Detection and measurement of obstacles on a track using color segmentation with background subtraction and morphological operation

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Abstract. The process of detecting objects in a path of the image frame is a complex process. Generally, the identification process to find out the condition of a track in the form of objects and the size of objects is done manually by humans, namely using measuring instruments such as rulers, etc. It requires long processing time, and is less efficient, besides that it cannot be done remotely in the form of monitoring on the computer from the camera in terms of measurement. This study aims to create a system of detection and measurement of obstacle on a track using color segmentation method with background subtraction and morphological operation as a result of decision support. This detection and measurement system consists of webcam image acquisition, video extraction, converting frames of RGB to HSV images, color segmentation with background subtraction, gray scaling and thresholding, morphological analysis to improve the results of segmentation, detection and measurement displayed in the form of a Graphical User Interface (GUI).

The performance of the system was tested on two background color references in the form of black, namely the asphalt track and white, namely the concrete cement track. The result of testing with the black background, produces an accuracy value of 96\%, and with a white background of 100\%. The system results in measuring obstacle have an average length of accuracy of 96.16\% and a height of 85\% on a black background in the form of an asphalt track, and on a white background in the form of cement concrete track results in a length measurement accuracy of 95.99\% and a height of 90.88\% with the camera moving or fixed.

1. Introduction
The development of the field of digital image processing has been widely used to help humans. One of them is the process of recognition or detection and measurement of the dimensions of objects on a track. In monitoring the condition of a track there can be an obstacle that is stone or wood, therefore the object recognition process requires the separation of certain segments in an image known as the segmentation process.

Image segmentation is the process of presenting an area of an image into a number of segments so that it is more meaningful and easier to analyze [6]. One of the segmentation processes to be able to separate objects from the background is through the color approach in the HSV space (hue, saturation, value) with the background subtraction method. Background subtraction is a method that is generally used to detect moving objects in a video based on the difference between the reference background and frame [7], [11], [12]. The results of segmentation in the form of objects that are segmented with the
background still have a lot of noise and need to be improved by morphological operations. Morphological operations are operations that are imposed on binary images to change the shape structure of objects contained in images [5], [13].

The identification process to determine the condition of a track in the form of an object and the size of the object dimensions done manually by humans is to use measuring devices such as rulers and so on. The process requires a long time, and is less efficient, other than that it cannot be done remotely in the form of monitoring on a computer from the camera. Therefore, it required a detection and measurement system that can display the detection results and dimensions of the barrier object on a track independently as a result of decision support.

In 2016 Bakti, et al conducted research on image segmentation and improvement for the process of measuring the dimensions of rice. Measurement of the width and height dimensions of rice is obtained based on measurements in the number of pixels of the outer distance of the rice object then divided by the calibration results [1]. Umam & Negara in 2018 in their research detected and counted the number of pedestrian objects automatically offline in a static background using the background subtraction method and morphological operations [10].

2. Basic theory

2.1. Track

Tracks according to the Big Indonesian Dictionary (KBBI) are roads that are traversed or traversed. The track can mean a road, according to Law Number 22 the Year 2009, the road is an entire section of the Road, including complementary buildings and equipment intended for general traffic, which is on the surface of the land, above the surface of the land, below the surface of the land and / or water, as well as above the water level, except railroads and cable roads.

2.2. Color space

The color space or color system is a coordinate system specification and a subspace in the system with each color expressed by a dot in it [5]. There are several color spaces, namely the RGB color space (Red, Green, Blue) is an additive color space, which means that all colors start from black and are formed by adding basic colors R, G, and B [6].

The HSV color space refers to hue, saturation, and value. Hue is a value that represents the color spectrum of visible light (red, orange, yellow, green, blue, and purple). Saturation is a value that indicates the degree of saturation or purity of a color. The greater the saturation value, the purer the resulting color. Then the value can be defined as a value that indicates the level of color brightness.

2.3. Image segmentation

Image segmentation is the process of separating between foreground and background. The image segmentation process can be done with a color approach or based on color similarity is called image color segmentation. This segmentation process will form segments according to their respective color characteristics. There are two important things that become the basis for developing color segmentation theory that is, (1) analysis of similarity or similarity in intensity / color and (2) a group of neighboring pixels [6].

