Proceedings of the 5th WSEAS International Conference on Applied Computer Science, Hangzhou, China, April 16-18, 2006 (pp109-113)

New Spatial Filters for Image Enhancement and Noise Removal

MOH'D BELAL AL-ZOUBI[1], AMMAR M. KAMEL[2], MAKKI J. RADHY[3]

[1]Computer Science, KASIT
University Of Jordan
Amman
JORDAN

[2]Computer Science, Education College
Al-Mustansiriah University
Baghdad
IRAQ

[3]Computer Science, Science College
Baghdad University
Baghdad
IRAQ

Abstract
In this paper, two novel image filters are presented. These filters, named as Far Distance Filter (FDF) and Near Distance Filter (NDF), are actually based on calculating the distance between image pixels and their neighbors in order to construct arbitrary values used to enhance abnormal pixels (noise). FDF and NDF use (5 x 5) kernel instead of the usual (3 x 3) kernel to produce better image results. The performance of proposed filters and the well-known mean filters is investigated through the measurement of PSNR and MSE. This performance shows clearly the efficiency of the proposed filters.

Keywords: Image enhancement, Image restoration, Noise removal, Spatial filters.

1. Introduction

In the recent years, image enhancement has become the interior of many important image processing and computer vision applications. Image enhancement involves taking an image and improving it visually, typically by taking advantage of the HVS (Human Visual System) response [5].

Sequences of enhancement techniques are widely used to facilitate the development of a solution for computer image problems. Many of these techniques require the use of low illumination or high magnification where problems associated with noise persist. For this reason, noise removal continues to be an important image processing task [4], [7], [8].

Image noise represents unwanted or undesired information that can occur during the image capture, transmission, processing or acquisition, and may be dependent or independent of the image content.

In typical images, the noise can be modeled with either a Gaussian, uniform or salt-and-pepper distribution [5]. Special operations (filters), which operate in spatial domain, represent an important enhancement technique that can effectively be used to remove various types of noise in digital images. These spatial filters typically operate on small neighborhood, 3 x 3 to 11 x 11, and some of them can be implemented as convolution masks [6].

Mean filters are the most commonly spatial filters used as a simple method for reducing noise in an image, particularly Gaussian noise. The idea of mean filtering is simply to replace each pixel value in an image with the mean 'average' value of its neighbors, including itself. The extracted average values are the result of the convolution process, which is commonly based on specified fixed convolution mask (kernel).

Differently sized kernels containing different patterns of number achieving different results under convolution. By increasing the size of the mean filter to 5 x 5, the obtained image will be characterized with less noise and less high-frequency detail.

In this paper, two new image enhancement filters have been developed; to remove and enhance the appearance of an image according to the distance measure between adjacent pixels. These filters are Far Distance Filter (FDF) and Near Distance Filter (NDF). Compared to the well-known mean filter, the proposed filters can achieve better results in visual and quantitative measures.

2. Background

Image enhancement approaches fall into two broad categories: spatial domain and frequency domain approaches. [8]. Spatial domain methods are procedures that operate directly on the image pixels, while frequency domain methods are based on modifying the Fourier transformation of an image.

In many image processing applications, spatial domain filters have been employed very effectively in removing different types of noise [9]. The most common and the simplest type of these filters is the mean filter. Mean filters show very good performance for the removal of many noise types (e.g., Gaussian noise present in the data) [9].

As mentioned before, the mean filter is essentially an averaging filter. It operates on a local group of pixels called neighborhoods and replaces the center pixel with an average of pixels in these neighborhoods [5].

The replacement is done with a convolution mask such as the 5 x 5 following mask:

$$\begin{bmatrix} 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \\ 1/25 & 1/25 & 1/25 & 1/25 & 1/25 \end{bmatrix}$$

3. The Proposed DF-Filters

Contrasting to the mean filter, the distance between the centralized pixel and its neighbors will be calculated to minimize the effectiveness of noisy pixels. The distance values represent the relation between good pixels and noisy pixels which satisfy the assumption, that "far noisy pixels have less effect on surrounded good ones". From this assumption we are not going to give a static weight (distance value) to all pixels and treat them in same manner. Several methods can be applied to measure the distance between pixels.

The Euclidean distance is quite an appealing method in measuring the distance between two points. The difference in position is simply [10]:

$$d = \sqrt{\left[(x_1 - x_2)^2 + (y_1 - y_2)^2\right]}$$

X1	X2	X3	X4	X5
X6	X7	X8	X9	X10
X11	X12	X13	X14	X15
X16	X17	X18	X19	X20
X21	X22	X23	X24	X25

Fig.1: 5x5 pixels map

Applying the distance equation on our assumption, we can easily assume the following:

Let D(x, y) = distance between x and y. According to Fig.1, X14, X8, X18 and X12 are four neighbors of X13.

