Image De-noising: Comparative Study

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Abstract

The need for efficient image restoration methods has grown with the massive production of digital images and movies of all kinds have often been taken in poor conditions. No matter how good cameras are, an image improvement is always desirable to extend their range of action.

The search for efficient image de-noising methods still is a valid challenge, at the crossing of functional analysis and statistics. In spite of the sophistication of the recently proposed methods, most algorithms have not yet attained a desirable level of applicability. The main focus of this paper is to analyses, examines and compares various filters and de-noising methods such as morphology de-noising, singular value decomposition (SVD) de-noising, median and Gaussian filters, in addition to hybrid methods which combine two method.

The aim of this paper is to embark on the study of four types of noises such as Gaussian, Salt and Pepper, Poisson, and Speckle noise.

The resulted images after de-noising are evaluated visually and by using some performance evaluation methods such as PSNR.

Keywords: de-noising, SVD, morphology, Gaussian, median filter, image processing.

الخلاصة

تطورت الحاجة لطرائق استرجاع الصورة الكفوءة مع الانتاج الهائل للصورة الرقمية والسينما لكل الانواع وعادة ما تؤخذ بظروف رديئة. ليس هنالك حاجة لكاميرات جيدة حيث ان تحسين الصورة عادة ما يكون مرغوب لتوسيع مدى فعاليته.

ان البحث عن طرائق ازالة ضوضاء كفوءة يمثل تحديات مقبولة عند التحليل الوظائفي والاحصائي. بالرغم من تعقيد الطرائق المقترحة حاليا فان معظم الخوارزميات لحد الان لا تمتلك مستوى مرغوب من التطبيق. التركيز الرئيسي من البحث هو تحليل وتفحص ومقارنة مرشحات مختلفة وطرائق ازالة الضوضاء مثل ازالة الضوضاء بالمرفولوجي وازالة الضوضاء بتحليل القيمة المفردة ومرشحات كاوسن والمتوسط بالاضافة الى الطرائق الهجينة التي تجمع طريقتين.

الهدف الرئيسي من البحث هو دراسة اربعة انواع من الضوضاء مثل كاوسن والملح والفلفل وبويسن وضوضاء البقعة.

قومت الصورة الناتجة بعد ازالة الضوضاء نظرياً وبوساطة استخدام بعض طرائق تقويم الكفاءة مثل قمة نسبة الاشارة الى الضوضاء (PSNR).

كلمات مفتاحية: ازالة الضوضاء، تحليل القيمة المفردة, مورفولوجي، كاوسن، مرشح المتوسط، معالجة الصور.

1. Introduction

Noise is a random variation of image intensity and appear as grains in the image. It may arise in the image as effects of basic physics-like photon nature of light or thermal energy of heat inside the image sensors. Noise production occurs at the time of capturing or image transmission. Noise means, that the pixels in the image show different intensity values instead of true pixel values.

Noise removal algorithm is used to remove or reduce the noise from the image. The noise removal algorithms aim to reduce or remove the visibility of noise by smoothing the entire image leaving areas near contrast boundaries, but these methods can obscure fine, low contrast details. The common types of noise that arises in the image are: Impulse noise, Additive noise, Multiplicative noise (Kaur and Singh, 2011). Different noises have their own features which make them distinguishable from others (Verma and Ali, 2013).

Noises causes degradation of images. Noise can occur during image capture, transmission, etc. Noise removal is an important step in image processing. In general the results of the noise removal have a strong effect on the quality of the image processing technique (Mythili and Kavitha, 2011).

Several techniques for noise removal are well established in color image processing. Type of the noise corrupting the image determines the nature of the noise removal problem (Mythili and Kavitha, 2011).

Getting an efficient method of removing noise from the images, before processing them for further analysis is considered a great challenge for the researchers. Image is degraded by noise at the time of capturing or transmission of the image. Before applying image processing tools to an image, noise removal from the images is achieved at highest priority. Ample algorithms are available, but they have their own assumptions, merits and demerits. The type of the noise removal algorithms to remove the noise depends on the type of noise present in the image. Best results are obtained if testing image model follows the assumptions and they may, otherwise fail (Verma and Ali, 2013).

