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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, Gabour 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 Gaussion 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].

Koushlenda 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 □ as $Y(t)$ and $\tilde{Y}(t)$ which are observed function and original function respectively. The observed function can be written as

$$Y(t) = \tilde{Y}(t) + \xi(t) \tag{1}$$

here $\xi(t)$ 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]

$$Y(t) = \sum_{k=0}^{n} c_k T_k(t) \tag{2}$$

$t = 1,2,3...,L$ is the position of the t^{th} point in the filtering window and 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:

$$\begin{aligned}
&T_0(1)c_0 + T_1(1)c_1 + T_2(1)c_2 + \dots + T_n(1)c_n = y_1 \\
&T_0(2)c_0 + T_1(2)c_1 + T_2(2)c_2 + \dots + T_n(2)c_n = y_2 \\
&T_0(3)c_0 + T_1(3)c_1 + T_2(3)c_2 + \dots + T_n(3)c_n = y_3 \\
&\qquad \dots\ \dots\ \dots\ \dots\ \dots \\
&\qquad \dots\ \dots\ \dots\ \dots\ \dots \\
&T_0(L)c_0 + T_1(L)c_1 + T_2(L)c_2 + \dots + T_n(L)c_n = y_L
\end{aligned} \tag{3}$$

here $Y = [y_1, y_2, ..., y_L]^T$ denotes the measured function points in the filtering window. T is a matrix of order $L \times (n+1)$ and can be defined as

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$$T = \begin{bmatrix} T_0(1) & T_1(1) & T_2(1)\cdots & T_n(1) \\ T_0(2) & T_1(2) & T_2(2)\cdots & T_n(2) \\ \vdots & \vdots & \vdots & \vdots \\ T_0(L) & T_1(L) & T_2(L)\cdots & T_n(L) \end{bmatrix} \quad (4)$$

The elements of matrix T are calculated by using Chebyshev polynomial [18]

$$T_{n+1}(t) = 2tT_n(t) - T_{n-1}(t) \quad (5)$$

here $T_0(t) = 1,\ \ T_1(t) = t$.

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

$$C = (T^T T)^{-1} T^T Y \quad (6)$$

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

$$\hat{Y} = TC = T(T^T T)^{-1} T^T Y = WY \quad (7)$$

here *W* denotes window's coefficient matrix. Smoothing can be performed by use of different window coefficient matrix.

Riemann-Liouville fractional order derivative can be expressed as:

$${}_0D_x^{\alpha} Y(t) = \frac{1}{\Gamma(l-\alpha)} \frac{d^l}{dt^l} \int_0^x (t-x)^{l-\alpha-1} f(x)dx \quad (8)$$

here $0 \le l-1 < \alpha < l$, and $\Gamma(l-\alpha)$ is the Gamma function of $(l-\alpha)$. α is the positive order of differentiation and its value lies between $l-1$ to l [19].

The fractional order differentiator, corresponding to window coefficient matrix *W*, can be obtained by (8). Different properties of fractional order differentiation are applied on (7) and we will get

$$\hat{Y}_t^{\alpha} = T_t^{\alpha} C = W_t^{\alpha} Y = c(T^T T)^{-1} T^T Y \quad (9)$$

It is generalized form of (7). Here $\hat{Y}_t^{\alpha}$ denotes the α^{th} derivative of the t^{th} point in the filtering window, W_t^{α} denotes the α^{th} derivative coefficient vector of the t^{th} point in the filtering window.

Quadrature mirror filter (*QMF*) concept is used for design the high pass filter with newly designed digital fractional order differentiator [16], [17]. The low pass and high pass filters are used here $G_0(n)$ and $h_0(n)$ respectively. The high pass filter $h_0(n)$ is a mirror image of low pass filter $G_0(n)$ and can be expressed as

$$h_0(n) = (-1)^n G_0(n) \quad (10)$$

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

Algorithm I

The algorithm can be expressed as follow

Algorithm (***L***, ***n***, $\boldsymbol{\alpha}$,)

