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

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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.

Keywords: Brain Tumor; Edge Detection; Sobel Algorithm; Eight-Sobel Algorithm

1. Introduction

Brain tumor is a serious type of tumor. It is caused by the uncontrolled and abnormal tissue growth in the brain or the spinal canal. The World Health Organization (WHO) estimates that more than four lakh children are suffering from tumor in world per year [1]. Diagnosis and treatment are very important for all tumor affected patients. In order to reduce the growth of mortality rate due to brain tumor, early detection and treatment of disease is extremely critical [2].

The main causes of brain tumors include age, radiation hazards, heredity, smoking, substance abuse, etc. Primary tumors are those which originate in the brain. They can be categorized into Gliomas, Meningiomas, Pituitary ade-

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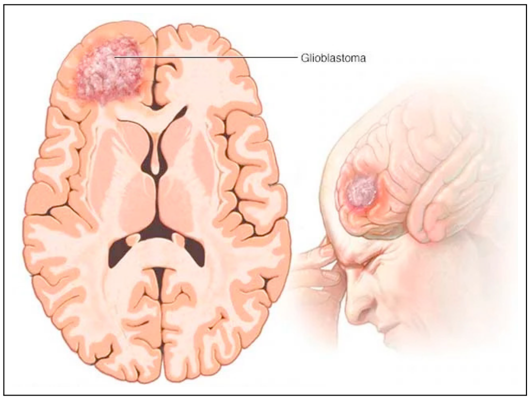

Fig. 1. Glioma type Brain Tumor[3]

nomas and Nerve sheath tumors. Metastatic or Secondary brain tumors begin as cancer else where in the body and spread to the brain. Diagnosing tumor at an early stage can prove critical in saving the life of the patient. MRI brain scans help identify the presence of tumor in the very early stages of its development. Even an experienced radiologist analysing the tumor manually may reach to wrong decision in grading.

Rapid progress in computer vision techniques have paved the way for highly improved tumor prediction algorithms. Recent developments in this area identify better classification models which grade the tumor with higher accuracy. This helps in the immediate identification of tumor disease even in the absence of a medical expert. Once the disease is detected, further diagnosis can be done under the care of a doctor. Early detection of tumor in low grade range leads to not only better chances of survival, but it can also help in better recovery and better life post the cancer treatment [1].

Glioma type is a broad category of brain and spinal cord tumors. Glioma tumor occurs from glial cells of the brain. Glial cells are the ones that support nerve cells. As per American Cancer Society, three types of gliomas are possible. They are astrocytoma, oligodendroglioma and ependymoma. According to the current World Health Organization (WHO) scheme, tumors are categorized into four grades - grades I, II. III and IV. Grades I and II are usually considered as low grade tumors. Grades III and IV are considered as high grade tumors. High grade tumors are malignant and need much attention. For analysing the danger of tumor initially, radiologists classify the tumor into benign and malignant type. Further diagnosis can be done to determine the actual grade. Analysis of brain tumor is an application in biomedical image processing domain. Brain tumor analysis involves biomedical data acquisition, noise removal,image pre-processing and extracting relevant information to detect tumor. Significant step in classification of image data is the effective segmentation of tumor. These tumors are of irregular shapes and sizes. Identifying the best segmentation algorithm to separate tumor from non-tumor regions of a brain MRI scan images is a prominent research area. In Image segmentation method, various objects present in an image are segmented. This is based on the variation of pixel intensities. Edge detection algorithms are a subtopic in image segmentation algorithms. Here,the edge of an object is identified by locating the boundaries of the objects. Boundaries can be lines, curves etc within the image. In edge detection techniques, various features are observed. Features help in identifying the significant gray level changes. Edge indicates the boundary of an image. Edges preserve the structural property of an image. Edge detection methods using various operators such as Canny operator, Sobel operator, Laplacian operator, Laplacian of Guassian(LoG) operator, Robert operator and Prewitt operator are widely used for various applications. However, edge detection using 8-sobel algorithm has been shown to improve the hardware performance better than the other techniques [4].

Our work focuses on an effective analysis of various edge detection algorithms to detect brain tumors from MRI image data. The raw image data is first pre-processed for noise removal using selected pre-processing algorithm. Then the image is segmented for extracting the boundary of tumor. These tumor images are further processed using Deep Learning algorithms for grade classification.The accuracy of classification depends on efficient edge detection algorithm applied. Hence our work helps in identifying the best edge detection algorithm which can be applied in a brain tumor classification model.

