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Comparative analysis of different Edge detection techniques for biomedical images using MATLAB

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Abstract— Edge detection appreciably preserves the important structural properties in an image and filters out unwanted information while reducing the amount of data. Edges outline the boundaries and are therefore a problem of fundamental importance in image processing of biomedical signals. The method used in this paper is to detect the tumor boundaries in the MRI image using various edge detection techniques. The result of this method makes very clear for physician to distinguish the tumor portion for surgical planning. It has been shown that with proper selection of the threshold value of the image the filters gives better result in terms of edge and PSNR for a given image .It has been shown that Canny's edge detection algorithm performs better than all other operators under almost all scenarios. Experimental results presented in this paper are obtained by using MATLAB.

Keywords— *Edge detection, Prewitt, Robert, Sobel, Canny*

1. Introduction

A brain tumor is an abnormal growth of tissue in the brain or central spine that can disrupt proper brain function. Doctors refer to a tumor based on where the tumor cells originated, and whether they are cancerous (malignant) or not (benign).

- **Benign:** The least aggressive type of brain tumor is often called a benign brain tumor. They originate from cells within or surrounding the brain, do not contain cancer cells, grow slowly, and typically have clear borders that do not spread into other tissue.
- **Malignant:** Malignant brain tumors contain cancer cells and often do not have clear borders. They are considered to be life threatening because they grow rapidly and invade surrounding brain tissue.
- **Primary:** Tumors that start in cells of the brain are called primary brain tumors. Primary brain tumors may spread to other parts of the brain or to the spine, but rarely to other organs.
- **Metastatic:** Metastatic or secondary brain tumors begin in another part of the body and then spread to the brain. These tumors are more common than primary brain tumors and are named by the location in which they begin.

To mitigate this, recently, researchers are using multi-disciplinary approach involving knowledge in medicine, mathematics and computer science to better understand the disease and find more effective treatment methods. Magnetic resonance (MR) imaging and computer tomography (CT) scanning of the brain are the two most common tests undertaken to confirm the presence of brain tumor and to identify its location for selected specialist treatment options. Currently, there are different treatment options available for brain tumor. These options include surgery, radiation therapy, and chemotherapy. The choice for the treatment options depends on the size, type, and grade of the tumor. It also depends on whether or not the tumor is putting pressure on vital parts of the brain. Whether the tumor has spread to other parts of the central nervous system (CNS) or body, and possible side effects on the patient concerning treatment preferences and overall health are important considerations when deciding the treatment options. Accurate detection of the type of brain abnormality is highly essential for treatment planning in order to minimize diagnostic errors. The accuracy can be improved by using computer aided diagnosis systems to provide a computer output as a second opinion to assist radiologists' image interpretation and to reduce image reading time. This improves the accuracy and consistency of radiological diagnosis. However, detection of the image of brain tumors is a very difficult task. In the first place, there are a large class of tumor types which have a variety of shapes and sizes. Appearance of brain tumors at different locations in the brain with different image intensities is another factor that makes automated brain tumor image detection difficult.

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Edge detection is one of the most commonly used operations in image analysis, and there are probably more algorithms in literature for enhancing and detecting edges. An edge is point of sharp change in an image, a region where pixel locations have abrupt luminance change i.e. a discontinuity in gray level values.

2. SYTEM OVERVIEW

2.1 Introduction to Edge Detection

An edge is the boundary between an object and the background. The shape of edges in images depends on many parameters like the depth discontinuity, surface orientation discontinuity, reflectance discontinuity, illumination discontinuity, and noise level in the images.
The main steps in edge detection are:

1) Filtering which is gradient computation based on intensity values of two points which are susceptible to noise. Filtering reduces noise but there is a trade-off between edge strength and noise reduction.
2) Enhancement is done in order to facilitate the detection of edges, it is essential to determine intensity changes in the neighbourhood of a pixel in an improved manner. Enhancement emphasizes pixels where there is a significant change in local intensity values and is usually performed by computing the gradient magnitude.
3) Detection is done because many points in an image have a nonzero value for the gradient, but not all these points can be considered to be edges. Therefore, some method should be used to determine which points are edge points. Frequently, threshold provides the criterion for detection.
4) Localize/analyse mainly rejects spurious edges include weak but justified edges.

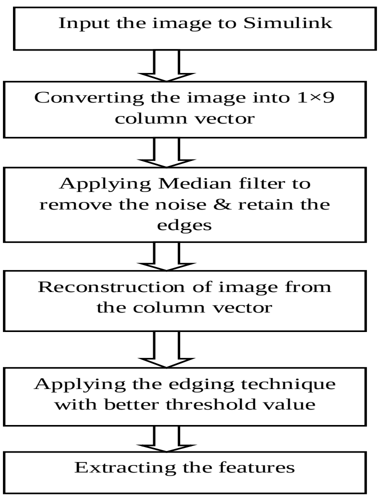

Fig. 1: Stages involved for brain tumor detection

Measuring the relative brightness of pixels in a neighbourhood is mathematically analogous to calculating the derivative of brightness. Brightness values are discrete, not continuous, so we approximate the derivative function. Different edge detection methods use different discrete approximations of the derivative function.

