

A nonlinear edge –preserving smoothing filter for edge detection on color and gray satellite images

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Abstract

A nonlinear filter for smoothing color and gray images corrupted by Gaussian noise is presented in this paper. The proposed filter designed to reduce the noise in the R,G, and B bands of the color images and preserving the edges. This filter applied in order to prepare images for further processing such as edge detection and image segmentation.

The results of computer simulations show that the proposed filter gave satisfactory results when compared with the results of conventional filters such as Gaussian low pass filter and median filter by using Cross Correlation Coefficient (ccc) criteria.

Keywords

Edge detection, nonlinear filters, Gaussian noise, Sobel operator, color image.

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مرشح التنعيم اللاخطي المحافظ على الحافة المستخدم لكشف الحافة لصور فضائية رمادية و ملونة

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الخلاصة

في هذا البحث تم تصميم المرشح اللاخطي لتنعيم صورة ملونة ورمادية مشوبة بضوضاء كاوسيه. وصمّم هذا المرشح لتخفيض الضوضاء في حزم (الأحمر)R،(الأخضر)G، و(الازرق)B للصور والمحافظة على حواف الصورة. وبتطبيق هذا المرشح تُهَيئ الصور للمعالجات الأخرى مثل كشف الحافة وتجزئة الصورة. تبين نتائج المحاكاة بالحاسوب ان المرشح المقترح اعطى نتائج مقبولة عندما قورنت بالمرشحات التقليدية مثل مرشح التنعيم المنخفض الكاوسين والمرشح الوسيط باستخدام معيار معامل الارتباط المتقاطع.

Introduction

Visual information processing is increasingly becoming widespread as multimedia becomes common in everyday life. With the expanding use of color images in multimedia applications and the proliferation of color capturing and display units, the interest in color imaging is rapidly growing. During image formation, acquisition, storage and transmission

many types of distortions limit the quality of digital images.

Edge detection plays a very important role in the realization of a complete image understanding system. Indeed, high-level processing tasks such as image segmentation and object recognition directly depend on the quality of the edge detection procedure. It is well known, however, that the generation of an accurate edge

map becomes a very critical issue when the images are corrupted by noise. In this respect, noises having Gaussian-like distribution are very often encountered during image acquisition. Methods that represent extensions of monochrome edge detector typically process the three-color channels independently and combine the resulting edge maps. As an example, the application of the well-known Sobel technique to the three image channels can be considered at a great aspect. An edge point in the color image could be estimated by evaluating the maximum of the gradient Components or their vector sum[1].

Edge detection in colored images has not gained much attention as in grayscale images. 10% more edges can be detected in colored images due to change in color. In colored images, color vector is assigned to each pixel because color component comprises of three color values[2].

Different methods to color edge-preserving and edge detection in presence of kind of noise have been proposed in the scientific literature.

C. Tomasi and R. Manduchi (1998) [3] has introduced the concept of bilateral filtering for edge-preserving smoothing. Bilateral filtering smooths images while preserving edges, by means of a nonlinear combination of nearby image values. Carsten Garnica, Frank Bochs, and Marek Twardchlib(2000) [4] are presented new approach for elimination noise within digital images this an essential step in applications like edge detection or image segmentation, the algorithm is based on the edge-preserving Maximum Homogeneity Neighbour Filter. A new technique for edge detection in color images corrupted by Gaussian noise is presented by Fabrizio Russo, and

Annarita Lazzari (2005) [5], the proposed approach adopts a multipass processing architecture that aims at reducing noise before extracting the image edges. Meng-Husiu Tsai, Yung-Kuan Chan, Zhe-Zheng Lin, Shys-Fan Yang-Mao, and Po-Chi Huang(2011)[6] present a cytoplasm and nucleus contour (CNC) detector to sever the nucleus and cytoplasm from a cervical smear image after smoothing image. They adopted median filter to sweep off noise. Yang Ou, and Dai Guang Zhi (2011)[1] suggested a nonlinear filtering to reduce Gaussian noise based on multichannel data fusion before edge detection. This method could smooth noise and preserve the details of edge without any a priori knowledge about the distribution of noise. Payun S. Tembhurne and Prof. V.K. Shandilya (2012)[7], proposed color image processing pipeline provide good reference, which can be implemented using multistage bilateral filters that integrates two types of noise filtering to identify the edges and smooth out the noises. Upneet Kaur(2013) [8], present Gaussian filter to smoothing color image before edge detection.

