Comparative Analysis of Eight Direction Sobel Edge Detection Algorithm for Brain Tumor MRI Images

Muhammad Zain Amin, Md. Imran Hossain

Erasmus +: Erasmus Mundus Joint Master Degree in Medical Imaging and Applications, University of Bourgogne, Le Creusot, France

Abstract

Brain Tumors are the leading cause of cancer death in children. They are caused by the abnormal and uncontrolled growth of cells inside the brain or spinal canal. Classification of brain tumors using machine learning technology is very relevant for radiologists to confirm their analysis more effectively and quickly. Segmentation algorithm identified for detecting the tumor from the MRI brain scans need to detect shapeless tumor growth perfectly. Sobel edge detection is one of the widely used edge detection techniques in which only information along horizontal and vertical directions are considered. In this research, Sobel algorithm with 8 directional template is implemented for improving the detection of edges in brain tumor MRI images. The proposed algorithm is compared with other traditional edge detection algorithms. The performance of the proposed algorithm is analyzed in terms of MSE, RMSE, Entropy, SNR and PSNR. Analysis shows that 8-Sobel is comparatively the most suitable technique for analyzing brain tumor MRI images. Active contouring segmentation algorithm is applied on the edge detected images to verify the classification accuracy of segmented tumor.

1. Introduction

A brain tumor is a serious type of tumor. It is caused by uncontrolled tissue growth in the brain or the spinal canal. The World Health Organization estimates that more than 0.4 million children are suffering from tumor in the world per year. Rapid progress in computer vision methods has paved the way for highly improved tumor prediction algorithms. This helps in the immediate identification of tumor disease in the absence of a medical expert. Early detection of tumors leads to better survival chances and better life post-cancer treatment.

Analysis of brain tumors is an application in the biomedical image processing domain. Brain tumor analysis involves biomedical data acquisition, noise removal, image pre-processing, and extracting relevant information to detect tumors. Significant step in the classification of image data is the effective segmentation of tumors. These tumors are of irregular shapes and sizes. Identifying the best segmentation algorithm to separate tumors from non-tumor regions of brain MRI scan image is a prominent research area. In image segmentation, various objects present in an image are segmented. Edge detection algorithms are a subtopic in image segmentation. Here, the edge of an object is identified by locating the boundaries of objects. In edge detection, various features are observed. Features help in identifying the significant gray level changes. An edge indicates the boundary of an image.

Our work focuses on the effective analysis of edge detection algorithms to detect brain tumors from MRI image data. Hence our work helps in identifying the best edge detection algorithm which can be applied in a brain tumor classification model.

2. Proposed Method

In order to apply the edge detection algorithm on any raw image data, we need to perform pre-processing. The dataset used in this study was taken from Kaggle as shown in figure 1.

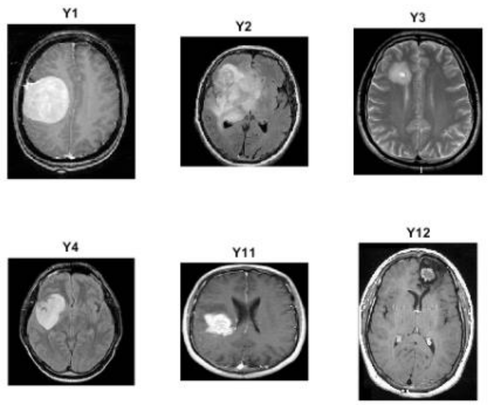

Figure 1. Sample Images from the Kaggle Brain Tumor Dataset

The MRI brain images are first processed through appropriate filters for removing unwanted noises. The image then can be sharpened for better clarity and fed to the edge detection block. After detecting the edges, the number of edges are counted. If more enclosed area is obtained, then the probability of having a tumor is high.

2.1. Edge Detection

2.1.1. Traditional Sobel Edge Detection Algorithm

The traditional Sobel edge detection operator is a discrete first order difference operator. It has two 3x3 matrices, in the vertical direction X and horizontal direction Y, and require an image 'A' to do convolution.

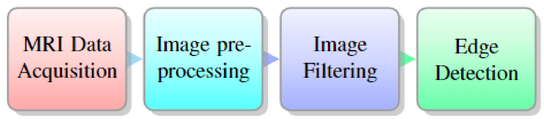

Figure 2. Steps Involved in Tumor Edge Detection from MRI images

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} * A \quad G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * A$$

The vertical and horizontal gradient approximation of each pixel of an image is combined to calculate the size of the gradient.

$$G = \sqrt{(G_x)^2 + (G_y)^2}$$

Limitation in Traditional Sobel Edge Detection

- It has only two direction templates, hence it is only sensitive to the edges in the vertical and horizontal directions and ignores the edge information in other directions of the image.