Input: ***L***, ***n***, $\boldsymbol{\alpha}$

- ***L*** **:** Length of differentiator
- ***n*** **:** Order of polynomial
- $\boldsymbol{\alpha}$ **:** Order of derivative
- ***T*** **:** Matrix
- ***a*** **:** Constant
- ***W*** **:** Window matrix
- Γ **:** Gamma function

Output: ***W*** , $\boldsymbol{h_0}$

begin
  for $i \leftarrow 1$ *to* L
    for $j \leftarrow 0$ *to* n
      Calculate matrix T_{ij}.
      $T_{ij}(i) = 2iT_j(i) - T_{j-1}(i)$
      (Here $T_0(i) = 1,\ T_1(i) = i$)
    end for
  end for
  for $i \leftarrow 1$ *to* L
    for $j \leftarrow 0$ *to* α
  Calculate $a = [\frac{\Gamma(n+1)}{\Gamma(n+1-\alpha)} i^{n-\alpha}]$
      $W_i^{(\alpha)} = a(T^T T)^{-} T^T$
    $G_0(i) \leftarrow W_i^{(\alpha)}$
    $h_0(i) = (-1)^L G_0(i)$
    end
    end
end

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, (I_n), has been processed by newly designed low pass and high pass filters. The output of low pass filtering operation (I_{nl}) has been relaxed with the relaxation coefficient. The relaxation coefficient varies from 0 to 2. The output image of high pass filtering operation, I_{nh} and image I_{nl} 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.

Algorithm II

Proposed algorithm is as follow

Algorithm $(\boldsymbol{I_E}, \boldsymbol{I}, \boldsymbol{h_0}, \boldsymbol{G_0}, \boldsymbol{\lambda})$

Input: $\boldsymbol{I}, \boldsymbol{h_0}, \boldsymbol{G_0}, \boldsymbol{\lambda}$

$\boldsymbol{I}$: Input Image

$\boldsymbol{h_0}$: High pass filter

$\boldsymbol{G_0}$: Low pass filter

$\boldsymbol{\lambda}$: Relaxation coefficient

$\boldsymbol{I_n}$: Normalized image

$\boldsymbol{I_{nl}}$: Filtered image with low pass filter

$\boldsymbol{I_{nh}}$: Filtered image with high pass filter

$\boldsymbol{I_1}$: Intermediate Image

$\boldsymbol{I'}$: Pre-processed Image

LoG ( ): Standard Laplacian of Gaussian edge detection algorithm

Normalization ( ): Normalization of image

Output: $\boldsymbol{I_E}$

begin

$I_n = Normalization\ (I)$

$I_{nh} = h_0(I_n)$

$I_{nl} = G_0(I_n)$

$I_{lr} = \lambda I_{nl}$

$I_1 = I_{lr} \times I_{nh}$

$I_E = LoG\ (I_1)$

end

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.

