Edge detection algorithm of medical image based on Canny operator

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Abstract. Edge detection is an important part of image segmentation, in this paper, the edge detection algorithm based on traditional Canny operator for medical images is studied. The Canny operator is improved using Otsu algorithm and double-gate limit detection method, and the ability of Canny operator edge detection is strengthened. The simulation of the algorithm is realized on the computer platform by MATLAB, and the experimental results are analyzed from two image objective evaluation indexes of information entropy and mean square error. The experimental results show that compared with the traditional Canny algorithm, the improved adaptive double threshold Canny algorithm has better edge detection effect, richer image details, better noise suppression and less false edges.

1. Induction

As an important image preprocessing process of image processing and pattern recognition, edge detection is the basis of target feature extraction, recognition and tracking [1]. As an important part of medical imaging, edge detection provides an effective technical means for medical image processing, pattern recognition and image matching [2].

In recent years, many mature edge detection algorithms have been formed.

(1) Differential operator method mainly includes Roberts operator, Sobel operator, Prewitt operator, Laplacian operator, etc. The edge location accuracy of these operators is not high, and they are only used for the extended basic operators.

(2) Optimal operator method includes log (Laplacian of Gaussian) operator, Canny operator, etc. This kind of algorithm has obvious effect on the step edge affected by Gaussian white noise.

(3) Medical image edge detection based on multi-scale morphological gradient can get ideal image edge information in noisy images. Its denoising performance is obviously better than the classical operator detection algorithm, and the detection accuracy is also improved compared with the classical single gradient operator detection method. This conclusion has been proved by simulation results.

(4) Among the edge detection algorithms based on adaptive smoothing filter, the better one is the simulated nealing method proposed by Geman.

(5) Lifting wavelet transform method not only inherits the multi-resolution characteristics of traditional wavelet transform, but also does not rely on Fourier transform, occupies less system memory, has good real-time performance, and reduces the complexity to about half of the original convolution method [3-5].

The basic requirement of edge detection is to obtain a lower false judgment rate and a higher positioning accuracy as far as possible. The lower false judgment rate requires that the actual edge of the image should not be missed and the false edge should not be reported; High precision positioning requires the edge to be able to determine the actual position of the pixel based on the width of the pixel.
However, in order to achieve the above goal, the algorithm needs to eliminate the noise interference as much as possible, detect the correct edge at the same time, or find a balance between the two [6]. In this paper, the classical Canny operator is improved to make up for the defects of threshold and false edge.

2. Canny operator and its improvement

2.1. Canny operator edge detection principle

Canny operator edge detection algorithm first smoothed the image, which mainly used Gaussian filter; Secondly, the amplitude and direction of the gradient must be suppressed by the maximum; Thirdly, double threshold algorithm is used to detect and connect the edges. The schematic diagram is shown in Figure 1.

![Figure 1. The schematic diagram of Canny operator](image)

Canny edge detection focuses on finding the local maximum of gradient amplitude. The gradient here is calculated by the derivative of the Gaussian filter. Canny operator mainly uses two thresholds to detect strong edge and weak edge respectively, and at the same time, when the strong edge and weak edge are connected [7].

Although Canny operator is a relatively good edge detection algorithm, there are some shortcomings. In fact, the digital images are usually discretized, and the filter also requires discretization. Therefore, in practical application, it is required to discretize the continuous filter into a selective template. This involves how to select template size [8].

Therefore, this paper mainly solves the following problems: firstly, under the influence of noise, Gaussian filtering is used to make the detected false edges lose some real edge information. Secondly, the traditional Canny operator needs human intervention in the process of determining the double threshold. Therefore, in the following content, this paper will introduce an improved algorithm to improve the Canny operator.

2.2. The improvement of Canny operator

2.2.1. Otsu segmentation algorithm

It is necessary to determine threshold value in image segmentation, and edge detection is a typical representation of image segmentation. Automatic selection of threshold is also a key topic in edge detection research. The selection of threshold is often studied on such a hypothesis. Then the best threshold should have the best and can be shown to separate the two types of thresholds. This algorithm is simple to calculate and will not be affected by the contrast and brightness of the image under certain circumstances. At the same time, the application of some images in the real-time processing system has become very wide, and has long been considered as the most optimized method in the field of threshold automatic selection [9,10].

The basic principle of Otsu's maximum inter class variance is: suppose that \( f(x,y) \) is the gray value of the point \((x,y)\) in the image \(M \times N\) (the gray level is \(L\)), set \( f(x,y) \in [0,L-1] \), record \( G = \{0,1,2,\ldots,L-1\} \), \( p(i) \) is the frequency of gray level \(i\), then the probability of gray level \(I\) is as follows:

\[
p(i) = \frac{1}{MN} \sum_{(x,y)\in G_i} f(x,y) \quad i \in G_L
\]