2.4. Background subtraction

Background subtraction is the process of detecting movement that occurs within a video frame when compared to a reference image. The purpose of background subtraction is to separate the object and background so that the movement of an object is detected [10]. This background subtraction method is using the difference frame technique defined in equation 1.

\[ |(frame_t) - (frame_{t-1})| > Th \] (1)
In equation 1, the estimated background image is the reduction between the 2 images captured from the current frame and the previous frame and is very sensitive to the threshold value [8].

2.5. **Morphological operations**

Morphological operations are techniques for the analysis and processing of geometric structures that refer to set theory, topology, and random functions [14].

2.5.1. **Opening operation**

Opening operation is an operation that functions to eliminate small objects that are sometimes considered as noise, where the size of objects that can be removed in an image is also dependent on the size of the matrix B [6].

\[
\text{Opening} : f \circ B = (f \ominus B) \oplus B
\]  

(2)

2.5.2. **Filling operation**

Region filling operation is an operation that functions to close a small hole in an image section. This operation will fill the part of pixels that has a value of 1 to 0. This operation refers to the neighboring pixels of a pixel [9].

2.5.3. **Clearing border operation**

Clearing border operations are operations that function to remove all components or objects that are connected and touch to the boundary of the image [3].

3. **Research methodology**

3.1. **Image sampling and determination**

The process of sampling images using a webcam by taking an image of stone and wood samples on asphalt and cement concrete track. The process of acquiring a sample image uses a camera application from Windows PC. The stone and wood material used as samples of obstacles each has 5 different lengths and heights. A sampling of samples taken with variations in the number of objects, variations in the trajectory in a state of a fixed camera still objects and shooting in a state of the camera rotating a still object. The distance between the camera and the object is fixed at 60 cm with the camera angle to the object at 75° and the height of the camera taking at the track at 15 cm.

3.2. **System Development**

Making the system is a stage of research conducted in obtaining a system of detection and measurement of length, height obstacles on a track. The flow chart in making this system is shown in Figure 1.

![Flow chart of development an image analysis system](image)

**Figure 1.** Flow chart of development an image analysis system

3.3. **Application Development**

In Figure 2, the initial process of the application in the system is shown, which is taking a background image and video. The sample image in the form of video is then extracted to calculate and take each frame in the video image. Each image is converted from RGB to HSV color space and segmented with
background subtraction so that the desired object (foreground) is obtained. The result of the segmented frame is then grayscaling and thresholding, so that a segmented binary image is obtained. The image results still have noise, so the morphological operation process needs to be done in the form of opening, filling, and clearing border operations. The last step is labeling, marking detection (bounding box) and measurement results of segmented objects.

**Figure 2.** Flow chart of image processing in the detection and measurement system
The entire results of the process are displayed sequentially and can be saved to Excel in the GUI system.

3.4. Data retrieval
The process of data retrieval is divided into two parts that are the retrieval of detection data and measurement data.

3.4.1. Detection data. This data retrieval is based on the detection results displayed by the system on the laptop screen. Furthermore, the data is processed in calculations to get the level of detection accuracy using Equation 3 [2].

\[
\text{Accuracy} = \frac{\text{number of images detected}}{\text{the total number of sample images}} \times 100\%
\]  

(3)

3.4.2. Measurement data. Retrieval of measurement data is done by measuring objects manually using a sigmat and ruler then compared with the results of the system measurement, shown as in Figure 3.
Figure 3. Retrieval of measurement data

The results of manual measurements are considered as standard measurement results used to obtain data for the calculation process in the system and as a comparison with the results of system measurements. The data obtained can then be calculated error and accuracy shown in Equations 4 and 5 [4].

\[
\begin{align*}
\text{Error} & = | \text{system results} - \text{manual results} | \\
\text{Accuracy} & = 100\% - \left( \frac{\text{Error}}{\text{Standard result}} \right) \times 100\%
\end{align*}
\]

Standard results are the results of manual measurements.