Smoothing filters types

1. Lowpass filters

The most commonly used smoothing algorithms are the $n \times n$ -box filter and the Gaussian Kernel Smoothing (Binomial Filter). Here, a square-sized convolution kernel is applied to each pixel. With the parameter "box size" (n) respectively "sigma", the degree of smoothing can be controlled.

This smoothing strategy results in very nicely smoothed homogeneous areas, however possessing the disadvantage to blur gray value edges[4].

2. Edge-preserving algorithms

Edge-preserving smoothing filters are much more suitable for edge detection. Some examples of this filter class are:

- Median Filter
- Symmetrical Nearest Neighbour Filter (SNN)
- Maximum Homogeneity Neighbour Filter (MHN)
- Conditional Averaging Filter

These nonlinear algorithms are calculating the filtered gray value in dependence of the content of a defined neighbourhood. Each edge-preserving filter has its own specific algorithm, but they all have in common, that the effect of this smoothing strategy is to preserve edges [4].

3- The proposed filter

The proposed method of filtering based on sliding neighbor operation where the new value of an output pixel is equal to the difference between the maximum value and the minimum value of the selected pixels under mask divided by the mean of value of pixels under the same mask as the following:

$$CCC = \frac{\langle \{f(x,y)g(x,y) - \langle f(x,y) \rangle \langle g(x,y) \rangle\} \rangle}{[\langle \{f(x,y) - \langle f(x,y) \rangle\}^2 \rangle \langle \{g(x,y) - \langle g(x,y) \rangle\}^2 \rangle]^{\frac{1}{2}}} \quad (3)$$

Where $0 < ccc \leq 1$, if $ccc=1$ means a perfect correlation, but when $ccc \approx 0$ means totally uncorrelated image [10].

Experimental work and results

Edge is high frequency also noise is high frequency it is particularly important to reduce the effects of noise before edge detection to improve the results of edge detection, so the gradient preserves the noise much more than structure to avoid this focused by smoothing image first which removes noise much more

$$outpixel = \frac{maxvalue - minvalue}{meanvalue} \quad (1)$$

Edge detection using Sobel operator

The Sobel operator is the magnitude of the gradient computed by [9]:

$$M = S_x^2 + S_y^2 \quad (2)$$

S_x and S_y can be implemented using convolution masks:

$$S_x = \begin{bmatrix} -1 & 0 & 1 & 1 & 2 & 1 \\ -2 & 0 & 2 & 0 & 0 & 0 \\ -1 & 0 & 1 & -1 & -2 & -1 \end{bmatrix} \quad S_y = \begin{bmatrix} 1 & 2 & 1 & 0 & 0 & 0 \\ 2 & 0 & 0 & 0 & 0 & 0 \\ 1 & -2 & -1 & 0 & 0 & 0 \end{bmatrix}$$

Note that this operator is placed on an emphasizing pixel that is closer to the center of the mask. The Sobel operator is one of the most commonly used edge detection [9].

Cross correlation coefficient (ccc)

The Cross Correlation Coefficient (ccc) which is used to measure the quality of an image. If we have two images, the original image $f(x,y)$ and the processed image $g(x,y)$, the (ccc) is given by [10]:

than it removes structure this mean preserving the desired details of image.

For testing the performance of the proposed filter we have focused on the filtering of images using the linear and nonlinear filtering techniques where linear filtering is done using the Gaussian while the nonlinear filtering is performed using a median filter then compared them with the proposed filter.

We implement the proposed, Gaussian and median filters on both

color and gray images for the sake of comparison between the results of these filters.

