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# SEGMENTATION OF DIGITAL IMAGES WITH WAVELET TRANSFORMATION USING MATLAB VERSION R2010B

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*Segmentation, Wavelet Transformation, MATLAB*

**ABSTRACT**

The purpose of this research is to explore and apply the use of wavelet transformation for the segmentation of digital images, utilizing MATLAB version R2010B. The study aims to analyze how wavelet transform can be used to enhance the accuracy and effectiveness of image segmentation, which is a critical process in image processing and computer vision. The research contributes to the field of digital image processing by demonstrating the application of wavelets transformation for segmenting digital images. In this study, the study provides insights into how wavelets can be utilized to improve the detection of image features, especially in identifying image features more accurately. The experimental results show that only the Canny operator's edge detection method has the best edge detector in detecting the edges of objects in wavelet images. The technique of determining the threshold value (thresholding) can be carried out in two ways, namely, automatic method and technique carried out by trial and error. Finally, improving automatic thresholding techniques using AI-driven algorithms to reduce the reliance on trial-and-error methods could provide more consistent results in varied application areas.

## INTRODUCTION

Technological advances in terms of data recording have now made it possible to provide data in the form of digital images. An image is an image on a two-dimensional plane. In a mathematical review, imagery is a continuous function of light intensity in a two-dimensional plane (Baek & Park, 2021; Bhandari et al., 2022; He et al., 2022; Hua et al., 2021; Schultheiss et al., 2020; Zhou et al., 2021). When a light source illuminates an object, the object reflects back some of that light. These reflections are captured by optical sensing devices, such as the human eye, cameras, scanners and so on. The shadow of the object will be recorded according to the intensity of the light reflection. When the optical device that records the reflection of light is a digital machine, such as a digital camera, then the resulting image is a digital image (Blahnik & Schindelbeck, 2021; Brady et al., 2020; Chávez Heras & Blanke, 2021; Fratz et al., 2021; Mennel et al., 2020). In digital imagery, the continuity of light intensity is quantized according to the resolution of the recording device.

Digital image processing is a process that aims to manipulate and analyze images with the help of computers with input data and output data in the form of images (Fernandes et al., 2020; Gurevich & Yashina, 2021; Prakash et al., 2022; Salvi et al., 2021; Thakur & Rohilla, 2020). Image segmentation is a stage in the image analysis process that aims to obtain information contained in an image by dividing the image into separate areas where each area is homogeneous and refers to a clear uniformity criterion.

Image is a two-dimensional function formed from visual perception in a scene, such as a photo. There are two types of images: analog and digital. Analog images are captured by a camera lens from a scene and scanned both vertically and horizontally by the camera's imager. Digital images, on the other hand, are those that can be processed by a computer. Mathematically, a digital image is expressed as an intensity function f(x,y), where x represents rows, y represents columns, and f(x,y) indicates the intensity at each point, representing the grayscale level or color of the pixel at that specific coordinate (Sutoyo, 2009). Pixels, or picture elements, are the smallest units of a digital image.

Digital images can be divided into different types based on the information they store. An RGB image, for instance, contains a 3D matrix of data representing red, green, and blue for each pixel, with each color stored using 8 bits, allowing for a total of over 16 million colors. Grayscale images, on the other hand, represent intensity levels in shades of gray, typically ranging from 0 (black) to 255 (white). These intensity values are used to produce a smooth gradation from black to white, which can be seen in an image with 256 levels of gray.

The concept of wavelets and wavelet transformations is relatively new in signal processing. Introduced by J. Morlet and A. Grossman, and later expanded by Daubechies and Mallat, wavelets became a powerful approach to signal analysis in 1987. Wavelet functions break data into different frequency components, allowing for the study of each at various resolutions. The wavelet transformation employs two key components: the scaling function (lowpass filter) and the wavelet function (highpass filter). These are used during both wavelet transformation and inverse transformation to analyze image data.

In discrete wavelet transformation (DWT), an image is decomposed into frequency subbands: LL, LH, HL, and HH, with each subband capturing different frequency details of the image. Subband LL contains the most information, and it can be further decomposed into new subbands through multilevel wavelet decomposition. This process is particularly useful in applications like image compression, where different levels of detail can be analyzed or discarded as needed. Additionally, models like raster and vector are used to represent and store spatial data in images, with raster focusing on grid-based pixel structures and vector on points, lines, and polygons.

