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An Improved Canny Edge Detection Algorithm for Detecting Brain Tumors in MRI Images

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Abstract: Medical image processing represents an important research topic. Computer aided diagnostic application both, reduce time and improve quality of diagnostic process. In this paper an edge detection algorithm, specially adjusted for processing brain MRI images is presented. LoG filer was introduced as the first step of improved Canny algorithm. Also, gradient magnitude and kernel gradient were adjusted specially for edge detection in brain MRI images. This algorithm is based on the improvement of the traditional Canny algorithm. The proposed method was compared with other standard edge detection methods, and it was noticed that it produces more detail edge detection. The simulation results have shown that the proposed algorithm is more noise-resilient and better in edge and detail detection than standard Canny algorithm.

Key–Words: MRI images, brain tumor, Canny algorithm, edge detection, image fusion

1 Introduction

Digital images and digital image processing are used in various fields and one of them is medicine. In medicine, different sources are used for obtaining digital images: ultrasound, X-ray, computed tomography (CT) scans, positron emission tomography (PET) scans, magnetic resonance imaging (MRI) and more. Different sources are needed since the body is very complex thus for example, bones are captured by X-rays while soft tissues are more visible on images obtained by MRI. These images are further processed in order to empathize important parts such as tumors, bleedings, veins, etc. Numerous methods for medical image processing and computer aided diagnostics were proposed in the past [1, 2, 3, 4, 5].

Magnetic resonance imaging is a medical imaging technique used in radiology to show internal structures of the body and it is considered to be an important tool for surgeons. It uses the property of nuclear magnetic resonance to display images of the nucleus of the atom inside the body. MRI also provides the perfect contrast between the various soft tissues of the body, which is especially useful for displaying the brain, muscles, etc. The brain is considered to be one of the sensitive organs and MR images of the brain should be carefully observed. One of the brain anomalies that can be captured by MRI is tumor. A brain tumor is any intra cranial mass created by abnormal and uncontrolled cell division. Tumors can destroy brain cells or damage them indirectly by causing inflammation. Brain tumors are classified into: primary brain tumor and secondary (metastatic) brain tumor. The difference is that primary brain tumors, whether they are malignant or benign, may be localized while secondary tumors could be in different locations [6]. In order to detect brain tumor, MRI images must be categorized and analyzed [7].

Brain tumor detection is often done by image segmentation which is an attempt to divide the digital image into multiple disjunct segments that separate image properties. Separation is done based on the intensity levels and on the similarities of the region [8]. Segmentation techniques such as edge detection, threshold, clustering and many others are used for tumor detection. Threshold is the simplest segmentation technique whose analysis depends on pre-defined thresholds. Threshold determination is a common research topic [9, 10] where entropy based methods [11] are frequent choice. Edge detection identifies the discrepancies in the image, and is more precisely aimed at finding unrelated illumination of the image, especially along the edges where the intensity changes sharply. Clustering is a process in which pixels are grouped into clusters, which represent a collection of pixels that have some common features. The goal of the segmentation is to simplify or change the image into something that makes more sense and is easier to analyze.

In this paper we propose improved Canny edge detection algorithm for detecting brain tumor in MRI images. Kernel gradient of the traditional Canny algorithm was modified and adjusted for the considering problem. Output of our proposed method and Canny edge detection algorithm were combined in order to obtain better segmentation.

2 Edge detection by traditional Canny algorithm

Identifying the edges of medical images is an important step towards identifying objects of human organs, such as soft brain tissue. Usually, once MRI image is obtained, various algorithms are used to extract useful information. This information is particularly useful for identifying tissue boundaries, for estimating the consequences of the stroke and tumors, for planning operations, etc. Nowadays, there is a group of edge detection algorithms based on the differential operators, such as Robert operator, Sobel operator, Prewitt operator, etc. These operators are simple, easy to implement and have a good execution time. On the other hand, they are sensitive to noise thus edge detection accuracy should be improved. Canny operator represents the improvement of traditional single threshold method, in which the high and low threshold are selected according to the gradient of the image histogram.

The primary goal of all edge detection algorithms is to locate the edge without some pre-given information. Some of the well-known edge detection algorithm are Sobel, Roberts, Laplace and Canny algorithm. However, all these algorithms are not designed to recognize high frequency impulse noise [12]. In practice, medical images contain the boundaries of objects, shadows and all kinds of noise, and therefore, with these algorithms it is difficult to distinguish the original edges of objects from noise or trivial geometric figures.

Canny method has been frequently used in medical applications [13]. In the Canny algorithm, Gaussian function is used to smooth the image before the edge detection process in order to reduce the Gaussian noise and to set the resolution of the image in which the change in intensity is more easily detected. All these factors contribute to precise edge detection. However, Canny algorithm has some weaknesses. Although the Canny operator accurately recognize edges, it is possible to recognize false edges due to the presence of the noise. Also, it fails to recognize the edges that branch out and some important details.