2. Literature Review

Basic steps in image analysis using computer vision involve edge detection. In the work done by Zotin et al, Fuzzy C Means clustering algorithm was used for tumor segmentation [5]. For getting fine tumor edges, canny edge detection is applied after segmentation. Use of Balance Contrast Enhancement Technique(BCET) as pre-processing technique also contributed for effective segmentation.

Patel et al implemented Sobel edge detection algorithm for brain tumor identification on a field programmable gate array using Xilinx system generator and Matlab [6]. High level system DSP block diagram was converted to to RTL. This was synthesized using Xilinx ISE. In this work, the author implemented other operators such as prewitts and Canny along with Sobel in Matlab for comparison. Sobel was shown to be less complex with high noise suppression. Hence Sobel was chosen to synthesize in FPGA. When compared with the Matlab output, the results was found to be very close to each other.

Two techniques namely Histogram Thresholding and Artificial Neural Network technique for tumor detection are explained by Chithambaram et al in his work [7]. The region of interests(ROIs) within the tumor area are extracted using histogram thresholding. Reddy et al discussed the levelset algorithm along with image thresholding to extract tumor cells [8]. The effective pre-processing of images helps to gain better accuracy for classification problems using machine learning approaches. Indumathi et al used Co-occurrence filtering for image filtering before segmentation to analyse breast cancer [9]. Recent researchers focus on deep learning approaches for analysing medical images. Kadry et al preferred U-Net scheme for segmenting isochemic stroke lesion from MRI slices [10]. VGG-16 net is applied in the work [11] by Kadri et al for detecting schizophrenia from MRI slices. Fuzzy based edge detection and U-Net classification algorithms are used by Masqood et al for brain tumor detection [12]. However, the need of larger datasets for analysing medical images using transfer learning technology is really challenging.

Edge detection techniques such as LOG and Canny are compared with that of Wavelet transform by Fu in his work [13] and identified that wavelet transform gives high PSNR rate with less speed compared to other operators. LoG operator, Canny and Wavelet approaches are compared. LoG based edge detection technique make use of the second order derivative function of images. In Canny, guassian filtering is applied to remove noises. Then intensity gradients are calculated.

Edge detection of color images based on area optimized VLSI approach is implemented by Singh et al. using Sobel algorithm in VIRTEX 5 FPGA platform. The proposed architecture contribute as reduction of around 35 percentage hardware utilization [14]. An interval based edge detection algorithm using laplacian technique was suggested by Zhang et al in for skin cancer detection.The proposed technique considered the brightness variations of skin images as uncertainty factor for prediction [15].

Sobel based edge detection approach is adopted for identifying brain tumor cells. Canny algorithm can produce sharp edges but it is computationally complex. Sobel is based on discrete first order difference. Basically it calculates the approximation of the first step of the luminance function of an image [16][6][17]. From the literature survey, we observed that sobel edge detection can be prefered for brain tumor edge detection with low error rate. Canny edge detection is good in performance but involve complex steps in processing. In 8-Sobel edge detection algorithm, all edges are considered since 8 kernels are used to detect the edges in all eight different directions. This guarantee that the irregular tumor edges are better identified.

3. Proposed Method

Inorder to apply the edge detection algorithm on any raw image data, we need to perform pre-processing.The MRI brain images from the available dataset 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.

3.1. Image Enhancement

The raw image needs to be pre-processed through various filters, which will reduce the noises. Noise removal avoids redundant pixel information and helps in further analysis of images [18]. In biomedical images, commonly