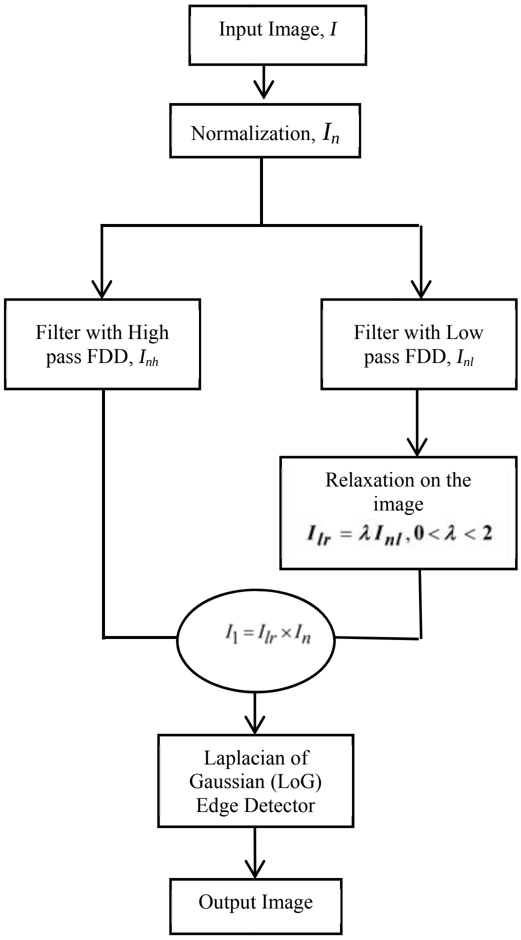

Fig. 1 Flow chart of proposed algorithm

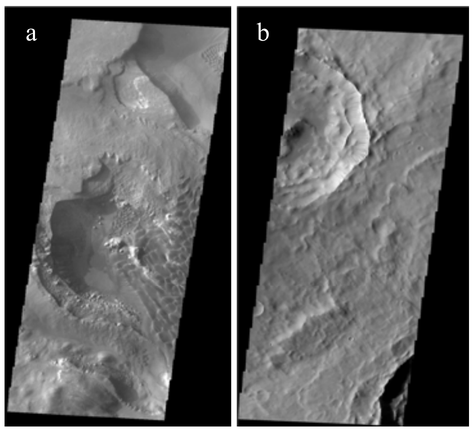

Fig. 2 (a) Test Case I (b) Test case II

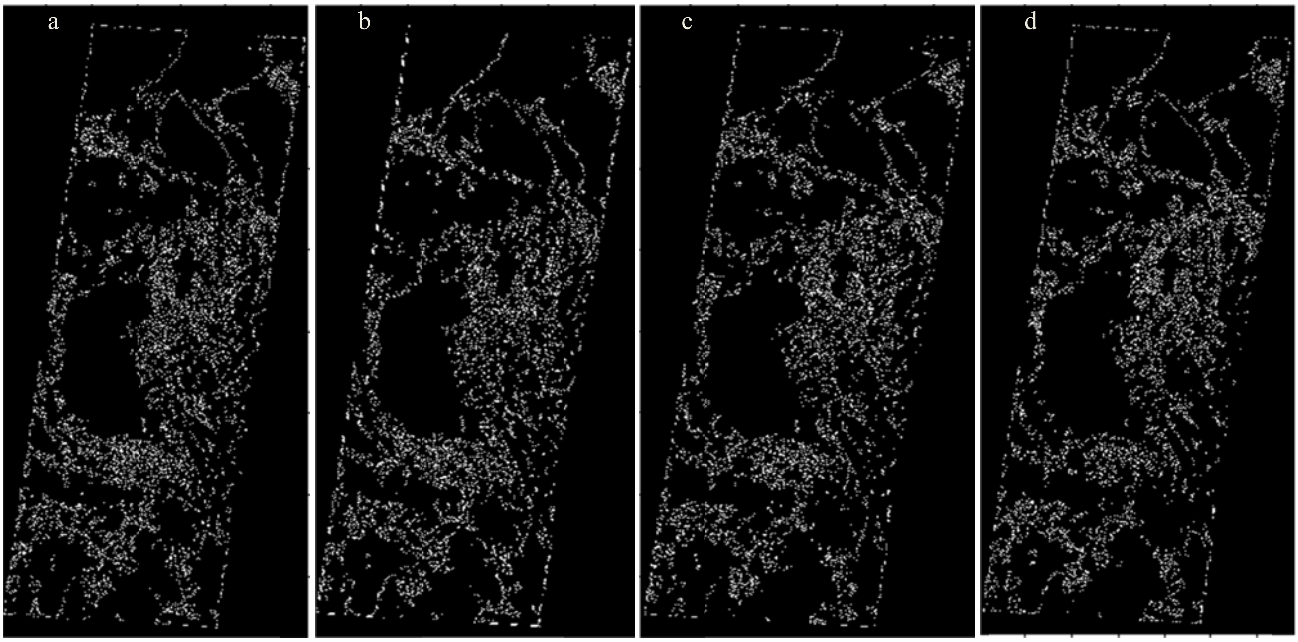

Fig. 3 Edge of proposed image of test case 1 for $L = 3, 4, 5\ and\ 7$

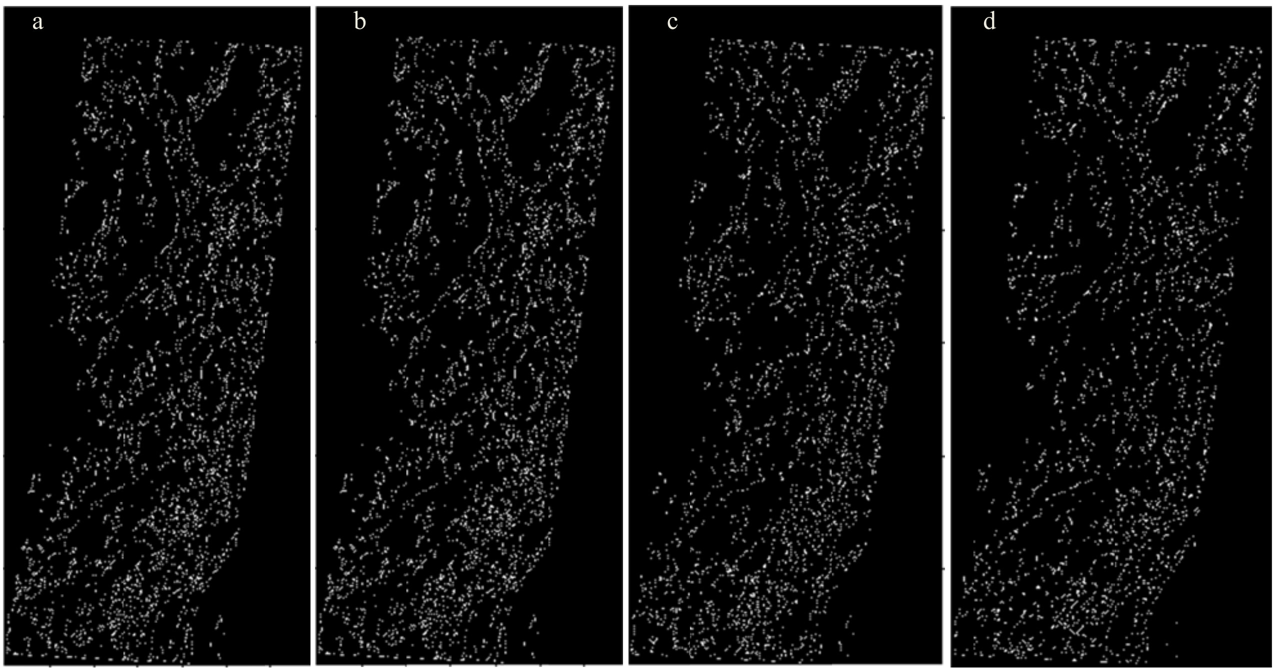

Fig. 4 Edge of proposed image of test case 2 for $L = 3, 4, 5\ and\ 7$