In the case of color image the procedures of processing by using Matlab programming's are:

- 1- The original image which is taken "24-bits RGB Color Satellite image "(24-bits i.e. 8-bits for each of the three color bands) with size (256 by 256) pixels and 1 meter resolution (university of Baghdad zone) as shown in Fig.1-a, where R(red), G(green), and B(Blue)
- 2- The input color image is separated to multiband R, G, and, B and processes them independently to prevent edges from unexpected colors or artifacts, also the processing becomes easy. The corresponding R, G, and B bands are represented in Figs.1(b), (c), and (d) respectively.
- 3- A noisy images, were generated by adding zero-mean Gaussian noise starting with standard deviation $\sigma=0.005$ upto $\sigma=0.01$ for every band of the original image to examine the filter's ability to reduce noise and preserving edges as shown in Figs.2(a), (b), and (c) respectively.
- 4- Gaussian filter was implemented smoothing on noisy multiband images separately.
- 5- Combing the smoothed images (R, G, and B bands) from step (3) which, the result is demonstrated in Fig. (3a).
- 6- Repeating the steps (3) & (4) using median and the proposed filters separately the results are represented in Figs.3(b), (c) respectively.
- 7- The gradient operator (Soble) was selected which is mention in Eq.(1) to applied on smoothed images which obtained from steps (4,5), the results are shown in Figs. 3(d), (e), and (f).

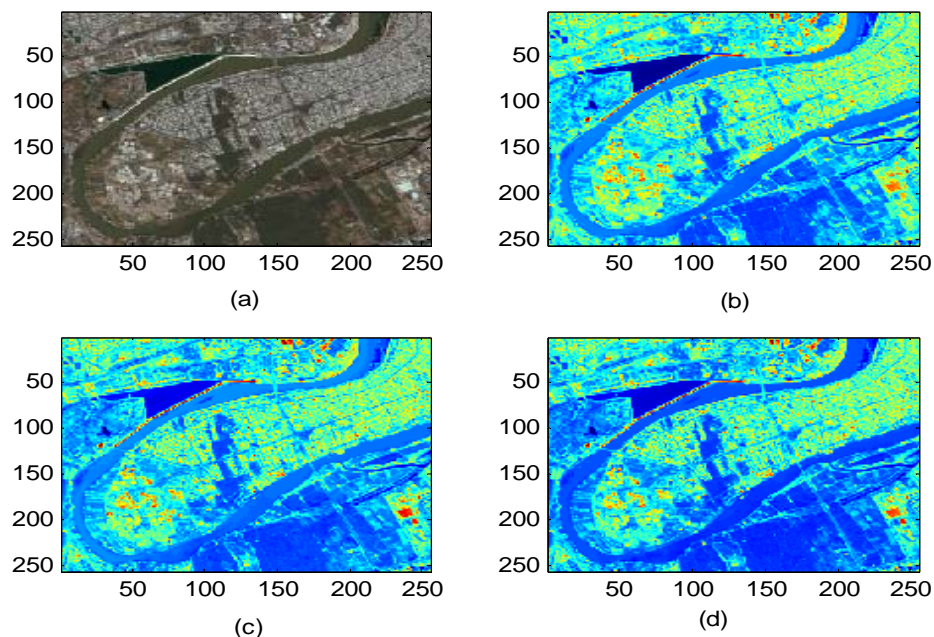


Fig. 1: (a)24-bit RGB color Satellite image (b)Red- band, (c)Green-band, and (d)Blue – band.