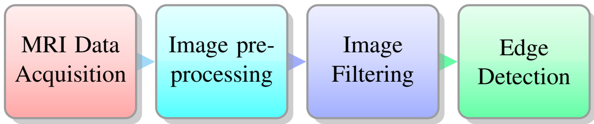

Fig. 2. Steps involved in Tumor Edge Detection from MRI Images

encountered noises are Salt and Pepper, Speckle, Gaussian, and Poisson noises [5]. Mean filter, Median filter, Gaussian filter and their modifications are widely used for noise removal. In mean filtering, the pixel values are replaced with the average of all pixel values surrounded by it. The kernel usually may be of square shaped but not mandatory. In median filtering, the central pixel is replaced with the median of all its neighboring pixel values. Thus it is very effective for salt and pepper noise which is quite common in images captured through imperfect sensors. A linear smoothening filter is a Guassian filter. By smoothening, it blurs the image and reduce the noise. We can subtract the original image with that of Guassian filtered output of the same image. This helps us to obtain an unsharp mask. Unsharp mask is useful for edge detection. This technique is called Unsharp masking. Various other enhancement methods used for pre-processing medical images include Contrast Limited Adaptive Histogram Equalization (CLAHE), Logarithmic image processing (LIP), Parameterized LIP (PLIP), Generalized LIP (GLIP) and Balance Contrast Enhancement Technique (BCET) algorithms [5].

3.2. Edge Detection Algorithm

The advantages of edge detection techniques is that it filters the image to get only the significant data.This tremendously reduces the size of data need for further processing. Important variations of gray levels in an image at various locations can be identified using edge detection algorithm. Thus it detects the geometrical and physical properties of objects in the scene of discussion. Kernel based convolution approach is used for filtering. Edge segmentation helps in detecting the tumor using deep learning based automated tools [19].

3.3. Roberts Edge Detection

The two dimensional spatial gradient of an image can be effectively measured using Roberts edge detection algorithm. Gx and Gy kernels are used as horizontal and vertical filtering respectively. The output gives pixel values in every point. This represent the spatial magnitude gradient estimated at that point.

3.4. Prewitt Edge Detection

Prewitt is a differentiation operator. It is discrete in nature. The gradient of image intensity at a particular point is calculated. Gradient gives the directional rate of changes. The result of prewitt edge detection algorithm on any image gives the way in which how smoothly or abruptly changes happen with respect to that point. The horizontal and vertical kernels for Prewitt algorithm are given by Gx and Gy. Prewitt is computationally simpler. But it gives noisy result in comparison with other traditional edge detection algorithms.

3.5. Laplacian of Guassian(LoG) Edge Detection

In this operation, Laplacian transformation is applied on the Guassian filtered input image. In this method, second order derivatives of the image is calculated. Since the Laplacian is computed over Guassian smoothed image, double egdes are detected. Thus the edges can be located by obtaining the zero crossings between the double edges. The horizontal and vertical kernels for LoG edge detetctor is given by Gx and Gy.

3.6. Canny Edge Detection

In canny edge detection algorithm, the initial step involved is Gaussian filtering. Guasian filtering will remove the noise by smoothening the images. Next, the intensity gradients will be calculated. Double thresholding is applied after performing non-maximum suppression technique. This ensures that only the prominent edges are detected. Edges are then tracked by hysteresis [20]. Canny operation gives very good performance in the case of noisy images.

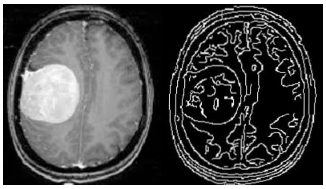

Fig. 3. Edge detection using Canny Operator

3.7. Sobel Edge Detection

The Sobel operator is a discrete first-order difference operator. It is used to calculate the image luminance function. Convolution of the image matrix with the horizontal and vertical direction templates Gx and Gy are calculated. Thus, we get the approximation of difference in the brightness as the gradients in X and Y directions.

