Literature Survey On Image Filtering Techniques

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Abstract

Filtering is an essential part of any signal processing system. This involves estimation of a signal degraded, in most cases, by additive random noise. Several filtering techniques have been proposed where linear processing techniques have been the method of choice for many years because of their simplicity. Most of these techniques, however, assume a Gaussian model for the statistical characteristics of the underlying process and try to optimize the parameters of a system for this model. Nonlinear techniques have recently assumed significance as they are able to suppress Gaussian noise to preserve important signal elements such as edges and fine details and eliminate degradations occurring during signal formation or transmission through nonlinear channels. Among nonlinear techniques, the fuzzy logic based approaches are important as they are capable of reasoning with vague and uncertain information. There are fuzzy filters available for removing additive noise. A detailed literature survey has been done here to compare these conventional image filters with a new fuzzy based approach. This paper includes an analysis about the significance of such a fuzzy based approach for image filtering.

1. Introduction

Additive noises are generally more difficult to remove from images than impulse noise because a value from a certain distribution is added to each image pixel, for example, a Gaussian distribution. Fuzzy set theory and fuzzy logic offer us powerful tools to represent and process human knowledge represented as fuzzy if-then rules. Several fuzzy filters for noise reduction have already been developed. Most of these state-of-the-art methods are mainly developed for the reduction of fat-tailed noise like impulse noise. Nevertheless, most of the current fuzzy techniques do not produce convincing results for additive noise.

The Fuzzy filter that recently developed can remove additive noise to an extent, but it does not take any action to maintain the original size of image . These filtering techniques can used as a pre – processing step for edge detection of Gaussian corrupted digital images and in case of additive noise corrupted images, this filter performs well in preserving details and noise suppression.

2. Literature Survey

Image processing has become a common technique for making images more comprehensible to the human eye. Images acquired are found to be corrupted with noise in many cases. There are many methods available to remove impulse noise in gray scale and color images. But very little has been done for the removal of additive noise in color images. Of the many filters presented, most of them are only for gray scale images. The filtering techniques developed for gray scale images can be extended to color images by applying it to the different color components separately but it is also evident that they can partially destroy image details. The existing systems includes Conservative Smoothing, linear filters, non-linear filters like median filter and fuzzy filter, adaptive filter, wavelet based filter etc. These techniques have a number of advantages and also disadvantages.

Image filtering techniques can be commonly classified as linear and non-linear. Linear filtering [1] can be used to remove certain types of noise. Certain filters, such as averaging or Gaussian filters, are appropriate for this purpose. For example, an averaging filter [2] is useful for removing grain noise from a photograph. Linear filtering is filtering in which the value of an output pixel is a linear combination of the values of the pixels in the input pixel's neighbourhood. It can be accomplished through an operation called convolution. Convolution is a neighbourhood operation in which each output pixel is the weighted sum of neighbouring input pixels. The main disadvantage of convolution filter is, it is not good for all type of noise. It is sensitive to variations in orientation and scale. It is also sensitive to non-uniform illumination.

One method to remove noise is to use linear filters by convolving the original image with a mask [5]. The Gaussian mask comprises elements determined by a Gaussian function. It gives the image a blurred appearance if the standard deviation of the mask is high, and has the effect of smearing out the value of a single pixel over an area of the image. Averaging sets each pixel to the average value of itself and its nearby neighbours. Averaging tends to blur an image, because pixel intensity values which are significantly higher or lower than the surrounding neighbourhood would smear across the area. Conservative smoothing is another noise reduction technique that is explicitly designed to remove noise spikes (e.g., salt and pepper noise) and is, therefore, less effective at removing additive noise from an image. Another method is to use conventional nonlinear filter such as Standard Median Filter (SMF) to remove the noise. Though it is good for removing impulse noise, it is not that much efficient in removing additive noise [5]. Wiener filter [2] is a good filter to remove additive noise, but the visual quality of the result obtained is not up to the mark compared to other filters.

A large amount of wavelet based methods [6] are available to achieve a good noise reduction, while preserving the significant image details. The wavelet denoising procedure usually consists of shrinking the wavelet coefficients. Shrinkage estimators can also result from a Bayesian approach, in which a prior distribution of the noise-free data (e.g., Laplacian [6], generalized Gaussian [7]) is integrated in the denoising scheme. The drawback of wavelet based methods is that the process is complex and consequently the time consumption is very high.

