Biomedical Signal Processing and Control 42 (2018) 73–88

Contents lists available at ScienceDirect

Biomedical Signal Processing and Control

journal homepage: www.elsevier.com/locate/bspc

Review

A review on CT image noise and its denoising

Manoj Diwakar[a,*], Manoj Kumar[b]

[a] Department of Computer Science and Engineering, UIT, Uttaranchal University, Dehradun, India
[b] Department of Computer Science, Babasaheb Bhimrao Ambedkar University, Lucknow, India

ARTICLE INFO

Article history:
Received 2 May 2017
Received in revised form
26 November 2017
Accepted 17 January 2018

Keywords:
Computed Tomography
Image denoising
Anisotropic function
Isotropic function
Total variation

ABSTRACT

CT imaging is widely used in medical science over the last decades. The process of CT image reconstruction depends on many physical measurements such as radiation dose, software/hardware. Due to statistical uncertainty in all physical measurements in Computed Tomography, the inevitable noise is introduced in CT images. Therefore, edge-preserving denoising methods are required to enhance the quality of CT images. However, there is a tradeoff between noise reduction and the preservation of actual medical relevant contents. Reducing the noise without losing the important features of the image such as edges, corners and other sharp structures, is a challenging task. Nevertheless, various techniques have been presented to suppress the noise from the CT scanned images. Each technique has their own assumptions, merits and limitations. This paper contains a survey of some significant work in the area of CT image denoising. Often, researchers face difficulty to understand the noise in CT images and also to select an appropriate denoising method that is specific to their purpose. Hence, a brief introduction about CT imaging, the characteristics of noise in CT images and the popular methods of CT image denoising are presented here. The merits and drawbacks of CT image denoising methods are also discussed.

Contents

* Corresponding author.
E-mail address: manoj.diwakar@gmail.com (M. Diwakar).

https://doi.org/10.1016/j.bspc.2018.01.010
1746-8094/

1. Introduction

Computed Tomography (CT), invented by Hounsfield [60] in 1972, was the first method that allowed to generate non-overlapping axial slices of the internal structure of a humans body without opening it [13,102]. The Nobel prize awarded to Hounsfield [60] and Cormack [29] for their work on the initial CT device which signifies the importance of CT imaging [61].

1.1. CT imaging

Today, CT is associated with high competency in radiologic diagnostics and has become an important tool in medical examinations. Traditional X-ray technique has many limitations such as it cannot distinguish between muscles, ligaments or vessels and other tissues. Another major disadvantage is the superposition and compression of 3D information into a 2D image. Compare to traditional X-ray technique, the computed tomography is more accurate technique that adds a mathematical reconstruction theory of an object from its projections to multi-angular X-ray scanning. The computed tomography involves mainly the presence of a computer, which processes the information received through the passage of an X-ray beam through an anatomical area. The benefits of CT imaging are speed, accuracy, small scanning time and many more.

Computed tomography (CT), originally known as computed axial tomography (CAT or CT scan), is a medical imaging method employing tomography where digital geometry processing is used to generate a three-dimensional image of the internals of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation [114]. Computed Tomography (CT) is a powerful nondestructive evaluation (NDE) technique for producing 2-D and 3-D cross-sectional images of an object from flat X-ray images. The characteristics of the internal structure of an object such as dimensions, shape, internal defects and density are readily available from CT images. The process through radon and inverse radon transform on the information received through the passage of an X-ray beam, an image can be reconstructed, is known as CT imaging.

As X-rays pass through the body, X-rays are absorbed or attenuated at different levels, creating a profile of beams of different intensities. A detector, that further transforms the profile in an image, analyzes this profile. The CT creates images representing cross sectional slices of the exposed area. The absorption of X-rays due to differences in elemental composition has an important effect on CT imaging. The absorption process is proportional to the atomic number which helps to differentiate gray from white matter in the CT images. Very little contrast is observable between blood and muscle as the density and the elemental compositions are very similar. To provide image contrast between them, usually a dense fluid with elements of high atomic number can be injected or swallowed during X-ray exposures.

2. CT image reconstruction

In Computed Tomography, a motorized X-ray source is used to transmit the X-rays over the patient with various angles. CT scanners use special digital X-ray detectors, which are located directly opposite the X-ray source. As the X-rays move through the patient, the detectors received the X-rays and change into electrical signals. These electrical signals are converted into the digital data by analog/digital converter. The data in the digital matrix can be changed into small boxes ranging from black to white gray through digital/analog converter. Finally, raw data (collected from various angles) are further mathematically computed using Radon transform to reconstruct the CT images. Backprojection is the most common concept for image reconstruction. The back projecting to the raw data with respective directions is generally known as backprojection [70].

Backprojection is conceptually simple but it does not correctly solve the inverse problem. To reconstruct the CT image, a simulation based example is shown in Fig. 1. In this example, a phantom image as shown in Fig. 1(a) is taken as an input object and Radon transform is applied to the phantom image by choosing $\theta = 180$. The raw data are collected from each unit angle. This raw data can be represented in the form of the image which is known as Sinogram as shown in Fig. 1(b). Finally, inverse Radon transform is performed over the Sinogram to obtain the reconstructed CT image as shown in Fig. 1(c). To overcome the blurry results (as in Fig. 1(c)), filter backprojection is widely used in CT image reconstructions. To correct this, the projections are first filtered in the Fourier domain by a filter such as ramp filter and then the filtered projections are projected using radon transform. An example of image reconstruction using filtered backprojection is shown in Fig. 2.

After, image reconstruction, the major issues and factors affecting the quality of CT images must be analyzed. A brief overview of these issues are given below:

2.1. Major issues on CT image reconstruction

Generally, CT images are obtained either from filtered back projection (FBP) technique or IR technique. There are some major issues which must understand or analyzed to get good quality of CT images over the low dose-data.

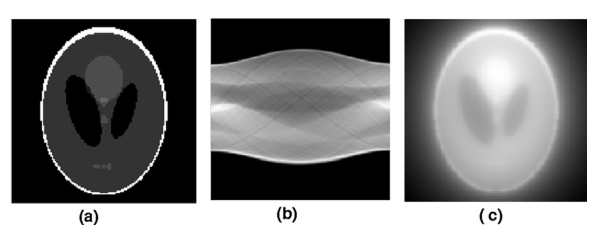

Fig. 1. Image reconstruction using Radon transform.

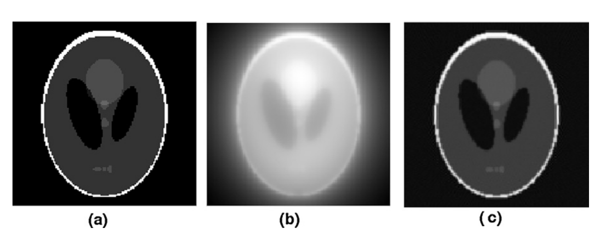

Fig. 2. Image reconstruction using filtered backprojection: (a) phantom image, (b) unfiltered image, and (c) filtered image.