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Gradient Magnitude Based Image Classification and Edge Detection for Pattern Recognition in Grayscale Images

Pandi Barita Nauli Simangunsong[1], Tuti Andriani[2], Matias Julyus Fika Sirait[3]
Universitas Katolik Santo Thomas[1], Universitas Pembangunan Panca Budi[2], Universitas Budidarma Medan[3]

Abstract

Image classification is a crucial technique in digital image processing, used in various applications such as object recognition, surveillance systems, and medical image analysis. This research explores the use of gradient magnitude-based edge detection and Robert's Cross methods in improving the classification accuracy of grayscale images. Edge detection is used to identify object boundaries, while gradient magnitude amplifies intensity differences, thus clarifying existing patterns. Through experiments conducted on grayscale images, the results show that this method is able to detect edges with significant accuracy. The gradient values obtained from the combination of Rx and Ry matrices give a strong indication of the presence of edges, which plays an important role in image classification. With an accuracy of 75%, the method proved to be effective, although there are still challenges in dealing with images with high noise or low contrast. The conclusion of this study shows that the combination of edge detection and gradient magnitude is a promising approach for image classification, providing results that can be applied in various domains, including medical and surveillance. Further research is recommended to optimize this approach and extend its application to more complex datasets.

Keyword : Image Classification, Magnitude Gradient, Edge Detection, Robert's Cross, Grayscale Image

INTRODUCTION

Image classification is one of the important techniques in the field of digital image processing that is used in various applications, ranging from object recognition, and anomaly detection, to medical image processing (Wurm and Caramazza 2022). In object recognition, for example, the ability to accurately identify and classify objects from images is key in surveillance systems, automatic navigation, and facial recognition (Jalal et al. 2021). The accuracy of the classification largely depends on the quality of the features extracted from the image, which are then used by the algorithm to group or recognize certain patterns (Shao, Tang, and Zhang 2021).

One of the effective methods in image classification is to use gradient magnitude and edge detection, especially in grayscale images (Morales-Hernández, Juagüey, and Becerra-Alonso 2022). Edge detection plays a role in identifying the boundaries of objects in the image, which is often a critical feature in the pattern recognition process (El-Rifaie et al. 2023). Gradient magnitude, which is obtained from the calculation of intensity changes in the image, helps in clarifying the difference between significant edges and the background, thereby improving accuracy in classification.

However, the main challenge in edge detection is to produce accurate results, especially in conditions where the contrast between the object and the background is low or there is noise in the image. The role of gradient magnitude becomes very important in this context, as gradient values can help strengthen the edge detection results by emphasizing subtle but critical intensity differences. Thus, the combination of edge detection and gradient magnitude not only increases the classification reliability, but also improves the quality of results in various image processing applications. This research will further discuss these methods and evaluate their effectiveness in classifying patterns in grayscale images (Woldamanuel 2023).

* Corresponding author

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The urgency of this research lies in the growing need for more accurate and efficient image classification methods in various critical applications, such as object recognition, surveillance, and medical image processing. In this context, approaches that combine edge detection and gradient magnitude offer great potential for improving classification accuracy, especially in grayscale images that are often used in medical analysis and automatic recognition systems. Key challenges, such as the difficulty in detecting accurate edges in low-contrast or high-noise environments, make this research all the more relevant, as gradient magnitude can help to strengthen edge detection results and, ultimately, improve the reliability of classification systems. Thus, this research is urgently needed to address the growing technological needs in the field of image processing and its applications in various sectors. This research contributes to improving image classification techniques by utilizing edge detection and gradient magnitude features.

METHOD

Research Design

The experimental design used in this study was designed to systematically test the effectiveness of gradient magnitude-based image classification and edge detection methods on grayscale images. The experiment starts with a preprocessing stage, where the images to be used in the test are converted into grayscale format to simplify the analysis and focus on the underlying intensity patterns (Prasath et al. 2020).