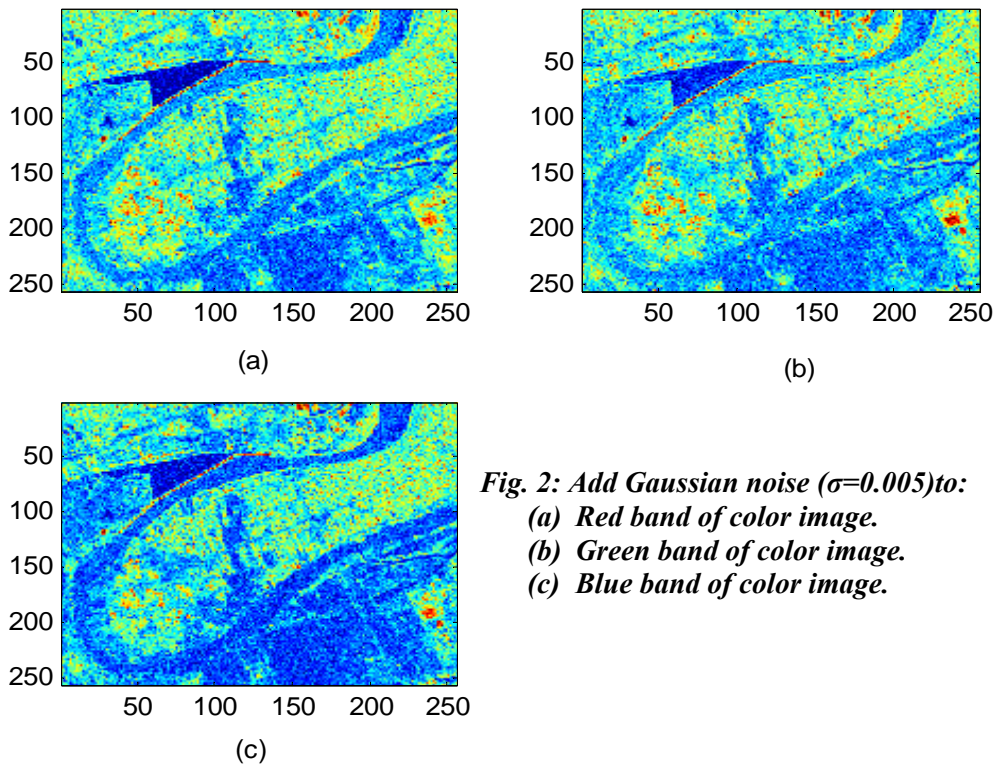


Fig. 2: Add Gaussian noise ($\sigma=0.005$) to:
(a) Red band of color image.
(b) Green band of color image.
(c) Blue band of color image.

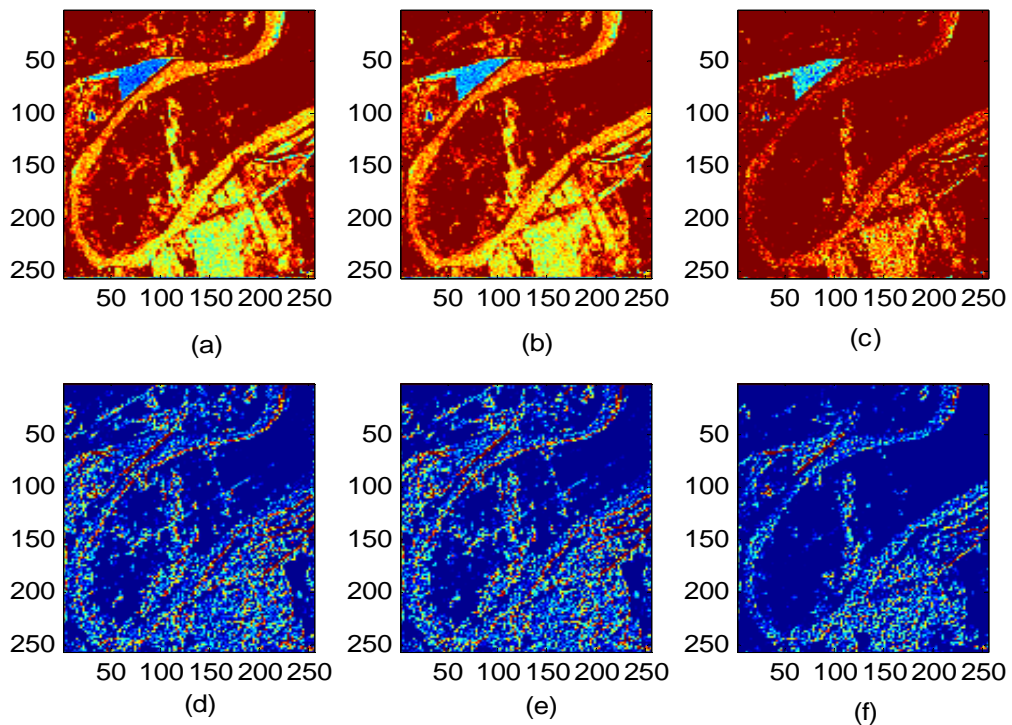


Fig. 3:
(a) Filtered noisy image by Gaussian filter.
(b) Filtered noisy image by median filter.
(c) Filtered noisy image by proposed filter.
(d) Sobel operator in the color image filtered by Gaussian filter.
(e) Sobel operator in the color image filtered by median filter.
(f) Sobel operator in the color image filtered by proposed filter.