2. Related Works

Four types of noise (Gaussian noise , Salt & Pepper noise, Speckle noise and Poisson noise) are used by (Patidar, et. al. 2010). Image de-noising is performed for different noise by Mean filter, Median filter and Wiener filter. Further results have been compared for all noises.

(Bansal *et. al.*, 2015) purposed new method in addition to Median filter, and Adaptive filter for noise removal in digital gray scale images that often observed in scanned documents. Generally, Data i.e. picture, text can be contaminated by an additive noise during the process of scanning. This methodology prevents this type of noise known as Salt and Pepper noise (SP Noise) which causes white and black spots on the original image. The proposed method firstly applies the Adaptive Histogram Equalization on the original image. Secondly applies Adaptive contrast Enhancement Technique on the resultant image. After Contrast Enhancement they apply filters such as Homomorphic filtering. These filters are applied sequentially on distorted images for removing the image.

(Himanshu Kuhad etl, 2013) aimed to embark on the study of four types of noises such as Gaussian, Salt and Pepper, Poisson, and Speckle noise.

Image de-noising is not only significant on the contrary to the problem of image processing which is helpful in the fields of remotely sensed scene interpretation, Biomedical imaging techniques, Gathering image's lost information, image retrieval, mining of image etc., and an essential preprocessing technique to preserve the clarity of the naturally corrupted image which may be affected by the various types of noises. This paper reviews the existing various filters having various variance of noises.

3. Methodology

The current paper present four main methods for noise removing which are morphologic filter, SVD de-noising, median filter and Gaussian filter, in addition to four hybrid methods, where each combine two of the main method, these methods are SVD followed by Gaussian, Median follow by Gaussian, SVD follow by Morphology and Morphology follow by SVD.

In the current study we compare between these filters and how the noise removing is affected when more than one filter are combined.

Four types of noise inserted on colored image, and then removed by suggested filters to check the relation between the noise type and noise removing methods.

The types of Noise are following:

- Amplifier noise (Gaussian noise)
- Salt and pepper noise
- Shot noise (Poisson noise)
- Speckle noise

The performance of these methods checked by visual checking of the resultant images, and by determining the PSNR.

The main de-noising methods are:

3.1 Morphological Filtering

Morphological filtering is conducted by considering compound operations like opening and closing as filters. They may act as filters of shape. These operations can filter out any details with size smaller than the structuring element from an image, e.g., opening is filtering the image at a scale defined by the size of the structuring element. Only the filter passes those portions of the image that fit to the structuring element; smaller structures are blocked and excluded from the output image. The size of the structuring element is most important to eliminate noisy details but not to damage objects of interest. Two morphological techniques ("opening by reconstruction" and "opening closing by reconstruction") are used to "clean" up the image, figure 1.

A. Opening by Reconstruction

The normal morphological opening is erosion followed by dilation. The erosion "shrinks" an image according to the shape of the structuring element, removing objects that are smaller than the shape. The dilation step "re-grows" the remaining objects by the same shape. Opening-by-reconstruction is erosion followed by a morphological reconstruction.

B. Opening-Closing by Reconstruction

In this case dilatation used to the opening by reconstruction followed by morphological reconstruction to the complement of the output of dilation and complement of the output resulting from opening by reconstruction, finally, the output of morphological reconstruction is complement.

Reconstruction based on opening and closing is more effective than standard opening and closing to removing small blemishes without affecting the overall shapes of the objects.

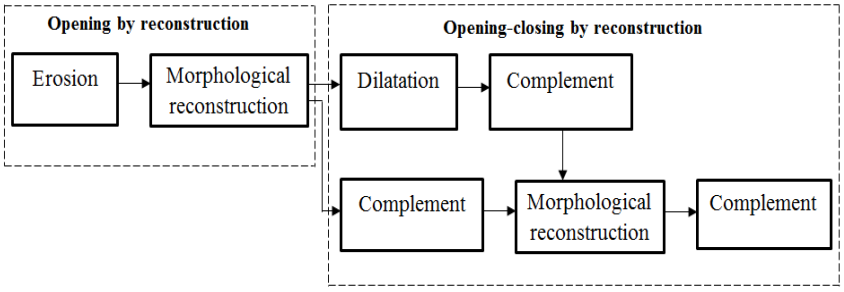

Figure 1: opening and closing reconstruction

3.2 Median filter

Median filtering is a nonlinear method used to remove noise from images. It is widely used as it is very effective in removing noise while preserving edges.

