced by several things so that they can reproduce. Several factors that influence this include temperature, pH, Osmose Pressure, Oxygen, and the water content of the media where the bacteria live [2].

2.2 Digital Image Processing

Image processing is a method used to process or manipulate images in 2-dimensional form image processing can also say any operation to fix, analyze, or change an image. The basic concept of processing an object in the image using image processing is taken from the ability of the senses of human vision that are next connected to the human brain's ability [1]. In general, the objectivity of image processing is to transform or analyze an image so that new information about the image is made more explicit. Image processing has four primary classifications: point, area, geometric, and frame.

- The point processes an image's pixel value based on that pixel's value or position. An example of the point process is adding, subtracting, contrast stretching, and so on.
- The area processes the pixel value of an image based on the pixel value and the pixel value around it. An example of the area process is convolution and blurring.
- Geometrics are used to change the position of pixels. An example of the geometric process is scaling, rotation, and mirroring. II-2 d. Frame processes a pixel value of an image based on an operation of two or more images. and figure 1.

2.3 Image Segmentation

Image segmentation is an image processing process to separate the desired object from the background. The results obtained from image segmentation are binary images where the desired object has a white color or a value of 1, while the background to be removed has a black color or a value of 0. [8] Image segmentation methods include discontinuity detection, thresholding, region-based segmentation, segmentation-based watershed algorithm, and line detection using hough transform. Segmentation is the initial step taken when you want to carry out object classification. The segmentation process is carried out to get features following the object taken.[9]

2.4 RGB Images

RGB (Red, Green, Blue) images are the primary color components we can see and receive by the human eye. Each pixel in a color image represents a combination of the three primary colors. Each point in the color image has 3 bytes of data and has its intensity level with a minimum value of zero (0) and a maximum value of 255 (8bit).[10] RGB is based on the human eye's sensitivity to wavelengths of 630 nm (red), 530 nm (green), and 450nm (blue).

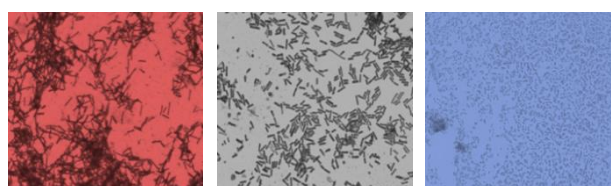


Figure 2. Color representation in RGB



2.5 L*a*b Color Space

The L*a*b color space, known as CIELAB, is the complete type of color space defined by the International Commission on color illumination. The L*a*b space can describe the color components that can be seen physically by the human eye and can be used as the default color space.[5][11] The process of calculating the L*a*b color space can be done using the XYZ color space through the following equation:

$$L^* = 116 \left(\frac{y}{y_0}\right)^{1/3} - 16 \text{ for } \frac{y}{y_0} > 0.008856 \tag{1}$$

$$L^* = 903.3 \frac{y}{y_0} \text{ for } 0.0 \leq \frac{y}{y_0} \leq 0.008856 \tag{2}$$

$$a^* = 500 \left[f\left\{\frac{x}{x_0}\right\} - f\left\{\frac{y}{y_0}\right\} \right] \tag{3}$$

$$b^* = 200 \left[f\left\{\frac{y}{y_0}\right\} - f\left\{\frac{z}{z_0}\right\} \right] \tag{4}$$

Where

$$f(w) = w^{1/3} \text{ for } w > 0.008856 \tag{5}$$

$$f(w) = 7.787 (w) + 0.1379 \tag{6}$$

$$\text{for } 0.0 \leq w \leq 0.008856 \tag{7}$$

An RGB image (Red, Green, Blue) consists of three components of the image field that are separated from each other, and each image consists of the primary colors, including red, green, and blue in each pixel. The L*a*b color space stands for Luminance, and A and B are components of a color. The L*a*b model can be represented between green to red and B direction blue to yellow.

