# A New Edge Detection Method Based on Contrast Enhancement

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***Abstract*—A new edge detection method (CEED(Contrast Enhancement Edge Detection)) using neighborhood contrast is proposed in this paper, which does not utilize template operator. The edge detection frame for contrast enhancement is established and the corresponding algorithm is given. After defining the contrast evaluation function and edge structure candidate set, the contrast matrix of original image is produced, where each element value measures the degree of belonging to edge. Experimental results show that the CEED method is efficient, especially for irregular edge detection.**

***Index Terms*—Edge detection; Contrast; Smooth; Non-maximum suppression**

## I. INTRODUCTION

As a basic property of image, edge is frequently used in the application of image segmentation, pattern recognition, and machine vision. We define edge to be a simply connected contour, one pixel thick, at the center of the slope between two adjacent regions with a considerable difference in grey level. Edge reflects the discontinuity property of image gray [1,2]. Edge detection [3,4] refers to the measurement, detection, and location of gray change. In an image, edge has two characteristics: direction and amplitude. The gray changes slightly along the edge, whereas greatly perpendicular to the edge direction. Thus, edge can be detected using the maximum gradient. Many classic approaches are based on this idea, including Roberts algorithm [5], Sobel algorithm [6], Prewiit algorithm [7], Kirsch algorithm [8], Hueckel algorithm [9], etc. These methods operate simply, but have poor performance against disturbing. Hence, some other methods are developed to improve the performance shortage in edge detection. For example, LOG algorithm [10] adopts Laplace operator which uses the second derivative across zero to detect image edge. However, there exists conflict between anti-disturbing and complicated edge detection. Canny algorithm [11] detects edge using an optimum operator derived by variational principle and Gaussian template derivative. Unfortunately, it ignores the disturbing edge that effects the correct detection and location.

Motivated by these concerns, an edge detection method (CEED(Contrast Enhancement Edge Detection)) is proposed in this paper. CEED algorithm uses neighborhood contrast to detect edge rather than utilize template operator as the previous methods. Neighborhood contrast is defined according to the property that the nearest adjacent regions divided by an edge have different gray values. Using contrast evaluation function, gray value of each pixel is set to measure the degree of according with edge request. After establishing the contrast matrix of original image, edge can be detected using threshold computation.

## II. EDGE DETECTION SCHEME

### *A. Edge definition*

As we know that most information of image is saved in the edge which leads to the discontinuity of local image character. Edge exists between the nearest adjacent regions with different gray values. Usually, edge has three types. Edge of ladder type lies between the adjacent region with different gray values. Edge of pulse type mainly corresponds to the lathy area with saltation gray. And that edge of roof type has a slow change whether increase or decrease. In most cases, image edge belongs to the ladder type. Edges of pulse and roof type can be looked as the complicated form of ladder type.

### *B. Edge detection*

Edge image refers to a special image in which each pixel gray denotes its degree of according to edge request. Edge image can be represented with binary image that includes only edge location without degree. In binary image, there are two gray levels (0, 1). 0 denotes black, on the contrary, 1 denotes white. In practice, edge detection can be interpreted as an operation with "point" in local area. Whether or not a pixel is on edge will be decided by detecting the state of both the pixel itself and its neighborhoods. The proposed CEED method for edge detection mainly contains four steps, shown as Figure 1.

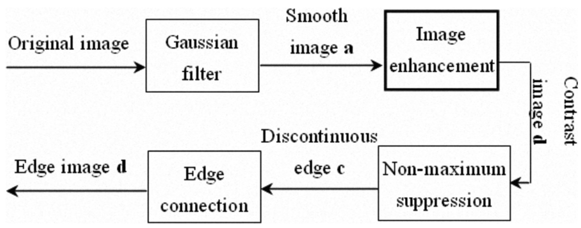


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Figure. 1 The edge detection model based on CEED.

①Gaussian filter. We adopt Gaussian filter which focus on blurring. Gaussian filter could weaken or eliminate component of high frequency in Fourier space without effect on component of low frequency.

②Image enhancement. We use contrast to enhance image. The contrast value of each pixel is calculated by traversing the whole image. Because the contrast value of pixel is proportional to the contrast of pixel neighborhood, the pixel with larger contrast value will has more possibility to be edge pixel.

③Non-maximum suppression. Through traversing the image, if the contrast value of certain pixel is not the maximum compare with the contrast of other two pixels along its gradient direction, then this pixel will not be edge.