It is particularly effective in removing 'salt and pepper' type noise. The median filter works by moving through the image pixel by pixel, replacing each value with the median value of neighboring pixels.

The pattern of neighbors is called the "window", which slides, pixel by pixel over the entire image pixels.

The median is calculated by first sorting all the pixel values from the window into numerical order, and then replacing the pixel being considered with the middle (median) pixel value.

3.3 Singular Value Decomposition (SVD)

The SVD has also applications in digital signal processing, e.g., as a method for noise reduction. The central idea is to let a matrix *A* represent the noisy signal, compute the SVD, and then discard small singular values of *A*. It can be shown that the small singular values

mainly represent the noise, and thus the rank-*k* matrix A_k represents a filtered signal with less noise. Since the singular values of S display in a diagonal in descending order, the algorithm is able to remove the lower values (corresponding to the noise).

Let $\boldsymbol{A}$ be m × n real matrix, then there exist matrices $\boldsymbol{U}$ orthogonal matrix of size m × m , $\boldsymbol{V}$ orthogonal matrix of size n × n and $\boldsymbol{S}$ diagonal matrix of size m × n where all the entries s_{ij} are 0 when i ≠ j

$$\mathbf{A_{mn}} = \mathbf{U_{mm}} \mathbf{S_{mn}} \mathbf{V_{nn}^{T}}$$

Where $U^TU = I$, $V^TV = I$ and $s_{11} \geq s_{22} \geq \cdots s_{pp} \geq 0$ where $p = \min\{m, n\}$.

The columns of **U** are orthonormal eigenvectors of AA^T, The columns of **V** are orthonormal eigenvectors of A^TA, And **S** is a diagonal matrix containing the square root of eigenvalue from U or V in decreasing order (Kolman and Hill, 2008).

3.4 Gaussian filtering

The Gaussian Filter is a convolution filter whose convolution matrix is a Gaussian distribution. The Gaussian function for two dimension is:

$$G_\sigma(x, y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right)$$

Where σ is the standard deviation of the distribution assumed to have a mean of 0.

Similar to the mean filter the Gaussian filter will smooth an image but will preserve edges better than the more basic mean filter.

The Gaussian filter gives more weight to the current pixel position and then tapers the weights as distance increases according to the Gaussian formula. By weighting a pixels contribution to the final pixel value this filter can better preserve edges than the mean filter which specifies equal weights to all pixels within the filter window.

This filter is applied to an image in a two phase approach. First the horizontal direction is filtered using the above filter in a similar manner to a convolution filter by taking each pixel in the image, centering the filter on that pixel (the middle value) and then multiplying the pixel values by the weight at each filter location followed by a final divide to get the resulting new pixel value. This process is then repeated vertically on the horizontally processed image to create the final image.

The Gaussian filter is one of the more popular blurring filters as it has its basis in the human visual perception system. It has been found that neurons create a similar filter when processing visual images.

3.5 The Results

❖ To test these algorithms we used many images, in this section we will show the colored Lena image as example for the results (figure 2):

Figure 2: Origin image (Lena image)

- We also used many types of noise (Salt & Pepper, Poisson, Speckle, and Gaussian noise). The images will be inserted with these types of noise and the implement the de-noising methods, the noisy images are shown in figure 3.
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Figure 3: Lena image with different type of noise.

By experiment we found that the salt & pepper has the more effect on the images. The images tested with noise concentration equals 0.01 which makes the image more noisy as shown in figure 3.

De-noising applied for noisy image use the morphology filter, SVD de-noising, and SVD followed by Gaussian filter, the results shown are in figure 4.

And Gaussian filter, Gaussian followed by Median filter, and Median filter, where there results shown are in figure 5.

Finally we used the SVD followed by Morphology and Morphology followed by SVD, the results are shown in figure 6.

Figure 4: results images from de-noising when using morphology, SVD, and SVD followed by Gaussian.