8- The cross correlation coefficient was calculated by using Eq.(2) for the images that

we get it from steps 4 & 5 and the results were present in Table 1.

Table 1: The results of calculating ccc for color image.

Standard deviation (σ) of Gaussian noise	Gaussian filter	Proposed filter	Median filter
.005	.8851	.8745	.7601
.006	.8802	.8686	.7334
.007	.8747	.8617	.7045
.008	.8693	.8546	.6792
.009	.8662	.8511	.6631
.01	.8610	.8440	.6376
.02	.8205	.7986	.4971
.03	.7825	.7568	.4175
.04	.7527	.73	.3666
.05	.7165	.6943	.3026
.06	.6928	.6729	.268
.07	.6651	.6476	.2458
.08	.6364	.6216	.2296
.09	.6180	.6067	.2079
.1	.5944	.5848	.1929

9- We plot the relationship between ccc and standard deviation of Gaussian noise and

the results are demonstrated in Fig.4.

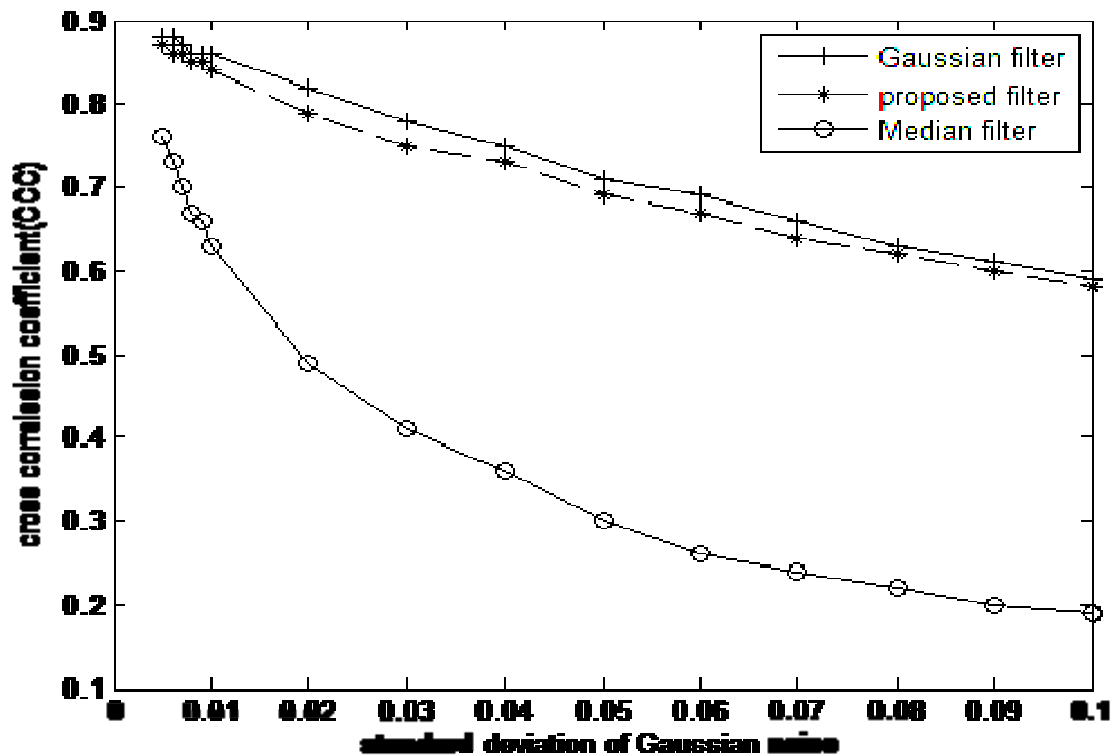


Fig. 4: The relationship between ccc and the standard deviation of the Gaussian noise in color satellite image.

