Edge Detection in Low Contrast Images

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Abstract—The edges of low contrast images are not clearly distinguishable to human eye. It is difficult to find the edges and boundaries in it. The present work encompasses a new approach for low contrast images. The Chebyshev polynomial based fractional order filter has been used for filtering operation on an image. The preprocessing has been performed by this filter on the input image. Laplacian of Gaussian method has been applied on preprocessed image for edge detection. The algorithm has been tested on two test images.

Keywords—Chebyshev polynomials, Fractional order differentiator, Laplacian of Gaussian (LoG) method, Low contrast image.

I. INTRODUCTION

CONTRAST is the difference in luminance that makes an object distinguishable to human eyes. It is determined by the difference in luminance reflected from two adjacent surfaces [1]. The edges of low contrast images are not clearly distinguishable to human eye. It is difficult to find the edges and boundaries in it. It has been found that the traditional edge detection algorithms are not well suited for these types of images. Edge detection is a common approach for detecting the discontinuities in gray scale value of images. Different approaches have been developed for detection of edges in literature. The popular edge detection methods like Roberts, Sobel, Prewitt operation, Finite impulse response filters, Deriche filter, First order derivative of Gaussian function etc. [2]-[5]. The filter based methods also draw attention of researchers for edge detection, corners detection and their shape detection etc. Major filter based methods are Low pass and High pass filtering approach, Gabor filter, Kirsh operators, Median filtering etc. [6]-[13]. The major challenge in the edge detection algorithms is that they are image dependent. Their performance depends on the quality and type of images.

The Canny edge detection approach is an optimal edge detection algorithm which is based on derivative of Gaussian function [8]. The Laplacian of Gaussian edge detections methods also based on the 2nd order derivative of pixel intensity value of images. The Laplacian has been calculated using standard convolution methods. John et al. has proposed a nonlinear strategy for edge detection with optimal isotropy [12].

Koushendra et al. have been proposed an algorithm for design of filter that is based on Chebyshev polynomial approximation of fractional order differentiator [14].

The present work encompasses design and development of an algorithm which uses prepressed image in Laplacian of Gaussian (LoG) algorithm. Fractional order differentiator has been used to perform the preprocessing.

The structure of this paper is as follows: Section II discussed design of filter. Section III describes the proposed algorithm for edge detection. Section IV describes the results and conclusion.

II. DESIGN OF FILTER

The detailed algorithm for design of fractional order differentiator is present in literature [14]. We are reproducing it here for better understanding.

Consider two higher order differentiable functions in $\mathbb{R}$ as $Y(t)$ and $\hat{Y}(t)$ which are observed function and original function respectively. The observed function can be written as

$$Y(t) = \hat{Y}(t) + \xi(t)$$

where $\xi(t)$ is error. The present work encompasses smoothing of observed function by the use of $n^{th}$ order derivative, $L$ point filtering window and $n$-degree polynomial approximation.

Any function $Y(t)$ can be obtained by polynomial expansion expressed as: [15]

$$Y(t) = \sum_{k=0}^{n} c_k T_k(t)$$

where $T_k(t)$ is the $k^{th}$ degree Chebyshev polynomial. $c_k$ is the $k^{th}$ coefficient of polynomial function.

Least-square method is used for the estimate the coefficients $c_k$. Equation (2) can be expanded in the form:

$$T_0(k_0) + T_1(k_1) + T_2(k_2) + \ldots + T_n(k_n) = y_1$$
$$T_0(2k_0) + T_1(2k_1) + T_2(2k_2) + \ldots + T_n(2k_n) = y_2$$
$$T_0(3k_0) + T_1(3k_1) + T_2(3k_2) + \ldots + T_n(3k_n) = y_3$$
$$\vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots$$
$$T_0(Lk_0) + T_1(Lk_1) + T_2(Lk_2) + \ldots + T_n(Lk_n) = y_L$$

Here $Y = [y_1, y_2, \ldots, y_L]^T$ denotes the measured function points in the filtering window. $T$ is a matrix of order $L \times (n + 1)$ and can be defined as
The elements of matrix $T$ are calculated by using Chebyshev polynomial \[18\]

$$n \sum_{k=0}^{n} T^{(k)}(t) = 2tT^{(n)}(t) - T^{(n-1)}(t)$$

(Here $T_0(t) = 1$, $T_1(t) = t$.)