Five basic steps of Canny edge detection algorithm are image smoothing and filtering, finding the gradient magnitude and gradient direction, non-maxima suppression, double threshold and edge tracking by hysteresis. The image can be smoothed by various Gaussian kernels. After the smoothing, Canny algorithm finds the edges where the intensity of the gray level changes the most. These regions are located by selecting image gradients. The gradient of each pixel is determined by Sobel operator, and the first step is to approximate the gradient directions of x and y using the following kernels:

$$K_(G_x) = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \tag{1}$$

$$K_(G_y) = \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix} \tag{2}$$

Then the gradient magnitude are calculated as the Euclidean distance:

$$|G| = \sqrt{G_x^2 + G_y^2}. \tag{3}$$

Sometimes, the edges are extended and for this reason, they cannot be accurately determined. In order to solve this problem, it is necessary to determine the edge direction:

$$\theta = \arctan \frac{|G_x|}{|G_y|}. \tag{4}$$

This converts the blurred edges into the sharp ones. This is done by keeping local maxima and rejecting all other points. For each pixel, the following procedure is followed:

- Round the gradient direction to the nearest 45°, based on the use of the 8 nearest neighbors.
- Compare the edge strength of the current pixel with the edge strength of the pixel in the positive and negative gradient directions. If the direction is north, i.e. 90°, then compare it with pixels south and north of the current pixel
- If the edge strength of the current pixel is the largest, the value will be preserved, otherwise, the value will be suppressed.

The preserved pixels are marked by their intensity. Many of these pixels represent points of the real edges, but there are also those that are created as a result of noise or color variation. Canny algorithm uses two thresholds, a higher and a lower one, for detecting and removing false edge pixels. Pixels that are bigger than the higher threshold are marked as *strong* pixels, while pixels with smaller value than the lower threshold are rejected. The pixels with value between these two thresholds are marked as *weak* pixels.

Strong edges are interpreted as reliable edges and can be included immediately in the final result and weak edges are included if and only if they are connected with the strong edges.

There are many suggestions for improving the Canny algorithm [14, 15, 16]. One improvement would be calculating 8 neighborhood pixels including not only the gradient directions of x and y, but also the first order partial finite differences of directions 45° and 135°, and calculating the gradient amplitude with certain weights [17]. However, it is difficult to design a general edge detection algorithm that works well in different contexts. Therefore, in this paper, modified Canny edge detection algorithm was designed specifically for MRI images of brain tumors.

3 The proposed improved Canny algorithm

Our proposed improved Canny algorithm as the first step applies the LoG filter, which emphasizes the region of fastest intensity change. LoG value is used to decompose the original image into two images. The first image is the image of interest and it contains information of the original image whose value is greater or equal to the corresponding LoG value. The second image contains all values that are less than the corresponding LoG value and we ignore this image because it contains mainly of the noise.

After applying LoG filter, the proposed method follows the usual steps: image smoothing and filtering, finding the gradient magnitude and gradient direction, non-maxima suppression and edge tracking by hysteresis.

In this paper we proposed modified kernel for smoothing the image. The proposed kernel emphasizes the edges of the image:

$$\begin{pmatrix} 1 & 1 & 1 \\ 1 & \alpha & 1 \\ 1 & 1 & 1 \end{pmatrix} \tag{5}$$

where $\alpha = 2, 4\ or\ 8$. If we change the alpha parameter in Gaussian function, we will see clear differences (Fig. 1). With increasing values, more details are detected, although more details do not necessarily result in better image. It can be noted that if the parameter value is set to 8, an unclear image is obtained. Based on this, in this paper we set $\alpha = 2$.

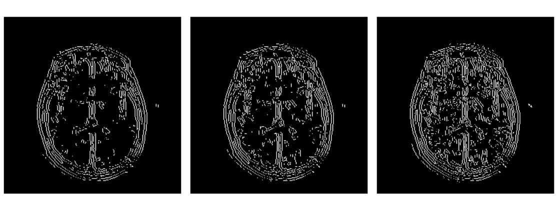


Figure 1: Effect of Gaussian filter for α = 2, 4 and 8

The second adjustment is modification of gradient magnitude. The proposed algorithm combines the gradient magnitude and gradient direction:

$$magnitude(x, y, \theta) = max(\cos\theta G_x, \sin\theta G_y). \tag{6}$$

Kernel gradient was also modified. The ordinary Canny method calculates the gradient magnitude and gradient direction based on pixels within the $2x2$ neighborhood and can easily detect false edges. One of the solutions is to calculate the gradient magnitude and gradient direction by using pixels within mxn neighborhood. New kernels are:

$$G_x = \begin{pmatrix} 2\sqrt{2} & 0 & -2\sqrt{2} \\ 4 & 0 & -4 \\ 2\sqrt{2} & 0 & -2\sqrt{2} \end{pmatrix} \tag{7}$$

$$G_y = \begin{pmatrix} 2\sqrt{2} & 4 & 2\sqrt{2} \\ 0 & 0 & 0 \\ -2\sqrt{2} & -4 & -2\sqrt{2} \end{pmatrix} \tag{8}$$