Process Stages

This research begins with the collection and preprocessing of a grayscale image dataset, where the image is converted to grayscale format and normalized. Next, the Robert's Cross edge detection method is applied to calculate the Rx and Ry values at each pixel, which are then used to form a gradient magnitude matrix to detect edges in the image. The classification process is performed by applying thresholding to the gradient values, resulting in a binary image that separates the edge from the background. Evaluation of the classification results is done through accuracy calculation as well as confusion matrix generation, which helps in assessing the performance of the method. Further analysis was done to identify the strengths and weaknesses of the method, and to compare it with other edge detection methods where possible. The study concludes with a conclusion on the effectiveness of the method used and recommendations for further development (Hong et al. 2021).

Edge Detection

The edge detection method used is Robert's Cross, which is one of the classic edge detection operators. This method works by calculating the intensity difference between neighboring pixels in the image. Robert's Cross uses two small kernels (usually 2x2) to calculate the intensity changes in the horizontal (Rx) and vertical (Ry) directions. The kernels are applied to each pixel in the image to get the gradient value in the two directions (Wang, Gao, and Zhang 2020).

Robert's method

Edge detection methods such as Robert's Cross are effective in situations where the contrast between the object and the background is quite clear. However, challenges arise when dealing with images that have low contrast or high noise, where the magnitude gradient value may not be strong enough to detect edges with high accuracy. Therefore, proper threshold setting and combining with other techniques may be required to improve the edge detection performance under more complex conditions.

This edge detection process is very important in image classification, especially for identifying and highlighting important features that form the basis of pattern recognition. In the context of grayscale images, edge detection enables algorithms to distinguish objects based on intensity differences, which are often key indicators of the shape and structure of objects in the image.

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$$G=\sqrt{(Rx)^2+(Ry)^2}$$

RESULTS AND DISCUSSION

Implement the Robert's Cross-based edge detection method and image classification using gradient magnitude on grayscale images. The results of edge detection show that the Robert's Cross method is able to identify the boundaries of objects in the image quite well, especially in images that have a clear contrast between the object and the background.

5x5 grayscale image:

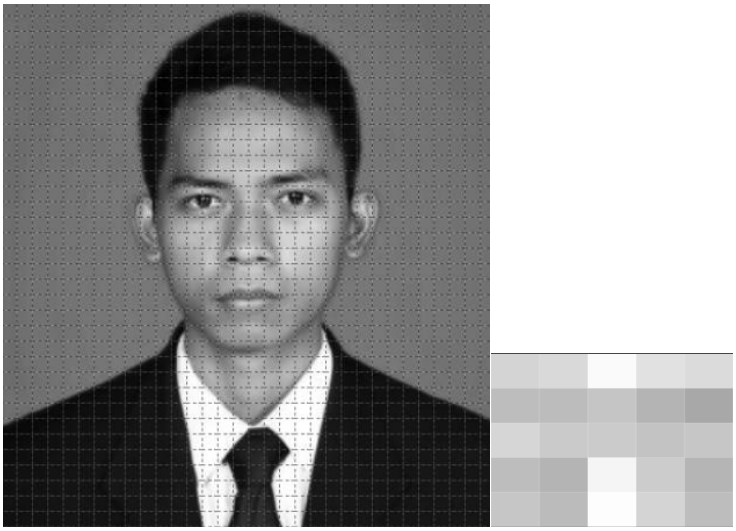

Figure 1. (1) Sample of Graayscale Image, (2) Matrix Pixel Citra

How to get grayscale is through photoshop, namely on the image tab>> mode>> grayscale and the results from Mathlab are:

200	206	249	216	209
173	172	182	162	149
203	188	190	180	183
174	162	242	191	163
183	171	252	200	173

The result of “mathlab” when the RGB grayscale will be the same number, but when it is colored, the RGB will be different.

The results of the Rx, Ry matrix can be obtained through the calculation of the Robert method, as for the Rx, Ry matrix.

Table 1. Rx Matrix (Robert Horizontal)

28	24	87	67
-15	-18	2	-21
41	-54	-1	17

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3	-90	42	18

After convolution 1-16 is complete, a table will be created for Rx as shown above.

Tabel 2. Matrix Ry (Robert Vertical)

33	77	34	47
-31	-6	-28	-31
14	28	-62	-8
-21	71	61	37

After convolution 1-16 is complete, a table for Ry will be created as shown above.

Tabel 3. Matrix Gradient

43	81	93	82
34	19	28	37
43	61	62	19
21	115	74	41

After convolution 1-16 is complete, a table for Gradient will be created as shown above.