Figure 5: resulted image from de-noising when using Gaussian, Gaussian followed by Median filter, and Median filter.

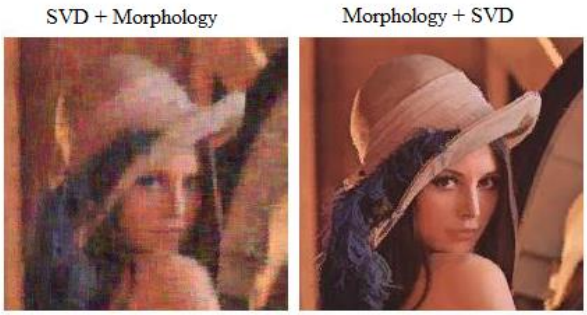

Figure 6: resulted image from de-noising when used SVD followed by Morphology and Morphology followed by SVD.

- We determined the PSNR for the images resulted from the previous methods, as shown in figure 7.

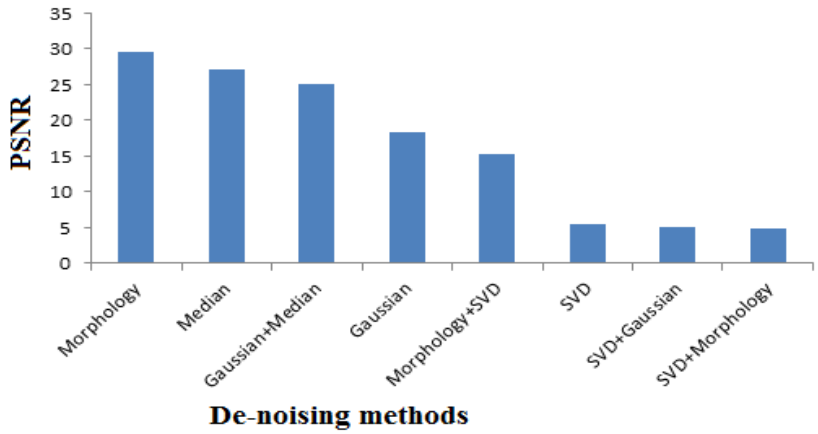

Figure 7: PSNR for Lena image with different denoising methods.

- The above methods tested with images embarked with different types of noise as shown in figure 8.

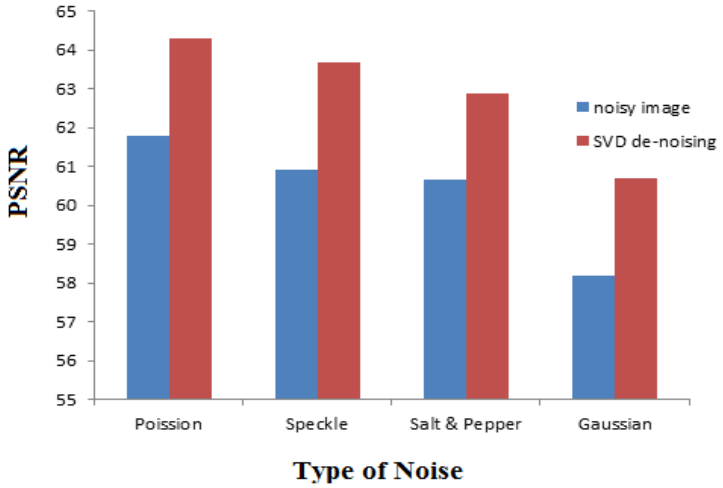

Figure 8: PSNR for the noisy image before and after de-noising when using SVD, for different types of noise.

Conclusion

In this paper we have studied what is a Noise in an image and the different types of noises available in an image.

We used the color images in "jpg" format, adding four types of noise (Speckle, Gaussian, Poisson and Salt & Pepper) in original image with standard deviation (0.01), De-noised all noisy images by all filters and we conclude that :

a) The performance of the Morphology Filter as de-noising for all Speckle, Poisson and Gaussian noise is better than SVD, Gaussian, and Median filter.
b) Median filter has good performance when used with salt & pepper noise.
c) The performance of the SVD becomes better when followed by Gaussian filter.
d) Using of Gaussian filter will blur the image.
e) Using SVD as de-noising will not give good results if it used alone.

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