Global Journal of Medical Research: D
Radiology, Diagnostic Imaging and Instrumentation
Volume 16 Issue 2 Version 1.0 Year 2016
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4618 & Print ISSN: 0975-5888

An Extensive Review of Medical Image Denoising Techniques

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Abstract- Image denoising is an important pre-processing step in medical image analysis. The basic intent of image denoising is to reconstruct the original image from its noisy observation as accurately as possible, while preserving important detail features such as edges and textures in the denoised image. In medical imaging, for the precise analysis of diseases denoising of medical images like X-RAY, CT (Computed Tomography), MRI (Magnetic Resonance Imaging), PET (Positron Emission Tomography) and SPECT (Single Photon Emission Computed Tomography) is essential since a small lose of a particular area in case of medical images may results in immense disaster similar to death. To mitigate such threat over the last few decades, image denoising has been extensively studied in the image and signal processing community and suggested various denoising techniques. Each approach has its assumptions, advantages, and limitations. In this paper a detailed survey has been carried out on various image denoising approaches and their performances on on medical images.

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GJMR-D Classification: *NLMC Code: WN 180*

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An Extensive Review of Medical Image Denoising Techniques

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Abstract- Image denoising is an important pre-processing step in medical image analysis. The basic intent of image denoising is to reconstruct the original image from its noisy observation as accurately as possible, while preserving important detail features such as edges and textures in the denoised image. In medical imaging, for the precise analysis of diseases denoising of medical images like X-RAY, CT (Computed Tomography), MRI (Magnetic Resonance Imaging), PET (Positron Emission Tomography) and SPECT (Single Photon Emission Computed Tomography) is essential since a small lose of a particular area in case of medical images may results in immense disaster similar to death. To mitigate such threat over the last few decades, image denoising has been extensively studied in the image and signal processing community and suggested various denoising techniques. Each approach has its assumptions, advantages, and limitations. In this paper a detailed survey has been carried out on various image denoising approaches and their performances on on medical images.

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I. Introduction

Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, and computed tomography as well as in areas of research and technology such as geographical information systems and astronomy. Noise removal is one of the very important aspect in the field of image processing. An image gets distorted with different types of noise during the process of transmission and reception. Noise may be classified as substitutive noise speckle noise and additive white Gaussian noise.

Therefore, denoising of medical images is further essential which leads physician for precise analysis of diseases. Medical images like X-RAY, CT (Computed Tomography), MRI (Magnetic Resonance Imaging), PET (Positron Emission Tomography) and SPECT (Single Photon Emission Computed Tomography) encompass diminutive information about heart, brain, nerves and more. For determining the internal structure of an object, X-ray Computed Tomography (CT) is a powerful method. As such it determines application, e.g. in the non-destructive testing of a variety of materials. From a huge number of systematic observations at diverse viewing angles, the CT image is derived, and with the support of a computer (Radon transform) the final CT image is then reconstructed. It is unfeasible to rescue a human being from harmful effects, when these medical images are corrupted by noise. In both Image Processing and Biomedical Engineering, CT image Denoising is a significant research theme. In the case of CT, numerous mathematical applications can be applied to conclude whether the normal tissue has been infected by the mutations of the cancer cell. The disease diagnosis procedure has been made more efficient by denoising the CT images where the noise is removed. The denoised images encompass a prominent level of elevation in its PSNR values, ensuring a smoother image for diagnosis function. For developing the quality of the CT images, a variety of methods have been established. While many algorithms have been proposed for the purpose of image denoising, the problem of image noise suppression remains an open challenge, especially in situations where the images are acquired under poor conditions where the noise level is very high. In this paper, we present a broad review of medical image denoising is presented in spatial domain and transform domain and each has their own assumptions, limitations and advantages. The rest of the paper is structured as follows. Section II briefly gives the literature reviews of the denoising techniques Section III presents the taxonomy of linear model of LPG-PCA denoising algorithm in detail. Section IV gives the direction to the research work in order find a appropriate non-linear denoising technique and Section V concludes the paper

II. Literature Survey

Pravin R. Dabhi at el. (2015), author worked on satellite images which as many applications such as in meteorology, oceanography, fishing, agriculture, biodiversity conservation, forestry, landscape, geology, cartography, regional planning, education, intelligence and warfare. Images can be in visible colors and in other spectra. There are also elevation maps, usually made by radar images. Low resolution is the major drawback in these kinds of images. The resolution of satellite images varies depending on the instrument used and the altitude of the satellite's orbit. In order to exploit the information and to analyze the image the resolution of the image has to be enhanced. Various image processing techniques exist for resolution enhancement. The latest being application of wavelet techniques for

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resolution enhancement. In this, a comparison of two main wavelet techniques i.e. DWT & SWT are studied based on the image quality metrics and a new image quality enhancement technique had been worked based on wavelet fusion algorithm. The computation results of the image enhancement and image quality metrics of the proposed technique is compared with existing techniques. It is proved that the proposed technique have higher resolution enhancement capability than existing techniques.