④Edge connection. All pixels greater than the high threshold are edge points, and all pixels smaller than the low threshold is not edge. Therefore, two edge images with high threshold and low threshold should be calculated respectively and connected.

## III. CONTRAST ENHANCEMENT

### A. Gaussian filter

In this paper, Gaussian filter is utilized to blur image, since it is the optimum approximation for the signal-to noise ratio and orientation multiplication. The two dimensional Gaussian function is

$$G(x,y)=\frac{1}{2\pi\sigma^2}\exp(-\frac{1}{2\sigma^2}(x^2+y^2)) \quad (1)$$

$G(x,y)$ is a function of circular symmetry. Its smooth degree can be controlled by parameter σ. Let $I$ denotes an image of $M\times N$. A smooth image $S$ can be obtained by convoluting image $I$ and Gaussian filter $G(i,j)$.

$$S(i,j)=\sum_{i=1}^{M}\sum_{j=1}^{N}G(i,j)I(i,j) \quad (2)$$

The convolution integral in equation (2) can be denoted in short as

$$S(i,j)=G(i,j)*I(i,j) \quad (3)$$

Based on smooth $S$ image, edge information can be obtained by calculating the contrast of each pixel.

### B. Local contrast

A contrast calculation method is introduced to detect image edge. Thus, the key task is the detection of local contrast. We define an edge to be a boundary in an image that separates two regions that have significantly dissimilar characteristics. Here, dissimilar characteristic refers to the obvious gray change of adjacent regions. Dissimilar characteristic can be calculated by traversing each pixel of the image. It is known that contrast of pixel is proportional to the dissimilar characteristic of regions nearest the pixel. Hence, the larger contrast of pixel leads to the more possible becoming edge. The following gives the method to calculate contrast.

Suppose that image $I=\{I(i,j);1\le i\le M,1\le j\le N\}$ is a $M\times N$ pixel matrix. Each pixel $I(i,j)$ denotes a gray value. $I(i,j)$ belongs to the range of [0, 255]. Let $Q(i,j)$ denotes the set of eight pixels that are adjacent with $I(i,j)$. Then the nine pixels including $Q(i,j)$ and $I(i,j)$ compose a 3×3 window $W(i,j)$, as Figure 2. The contrast is calculated based on each pixel window.

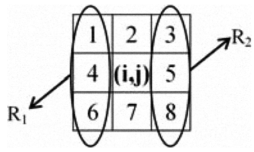


Figure. 2 Illustration of 3×3 window.

As shown in Figure 2, if edge is $(2,(i,j),7)$, then the window is divided into two regions, $R_1(1,4,6)$ and $R_2(3,5,8)$. Equation (4) gives the detailed evaluation function of contrast.

$$f(R_1,R_2)=\max(R_1/R_2,R_2/R_1)/3 \quad (4)$$

Hence, the contrast of 3×3 window $W(i,j)$ is the maximum of the ratio between two adjacent regions, i.e. $R_1/R_2$ or $R_2/R_1$. Here, $R$ denotes the standard derivative of all pixel gray in a region. Given the average gray of $R_1$, $S_1=\frac{I(i-1,j-1)+I(i,j-1)+I(i+1,j-1)}{3}$; and average gray of $R_2$, $S_2=\frac{I(i-1,j+1)+I(i,j+1)+I(i+1,j+1)}{3}$. Then, we have

$$R_1=\sqrt{(I(i-1,j-1)-S_1)^2+(I(i,j-1)-S_1)^2+(I(i+1,j-1)-S_1)^2} \quad (5)$$

$$R_2=\sqrt{(I(i-1,j+1)-S_2)^2+(I(i,j+1)-S_2)^2+(I(i+1,j+1)-S_2)^2} \quad (6)$$

From the above analysis, an edge must be assumed in order to calculate the gray contrast of adjacent regions. Therefore, we define an edge candidate $A=\{A_k(i,j);1\le i\le M,1\le j\le N,1\le k\le 16\}$ for each pixel window to calculate region contrast. $A_k(i,j)$ denotes a edge structure of 3×3 window $W(i,j)$. Figure 3 defines sixteen possible edge structures.

