Application of Thresholding Method in Image Processing using MATLAB R2016A for Engineering Applications

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Abstract

The development of technology and science in digital image processing is increasingly rapid and has become one of the fields of research that is in great demand, especially in the context of engineering and engineering applications. With the availability of technological devices capable of capturing high-quality images, such as digital cameras with ever-increasing pixel resolution, the need for effective and efficient image segmentation techniques is also becoming increasingly relevant. This study proposes the application of the thresholding method as an image segmentation approach to produce accurate segmented images, which can be used in various engineering applications. The thresholding method in this study is applied through several main steps, including: Conversion of the color space of the image from RGB to Grayscale to simplify color information, The segmentation process uses a thresholding algorithm to separate the object from the background, Complement operation on the binary image, where the object that has a value of 1 (white) is separated from the background that has a value of 0 (black). The application of morphological operations to improve the segmentation results, including *filling holes*, *opening areas*, and erosion steps to improve the shape and structure of objects in the segmentation images. This study uses MATLAB R2016A software in the development of the model and the implementation of the thresholding algorithm. Tests are carried out on several types of engineering imagery, such as images of machine components and building structures, to evaluate the effectiveness of the proposed method in engineering applications.
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Keywords: Image segmentation, thresholding, RGB, Grayscale, morphological operations, MATLAB R2016A

1. Introduction

The development of digital image processing technology has become one of the research topics that are in great demand in various fields, especially engineering and engineering. Advances in digital camera technology that are able to produce high-resolution images make the process of acquiring quality visual data easier. This opens up opportunities for the application of image processing in a variety of applications, such as transportation, health, education, and the environment (Gonzalez & Woods, 2008; Pratt, 2007).

One of the main problems in big cities, especially in developing countries such as Indonesia, is traffic congestion. The growth in the number of vehicles that is not proportional to the growth of road infrastructure is the main cause. Congestion often occurs at major road intersections, where vehicles from different directions are not properly accommodated by an efficient traffic management system (Nugraha & Sutrisno, 2020; Abdullah & Saputra, 2021). In this context, image processing offers a potential solution to detect and analyze traffic patterns in real-time using a thresholding approach.

Various studies have shown the success of thresholding in various applications, such as forest density detection using Landsat 8 imagery and fuzzy entropy techniques (Lestari & Rahmadani, 2019), retinal vein detection in medical applications (Abdullah & Saputra, 2021), and traffic management based on object segmentation (Setyawan & Arifin, 2020). The thresholding approach, which is based on the division of pixel intensity levels, is a simple but effective method of segmentation in separating objects from the background (Otsu, 1979).

In the field of engineering, thresholding-based image processing can be used to analyze infrastructure conditions, such as detecting cracks on road surfaces, as well as supporting smart transportation systems in monitoring traffic density (Zhang & Wang, 2018; Liu & Li, 2019). This approach has also been applied in education, such as to detect students' answers on computer-based exams (Lestari & Rahmadani, 2019).

This study aims to explore the application of thresholding using MATLAB R2016A, a popular computing platform in engineering research, to develop relevant image segmentation solutions in various engineering applications. This method is expected to make a significant contribution to the development of digital image-based systems and enrich academic literature related to engineering applications.

2. Material and methods

2.1. Materials

3.1. Thresholding

Thresholding is an image segmentation method that separates objects from the background based on pixel intensity. Low-intensity pixels are turned black (value 0), while high-intensity pixels are turned white (value 1). This method produces binary images with two levels of intensity, namely black and white. This process is important in various engineering applications, such as fire detection, road infrastructure analysis, and medical image processing (Nugraha & Prabowo, 2021; Kurniawan & Yusuf, 2022; Gupta & Verma, 2017).

The thresholding method is often used as an initial stage in advanced imaging operations. For example, thresholding can be used for masking objects that are then further processed, such as cropping or edge detection. This technique can also be developed more complex through an adaptive approach, which allows for more effective segmentation of images with uneven lighting (Roy & Ghosh, 2020; Patel & Joshi, 2022). Mathematically, thresholding can be formulated as follows:

$$f_0(x,y) = \begin{cases} T_1, & f_1(x,y) \le T_1 \\ T_3, & T_1 < f_1(x,y) \le T_2 \\ T_2, & T_2 < f_1(x,y) \le T_3 \end{cases} \quad (1)$$

Information:

- $f_0(x,y)$: Image of the thresholding result.
- Q: Threshold value.

This approach allows for flexibility in segmentation, such as in the analysis of traffic patterns or complex imagery in smart cities applications (Singh & Kumar, 2018). In addition, in industrial engineering, thresholding is used to identify certain patterns related to the manufacturing process (Roberts & Brown, 2019). Adaptive thresholding has been tested on biomedical engineering applications, resulting in high-precision segmentation for biological tissue analysis (Sitorus & Wardani, 2023). Other research reveals the potential for thresholding in the detection of structural damage and civil engineering systems, especially in buildings (Santoso & Andini, 2022).