Mirajkar Pradnya P (2013, defined Image fusion is the procedure of combining two or more unlike images into a new single image retaining their main features from each part of images with extensive information content. Two approaches of image fusion, Spatial Fusion and Transform fusion. Here, proposed an image fusion approach based on Stationary Wavelet Transform (SWT) that is firstly applied with the original image to get the edge image information in level 1 and level 2 both. Next, both edge images are combined to get a complete edge image using Spatial Frequency Measurement, which is compared with a few simple fusion Methods.

B Siva Kumar et al. (2013, proposed an image resolution enhancement technique based on interpolation of the high frequency subband images obtained by discrete wavelet transform (DWT) and the input image. The edges are enhanced by introducing an intermediate stage by using stationary wavelet transform (SWT). DWT is applied in order to decompose an input image into different subbands. Then the high frequency subbands as well as the input image are interpolated. The estimated high frequency subbands are being modified by using high frequency subband obtained through SWT. Then all these subbands are combined to generate a new high resolution image by using inverse DWT (IDWT). The quantitative and visual results are showing the superiority of the proposed technique over the conventional and state- of art image resolution enhancement techniques.

Kanagaraj Kannan et al. (2010, introduced the fast development of digital image processing leads to the growth of feature extraction of images which leads to the development of Image fusion. The process of combining two different images into a new single image by retaining salient features from each image with extended information content is known as Image fusion. Two approaches to image fusion are Spatial Fusion and Transform fusion. Discrete Wavelet Transform plays a vital role in image fusion since it minimizes structural distortions among the various other transforms. Lack of shift invariance, poor directional selectivity and the absence of phase information are the drawbacks of Discrete Wavelet Transform. These drawbacks are overcome by Stationary Wavelet Transform and Dual Tree Complex Wavelet Transform. This paper describes the optimal decomposition level of Discrete, Stationary and Dual Tree Complex wavelet transform required for better pixel based fusion of multi focused images in terms of Root Mean Square Error, Peak Signal to Noise Ratio and Quality Index.

Lei Zhang et al.(2010) et.al. had analyzed and developed an efficient PCA-based denoising method with local pixel grouping (LPG). PCA is a classical de-correlation technique in statistical signal processing and it is pervasively used in pattern recognition and dimensionality reduction. By transforming the original dataset into PCA domain and preserving only the several most significant principal components, the noise and trivial information can be removed. However, the PCA based scheme applies directly to the noisy image without data selection and many noise residual and visual artifacts will appear in the denoised outputs. In order to overcome this problem they enhanced by encapsulating the LPG (Local Pixel Grouping) method for selecting the local statistical feature group. In the enhanced LPG-PCA method they model a pixel and its nearest neighbors as a vector variable. The training samples of this variable are selected by grouping the pixels with similar local spatial structures to the underlying one in the local window. With such an LPG procedure, the local statistics of the variables can be accurately computed so that the image edge structures can be well preserved after shrinkage in the PCA domain for noise removal.

K.Prasad (2012), main work is of the image denoising. Corrupted image is called the noisy image, and the corrected is called the de-noised image. As we know different types of noises are there in the image processing like Gaussian noise, speckle noise, random noise, Salt & pepper noise etc. Among these the Salt and pepper noise is very dangerous noise compare to other noises. By using different algorithms we can reduce the noise from image. As color images in image processing is very widely as applications. So, a modified decision based unsymmetrical trimmed median filter algorithm for the restoration of gray scale, and color images that are highly corrupted by salt and pepper noise has worked out. Algorithm is worked which replaces the noisy pixel by trimmed median value when other pixel values, 0's and 255's as present in the selected window and when all the pixel values are 0's and 255's then the noise pixel is replaced by mean value of all the elements present in the selected window. Here algorithm shows better results than previous algorithm as tested against different grayscale and color images and gives better Peak Signal to-Noise Ratio (PSNR) and Image Enhancement Factor (IEF). So, MDBUTMF algorithm is effective for salt and pepper noise removal in images at high noise densities.

S. Preethi et al. (2012) proposed a Non linear model for denoising images mainly of medical images. While developing anon-linear model they have extensive literature survey for various image denoising processes

and based on similarity measures like PSNR, SSIM, SNR the PCA based NL-PCA provides better results in terms of image quality and similarity measures.

Rajenda Pandit et al. (2013), this paper discusses the Formulation, Process Flow Diagrams and algorithms of PCA(principal Component Analysis), DCT (Discrete Cosine Transform) and DWT (Discrete Wavelet Transform) based image fusion techniques. In this work they did the comparative study of PCA based image denoising techniques using DCT and DWT. After comparison they concluded giving upper hand to PCA-DWT based method over DCT based method.

G.Amar Tej (2015), preprocessing techniques hire filtration and resolution enhancement to remove noise and have good resolution is the main quality parameters in medical images. So as to preserve the edges and contour information of the medical images, an improved image enhancement technique and the efficient denoising is required. Here, concentrate on the average filtering, median filtering, wiener filtering and wavelet denoising for image denoising and an interpolation based Discrete and stationary Wavelet Transform technique for resolution enhancement is calculated on the base of some performance parameters such as PSNR which provides efficient denoising and resolution enhancement for image preprocessing.