While in the case of the gray image the procedure of the processing are:

- 1- The original image which is taken with size (256 by 256) pixels (university of Baghdad zone) as shown in Fig.(5-a).
- 2- A noisy images, were generated by adding zero-mean Gaussian noise starting with standard deviation $\sigma=0.005$ up to $\sigma=0.01$ to examine the filter's ability to reduce noise and preserving edges as shown in Fig.5(b).
- 3- Gaussian, median and proposed filters were

implemented smoothing on noisy images as represented in Figs.6(a), (b), and (c).

- 4- The gradient operator (Sobel) were selected which is mention in Eq.(1) to applied on smoothed images which obtained from steps 3, the results are demonstrated in Figs.6(d), (e), and (f).
- 5- The cross correlation coefficient were calculate by using Eq.(2) for the images that we get it from steps 4 and the results is represent in Table 2.

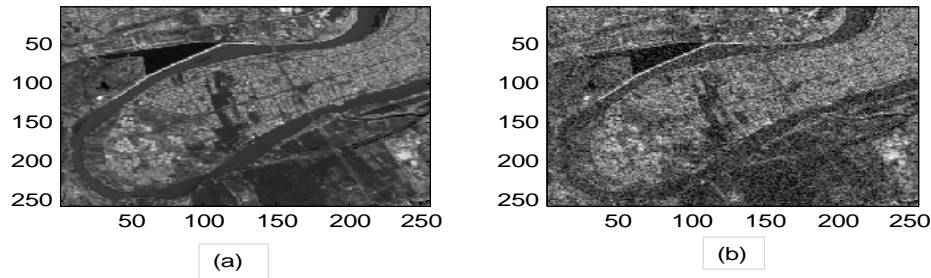


Fig. 5:
(a) Original gray scale satellite image.
(b) Noisy gray scale satellite image with ($\sigma=0.005$).

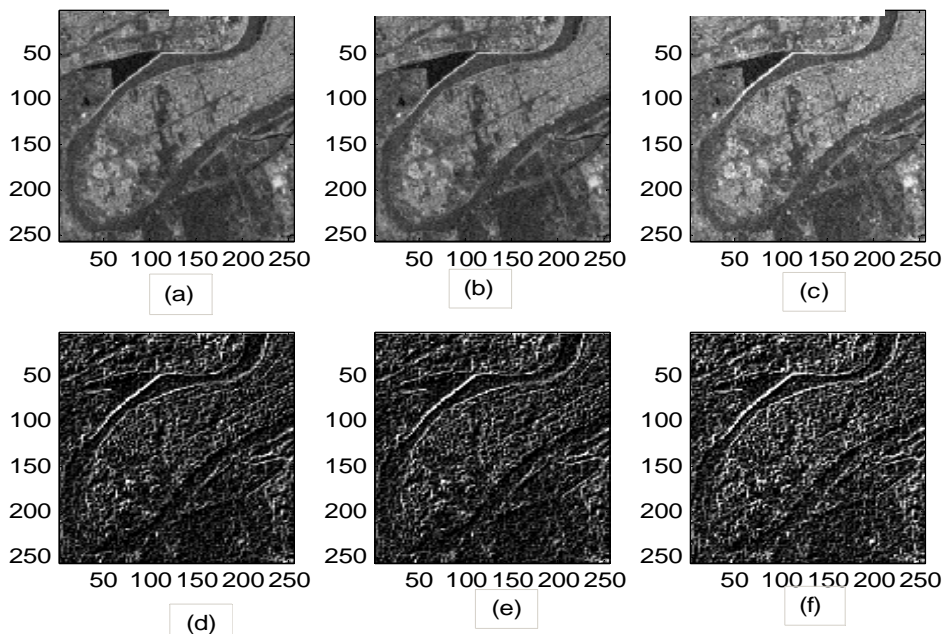


Fig. 6:
(a) Filtered noisy gray satellite image by Gaussian filter.
(b) Filtered noisy gray satellite image by median filter.
(c) Filtered noisy gray satellite image by proposed filter.
(d) Sobel operator in the noisy gray satellite image by Gaussian filter.
(e) Sobel operator in the noisy gray satellite image by median filter.
(f) Sobel operator in the noisy gray satellite image by proposed filter.