Now set the threshold value of image segmentation as \( t \), the image can be divided into two regions: target region \( O \) and background region, which are represented by \( \{ f(x,y) \leq t \} \) and \( \{ f(x,y) > t \} \) respectively, Therefore, there are:
Target ratio:
\[ \omega_b(t) = \sum_{0 \leq i \leq L-1} p(i) \]  
Target mean:
\[ \mu_b(t) = \sum_{0 \leq i \leq L-1} ip(i) / \omega_b(t) \]  
Background ratio:
\[ \omega_l(t) = \sum_{0 \leq i \leq L-1} p(i) \]  
Target mean:
\[ \mu_l(t) = \sum_{0 \leq i \leq L-1} ip(i) / \omega_l(t) \]  
Total mean:
\[ \mu = \omega_b(t)\mu_b(t) + \omega_l(t)\mu_l(t) \]  
The optimal threshold formula of Otsu algorithm is as follows:
\[ T = \text{Arg Max}_{t \in G_b} \left[ \omega_b(t)(\mu_b(t) - \mu)^2 + \omega_l(t)(\mu_l(t) - \mu)^2 \right] \]  
The actual value in brackets in Equation (7) is the variance value between classes. The larger the variance value is, the worse the uniformity of the image is, and the better the segmentation effect is.

2.2.2. Double threshold detection
Otsu algorithm has only one threshold, which is not conducive to double threshold detection. Therefore, in the following, this paper will multiply a scale coefficient to convert single threshold into double threshold. After many experiments and comparisons, this coefficient is determined to be 0.5. The specific implementation process is as follows:
(1) Gets the number of rows and columns of the original picture matrix.
(2) The first order Inverse Gauss matrix is obtained by using the row and column number of the original image.
(3) If the threshold is only one (or both values are the same), then multiply the low threshold by 0.5 times the high threshold, otherwise go to the next step.
(4) The edge matrix is obtained by using the original edge detection function of Canny operator.
(5) By comparing the function, the image with low threshold is obtained and the image is 1 when the threshold is low, and the high threshold edge graph is obtained.
(6) The low threshold edge has been assigned 1, so the horizontal and column coordinates can be connected after obtaining the high threshold edge fracture to fade the image above into a line once.
(7) After the above steps, we can get the result image of the improved adaptive double threshold Canny operator edge detection.

3. Experimental results and analysis
In order to verify the practicability of the algorithm, the Gaussian noise of [0, 0.01] is added to the image. Figure 3 shows the results of edge detection on brain CT images.
Figure 3. Edge detection results of brain CT image

Table 1. The quantitative comparison of results of various operators in CT edge detection of brain

| Algorithm             | Entropy | Mean Square Error | Operation Time (s) |
|-----------------------|---------|-------------------|--------------------|
| Noise image           | 29.224  | 74.475            | —                  |
| Laplacian operators   | 7.712   | 55.233            | 0.216              |
| Prewitt operators     | 59.589  | 89.631            | 0.288              |
| Roberts operators     | 109.396 | 91.124            | 0.299              |
It can be seen from the experimental results that:

1. Except Canny operator and improved Canny operator, the other operators cannot filter out the noise interference well. It is obvious that Laplacian operator cannot recognize the edge, and Prewitt operator and Roberts operator are also seriously disturbed by noise, which leads to edge blur. In contrast, canny and improved operators, the edges can be observed clearly, and the improved canny operators have fewer double edges and pseudo edges.

2. For the universality and stability of the algorithm, two groups of experimental data and some experimental results not listed here prove that all the above algorithms can not only detect the edge of ordinary images such as Lena, but also can be used for edge detection of medical images.

3. The processing time of the algorithm (as shown in Table 1) is longer than that of other operators because Canny operator and improved operator need more calculation, but generally speaking, the experimental results can be obtained in a short time.

The experimental results are analyzed and compared from two image objective evaluation indexes of information entropy and mean square deviation, and the results are shown in Table 1. It can be seen from the table that the information entropy of Canny operator is higher than that of other algorithms, which indicates that Canny operator has more information and richer image details. The information entropy of the improved Canny operator is slightly less than that of the classical operator, because after its more accurate Gaussian filtering, many double edges and pseudo edges are removed, so the information entropy is slightly less, but the detected edges are more accurate. Mean square error is image contrast. After adding noise, the mean square error of Laplacian operator, Prewitt operator and Roberts operator is greater than that of the image after adding noise because the noise is not filtered well. The mean square error of Canny operator and improved operator is lower than the image after adding noise, which indicates that the image level is lower and smoother. The mean square error of the improved operator is lower than that of the classical operator, which proves that the improved algorithm has better filtering and better noise suppression.

4. Conclusion

This paper first introduces the history and background of image processing and the current situation of edge detection at home and abroad, then briefly introduces the more commonly used edge detection methods, and then introduces some classic edge detection algorithms in detail, especially the famous Canny operator. Next, combining Otsu algorithm and double threshold detection method, an adaptive double threshold setting method is implemented to improve the edge detection ability of Canny operator. Finally, through a large number of experiments and objective data such as mean square error and information entropy, this paper proves the feasibility and superiority of the improved adaptive double threshold Canny operator.

Although the improved Canny operator has the above advantages, it still needs further improvement. For example, compared with the traditional edge detection operator, its processing time is relatively long, and its advantages in large-scale data processing are insufficient, so the application of the method is limited. The further work is to improve the method and try to shorten the processing time of the algorithm.

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