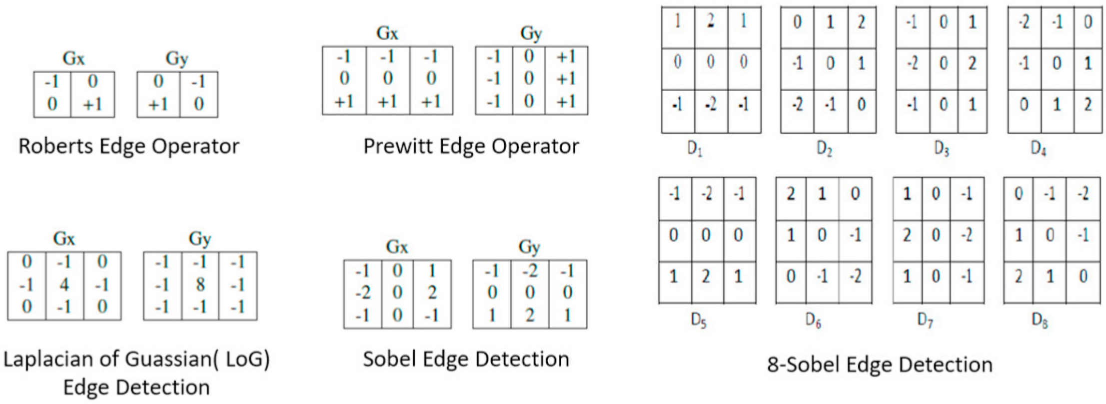

Fig. 4. Operators of edge detected algorithm considered for analysis

Fractional order Sobel filter gives frequencies of high range differences noticed in grey levels of images [21]. Enhancement of features with medium grey levels can be performed using this technique. 8-sobel edge detection algorithm is an improved solved algorithm. In this method, edges in all directions are detected. Sobel edge detection algorithm is comparatively provide good performance with less complex functionality. Operators of various filters are shown in figure4.

4. Validation and Analysis

The goal of the present paper is to analyse the 8 Sobel edge detection algorithm for brain tumor MRI images compared to other traditional edge detection algorithms like Canny, Laplacian, Laplacian of Guassian(LoG), Robert, Prewitt and normal Sobel techniques. The experimental analysis is done using Matlab 2020a. The input images needed for analysis are taken from Kaggle Brain Tumor Dataset [22]

The performance analysis is done using the metrics such as Mean Square Error(MSE), Root Mean Square Error(RMSE), Entropy, Signal to Noise Ration(SNR) and Peak Signal to Noise Ratio(PSNR). The execution speed of the algorithms are also analysed.

$$MSE = \frac{1}{mn} \sum_{i=1}^{m} \sum_{j=1}^{n} (x_{ij} - y_{ij})^2 \tag{1}$$

$$RMSE = \sqrt{MSE} \tag{2}$$

In Equation1, m refers to the number of rows in cover image and n refers to the number of columns in cover image.

$$PSNR(x,y) = \frac{10 \log_{10}[\max(\max(x), \max(y))]^2}{x - y^2} \tag{3}$$

Entropy is a statistical measure of randomness that can be used to characterize the texture of the input image. Entropy is defined as

$$Entropy = -\sum p \log_2 p \tag{4}$$

where p contains the normalized histogram counts returned from 'imhist' function in Matlab.

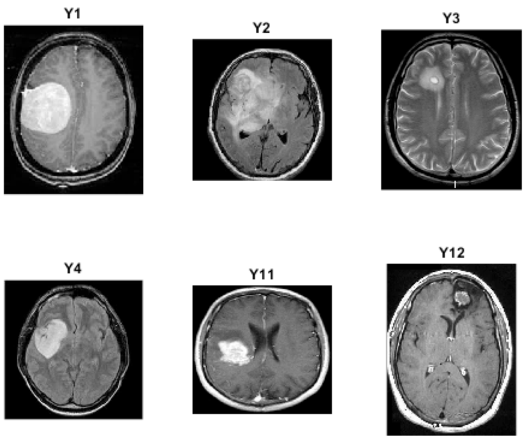

Fig. 5. Sample Images from Kaggle Brain Tumor Dataset

After detecting the edges, the number of edges can be counted. If more than one enclosed area is obtained, then the probability of having a tumor is high. Computational speed depends on the type of pre-processing techniques used and number of kernels used. Robert, Prewitt,LoG and Sobel uses horizontal and vertical kernels only. However 8 Sobel operator uses eight different kernels to detect edges in all eight directions. The eight-directed sobel edge detected images are also validated by applying active contouring segmentation technique. Compared to linear kernal SVM, KNN is more suitable for brain tumor classification when active contouring without edges method of segmentation techniques are used [23].