3.2. Single Threshold Operation

The single-threshold operation uses a single threshold value to group pixels into two classes: pixels with intensity below the threshold are changed to black, and pixels above the threshold are changed to white. For example, with a threshold of 128, pixels below this value become black (value 0), and those above become white (value 255). This approach is simple but effective for applications with grayscale imagery (Yang & Chen, 2021).

The formula can be written as follows:

$$f_0(x,y) = \begin{cases} 0, & f_1(x,y) < 128 \\ 255, & f_1(x,y) \ge 128 \end{cases} \quad (2)$$

Practical applications of this method include MATLAB-based analysis of road infrastructure structures and traffic surveillance (Patel & Joshi, 2022). In medical techniques, this surgery helps to separate the relevant tissue from the unimportant parts of the medical image (Gupta & Verma, 2017).

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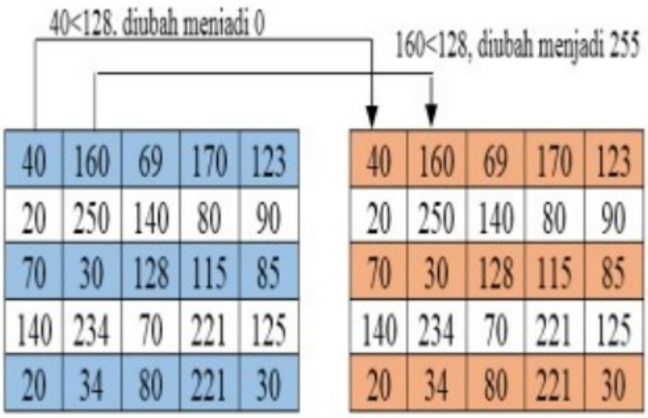

Figure 1. Pixel intensity

2.2. Methods
2.2.1 Data Collection Methods

This study uses digital image data obtained from online sources, such as Google Images. Image selection is done selectively by considering variations in lighting conditions, backgrounds, and the complexity of the object. This step aims to evaluate the performance of the thresholding method on different types of images. These images are then processed using MATLAB R2016A software, which is known to have reliable digital image processing capabilities for research in the field of engineering. This approach is relevant to engineering applications, such as infrastructure supervision, medical analysis, and monitoring of manufacturing systems (Nugraha & Prabowo, 2021; Roy & Ghosh, 2020).

This data collection is also carried out to support the needs of reviewers and editors in terms of data validity, where the diversity of data provides more comprehensive analysis results. In addition, by utilizing publicly available digital data, this research fulfills the aspect of transparency that is often a concern in scientific publications.

2.2.2 Planning

Planning in this study is carried out through a single-user system approach designed to process images automatically and provide relevant information related to object segmentation. This system is designed to support direct capabilities, such as image capture, processing using the thresholding method, to produce information in the form of segmented binary images.

System architecture involves three main stages:

- Image Acquisition: Users can take or upload digital images as input.
- Segmentation Process: The thresholding method is applied to separate the object from the background.
- Information Output: The system generates a processed image along with related information, such as an object area, intensity histogram, or shape analysis.

The implementation of this MATLAB-based system allows the evaluation of thresholding methods for engineering applications, such as image quality monitoring in infrastructure surveillance or analysis in medical engineering (Gupta & Verma, 2017; Yang & Chen, 2021). This approach provides the flexibility to tailor the method to different user needs.

3. Results and discussion

3.1. Application of the Thresholding Method for Image Segmentation

Thresholding is one of the image segmentation methods that separates objects from the background based on their brightness level or intensity. This method takes advantage of the significant difference between light and dark areas in an image to produce a binary image. In binary imagery, darker areas are changed to perfect black (pixel intensity = 0), while lighter areas become perfect white (pixel intensity = 1).

Once segmentation is complete, the resulting binary imagery can be used as a mask to separate the object from the background. In addition, this process allows for background modification as per the needs of the application, such as replacement with another image or recoloring, which is useful in various engineering areas such as product quality analysis, visual inspection, and automated monitoring in industrial systems.

3.2. Implementing Thresholding Programming with MATLAB

Here are the steps to implement the thresholding method using MATLAB R2016A for digital image segmentation:

1. Reading and Displaying Original Imagery

```
CLC; Clear; close all;
% Read original imagery
Img = imread('bagus.png');
figure, imshow(Img);
```