2.1.2. Eight Directional Sobel Edge Detection

To offset the shortcomings of the traditional Sobel algorithm for edge detection and increase edge information in other directions, The traditional Sobel algorithm templates is expanded, by using the extended eight directional template operators for edge detection.

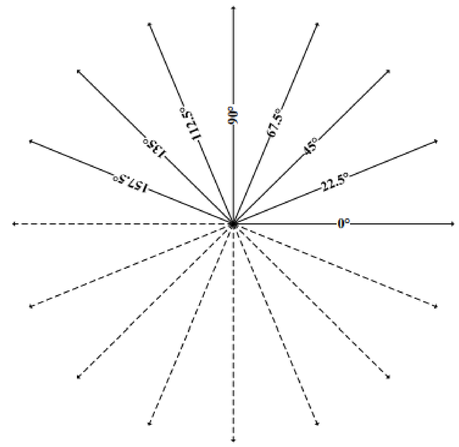

Figure 3. Eight Directional Sobel Edge Detection Overview

The Eight Directional Sobel uses templates of 0°, 22.5°, 45°, 67.5°, 90°, 112.5°, 135°, 157.5° for detection.

Advantages of Eight Directional Sobel Edge

- Edges in all directions are detected.
- Comparatively provide good performance with less complex functionality.
- Increase edge information in almost all directions.

3. Performance and Results

We analyze the 8-directional Sobel algorithm for brain tumor MRI images compared to other traditional edge detection algorithms.

3.1. Performance Matrices: The performance analysis is done by using the metrics such as Mean Square Error (MSE), Root Mean Square Error (RMSE), Entropy, Signal to Noise Ratio (SNR) and Peak Signal to Noise Ratio (PSNR).

3.2. Results

Performance comparison results of eight directional Sobel and other edge detection methods on Brain Tumor MRI images dataset is shown in table 1.

Table 1. Performance comparison of 8-Sobel with other algorithms

Metrics	Canny	Laplacian	LOG	Sobel	8 Sobel
MSE	7.6+e03	7.4+e03	7.6+e03	8.4+e03	**6.1+e03**
RMSE	87.5621	86.5603	87.6185	91.9974	**78.4808**
SNR (dB)	0.0056	0.0078	-9.6+e-16	-0.4233	**0.9567**
PSNR (dB)	9.2845	9.3844	9.2789	8.8556	**10.2355**
Time(s)	1.2394	0.6729	1.0501	0.8501	**2.7765**
Entropy	0.3404	0.0194	0	0.6741	**0.7663**

- The 8-Sobel has the least Mean Square Error and Root Mean Square Error. Lower MSE indicate that the edge detected image is closer to the original image.
- The Peak Signal to Noise Ratio value is the highest for 8-Sobel. This indicates that the quality of the edge detected image is the highest in case of 8-Sobel.
- The Signal to Noise Ratio is highest for the 8-Sobel which show output is more correct than other methods.
- Entropy is also the highest for 8-directional Sobel since the output has more edge detection information.

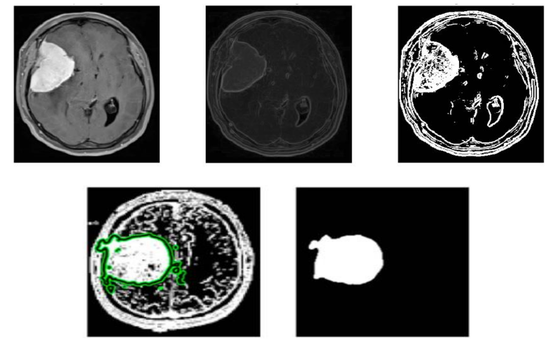

Figure 4. Edge Detection and Segmenting the Tumor using 8 Directional Sobel Algorithm

Conclusion

Analysis shows that 8-Sobel is more suitable for detecting tumors in brain MRI images. The scope of FPGA implementation of 8-Sobel as future work will ensure the improvement in execution speed. Better feature extraction models can be designed for machine learning classifiers with the 8-Sobel algorithm as an edge detector.

References

[1] A S, R. A., & Gopalan, S. (2022). Comparative Analysis of Eight Direction Sobel Edge Detection Algorithm for Brain Tumor MRI Images. Procedia Computer Science, 201, 487-494.