4. Results and Discussion

4.1. Sampling Results

The process of retrieval data to generate 2 reference background images with the format .jpg shown in Figure 4 and 42 video images shown in Figure 5.
4.2. Application testing results

4.2.1. Convert RGB to HSV images. Image changes to the HSV color space are done to obtain pixel values that contain hue, saturation, and value components. The results of the conversion are shown in Figure 6.

![Figure 6. The results of conversion from RGB to HSV](image)

4.2.2. Background subtraction. The converted image is processed using the background subtraction technique, which is to reduce the pixel values of the image between the reference background and the current frame (video), the results shown in Figure 7.

![Figure 7. The results of the background subtraction process](image)

4.2.3. Grayscaling and thresholding. After the segmented image, the image is converted to a gray-scale color image, and then converted to binary using thresholding technique so that morphological processes can be carried out with an easy process. The results of the process are shown in Figure 8.

![Figure 8. Grayscaling and thresholding results](image)

4.2.4. Morphological operations. In Figure 8 we can see the resulting image is still noise, because that is the process of morphological operations to eliminate the noise as in Figure 9.
4.2.5. Detection and measurement. The labeling process is to count the number of objects detected and rectangle marking on the object, given using the bounding box property function of regionproops. The measurement process is carried out to get the calibrated centimeter measurement results by measuring in pixels first using the image viewer tool from MatLab. Thus, the calibration calculation can be done by means of the reference pixel length value on one of the standard objects divided by the results of the standard object's manual measurement \[1\].

\[
calibration = \frac{\text{pixel length value (px)}}{\text{manual length value (cm)}}
\]

\[
= \frac{271 \text{ (px)}}{15 \text{ (cm)}} = 18,067 \text{ px/cm}
\]

Then the calibration results are obtained every 1 cm = 18.067 px. Next is the process of converting to centimeters in the system into equations 8 and 9.

\[
system length measurement = \frac{\text{pixel length (px)}}{18,067 \text{ (px/cm)}}
\]

\[
system height measurement = \frac{\text{pixel height (px)}}{18,067 \text{ (px/cm)}}
\]

Based on the formula, we will get the length and height of objects in the system as shown in Figure 10.

4.3. Detection data testing results
Detection test results are performed on different objects and track as well as the state of the camera at the time of the acquisition, which is still or moving.

4.3.1. Detection of objects on the asphalt track with the state of the camera and fixed objects. The results of the first detection test as shown in Table 1. Based on these results it can be seen that the average success rate of the system in detecting obstacles on a black background in the form of asphalt track with the state of the camera and fixed objects is 92%.
Table 1. First detection test results

| Object Index | Detection Results | Accuracy |
|--------------|-------------------|----------|
| B1           | ✓                 |          |
| B2           | ✓                 |          |
| B3           | ✓                 |          |
| B4           | ✓                 |          |
| B5           | ✓                 |          |
| K1           | ✓                 | 100%     |
| K2           | ✓                 |          |
| K3           | ✓                 |          |
| K4           | ✓                 |          |
| K5           | ✓                 |          |
| B1K1         | ✓                 |          |
| B2K2         | ✓                 |          |
| B3K3         | ✓                 | ×        |
| B4K4         | ✓                 | ✓        |
| B5K5         | ✓                 | ✓        |
| B1B2K1       | ×                 | ✓        |
| B3B4K2       | ✓                 | ✓        |
| K1K2B1       | ✓                 | ✓        |
| K3K4B2       | ✓                 | ✓        |
| K5B3B4       | ✓                 | ✓        |
| Average      |                   | 92%      |

· B1 = Stone 1
· K1 = Wood 1

4.3.2. Detection of objects on the cement concrete track with the state of the camera and fixed objects. In the second test result, the success rate of all detection objects on the white background in the form of a concrete track is 100% with the state of the camera and fixed objects. This shows the detection system is very good in distinguishing objects against white color backgrounds due to differences in background colors and significantly different objects.