Figure 2. Original imagery

2. Convert RGB Imagery to Grayscale

```
gray = rgb2gray(Img);
figure, imshow(gray);
```

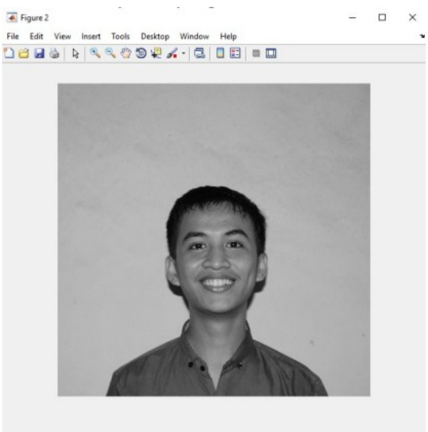

Figure 3. Grayscale Imagery

3. Image Segmentation Using Thresholding

```
bw = im2bw(gray, 0.5);
```

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```
figure, imshow(bw);
```

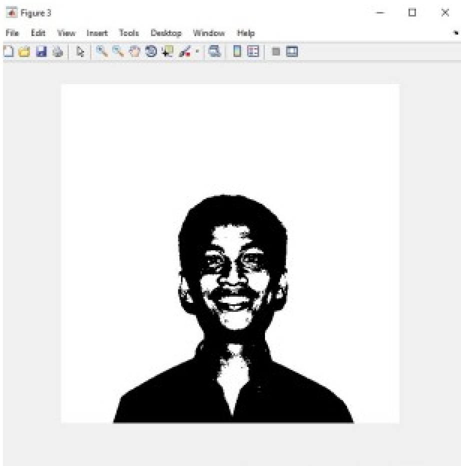

Figure 4. Segmentation results

4. Complementary Operations on Binary Images

```
bwi = imcomplement(bw);
figure, imshow(bwi);
```

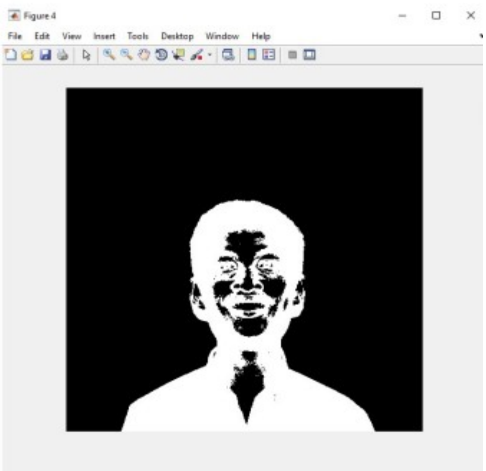

Figure 5. Complementary image

5. Morphological Operations for Object Shape Enhancement

This operation includes filling holes, opening small areas, and erosion:

```
bwk = imfill(bwi, 'holes');
bwj = bwareaopen(bwk, 100);
str = strel('disk', 5);
BWM = Imerode(BWJ, STR);
figure, imshow(bwm);
```

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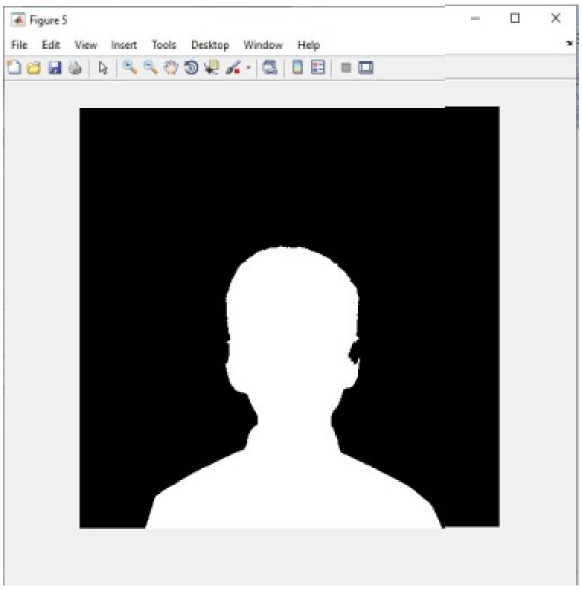

Figure 6. Morphological image

6. Background Replacement with New Imagery

Read the background image and implement the segmentation results to replace the background:

```
% Background Reading
Img2 = imread('background1.png');
figure, imshow(Img2);

% Implementation of segmentation results
R = Img(:,:,1);
G = Img(:,:,2);
B = Img(:,:,3);
R2 = Img2(:,:,1);
G2 = Img2(:,:,2);
B2 = Img2(:,:,3);
R2(bw) = R(bw);
G2(bw) = G(bw);
B2(bw) = B(bw);
RGB = paint(3, R2, G2, B2);
figure, imshow(RGB);
```

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Figure 7. Image Impregnation

4. Conclusion

The thresholding method is one of the effective image segmentation approaches in separating objects from the background based on differences in brightness or intensity levels. This process produces a binary image with a pixel intensity value of 0 for darker areas (black) and a pixel intensity value of 1 for lighter areas (white). The application of this method is carried out through several systematic stages which include:

1. **Conversion of RGB Image Color Space to Grayscale** This initial step was taken to simplify the image data by retaining only intensity information, thus facilitating the segmentation process.
2. **Image Segmentation Using the Thresholding Method** This method separates the object from the background based on a specified threshold, resulting in a binary image.
3. **Complementary Operation This** operation is performed to flip the pixel value, where the object becomes white (value 1), while the background becomes black (value 0), providing a visual result that is more suitable for further analysis.
4. **Morphological Operations** To improve the shape of the segmented object, morphological operations such as filling holes, opening areas, and erosion are applied. This stage is important for removing artifacts and improving the accuracy of the shape of the object in the imagery.

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