2.2 Edge Detection Techniques

2.2.1 Sobel Operator

The Sobel operator performs a 2-D spatial gradient measurement on an image. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. The Sobel edge detector uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows). A convolution mask is usually much smaller than the actual image. As a result, the mask is slide over the image, manipulating a square of pixels at a time. The actual Sobel masks are shown below:

The operator consists of a pair of 3×3 convolution kernels as shown in Figure 2. One kernel is simply the other rotated by 90°.

-1	0	+1
-2	0	+2
-1	0	+1

G_x

+1	+2	+1
0	0	0
-1	-2	-1

G_y

Fig. 2: Masks used by Sobel Operator

These kernels are designed to respond maximally to edges running vertically and horizontally relative to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these G_x and G_y). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by:

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

Typically, an approximate magnitude is computed using:

$$|G| = |G_x| + |G_y|$$

which is much faster to compute.
The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by:

$\theta = \arctan(G_y / G_x)$

2.2.2 Robert's cross operator

The Roberts Cross operator performs a simple, quick to compute, 2-D spatial gradient measurement on an image. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point. The operator consists of a pair of 2×2 convolution kernels as shown in Figure 3. One kernel is simply the other rotated by 90°. This is very similar to the Sobel operator.

+1	0
0	-1

G_x

0	+1
-1	0

G_y

Fig. 3: Masks used for Robert operator

These kernels are designed to respond maximally to edges running at 45° to the pixel grid, one kernel for each of the two perpendicular orientations. The kernels can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *Gx* and *Gy*). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by:

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

Although typically, an approximate magnitude is computed using:

$$|G| = |G_x| + |G_y|$$

which is much faster to compute.

The angle of orientation of the edge giving rise to the spatial gradient(relative to the pixel grid orientation) is given by:

$$\theta = \arctan(G_y/G_y) - 3\pi/4$$

2.2.3 Prewitt's operator

Prewitt operator is similar to the Sobel operator and is used for detecting vertical and horizontal edges in images.

-1	0	+1
-1	0	+1
-1	0	+1

G_x

+1	+1	+1
0	0	0
-1	-1	-1

G_y

Fig. 4: Masks for the Prewitt gradient edge detector

2.3 Canny Edge Detection Algorithm

The Canny edge detection algorithm is known to many as the optimal edge detector. Canny's intentions were to enhance the many edge detectors already out at the time he started his work. He was very successful in achieving his goal and his ideas and methods can be found in his paper, "A Computational Approach to Edge Detection". In his paper, he followed a list of criteria to improve current methods of edge detection. The first and most obvious is low error rate. It is important that edges occurring in images should not be missed and that there be no responses to non-edges. The second criterion is that the edge points be well localized. In other words, the distance between the edge pixels as found by the detector and the actual edge is to be at a minimum. A third criterion is to have only one response to a single edge. This was implemented because the first two were not substantial enough to completely eliminate the possibility of multiple responses to an edge. Based on these criteria, the canny edge detector first smoothes the image to eliminate and noise. It then finds the image gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum (non maximum suppression). The gradient array is now further reduced by hysteresis. Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a non edge). If the magnitude is above the high threshold, it is made an edge. And if the magnitude is between the 2 thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above T2.

Step 1:-

In order to implement the canny edge detector algorithm, a series of steps must be followed. The first step is to filter out any noise in the original image before trying to locate and detect any edges. And because the Gaussian filter can be computed using a simple mask, it is used exclusively in the Canny algorithm. Once a suitable mask has been calculated, the Gaussian smoothing can be performed using standard convolution methods. A convolution mask is usually much smaller than the actual image. As a result, the mask is slid over the image, manipulating a square of pixels at a time. The larger the width of the Gaussian mask, the lower is the detector's sensitivity to noise. The localization error in the detected edges also increases slightly as the Gaussian width is increased.

Step 2:-

After smoothing the image and eliminating the noise, the next step is to find the edge strength by taking the gradient of the image. The Sobel operator performs a 2-D spatial gradient measurement on an image. Then, the approximate absolute gradient magnitude (edge strength) at each point can be found. The Sobel operator uses a pair of 3x3 convolution masks, one estimating the gradient in the x-direction (columns) and the other estimating the gradient in the y-direction (rows). They are shown below:

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-1	0	+1
2	0	+2
1	0	+1

G_x

+1	+2	+1
0	0	0
-1	-2	-1

G_y

The magnitude or edge strength of the gradient is then approximated using the formula

$$|G| = |G_x| + |G_y|$$

Step 3:-

The direction of the edge is computed using the gradient in the x and y directions. However, an error will be generated when sum X is equal to zero. So in the code there has to be a restriction set whenever this takes place. Whenever the gradient in the x direction is equal to zero, the edge direction has to be equal to 90 degrees or 0 degrees, depending on what the value of the gradient in the y-direction is equal to. If G_y has a value of zero, the edge direction will equal 0 degrees. Otherwise the edge direction will equal 90 degrees. The formula for finding the edge direction is just:

$$\theta = \tan^{-1}(G_y/G_x)$$

Step 4:-

Once the edge direction is known, the next step is to relate the edge direction to a direction that can be traced in an image. So if the pixels of a 5x5 image are aligned as follows:

x x x x x
x x x x x
x x a x x
x x x x x
x x x x x

Then, it can be seen by looking at pixel "a", there are only four possible directions when describing the surrounding pixels - 0 degrees (in the horizontal direction), 45 degrees (along the positive diagonal), 90 degrees (in the vertical direction), or 135 degrees (along the negative diagonal). So now the edge orientation has to be resolved into one of these four directions depending on which direction it is closest to (e.g. if the orientation angle is found to be 3 degrees, make it zero degrees). Think of this as taking a semicircle and dividing it into 5 regions.