Assume that D(X13, any pixel -centralize pixel- of four neighbors) = 1, then we will have the following distances:

$$D(X13, X9) = \sqrt{\left[(D(X13 - X14))^2 + (D(X13 - X8))^2\right]}$$

$$= \sqrt{1^2 + 1^2} = \sqrt{2} = 1.4$$

$$D(X13, X15) = 2$$

$$D(X13, X10) = \sqrt{\left[(D(X13 - X15))^2 + (D(X13 - X8))^2\right]}$$

$$= \sqrt{2^2 + 1^2} = \sqrt{5} = 2.2$$

$$D(X13, X5) = \sqrt{\left[(D(X13 - X15))^2 + (D(X13 - X3))^2\right]}$$

$$= \sqrt{2^2 + 2^2} = \sqrt{8} = 2.8$$

The distance measure operation will apply to all points of Fig. 1 producing new values as shown in Table1 below:

Table 1: 5x5 NDF mask (filter)

2.8	2.2	2	2.2	2.8
2.2	1.4	1	1.4	2.2
2	1	X13	1	2
2.2	1.4	1	1.4	2.2
2.8	2.2	2	2.2	2.8

If we inverse the natural order (i.e., higher values will surround X13 instead of lower values), we can get newer distance values as shown in Table 2 below, producing FDF:

Table 2: 5x5 FDF mask (filter)

0	1	1.5	1	0
1	2	3	2	1
1.5	3	X13	3	1.5
1	2	3	2	1
0	1	1.5	1	0

4. Experimental Results

In order to test the proposed NDF and FDF and well-known mean filters, a number of real life images were used using Matlab software package version 5.3. For all images, the Salt and Pepper noise type was added to produce noisy images.

Peak-to-Signal Ratio (PSNR) and Mean Square Error (MSE) are used as the evaluation criteria to measure the effectiveness of the proposed NDF, FDF and the well-known mean filters.

The obtained PSNR and MSE measures are shown in Table 3 and Table 4 respectively. It can be observed from these tables that the NDF filter gives better results compared to the mean filter. In accordance with the visual quality assessment, the FDF produces images sharper than the ones produced by the mean filter.

Table 3: Constructed PSNR and MSE results of Lena image by applying NDF, FDF and mean filters

Filter	PSNR (dB)	MSE
NDF	+25.4291	0.0029
FDF	+23.5892	0.0044
Mean	+24.3693	0.0037

Table 4: Constructed PSNR and MSE results of Tiger image by applying NDF,FDF and mean filters

Filter	PSNR (dB)	MSE
NDF	+25.5607	0.0028
FDF	+22.6949	0.0053
Mean	+23.6370	0.0043

The new filters were tested on two well-known images: Lena (Fig.2) and Tiger (Fig.3) images.

Fig.2: Original Lena Image

Fig.3: Original Tiger Image

Fig. 4 shows the Lena image when infected with Salt-and Pepper noise. Figures 5, 6 and 7 show the Lena image after applying mean, NDF and FDF filters respectively.

Fig. 8 shows the Tiger image infected with Salt and Pepper noise. Figures 9, 10 and 11 show the Tiger image after applying mean, NDF and FDF filters respectively.

5. Conclusions

In this paper, two new spatial image de-noising filters have been developed. These filters work to remove abnormal pixels (noise) from an image by using some calculations that depend on the pixel distance and inverting the distance between pixels. The extracted results obviously illustrate the efficiency of the proposed filters and give better image quality compared to the mean filter, which is used widely in image enhancement of the cardinality of 5 (5 x 5 kernel). It is possible to improve these filters further by adding more criteria, such as threshold, or by expanding the filter kernel cardinality. This is left for future work.

Fig. 4: Lena Image with Salt and Pepper noise (intensity = 0.01)

Fig. 5: Filtered Lena Image using mean (5x5) kernel filter

Fig. 6: Filtered Lena Image using NDF (5x5) kernel filter

Fig. 7: Filtered Lena Image using FDF (5x5) kernel filter

Fig. 8: Tiger Image with Salt and Pepper noise (intensity = 0.01)

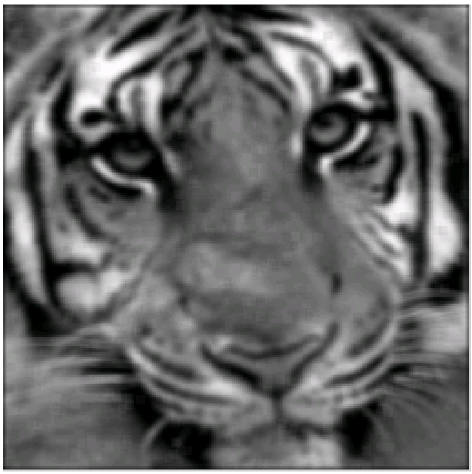

Fig. 9: Filtered Tiger Image using mean (5x5) kernel filter

Fig. 10: Filtered Tiger Image using NDF (5x5) kernel filter

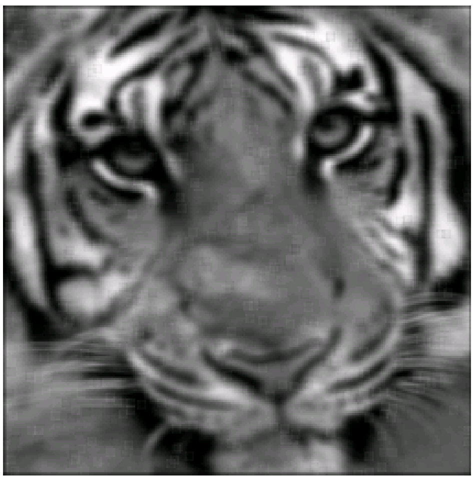

Fig. 11: Filtered Tiger Image using FDF (5x5) kernel filter

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