Fuzzy set theory and fuzzy logic offer us powerful tools to represent and process human knowledge represented as fuzzy if-then rules. Several fuzzy filters for noise reduction have already been developed, e.g., the iterative fuzzy control based filters from, the Goa filter [3], and so on. Most of these state-of-the-art methods are mainly developed for the reduction of fat-tailed noise like impulse noise. Nevertheless, most of the current fuzzy techniques do not produce convincing results for additive noise. Another shortcoming of the current methods is that most of these filters are especially developed for grayscale images. It is, of course, possible to extend these filters to color images by applying them on each color component independently. A detailed literature survey has been done to analyze the existing method for noise removal. The common techniques that use today is given below.

2.1 Conservative Smoothing

Conservative smoothing [8] is a noise reduction technique which employs a simple, fast filtering algorithm that sacrifices noise suppression power in order to preserve the high spatial frequency detail (*e.g.* sharp edges) in an image. It is explicitly designed to remove noise spikes, i.e. isolated pixels of exceptionally low or high pixel intensity (*e.g.* salt and pepper noise) and is, therefore, less effective at removing additive noise (e.g. Gaussian noise) from an image. Like most noise filters, conservative smoothing operates on the assumption that noise has a high spatial frequency and, therefore, can be attenuated by a local operation which makes each pixel's intensity roughly consistent with those of its nearest neighbors. However, whereas mean filtering accomplishes this by averaging local intensities and median filtering by a non-linear rank selection technique, conservative smoothing simply ensures that each pixel's intensity is bounded within the range of intensities defined by its neighbors.

Conservative smoothing is less corrupting at image edges than either of these noise suppression filters. Conservative smoothing works well for low levels of salt and pepper noise. But it is unable to reduce much Gaussian noise as individual noisy pixel values do not vary much from their neighbors. Conservative smoothing works well for low levels of salt and pepper noise. However, when the image has been corrupted such that more than one pixel in the local neighborhood has been effected, conservative smoothing is less successful.

2.2. Linear filters

Linear filtering [5] can be used to remove certain types of noise. Certain filters, such as averaging or Gaussian filters, are appropriate for this purpose. For example, an averaging filter is useful for removing grain noise from a photograph. Because each pixel gets set to the average of the pixels in its neighbourhood, local variations caused by grain are reduced. Linear filtering is filtering in which the value of an output pixel is a linear combination of the values of the pixels in the input pixel's neighbourhood. Linear filtering of an image is accomplished through an operation called convolution. Convolution is a neighbourhood operation in which each output pixel is the weighted sum of neighbouring input pixels. The matrix of weights is called the convolution kernel, also known as the filter. The main disadvantage of convolution filter is, it is not good for all type of noise. It is sensitive to variations in orientation and scale. It is also sensitive to non-uniform illumination.

2.3. Nonlinear filters

In recent years, a variety of nonlinear median type filters [2] such as weighted median, rank conditioned rank selection, and relaxed median have been developed. Two important nonlinear filters include median filter and fuzzy filter.

2.3.1. Median Filter

A median filter [1] is an example of a non-linear filter and, if properly designed, is very good at preserving image detail. To run a median filter:

1. Consider each pixel in the image

2. Sort the neighbouring pixels into order based upon their intensities

3. Replace the original value of the pixel with the median value from the list

A median filter is a rank-selection (RS) filter, a particularly harsh member of the family of rank-conditioned rank-selection (RCRS) filters; a much milder member of that family, for example one that selects the closest of the neighbouring values when a pixel's value is external in its neighbourhood, and leaves it unchanged otherwise, is sometimes preferred, especially in photographic applications. Median and other RCRS filters are good at removing salt and pepper noise from an image, and also cause relatively little blurring of edges, and hence are often used in computer vision applications. Median filtering is similar to using an averaging filter, in that each output pixel is set to an average of the pixel values in the neighbourhood of the corresponding input pixel. However, with median filtering, the value of an output pixel is determined by the median of the neighbourhood pixels, rather than the mean.

The median is much less sensitive than the mean to extreme values. Median filtering is therefore better able to remove these outliers without reducing the sharpness of the image. Median filter removes impulse noise, but it also smoothes all edges and boundaries and may erase details of the image. Median filter is not efficient for additive Gaussian noise removal, it yields to linear filters.

2.3.2. Fuzzy Filter

Fuzzy filters [4] provide promising result in image-processing tasks that cope with some drawbacks of classical filters. Fuzzy filter is capable of dealing with vague and uncertain information. Sometimes, it is required to recover a heavily noise corrupted image where a lot of uncertainties are present and in this case fuzzy set theory is very useful. Each pixel in the image is represented by a membership function and different types of fuzzy rules that considers the neighborhood information or other information to eliminate filter removes the noise with blurry edges but fuzzy filters perform both the edge preservation and smoothing. Image and fuzzy set can be modeled in a similar way.