Wavelets are mathematical functions that cut data into sets of different frequencies, so that each of these components can be studied using different resolution scales. Some of the applications of wavelet transformation in digital image processing include fingerprint recognition preprocessing, noise reduction in images, steganography, biometrics and so on. Therefore, it is important to raise how to apply wavelet transformation in digital image processing using Matlab version R2010b.

The purpose of this research is to explore and apply the use of wavelet transformation for the segmentation of digital images, utilizing MATLAB version R2010B. The study aims to analyze how wavelet transformation can be used to enhance the accuracy and effectiveness of image segmentation, which is a critical process in image processing and computer vision. The research contributes to the field of digital image processing by demonstrating the application of wavelet transformation for segmenting digital images. By using MATLAB version R2010B, the study provides insights into how wavelet transformation can improve the segmentation process, especially in identifying image features more accurately. This contribution is valuable for further developments in image analysis, machine vision, and related technologies that rely on effective image segmentation techniques.

## METHODS

The research materials needed to carry out the entire process of segmentation of digital images in this application use two digital images with a grayscale image type that has a color depth of 8 bits, namely from 0 to 255 and an RGB image type which is a combination of three color components R (Red), G (Green), B (Blue) with a depth of 24 bits or commonly called truecolor image. Each component consists of 8 bits, so for 3 color components it uses 24 bits or equal to 3 bytes per pixel. In this experiment, before the experimental image is segmented, a short wave (wavelet) decomposition is first carried out to emphasize the information on the image objects. Both images are shown in Figure 1.

**Figure 1.** Experimented Image

## RESULTS

### Wavelet Decomposition Testing Process

The first experiment uses the "lena.bmp" image with the initial format is truecolor. Then, the resulting image of the grayscale wavelet decomposition is as follows:

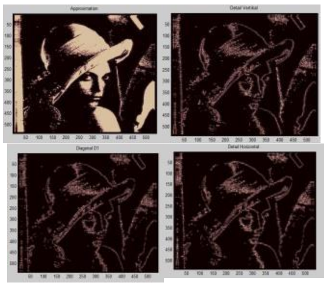

**Figure 2.** Grayscale image of Wavelet Decomposition "Lena.bmp"

After conducting experiments with grayscale wavelet decomposition, the next experiment uses the same image file name and RGB wavelet decomposition method. So the resulting wavelet decomposition RGB image can be seen as follows:

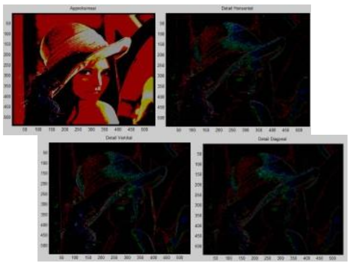

**Figure 3.** RGB image of Wavelet Decomposition "Lena.bmp"

The second experiment uses the "pelabuhan_ratu.jpeg" image with the initial format being *grayscale* , so the resulting image of the grayscale decomposition *wavelet* is as follows:

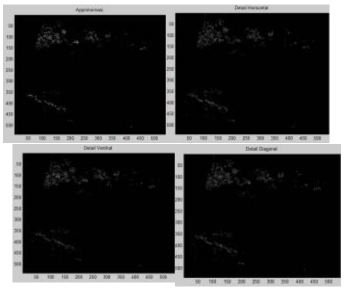

**Figure 4.** Grayscale image of Wavelet Decomposition "pelabuhan_ratu.jpeg"

After conducting experiments with grayscale wavelet decomposition, the next experiment uses the same image file name and RGB wavelet decomposition method. So the resulting wavelet decomposition RGB image can be seen as follows:

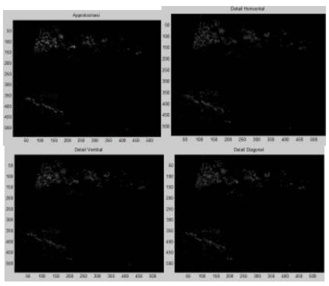

**Figure 5.** RGB image of Wavelet Decomposition "pelabuhan_ratu.jpeg"

In the above two experiments, the analysis process with the visual vision method can only be carried out in the first experiment which is quite clear the intensity and contrast values of the image resulting from the wavelet decomposition process. While in the second experiment, the resulting wavelet decomposition image is quite complicated to be analyzed visually, so the two experiments above can be analyzed specifically using the wavelet toolbox. Where the following values are obtained:

**Table 1.** Statistical calculation of wavelet decomposition images

| Name of Image | Method | Mean | St. Deviation |
|---|---|---|---|
| Lena.bmp | Grayscale Decompost Wavelet Contents | 192,5 | 90,01 |
| | RGB Decompose Wavelet Contents | 192,4 | 110 |
| Pelabuhan_ra tu.jpeg | Grayscale Decompost Wavelet Contents | 64,78 | 70,59 |
| | RGB Decompose Wavelet Contents | 64,77 | 70,54 |

In which:

Mean is the average intensity of an image. Standard deviation is the distribution of values from the average intensity (describing the contrast of the image). Contrast is a difference in the high intensity of the image. Save the approximized wavelet image and since the contrast of the detailed wavelet image is the same, it is enough to save one of the detailed wavelet images.

**Image Segmentation Testing Process**

The segmentation process in this application is an image segmentation process with an edge detection method which includes five operators, namely Sobel, Prewitt, Robert, Canny and Laplacian of Gaussian as well as with the segmentation of the threshold method.

***Edge Detection Segmentation Testing***

In this first discussion, we will first discuss image segmentation based on the edge detection method using grayscale decomposition wavelet approxismotic "lena.bmp" images.

In this first experiment, the image of the segmentation results is as follows:

**Figure 6.** Segmentation Image of Wavelet Image "lena.bmp"

From the results of the experiments that have been carried out above, it can be concluded that:

1) The best edge detector in detecting the edges of objects in wavelet images is the Canny operator. From Figure 6, it can be seen that of all the edge detection images produced, only the Canny operator's edge detection image has a shape and information content that resembles the input image. Although the boundaries of the edges of the object in the image are not so clear in intensity compared to the other four operators. However, the Canny image can provide a better picture of the boundaries of the object's edges.

2) As for Gaussian operators, there are several objects whose edges are not so clear, thus reducing the content of the information they carry.
3) For Roberts operators, the resulting edge detection is quite good. Although this operator is one of the operators that uses masking with a size of 2 x 2 pixels as well as a simple operator. The Roberts operator only checks for an additional pixel in one direction of the gradient, but since it is a pixel in the diagonal direction, the difference located on the beveled sides of the object will be detected.

As for the sobel and prewitt operators, the visually generated edge imagery has a strong intensity, as a result of which the detail of the edge image is reduced.

**Threshold Segmentation Testing**

In the second discussion, image segmentation based on the thresholding method will be discussed. Single thresholding and double thresholding operations require an image whose histogram contains two or more dominant modes, where one or more modes are the accumulation of object pixels and the other mode is the accumulation of background pixels, then in this experiment will use a grayscale "pelabuhan_ratu.jpeg" image that has 2 dominant colors.

In this second experiment, thresholding segmentation will first be tested based on the double thresholding method. The double thresholding method is a method of determining the threshold that is carried out automatically without the need to specify the input of the threshold value itself. The results of this threshold method can be seen as follows:

(r1 = T, r2 = 255)

**Figure 7.** Double Thresholding Image

The next experiment will be tested thresholding segmentation based on the single threshold method, and will be tested in comparison with two different threshold input values with the following threshold values:

T = 0.1    T = 0.5

**Figure 8.** Single Thresholding Image

From the results of the experiments that have been carried out above, it can be concluded that:

1) From Figure 7, it can be seen that the double thresholding operation is relatively faster than the single thresholding operation because in this operation the determination of the thresholding value has been carried out automatically (the user does not need to look for a thresholding value that is considered good).
2) From Figure 8, it can be seen visually that the selection of threshold values greatly determines the success of the thresholding operation. If the threshold selection is not optimal, this operation will give poor results.
3) In the two experiments above, it can be seen that the technique of determining the threshold value (thresholding) can be carried out in two ways, namely by automatic method and technique carried out by trial and error.

## CONCLUSION

The study focuses on the segmentation of digital images using wavelet transformation. The process produces two coefficients: the approximation coefficient, which contains the low-frequency components of a signal, and the details coefficient, which contains the high-frequency components. The Canny operator's edge detection method is found to be the best in detecting object edges in the image. Vector data requires less space in computer memory, making it an advantage. The threshold method can be determined automatically or through trial and error. Future research should explore different wavelet families beyond bior 3.7, combining wavelet transformation with advanced edge detection methods like machine learning, and exploring real-time image segmentation in high-performance computing environments. Additionally, improving automatic thresholding techniques using AI-driven algorithms could provide more consistent results in various image segmentation applications.

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