2.6 XYZ Color Space

The XYZ color space is a component of the CIE XYZ color space obtained from the RGB color space transformation process, which is transformed into a 3x3 matrix. [12] The transformation involves a tristimulus value, a configuration of three linear light color components using color matching. Click or tap here to enter text. The transformation calculation from RGB to XYZ color space can be done by calculating the transformation matrix with the following equation.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.412453 & 0.357580 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{8}$$

2.6 Gabor Filter

The Gabor function is one type of filter that can simulate the characteristics of the visual system in humans by isolating specific frequencies and orientations to the image. These characteristics make the Gabor filter suitable for texture recognition in computer vision. [5] Denis Gabor first introduced the Gabon filter as a tool to perform the signal detection process[13]. Gabon filter is a linear filter used in the feature extraction process as a feature detector. This filter can eliminate variability cause by the contrast illumination process, image shift, and deformation. To use the Gabor filter kernel by using the equation.

$$(x, y, \theta, u, \sigma) = \frac{1}{2\pi\sigma^2} \exp\left\{-\frac{x^2+y^2}{2\sigma^2}\right\} \exp\{2\pi \cdot i (u \cdot x \cdot \cos\theta + u \cdot y \cdot \sin\theta)\} \tag{9}$$

With

$$i = \sqrt{-1} \tag{10}$$

u is the frequency of the Sinusoidal waves

θ is control of orientation of *Gabor function*

σ standard deviation *Gaussian Envelope*

x,y is the coordinate of *Gabor Filter*

The Gabor Filter equation above is formed from two components, namely the Gaussian envelope and the Sinusoidal wave, in complex form. The Gaussian envelope function uses the following equation:

$$g(x, y) = \frac{1}{2\pi\sigma^2} \exp\left\{-\frac{x^2+y^2}{2\sigma^2}\right\} \tag{11}$$

There are five frequencies used, namely (u = 0,1,2,3,4) and the orientation angle used is eight, namely (=0,1,2,3,4,5,6,7) so as to produce 40 Gabor Response (*Magnitude Response*).

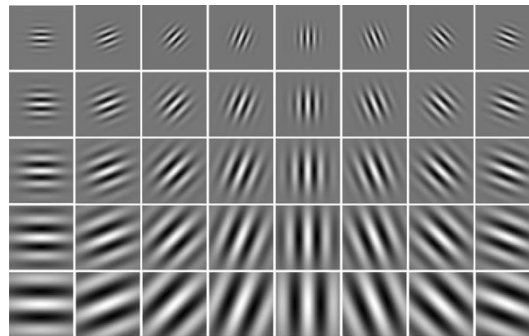


Figure 3. Gabor Kernel

Suppose an input image contains two different texture regions and has local frequency differences between the regions. In that case, it will detect the texture in one or more sub-image output filters. The essential Gabor function determines each Gabor filter because the spatial and spatial frequency values have filter localization values used in segmentation.

2.7 K-Means Clustering

K-Means clustering is one of the most widely used methods to get a description of a data set by finding the trend of each other data. [14] This algorithm performs the process of grouping data based on the distance between the data to the cluster centroid point obtained from an iterative process. Kmeans clustering is a type of unsupervised learning so that it can be used in various processes including image segmentation, compression to classification.[10], [14], [15]

$$d_{ij} = \sqrt{\sum_{k=1}^p \{x_{ik} - x_{jk}\}} \quad (12)$$

Formula:

- d_{ij} = Distance Between Objects
- P = Dimensions Data
- x_{ik} = Dimensions i and k
- x_{jk} = Dimensions j and k

The Kmeans algorithm is a non-hierarchical method that takes some of the many components of the population to be used as the initial cluster. [16][14] The K-Means algorithm performs two processes, namely, the process of detecting the central location of each cluster and the process of searching for members of each cluster. Technically, the K-Means algorithm runs as follows:

- a. Determine k as the number of clusters to be formed
- b. Generate initial k centroids (*cluster center points*) randomly
- c. Calculate the distance of each data to each centroid
- d. Each data selects a centroid closest to them
- e. Determine the position of the new centroid by calculating the average value of the data set in the same centroid
- f. Return to step 3 if the position of the new centroid with the old centroid is not the same

2.7 Systematic research

A microbial image is an RGB format; before further processing, the image is converted into L*a*b format. The color parameters in L*a*b have been predetermined based on standards from the International Commission, which refer to 3 dimensions or the direction of the color space. In addition to carrying out the conversion process at the initial stage, filtering and thresholding processes are carried out to obtain an image with an intensity level of 256 pixels. This step is done to get maximum results when the image is segmented. In the next step, the segmentation process is carried out, and the segmentation process aims to separate the background object from the background, where this process will produce an image in binary form. The object (foreground) you want will be white, while the background you want to delete will be black. This research will use Kmeans in the segmentation process, and this algorithm will play a role in the color space representation process with optimization based on Euclidean distance. This distance will have a quadratic size between the instances in the cluster and the centroid. On the other hand, the image segmentation process based on the clustering method must perform the division process based on separate groups. The objective function in this method is called a distortion measure which we can understand through the following function: This distance will have a quadratic size between the instances in the cluster and the centroid. On the other hand, the image segmentation process based on the clustering method must perform the division process based on separate groups.