A fuzzy set is a class of points possessing a continuum of membership grades, where there is no sharp boundary among elements that belong to this class and those that do not. This membership grade is expressed by a mathematical function called membership function or characteristic function. This function assigns to each element in the set. The membership maps each element to a membership grade between 0 and 1. In this way, the image is considered as a fuzzy set and thus filters are designed. In the case of fuzzy filters also there no existing method to remove additive based on fuzzy set theory.

2.4. Adaptive Filter (Weiner filter)

The wiener function applies a Wiener filter [8] (a type of linear filter) to an image adaptively, tailoring itself to the local image variance. If the variance is large, wiener performs little smoothing. If it is small, wiener performs more smoothing. This approach often produces better results than linear filtering. The adaptive filter is more selective than a comparable linear filter, preserving edges and other high-frequency parts of an image. In addition, there are no design tasks; the wiener2 function handles all preliminary computations and implements the filter for an input image. It require more computation time than linear filtering. Wiener works best when the noise is constant-power ("white") additive noise, such as Gaussian noise. Another method for removing noise is to evolve the image under a smoothing partial differential equation similar to the heat equation which is called anisotropic diffusion.

Wiener filter is unsuitable for image containing more edges. The filtered image will have less visual quality and is time consuming.

2.5. Fuzzy Filter for Impulse Noise Removal

A simplified fuzzy filter [8] can be used to remove impulse noise in an image. It uses fuzzy thresholding technique to preserve edges and fine details of the image. The pixels lying outside the trimming range after ranking in the filter are further tested for being noisy by the process of fuzzy thresholding. The algorithm uses range of threshold values rather than a crisp threshold value as the level of contamination varies from pixel to pixel. The modified value for the noisy pixel is calculated depending on the impulse noise present in it.

The filter is composed of two parts. The first determines if the central sample of pixels lies in the trimming range in the rank order set. If so, it is left unchanged. Otherwise, the second part compares it with its neighbouring pixels that lie in the trimming range. The differences between these pixels determine the amount of impulse present in the central sample. The algorithm works on the fact that the difference between an impulse and its neighbour is usually larger than the difference between a pixel on an edge with any of its neighbouring pixels. As this difference increases the impulsiveness goes on increasing. Finally by fuzzy switching, the output pixel is correspondingly changed depending on the level of corruption of the input pixel. The main disadvantage of this image filter is, it does not work to reduce additive noise.

2.6. Wavelet based filter

Wavelet based image denoising [6] method uses linear elementary parameterized denoising functions in the form of derivatives of Gaussian of a set of estimated wavelet coefficients. These coefficients are derived from an improved context modelling procedure in terms of mean square error estimation combining inter- and intra-subband data. The denoising method results in a two-step denoising effort which outperforms the state-of-the-art non-redundant methods. This method is also extended to the over complete wavelet expansion by applying cycle spinning, which provides additional denoising performance. But the wavelet based technique includes complex calculations which is time consuming. It does not provide accurate information about analyzed surface.

A new fuzzy method proposed by Schulte *et al*. [9] is a simple fuzzy technique for filtering color images corrupted with additive noise, which gives better results compared to all other above mentioned filters. Madhu *et al*. [10] proposed a modified version of the fuzzy approach proposed by Schulte *et al*., which uses a Gaussian combination membership function to yield a better result, compared to the fuzzy filter proposed. Both these methods outperform the conventional filter as well as other fuzzy noise filters. But the drawback of the above mentioned fuzzy filters is that both these filters compute color component distances instead of difference measure, which will lead to more time consumption. Similarly, the filtering operation has to be applied on other color components leading to more time consumption. Another disadvantage is that it does not take any action to maintain the original size of image. That is, some image pixels from the border were lost during processing. A modified version of this fuzzy filter to remove additive noise can be developed with lesser time consumption and effective maintain the original size of input image.

3. Conclusion

There are many noise filtering techniques available today for filtering images. Most of them are used for filtering impulse noise but few filters are available for additive noise. Fuzzy based image filters are available today for both impulse and additive noise. These fuzzy filters are efficient than traditional filters like averaging filter, median filter or Wiener filter. Future work is to modify these fuzzy technique to effectively maintain the original size of image. Also it focused on the construction of other fuzzy filtering methods for color images to suppress multiplicative noise such as speckle noise.

4. References

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