5. Result and Analysis

The input image, filtered image after applying 8 sobel kernel and the edge detected output after applying a threshold value of 30 are shown in figure6. The different performance metric values for various algorithms are computed. The experimental analysis is done for the effective edge detection of brain tumor MRI image. The 8-Sobel algorithm provides the least MSE and RMSE. Lower MSE indicates that the edge detected image is closer to the

Table 1. Performance comparison of 8-Sobel algorithms with other traditional algorithms for brain tumor MRI images

Metrics	Canny	Laplacian	LOG	Robert	Prewitt	Sobel	8 Sobel
MSE	7.6+e03	7.4+e03	7.6+e03	6.9+e03	6.8+e03	8.4+e03	6.1+e03
RMSE	87.5621	86.5603	87.6185	83.6161	82.9747	91.9974	78.4808
SNR(dB)	0.0056	0.0078	-9.6+e-16	0.4061	0.4730	-0.4233	0.9567
PSNR(dB)	9.2845	09.3844	9.2789	9.6850	9.7519	8.8556	10.2355
Time(s)	1.2394	0.6729	1.0501	0.6684	0.9740	0.8501	2.7765
Entropy	0.3404	0.0194	0	1.9+e-04	0.4208	0.6741	0.7663

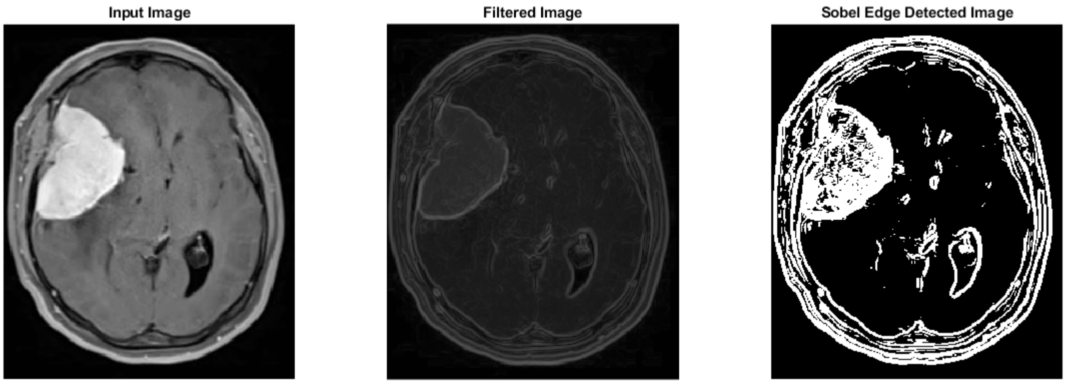

Fig. 6. Edge Detection using 8 Sobel Algorithm

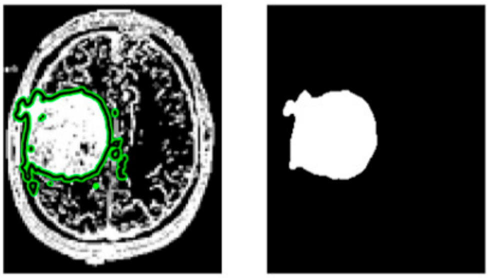

Fig. 7. Segmenting the tumor from the 8-Sobel edge detected image

original image. Also, the PSNR value is the high for 8 Sobel algorithm. This indicates that the quality of the edge detected image is the highest for 8-Sobel. Entropy is also the high for 8 Sobel since the edge detected output has more information. Also, the SNR is high for the 8-Sobel edge detected image which indicates that the output is more correct compared to other algorithms. For evaluating the effectiveness of proposed algorithm, the 8-Sobel edge detected images are segmented using active contouring techniques. Highly detected edges of the irregularly shaped tumors are effectively segmented out using active contouring technique as shown in figure7. This guarantees that the features of shapeless tumors are better detected for classification problems. The resultant images are used as dataset for a KNN classifier to analyse the performance of the proposed model.The test accuracy obtained was 86 percentage.

6. Conclusion

Analysis shows that 8-Sobel is more suitable than other techniques for detecting tumor in brain MRI images. Although the 8-Sobel method takes more computing time than the other traditional methods, it gives much higher accuracy in detection of tumor cells from Brain MRI images. The longer time taken is due to more number of kernels used. Since accuracy is preferred over speed, the high execution time for preferred 8-Sobel is convincing. The scope of FPGA implementation of 8-Sobel as future work will ensure improvement in execution speed. Better feature extraction models can be designed for machine learning classifiers with 8-Sobel algorithm as edge detector. Current work use only the online available dataset. Raw MRI images may need noise filtering before applying to 8-Sobel edge detection block since speckle noises may reduce the classification accuracy of irregular tumor classifiers.

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