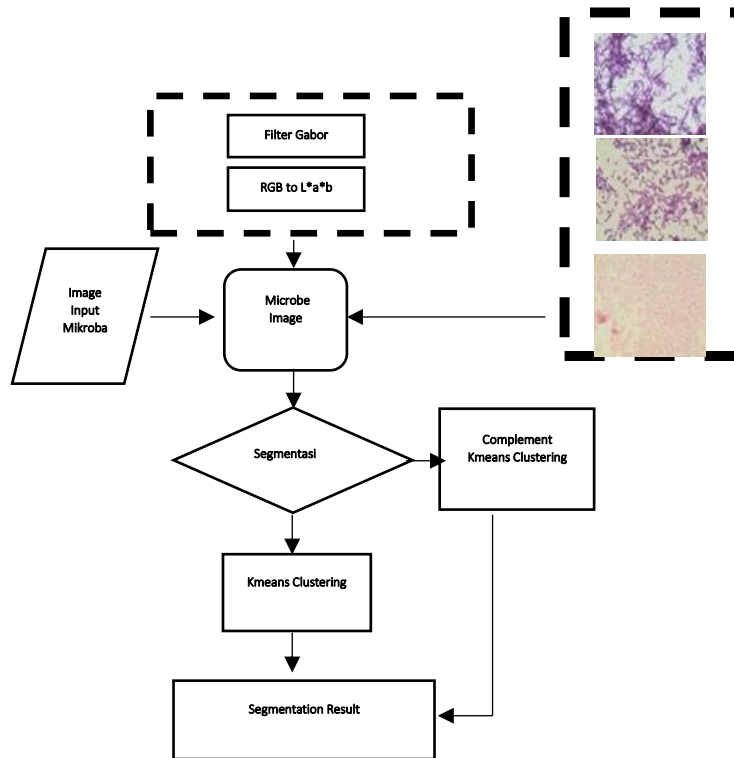


Figure 4. Microbial Segmentation Process Flowchart

The objective function in this method is called a distortion measure which we can understand through the following function: This distance will have a quadratic size between the instances in the cluster and the centroid. On the other hand, the image segmentation process based on the clustering method must perform the division process based on separate groups. The objective function in this method is called a distortion measure which we can understand through the following function:

$$J = \sum_{n=1}^N \sum_{k=1}^K r_{nk} \|X_n - \mu_k\|^2 \tag{13}$$

3. RESULT AND DISCUSSION

The inputted microbe image is in RGB format; before the segmentation process, the image will be converted into L*a*b.

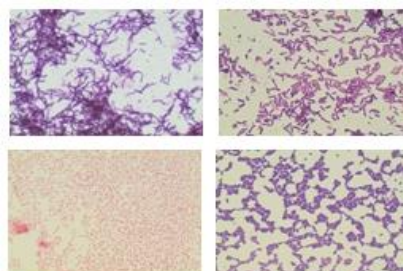


Figure 5. Microbial Dataset

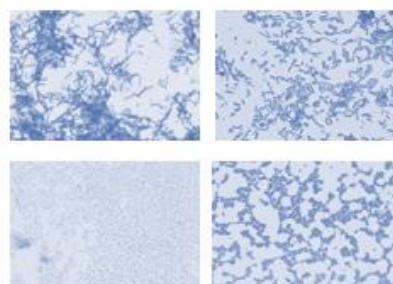


Figure 6. L*a*b Conversion Result Image Date

The L^*a^*b image is then segmented using the K-Means Clustering algorithm and then displayed as a black and white binary image. The white color in the binary image, which we often refer to as the lesion image, indicates the foreground, while the black color indicates the background. In this case, the white color is the area of the microbial colony, while the black indicates the area or part of the bottom plate where the microbes live.