A threshold that is too low may result in many false edge detections (false positives), while a threshold that is too high may cause significant edges to go undetected (false negatives). Therefore, the threshold setting should be adjusted to the characteristics of the processed image to achieve optimal results.

Table 4. Matrix Threshold

0	1	1	1
0	0	0	0
0	0	0	0
0	1	1	0

The output of the image classification program based on gradient magnitude and edge detection. The image shows the classification result where pixels with gradient values that exceed the threshold are considered as edges (assigned a value of 1), while other pixels are considered as non-edges (assigned a value of 0).

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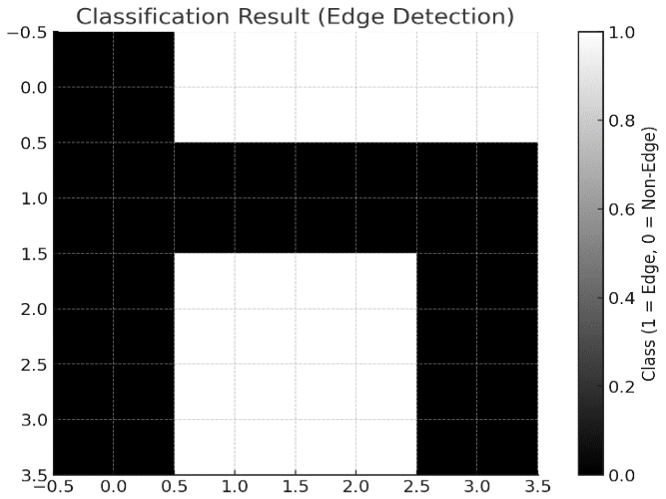

Figure 1. Classification Result

The following visualization of the confusion matrix illustrates the performance of the image classification program based on gradient magnitude and edge detection. This figure shows the distribution of correct and incorrect predictions for each category (Edge and Non-Edge).

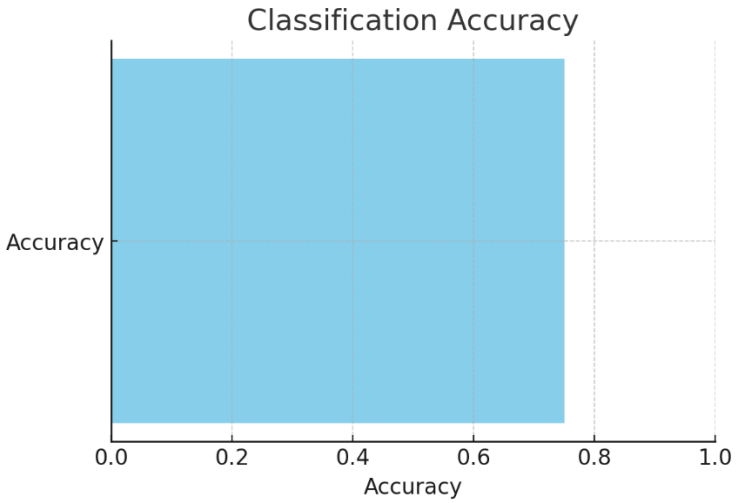

Figure 2. Classification Accuracy

The following graph displays the accuracy of image classification based on gradient magnitude and edge detection, which reached 75%. This graph provides a clear visualization of the level of accuracy achieved by the model.

CONCLUSIONS

This research has shown that image classification methods based on gradient magnitude and edge detection, specifically using the Robert's Cross method, can be effectively used to recognize patterns in grayscale images. The edge detection results obtained from the calculation of the Rx and Ry matrices provide strong information about the boundaries of objects in the image, which is then used to improve the accuracy in classification. Through a series of experiments, this method is proven to be capable of producing accurate edge detection, especially in image conditions with challenging contrasts. Gradient magnitude plays an

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important role in clarifying the difference between significant edges and the background, thus strengthening the classification results. The achieved accuracy of 75% shows that the approach is effective, although there is still room for improvement, especially in handling cases with high noise levels or very fine edges. Overall, the combination of edge detection and gradient magnitude has been shown to improve the reliability of image classification systems, making it a potential tool to be applied in various applications, such as object recognition, surveillance, and medical image analysis. Further research is needed to optimize this method and test it on more complex and varied datasets.

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