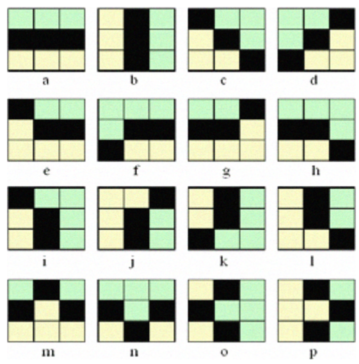


Figure. 3 Sixteen candidates of edge structure

Given the candidates of edge structure, the contrast image can be calculated. An empty (gray value of pixel is zero) contrast image with the same size as the original image should be established beforehand.

$$D = \{D(i,j) = 0;\ \ 1 \le i \le M, 1 \le j \le N\} \quad (7)$$

Through traversing each pixel $I(i,j)$ of image $I$, compare each edge structure in candidate set within pixel window $W(i,j)$. The edge structure $A_k^*(i,j)$ with maximum contrast of $f(R_1, R_2)$ will be selected. Let the contrast of $A_k^*(i,j)$ is $f^*(R_1, R_2)$, and the three edge pixels in the edge structure is $I(e_i^1, e_j^1), I(e_i^2, e_j^2), I(e_i^3, e_j^3)$ respectively, then

$$D^{(t+1)}(e_i^1, e_j^1) = D^{(t)}(e_i^1, e_j^1) + f^*(R_1, R_1)/3 \quad (8)$$

In equation (8), the superscript $t$ of contrast $D$ denotes that traverse arrive at the $t$-th pixel. Thus, the contrast of other two pixels can be obtained as $D^{(t+1)}(e_i^2, e_j^2)$ and $D^{(t+1)}(e_i^3, e_j^3)$. After traversing the whole image $I$, the corresponding contrast image $D$ is constructed. Based on image $D$, edge detection can be performed by threshold calculation. Threshold calculation is to set a threshold. Pixel is edge point if its value exceeds the threshold. For example, normalize the pixels of $D$ to make its value distributing among the range of [0, 1]. Then, pixels with value close to 1 will become edge point. But, there are still two problems. One is the false edge, another is the edge gap. These can be solved using the non-maximum suppression and edge connection method.

### C. *Non-maximum suppression*

Non-maximum suppression can be implemented as follows. The contrast of shifted structure should be calculated using 3×4 or 4×3 window instead of 3×3 window. This is because that edge structure needs to be moved by one pixel in each of the directions perpendicular to the edge. The two adjacent regions $R_1$, $R_2$ of shifted edge structure have a little change. The original edge structure should be compared with the other two edge structures shifted by one pixel in each of the directions perpendicular to the original edge. If the contrast $f(R_1, R_2)$ of original edge structure is not larger than the other two edge structures, then the three pixels on the original edge structure is set to zero in the contrast image. This process could thin the wider roof ridge to the width of one pixel and eliminate false edge points.

### D. *Edge connection*

We adopt Double threshold method to detect and connect discontinuous edge. Firstly, non-maximum suppression is performed with double threshold $\delta_1$(low) and $\delta_2$(high) to produce two edge image $E_1$ and $E_2$. Then, contour is formed by connecting edges in $E_2$. When endpoint is arrived, double threshold method searches the possible connective points in the adjacent region of endpoint in $E_1$. This step is repeated until finally all the gaps in $E_2$ are connected as a continuous edge.

## IV. ALGORITHM

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The edge detection algorithm based on contrast enhancement mainly contains four steps: Gaussian filter, image enhancement, non-maximum suppression and edge connection. As mentioned before, the two steps of image enhancement and non-maximum suppression are integrated. The pseudo-code for the CEED edge detection algorithm is shown as follows.

**Algorithm 1 Edge detection based on contrast enhancement**
**Input:** original image, threshold1(low), threshold2(high)
**Output:** edge image

```
Begin
  Initialize contrast matrix D and edge matrix E, E' with the same size as the original image;
  Smooth the original image by convolving 2D Gaussian filter with the original image in each direction;
  /* Calculate contrast image using non-maximum suppression
  For each pixel p in the smoothed image do
    For edge structure in candidate set do
     Fit edge structure onto the window centered on p;
     Calculate the local contrast f(R1,R2);
    End for
     Select the edge structure with maximum contrast f(R1,R2) and denote the three edge pixels in the edge structure as p1, p2, p3;
     Perform non-maximum suppression by shifting the best edge structure and generate two dissimilarities f1(R1,R2), f2(R1,R2);
     If f> f1 and f> f2 then
       Increase the value of each of the pixel D(p1), D(p2), D(p3) by f;
     End if
  End for
  /* Calculate edge image using double threshold method
  For each pixel b in the contrast image D do
  If D(b)> threshold1 then
    E(b)=1;   /* Set this pixel as white
    Else
    E(b)=0;   /* Set this pixel as black
    End if
    If D(b)> threshold2 then
    E'(b)=1;
    Else
    E'(b)=0;
    End if
  End for
  Connect edge in both E and E';
  Thin the contours in edge image E;
  Output edge image E in reverse color;
    End
```

## V. EXPERIMENTS

The contrast enhancement edge detection algorithm CEED is evaluated using MATLAB simulation tool and compared with other edge detection algorithms. LOG (Laplacian of Gaussian) algorithm and Canny algorithm are the most commonly used edge detection algorithms. We select them to perform comparison experiments. Threshold parameters for the three algorithms are given in Table I. In order to evaluate the algorithms sufficiently, three types of images are selected. The size parameters are summarized in Table II.

