



Research on the improvement of image edge detection algorithm based on artificial neural network



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ABSTRACT

Image edge detection is an essential basis of computer vision that has made rapid progress these years. Given the importance of the edge detection and the maturity of ANN (artificial neural network), we provide a research paper on the algorithms of image edge detection based on ANN. Firstly, we review the classic methods of edge detection and introduce some new methods proposed these years. Secondly, the foundations of ANN are briefly introduced. Subsequently, we present a traditional edge detection method based on ANN and summarize some disadvantages of this method. Finally, a new edge detection method based on ANN and parallel computing is put forward. The new method is superior to the old one in the efficiency and accuracy of detection.

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1. Introduction

Image edge detection plays an important role in many scopes, such as image segmentation, pattern recognition and computer vision. It is also a problem which does not have a perfect solution. The solution of this problem has a positive role in promoting the development of feature extraction, image understanding and target recognition. The traditional operators of image edge detection are based on the gradient mostly, such as the Roberts operator, the Prewitt operator, the Sobel operator and the LOG operator (Laplace of Gauss). These operators can detect the edge roughly, but the detection ability is not strong.

In 1986, John Canny proposed three criteria of image edge detection: (i) high the signal-to-noise ratio; (ii) better positioning performance; (iii) Uniqueness of Response. On the basis of these criteria, a famous operator called Canny is obtained. To some extent, the detection result of Canny is better than that of the traditional operator.

The operators mentioned above are called classic operators. Though these classic operators are simple and convenient, they can only be applied to some finite edges. They have the problem of poor self-adaptability and sensitivity of noise. To different images, the

same classic operators always have different results. The optimal model is different for different situations.

With the increasing requirements of the accuracy of algorithms in the image processing fields, some intelligent algorithms are used, such as artificial neural network, Genetic algorithm, ant colony optimization and Particle Swarm Optimization. Especially in 1990s, a huge success is achieved in the application of artificial neural network in the edge detection fields. Neural network is suitable for the field that cannot be modeled by the classic operators. It learns from samples, builds the model by itself. That is to say, the corresponding relation between the physical change of image edge and local spatial brightness in the image can be solved by sample set of the network training.

Although the neural network has the above mentioned advantage in the edge detection of image, the difficulty of choosing the image window size, the number of neurons and the number of network layers limit the development of it in the edge detection. When the image or the number of neurons is large, the amount of calculation will be great. We improve the algorithm of edge detection based on neural network to enhance the precision and efficiency. The new algorithm takes advantage of parallel computing and dynamic window.

Here is the structure of the paper. Section 2 introduces some classic edge detection operators and some recent research hotspots briefly. Elementary knowledge of artificial neural network is described in Section 3. Section 4 introduces the traditional edge detection algorithm based on artificial neural network and the improvement of it. Section 5 presents the comparative experiments

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between the traditional algorithm and the improved technique. Section 6 gives the analysis and conclusion.

2. Some edge detection algorithms

2.1. Algorithms based on gradient

The gray change of pixels around the most common edge presents the shape of a ladder or the shape of pulse. From the first-order derivative and the second derivative of these shapes, it can be drawn that the points of the edge appear in the maximum or minimum position of these derivatives. It may also occur in the zero position of these derivatives. Based on the above theory, researchers have proposed a gradient operator based on the first derivative, as follows:

$$G[f(m, n)] = \left[\left(\frac{\partial f}{\partial m} \right)^2 + \left(\frac{\partial f}{\partial n} \right)^2 \right]^{1/2}$$

where $f(m, n)$ represents the gray of the pixel (m, n) . By taking appropriate threshold T , the image edge can be judged. If $G[f(m, n)] > T$, the pixel (m, n) is the point of edge. For digital image, derivatives can be approximated by differential, partial derivative can be expressed as:

$$\frac{\partial f}{\partial m} = f[m + 1, n] - f[m, n] \quad \frac{\partial f}{\partial n} = f[m, n] - f[m, n + 1]$$

The image can be regarded as a collection of discrete points. In order to reduce the amount of calculation, some operator templates are used to match with the image, replacing the above calculation. The most common operator templates are Robert operator, Sobel operator and Prewitt operator template, as follows:

$$\begin{matrix} \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} & \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \\ \text{Robert operator} & \end{matrix} \quad \begin{matrix} \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} & \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \\ \text{Sobel operator} & \end{matrix} \\ \\ \begin{matrix} \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} & \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \\ \text{Prewitt operator} & \end{matrix}$$

The edge got from the first-order derivative operator is always blur and coarse, so researchers have proposed the Laplace operator based on second order derivative, as follow:

$$\nabla^2 f = \frac{\partial^2 f}{\partial m^2} + \frac{\partial^2 f}{\partial n^2}$$

where the second order derivative can be replaced by differential as:

$$\begin{aligned} \frac{\partial^2 f}{\partial m^2} &= (f[m, n + 1] - 2f[m, n]) + f[m, n - 1] \quad \frac{\partial^2 f}{\partial n^2} \\ &= (f[m + 1, n] - 2f[m, n]) + f[m - 1, n] \end{aligned}$$

The second order method have higher Positioning accuracy than the first order one, but it strengthens the noise in the image.

2.2. Canny algorithm

In 1986 Canny put forward the optimization algorithm of the edge detection. He thought that an excellent edge detection operator should have three characteristics:

- 1) The signal-to-noise ratio must be high. The point of non-edge should not be detected as the point of edge.
- 2) The positioning performance must be improved. The edge point detected by the algorithm must be very close to the actual one.
- 3) Each edge point must have a unique response.

According to these the criteria, the implementation of Canny operator is as follow.

- 1) The original image is smoothed to remove noise by Gauss filter.
- 2) Calculate the gradient magnitude and direction by the first order partial derivative.
- 3) Conduct nonmaxima suppression of gradient magnitude.
- 4) Detect and connect edge with the two thresholds.

The Canny operator has better capability of edge detection and locating ability. It also has strong anti noise ability. In Section 5, the edge obtained from Canny operator will be used as the sample for neural network training.

2.3. Algorithms based on Fuzzy Theory

There are many events and phenomena, including image, that are fuzzy, cannot be simply classified as 0 or 1. It makes researchers seek to establish a suitable model to describe fuzzy things. In this situation, Fuzzy Theory has emerged to meet the requirement.

The basic idea of edge detection based on Fuzzy Theory is mapping the image from spatial domain to fuzzy feature domain through membership function firstly. Secondly, fuzzy is enhanced in order to enhance gray contrast of pixels around the edge point. Then image is transformed from fuzzy domain to spatial domain through inverse transformation of the membership degree matrix. Finally, detection of edge will be performed.

This method can separate the object from the background effectively, but the matrix calculation is complex and the anti noise performance is poor.

2.4. Algorithms based on multi-scale

Due to the physical, illuminating and other reasons, each edge in an image is usually produced in different scales. These different edges cannot be correctly detected by a single scale edge detection operator, so the edge detection method applying multiple scale attracts more and more attention. Multiscale edge detection method detects edge in different scale space, then synthesize the output to obtain the ideal edge.

3. Artificial neural network

There are many neurons which constitute network to store and process information in the brain,. Artificial neural network is a special network which simulates the way the brain works. Neural network is a nonlinear system that is composed of many simple computing element. In a certain extent, it imitates the processing and storing information function of the human nerve system. Due to its unique structure, neural network is expected to solve what cannot be solved by the traditional methods.

3.1. The neuron model

The neuron of neural network is the simulation and simplification of the neuron of human brain. A classical neuron model is

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