The vectors $C$ storing the coefficients of the polynomial are obtained by:

$$C = (T^T T)^{-1} Y$$

Equations (5) and (6) are used to solve (3). It will result

$$\hat{Y} = TC = T(T^T T)^{-1} T^T Y = W Y$$

(Here $T_0(i) = 1$, $T_1(i) = i$.)

III. ALGORITHM FOR EDGE DETECTION OF LOW CONTRAST IMAGES

The preprocessing has been performed on the input image before applying the Laplacian of Gaussian method for edge detection. Normalization operation has been performed on the input image ($I$). The normalized image, ($In$), has been processed by newly designed low pass and high pass filters. The output of low pass filtering operation ($Inl$) has been relaxed with the relaxation coefficient. The relaxation coefficient varies from 0 to 2. The output image of high pass filtering operation, ($Inh$) and image ($Inl$) has been multiplied. The output image of this operation is input image for Laplacian of Gaussian method (LoG). The Laplacian of Gaussian algorithm has been performed on $I_1$. The algorithm has been described in algorithm II. Fig. 1 has described the flow chart of proposed algorithm.

Full algorithm for the design of filter is described in algorithm 1.
**Algorithm II**

Proposed algorithm is as follow

**Algorithm (I_E, I, h_0, G_0, \lambda )**

**Input:** I, h_0, G_0, \lambda  
I : Input Image  
h_0 : High pass filter  
G_0 : Low pass filter  
\lambda : Relaxation coefficient  
I_n : Normalized image  
I_{nl} : Filtered image with low pass filter  
I_{nh} : Filtered image with high pass filter  
I_i : Intermediate Image  
I : Pre-processed Image  
LoG ( ) : Standard Laplacian of Gaussian edge detection algorithm  
Normalization ( ) : Normalization of image

**Output:** I_E  
begin  
I_n = Normalization ( I )  
I_{nh} = h_0(I_n)  
I_{nl} = G_0(I_n)  
I_r = \lambda I_{nl}  
I_l = I_r \times I_{nh}  
I_E = LoG ( I_l )
end

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**IV. EXPERIMENTS**

The proposed algorithm has been validated with the two low contrast images shown in Fig. 2. Images have low contrast properties as well as smooth properties. Test images are available in the open domain [20].

**V. RESULTS**

The proposed algorithm has been tested on two test images We have taken \( \alpha = 0.5 \) and order of polynomial \( n = 2 \). Four different lengths of filters i.e. \( L = 3,4,5,7 \) have been taken for validation of our proposed algorithm. The effect of length of filters has been also analyzed. The high pass filter coefficients are calculated from (10). These calculated filters have been used for intermediate stage of preprocessing. We have taken the value of relaxation coefficient, \( \lambda = 0.1 \) corresponding to every filter.

Figs. 3 (a)-(d) show the test results obtained from proposed algorithm for test case 1 (a) for filter size 3, 4, 5 and 7 respectively. Result obtained by proposed algorithm for test case 1 (b) has been shown in Fig. 4. Figs. 4 (a)-(d) have been reported for filter size 3, 4, 5 and 7 respectively. Figs. 5 (a) and (b) show the result obtained by Laplacian of Gaussian (LoG) for test case 1 (a) and test case 1 (b). Results clearly show that the proposed algorithm has been performed better than the Laplacian of Gaussian algorithm. It is difficult to predict in edges in Fig. 5. Figs. 3 and 4 are more clear visibility. It has been also reported from results that for lower order filter, results are not clearer.

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Fig. 1 Flow chart of proposed algorithm

Fig. 2 (a) Test Case 1 (b) Test case II
Fig. 3 Edge of proposed image of test case 1 for \( L = 3, 4, 5 \text{ and } 7 \)

Fig. 4 Edge of proposed image of test case 2 for \( L = 3, 4, 5 \text{ and } 7 \)
VI. CONCLUSION

The major part of algorithm has preprocessing of input image. The preprocessing has been performed by newly designed Chebyshev polynomial based fractional order filter. The Laplacian of Gaussian method has not giving better results in case of low contrast images. Visible results clearly shows that algorithm perform better for higher order of filter.

REFERENCES


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