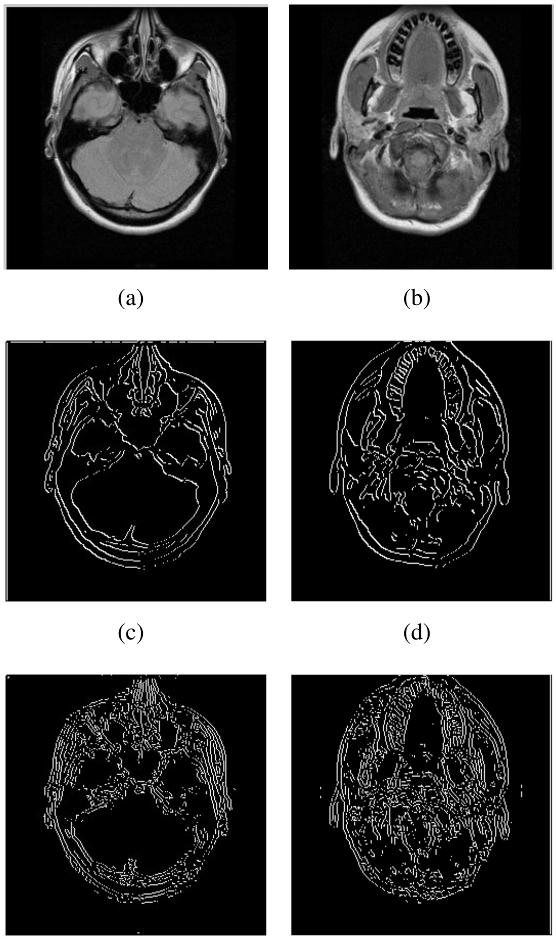
The traditional Canny algorithm uses a non-maxima suppression method to ensure that the edge width is exactly 1 pixel. In this method, a fusion of two images is suggested. The first image is obtained by using the previously mentioned modified kernel, while the second image is obtained by using modified kernel and a modified gradient magnitude. The fusion of these two images guarantees the existence of all edges that one of these two images alone might not detect [18].

4 Results

The proposed algorithm is implemented in C# programming language, Visual Studio 2017 with .NET Framework 4.7. All tests were done on an Intel ® Core$^{\text{TM}}$i7-3770K CPU at 4GHz, 8GB RAM and Windows 10 Professional OS.

MRI images of the brain used for testing are from web-based medical image depository [19] where they are freely available. Results of the traditional Canny algorithm were compared with the results of the proposed improved algorithm.

Result images of our proposed method as well as traditional Canny edge detection algorithm are shown in Fig. 2. It can be noticed that the improved Canny algorithm has managed to find more details than the original one. The proposed method produces small curves that are not fully connected. The cause of these disconnections is the performance of LoG. Laplace filter reduces sensitivity to the orientation of the edges of the corners and curves whose intensity varies widely.



(a) (b)

(c) (d)

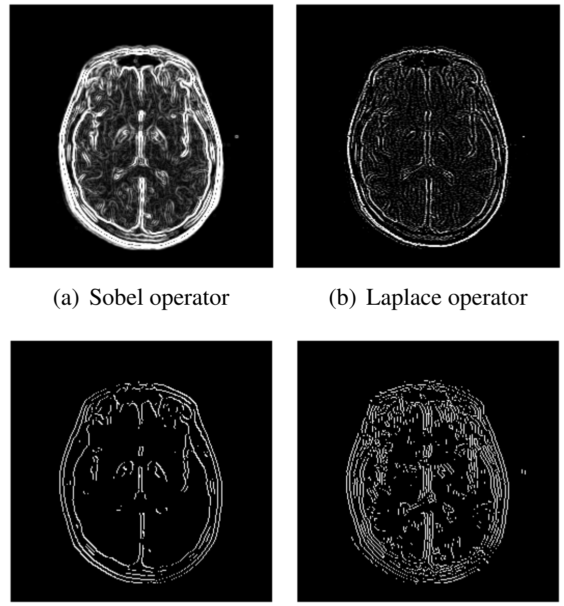
(e) (f)

Figure 2: Two examples of the proposed method: (a)-(b) Original image, (c)-(d) the output of an original Canny algorithm, (e)-(f) the ouput of the proposed Canny algorithm

Additionally we compared the results of some standard edge detection operators with the proposed improved Canny edge detection algorithm for brain MRI images. Resulting images are presented in Fig. 3. Based on this images we can conclude that our proposed method detects edges more detailed.

5 Conclusion

This paper describes an edge detection algorithm that is particularly adapted to work with MR images of brain tumor. An improvement of Canny algorithm has been proposed and then improvement was used in the fusion of detected edges. Various MRI images of brain tumor were used for testing. The results have shown that the proposed algorithm can recognize more details, which can help a lot in detecting the type of brain tumor.



(a) Sobel operator (b) Laplace operator

(c) Canny operator (d) Improved Canny algorithm

Figure 3: Comparison between the proposed method and some standard edge detection algorithms

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