Ashish goud Purushotham (2015), result of fusion is a new image which is more suitable for human and machine perception. Pixel level image fusion using wavelets and principal component analysis have implemented and worked on different performance metrics with and without reference image which concluded that image fusion using wavelets with higher level of decomposition showed better performance in some metrics and in other metrics PCA showed better performance. DWT in all parameters performs better than the PCA fusion algorithm so finally we can conclude that DWT is performs better than PCA.

III. Taxonomy of LPG-PCA Based Medical Image Denoising Technique

Principal Component Analysis (PCA) is a second order statistical approach, which has been used to extract the features of data set or perform data reduction (compression). Specially, when data set is, redundant and overwhelming large, PCA is very effective linear technique as a preprocessing step to extract data features and to cluster data for classification. It can play as optimal linear transform known as Kahunen- Louvre (LK) for data compression. To obtain the principal component vectors, traditionally the covariance matrix is calculated then eigen values are obtained, and corresponding to each eigen value, a component (eigen) vector is found. This procedure is complicated and computationally intensive thereby making it restrictive to apply for real world applications such as data compression and data extraction.

Moreover, the PCA hardware implementation for real time application becomes even more challenging. To get over the hurdles from the traditional PCA technique, the simple sequential PCA techniques are introduced. These techniques are based on learning approach to obtain sequentially principal component vectors. Some works in PCA are reported using Hebbian or anti-Hebbian learning and gradient-based learning. There are several reports that are successful in using PCA for data reduction and detection. Most of the works are software-based due to the complication of the hardware requirements.

In LPG-PCA scheme, a pixel and its nearest neighbors as a vector variable is obtained. The training samples of this variable are selected by grouping the pixels with similar local spatial structures to the underlying one in the local window. With this LPG procedure, the local statistics of the variables can be accurately computed so that the image edge structures can be well preserved after shrinkage in the PCA domain for noise removal

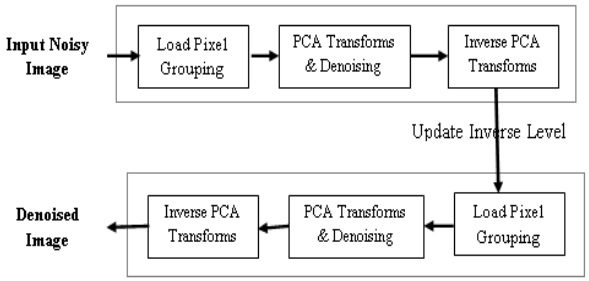

Fig.1: Process flow of CT Image Denoising using PCA

This LPG-PCA algorithm consists of two stages. The first stage yields an initial estimation of the image by removing most of the noise and the second stage will further refine the first stage output. The procedures of both the stages have the same except for the parameter of noise level. Since the noise is significantly reduced in the first stage, the LPG accuracy will be much improved in the second stage so that the final denoising result is visually much better. This method is a spatially adaptive image representation so that it can better characterize the image local structures.

In image denoising by using local pixel grouping using principal component analysis (L.Zang et al. 2010) the main steps are

1) LPG (Local Pixel Grouping)
2) Apply PCA transform and denoise
3) Apply Inverse PCA transform

In order to calculate the local statistics in LPG-PCA method a moving window is used from which the

local PCA transformation matrix was estimated. The process of denoising in LPGPCA algorithm get completed in two stages,

1. In the first stage it gives an initial estimation of the image by removing most of the noise and
2. Second stage will further refine the output of the first stage 1 (L.Zang et al. 2010).

Steps involved in calculation of PCA are:

1) Subtraction of mean
2) Calculation of covariance matrix
3) Calculation of eigen vector and eigen values.
4) Multiply eigen vector and image

Noise is suppressed by using linear minimum mean square error estimation (LMMSE) technique. Shrinkage coefficient is multiplied with covariance values and then mean values are added back to get denoised dataset.

IV. Directions for the Future Research

In this review paper, different methods developed for denoising the medical images are thoroughly analyzed. Analysis has been done on the Radiography, Ultrasound, MRI and CT images are analyzed. Besides others, the CT image plays a more important role because it is one of the most common and very significant modalities employed in medical imaging. Hence due to its prevalent utilization, obtaining better results is essential for CT images. This paper will be a healthier foundation for the budding researchers in identifying appropriate denoising techniques for medical images and especially for CT images. In future we expect numerous brainwaves will rise by means of our review work.

V. Conclusion

From thorough analysis it is perceived that the medical image denoising is an emergent research area and has received great attention among the researchers from image and signal processing in recent years. As such, a broad review of the significant researches and techniques that exist for medical image denoising is pursued. Here the researches are first categorized into Radiographic, Ultrasound, MRI and CT images based on the type of the medical image. Then, followed by a concise description on digital images and medical images and a brief discussion about each category of medical images the salient features of the important researches existing in the literature are reviewed.

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