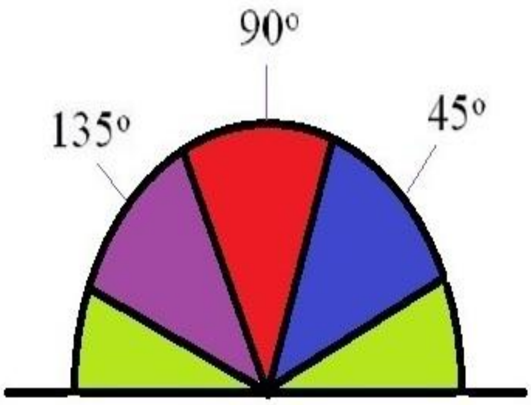


Fig. 5: Edge orientation

Therefore, any edge direction falling within the yellow range (0 to 22.5 & 157.5 to 180 degrees) is set to 0 degrees. Any edge direction falling in the green range (22.5 to 67.5 degrees) is set to 45 degrees. Any edge direction falling in the blue range (67.5 to 112.5 degrees) is set to 90 degrees. And finally, any edge direction falling within the red range (112.5 to 157.5 degrees) is set to 135 degrees.

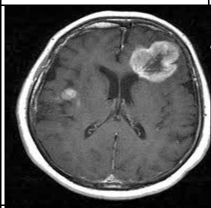
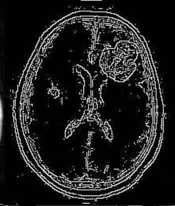
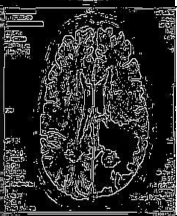
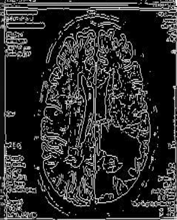
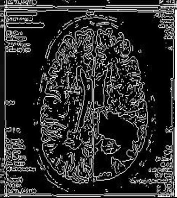
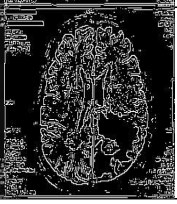
Step 5:-

After the edge directions are known, non-maximum suppression now has to be applied. Non-maximum suppression is used to trace along the edge in the edge direction and suppress any pixel value (sets it equal to 0) that is not considered to be an edge. This will give a thin line in the output image.

Step 6:-

Finally, hysteresis is used as a means of eliminating streaking. Streaking is the breaking up of an edge contour caused by the operator output fluctuating above and below the threshold. If a single threshold, T1 is applied to an image, and an edge has an average strength equal to T1, then due to noise, there will be instances where the edge dips below the threshold. Equally it will also extend above the threshold making an edge look like a dashed line. To avoid this, hysteresis uses 2 thresholds, a high and a low. Any pixel in the image that has a value greater than T1 is presumed to be an edge pixel, and is marked as such immediately. Then, any pixels that are connected to this edge pixel and that have a value greater than T2 are also selected as edge pixels. If you think of following an edge, you need a gradient of T2 to start but you don't stop till you hit a gradient below T1.

3. Experimental Result and Analysis

Sl No	Type of Edging Technique	Input	Output	Threshold value	Mean	Variance	Standard Deviation	PSNR
1	Robert			0.3	0.125	0.1094	0.3307	7.45
2	Prewitt			0.3	0.08978	0.08172	0.2859	7.6
3	Sobel			0.3	0.08881	0.08092	0.2845	7.6
4	Canny			0.3	0.06865	0.07246	0.2741	7.9
5	Robert			0.1	0.1677	0.1396	0.3736	6.314
6	Prewitt			0.1	0.1672	0.1392	0.3731	6.181
7	Sobel			0.1	0.1671	0.1392	0.3731	6.199
8	Canny			0.1	0.1438	0.1267	0.2893	7.263

Since for recognition of object it is always necessary to detect edges at first before the further procedure is to be followed, so it is always important to get ideas about the different edge detection techniques .In this paper some commonly used edge detection techniques were studied and the simulated results as well as some parameters such as Threshold value, mean, variance, standard deviation and PSNR were calculated and compared using MATLAB. It is found that the Canny's edge detection algorithm performs better than all these operators under almost all scenarios. Simulation results using this algorithm showed its ability to accurately detect and identify the contour of the tumor, its computational time was less and accuracy was more. Evaluation of the images showed that under noisy conditions, Canny, Sobel, Prewitt, Robert's exhibit better performance respectively.

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