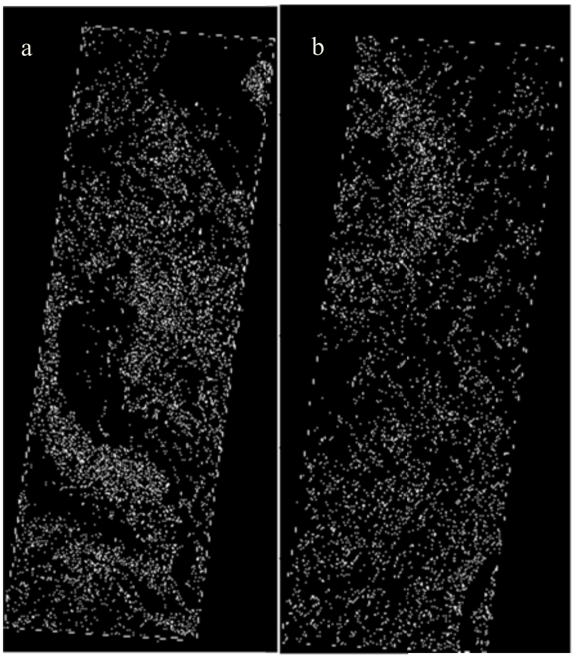

Fig. 5 Edge of image using LoG for test case 1and 2

VI. Conclusion

The major part of algorithm has preprocessing of input image. The preprocessing has been performed by newly designed Chebysheby 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.

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