4.3.3. Detection of objects on the asphalt track of the camera moving state and fixed objects. The third detection test results obtained an average success rate of 100% with the camera moving state rotating from 0° to 180°. Based on the results of the three-detection accuracy, it is found that the average success rate on a black background is asphalt trajectory of 96% with the condition of the camera moving or fixed.

4.4. Measurement data testing results
The results of the measurement of the length and height of the first object are on the asphalt track with the state of the camera and fixed objects. From Tables 2 and 3, the average level of system accuracy in the process of measuring object length is 94.44% and the object height is 80.61%.
As for the second object measurement test on a white background in the form of a cement concrete track with the state of the camera and a fixed object, the average value of the measurement of the object length accuracy is 95.99% and the object height is 90.88%. Then in the results of the last measurement test that is on a black background in the form of asphalt track with the state of the camera moving and the object is still obtained the average value of the measurement of the length of obstacles with the system is 97.87% and the object height is 89.37%.

Based on the overall measurement results that have been obtained that, the average level of success (accuracy) on the measurement system of obstacles on a track in measuring the length and height of objects with a black background in the form of asphalt track with a state of moving or fixed camera is for length \( (94.44\% + 97.87\%)/2 = 96.16\% \) and for height \( (80.61\% + 89.37\%)/2 = 85\% \). As for the results of measurements with a white background in the form of a cement concrete track for the length measurement results obtained an accuracy level of 95.99% and for a height of 90.88%.

Table 2. First length measurement test results

| Object type | Index object | Asphalt track | Length (cm) | Error (cm) | Accuracy (%) |
|-------------|--------------|---------------|-------------|------------|--------------|
|             | Manual results | System results |             |            |              |
| Stone B1    | 8.33          | 7.62          | 0.71        | 91.47      |
| B2          | 10.20         | 10.38         | 0.18        | 98.20      |
| B3          | 11.92         | 10.59         | 1.33        | 88.86      |
| B4          | 14.27         | 15.08         | 0.81        | 94.34      |
| B5          | 21.00         | 21.06         | 0.06        | 99.72      |
| Wood K1     | 8.22          | 8.82          | 0.60        | 92.75      |
| K2          | 15.00         | 15.78         | 0.78        | 94.81      |
| K3          | 18.00         | 19.28         | 1.28        | 92.91      |
| K4          | 20.00         | 20.63         | 0.63        | 96.83      |
| K5          | 23.00         | 24.27         | 1.27        | 94.47      |
| Average     | 94.44         |               |             |            |              |

Table 3. First height measurement test results

| Object type | Index object | Asphalt track | Height (cm) | Error (cm) | Accuracy (%) |
|-------------|--------------|---------------|-------------|------------|--------------|
|             | Manual results | System results |             |            |              |
| Stone B1    | 5.54          | 5.19          | 0.35        | 93.70      |
| B2          | 4.40          | 5.22          | 0.82        | 81.33      |
| B3          | 7.33          | 4.03          | 3.30        | 55.02      |
| B4          | 9.30          | 10.48         | 1.18        | 87.26      |
| B5          | 10.71         | 11.77         | 1.06        | 90.08      |
| Wood K1     | 2.20          | 2.80          | 0.60        | 72.53      |
| K2          | 6.06          | 7.32          | 1.26        | 79.24      |
| K3          | 7.20          | 8.86          | 1.66        | 77.01      |
| K4          | 5.00          | 5.93          | 0.93        | 81.50      |
5. Conclusion
Obstacles detection and measurement system have been produced using a color segmentation method
with background subtraction and morphological operations to detect and measure the length, as well as
the height of the obstacles on the asphalt and cement concrete track in the video image.

The system can detect obstacles on a black background in the form of asphalt track with an accuracy
value of 96%, and on a white background in the form of the concrete track with an accuracy value of
100% with a camera moving or fixed.

The results of the system in measuring obstacles have an average length of accuracy of 96.16% and
a height of 85% on a black background in the form of asphalt track, and on a white background in the
form of a cement concrete track the results of measurement accuracy length of 95.99% and a height of
90.88% with the state of the camera moving or fixed.

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