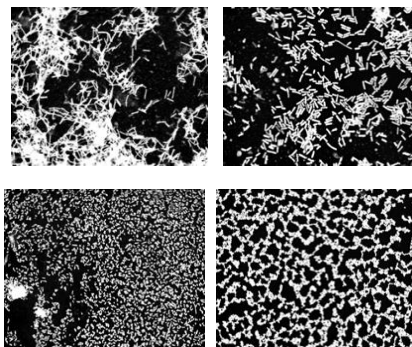


Figure 7. Image result of binaryzation process

After the microbial colony has been detected, a different image of the final segmentation process will be produced. In some images, the segmentation results are reversed in distinguishing microbes from living media. Hence, the segmentation process needs to be carried out with the complement results from the previous segmentation to reverse the foreground value.

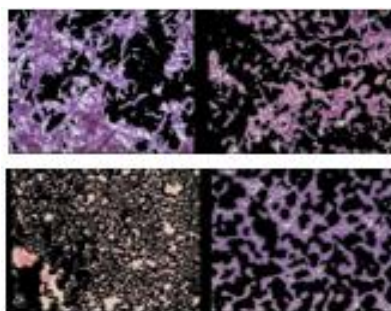


Figure 8. Image data from the segmentation process

After the bacterial colonies have been found, the process will continue to display or delete non-linear areas in the next step. The next step is to perform an ROI (*Region Of Interest*) test, and Figure 8 shows the area where these microbes live.

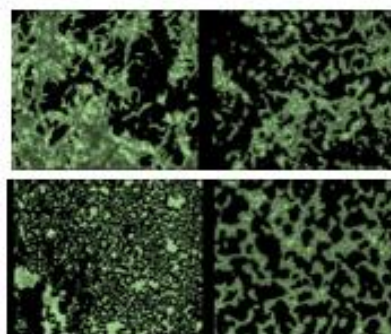


Figure 9. Image data from the segmentation process

After the bacterial colonies have been found, the process will continue to display or delete non-linear areas in the next step. The next step is to perform an ROI (*Region Of Interest*) test, and Figure 8 shows the area where these microbes live. Of the 60 images used, 20 were correctly detected. At the same time, the remaining 40 were unfinished, some of which resulted in poor quality, so further processing or improvement of the segmentation method was needed so that the results obtained were optimal. After the segmentation process is carried out, the following process tests the segmentation results to see their suitability of the segmentation results that have been carried out. Testing on microbial segmentation focuses on finding the optimal number of clusters in the Kmeans algorithm when processing microbial segmentation. To support the testing process carried out, several additional parameters are needed, including:

- a. Image size resizing process 375x 500
- b. Value on Scale Factor rescale process 1: 1

- c. Then on the number of clusters in the
- d. initial Centroid microbial colony segmentation in this study using the L^*a^*b space value with the input image in the first n data, n data adjusted to the number of parameters tested clusters.

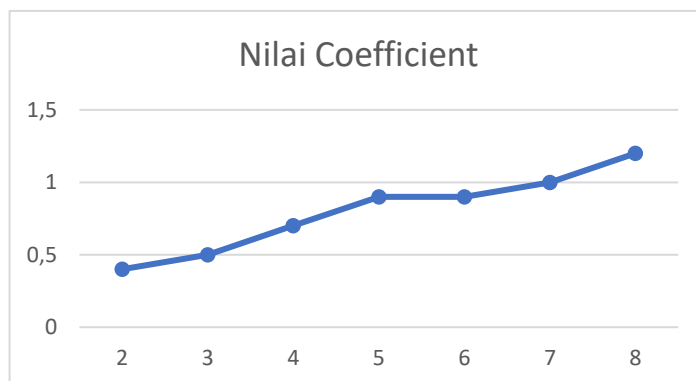


Figure 10. Diagram of the results of testing the optimal number of clusters on microbial segmentation

4. CONCLUSION

Based on the results of the separation and testing carried out, it can conclude that texture property extraction can be maximized using the Gabor Filter and continued with the image segmentation process using K-Means Clustering using the parameters previously specified. In addition, when performing the K-Means implementation process as an image segment method, a resize process and converting RGB color space to L^*a^*b is required. Segmentation quality enhancement can also be done by adding steps at preprocessing time by performing Rescaling and other steps so that output image results can be used in the classification process. In testing the segmentation results, the optimal cluster value obtained a value of 1,2. Further testing is required by performing the optimal k-value test to obtain the appropriate cluster value from each image.

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