6- The cross correlation coefficient were calculate by using Eq.(2) for the images that

we get it from steps 4 & 5 and the results is represent in Table1.

Table 2: The results of calculating ccc.

Standard deviation (σ) of Gaussian noise	Gaussian filter	Proposed filter	Median filter
.005	.8576	.8429	.82651
.006	.8507	.8352	.8146
.007	.8444	.8281	.8080
.008	.8391	.8218	.7974
.009	.8336	.8155	.7898
.01	.8285	.8099	.7798
.02	.7743	.7494	.7043
.03	.7310	.7029	.6484
.04	.6918	.6624	.5983
.05	.6630	.6339	.5614
.06	.6352	.6045	.5306
.07	.6015	.5733	.4947
.08	.5768	.5479	.4696
.09	.5621	.5327	.4591
.1	.5461	.5170	.4376

7- The relationship between ccc and standard deviation of Gaussian

noise were plotted and the results are demonstrated in Fig.7.

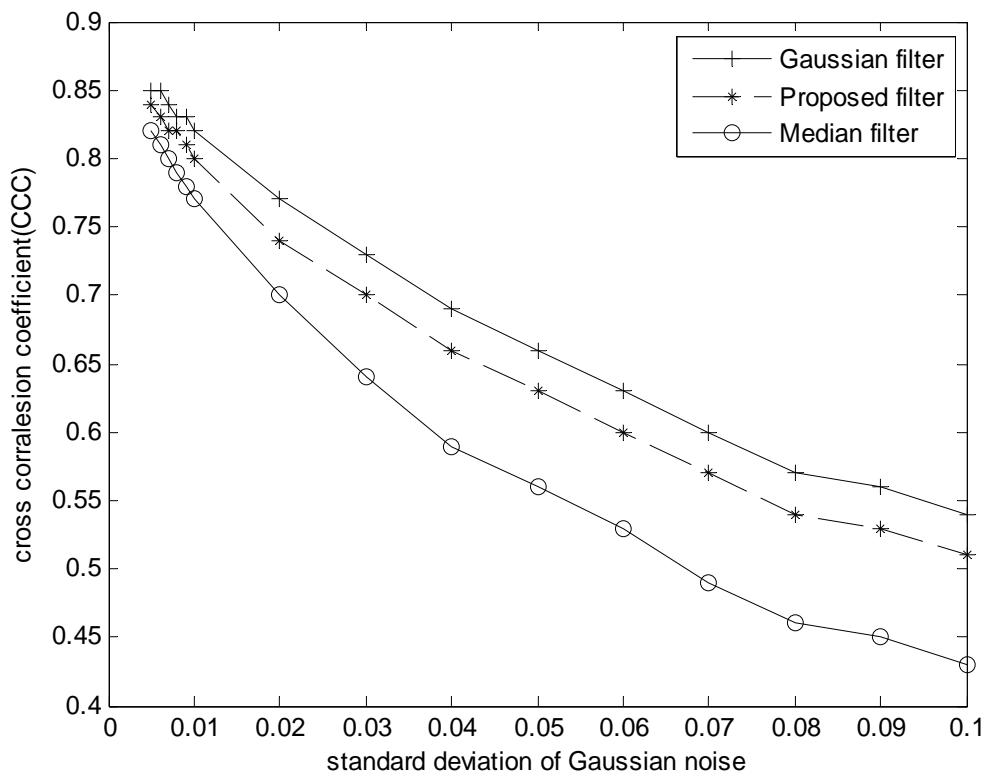


Fig. 7: The relationship between ccc and the standard deviation of the Gaussian noise in gray satellite image.

Conclusions

After applying the proposed filter and compared with Gaussian filter and median filter, we conclude that:

- 1- The edges are remaining clear after applied the proposed filter, this mean that the filter preserves all image structure such as edges or corners.
- 2- We conclude from Figs.4, 7 that the proposed filter gavenerly approximately the same results of Gaussian filter.
- 3- Unexpected color combinations appeared when smoothing carried out for each band because each band has different levels of contrast.

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