TABLE I. THRESHOLD PARAMETERS FOR THREE EDGE DETECTION ALGORITHMS

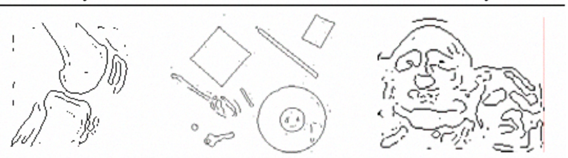
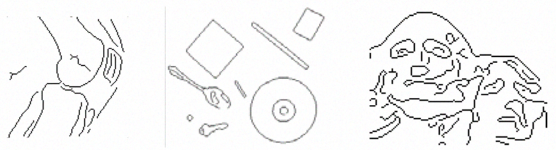
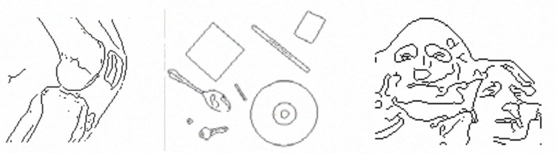
| Algorithm | LOG | Canny | CEED |
|---|---|---|---|
| x-ray | 0.0040 | 0.1300 | 0.0030, 0.0050 |
| desk | 0.0040 | 0.2500 | 0.1500, 0.2000 |
| statuary | 0.0050 | 0.2300 | 0.0060, 0.0110 |

TABLE II. SIZE PARAMETERS FOR IMAGES

| image | x-ray | desk | statuary |
|---|---|---|---|
| size | 127×127 | 231×196 | 124×102 |

For the proposed CEED algorithm, Table III gives the smooth results and contrast image of four images. From the results of Table III, we can see that original images are blurred to achieve smoothing. Through Gaussian filtering, gray parts with large change are weakened, and gray parts with small change keep no change. The contrast image afterwards is the direct source of edge detection. Table III compares the detection result of CEED with other two algorithms LOG and Canny. It is shown in Table III that, the detection results of three algorithms are different in quality. LOG algorithm performs worst, especially for complicated image such as sky and statuary. There exist many single points and short boundary. This is because of slope fusion at zero-crossing point when boundary width less than operator width. Since boundary details less than certain threshold lose, edge will not be continuous. Canny has better results than LOG in terms of continuous edge. However, Canny can only detect the rough contour because the matching process using the maximum region gradient eliminates many false edge points as well as the real edge points. CEED algorithm performs best. It has advantages of continuous boundary, precise location, and detection of weak contrast. Take x-ray image as an example, Canny cannot detect clearly the out boundary of knee with any threshold. But CEED algorithm performs well because it takes all kinds of conditions in calculating contrast image. As for other images, CEED also gives preferable outcome, since it is able to keep some detailed edge when detecting continuous edge.

TABLE III. COMPARISON RESULTS OF THREE ALGORITHMS

| | x-ray / desk / statuary |
|---|---|
| LOG |  |
| Canny |  |
| CEED |  |

## VI. CONCLUSION

This work addresses edge detection issues based on the existed technology of smoothing and optimization. A new edge detection method using neighborhood contrast enhancement is proposed. Firstly, contrast evaluation function and edge structure candidate set are initialized to form contrast matrix. Secondly, contrast image calculation and non-maximum suppression are performed simultaneously after Gaussian smoothing. Each element in the contrast image reflects degree of belonging to edge. Finally, double threshold calculation is used to form the final edge image. Experiments are performed to evaluate the proposed CEED algorithm. Comparison results show that CEED produced promising edge results, especially for the case of irregular edge detection. The advantage of CEED is to ensure edge continuous and edge detection of weak contrast. But, for the point to be detected, there are eight pixels of adjacent region should be considered, which leads to a longer computation time. In addition, different edge structures can be designated according to particular image, as well as contrast evaluation function. So, CEED algorithm is more scalable, and hence is a very potential candidate for edge detection.

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