BIOCYBERNETICS AND BIOMEDICAL ENGINEERING XXX (2018) XXX–XXX

Available online at www.sciencedirect.com

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Original Research Article

Fuzzy genetic-based noise removal filter for digital panoramic X-ray images

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ARTICLE INFO

Article history:
Received 30 April 2018
Received in revised form
6 July 2018
Accepted 16 August 2018
Available online xxx

Keywords:
Orthopantomography images
Genetic algorithm
Poisson noise
Anscombe transformation

ABSTRACT

This paper proposed a novel fuzzy genetic-based noise removal filter and surveyed the gain of popular filters for noise removal in the digital orthopantomography (OPG) images. The proposed filter is a non-invasive technique for attaining sub-clinical information from the areas of interest in each tooth, both jaws and maxillofacial.

The proposed Poisson removal filter combines 4th-order partial differential equations (PDE), total variation (TV) and Bayes shrink threshold accompanied by fuzzy genetic algorithm (FGA) and the exact unbiased inverse of generalized Anscombe transformation (EUIGAT). Experiments were performed in order to show the effect of noise removal filters on 110 simulated, 106 phantom and 104 panoramic radiographic images for subjects (aged 30–60 years old, 50 males and 54 females). Various noises degraded filters and Canny edge detection was performed separately in three kinds of images. The program measured mean square error (MSE), peak signal to noise ratio (PSNR), image quality index (IQI), structural similarity index metric (SSIM) and figure of merit (FOM).

The results verify that the proposed filter enhances physicians' and dentists' skill of diagnosing normal and pathological events in the teeth, jaws, temporomandibular joint (TMJ) regions and changeable anatomical panoramic landmarks related to osteoporosis progress in the mandible bone using noise removal and improving images quality. Experimental results show the superiority of this filter over other noise removal filters.

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https://doi.org/10.1016/j.bbe.2018.08.005

1. Introduction

Over past three decades, conventional radiography is replete with more electronic equipments and computational programs. These appendices have become effective alternatives due to their great impact on image quality and workflow such as replacing traditional photographic films with digital X-ray detectors. This replacement caused higher time efficiency, a better digital transition and images enhancement [1]. In addition, though using less radiation, the resulting image has the same contrast as conventional radiography. It also offers other advantages including instantaneous image preview and access, a wider dynamic access to over-and under-exposure, deletion film processing steps and possibility of using special processing techniques which enhance image quality [1]. Recently, orthopantomography (OPG) has expanded to be one of the main supplementary trials in dentistry. It is a view of lower face which shows all the teeth of upper and lower jaws with their number, position and growth. Besides, OPG has more benefits than radiography of individual teeth [2,3].

The problems with the jaw bone and temporomandibular joint (TMJ), the joint which connects the jaw bone to the head, are possible to be diagnosed in this radiography [2]. An OPG can be effective in planning orthodontic treatment and diagnosing of wisdom teeth. OPG is widely used to produce a comprehensive survey of the maxillofacial complex and as a useful tool in the primary trial of osteoporosis [4]. Gaussian, Poisson, speckle and salt-and-peppers are different types of noises which cause by various sources in the transmission system and environmental factors [5]. Therefore, X-ray images have a statistical nature, because they are produced by digital receptors [6]. Poisson noise is one of the major noises which on one hand, quality of X-ray images degraded; because of being close to discrete photons nature. On the other hand, smoothing images is necessary to remove the noise by standard filters that also can preserve the edges [7]. Both linear and nonlinear conventional filtering methods reduce noises by smoothing the image and may also smooth edge information [8]. Besides, data can be transformed to the space domain or frequency domain for filtering the bandwidth, which should be determined precisely. If the bandwidth becomes narrow or wide, the noise cannot be decreased well or some information will be omitted. It seems that they have no proper filtering effects [9,10].

Partial differential equations-based methods (PDE) utilize the heat conduction and control on diffusion direction which can preserve the edge information. It is important that the noise reduced and edge details can be preserved precisely [11]. The major substantial tools for denoising in medical image are the total variation (TV) model suggested by Rudin et al. and the proposed model of Perona and Malik based on anisotropic noise smoothing [12,13]. Deledalle et al. suggested a non-local mean algorithm with iterative characteristic of Poisson noise reduction in X-ray images [14]. Another survey was proposed a combined method including block matching and three dimensions filtering (BM3D). They concluded that the performance of spatial domain for Gaussian noise reduction is more useful than other filters [15]. Makitalo et al. showed that Anscombe transform stabilized the variance of Poisson noise and then, adjusted BM3D [16]. Wang et al. proposed Bayes shrink threshold using Daubechies wavelet transform for denoising in medical images [17]. In another study, median filtering was better than Gaussian and finite impulse response (FIR) filtering for speckle and Poisson noises in dental X-ray images [18]. Du et al. showed that the performance of dual tree complex wavelet transform (DTCWT) is more proper than wavelet transform for Poisson noise reduction from X-ray images [19]. Jisha et al. presented that a hybrid of curvelet transform and variance stabilization transform is better than wavelet transforms for Poisson denoising [20].

Fuzzy genetic algorithm (FGA) is inspired by nature-based evolutionary process and has popularity in different fields of medicine [21]. Due to the importance of OPG images in diagnosis and therapeutic measures, oral and maxillofacial surgery, fractures and extraction for evaluating parameters of osteoporosis in the mandible, the proposed filter combines 4th-order PDE, TV and Bayes shrink threshold for optimum noise reduction and edge preservation in OPG images. This combination is accompanied by the fuzzy genetic algorithm in order to exact unbiased inversed (EUI) of generalized Anscombe transformation with other denoising filters. This method may provide physicians and dentists with useful information about injuries of oral and maxillofacial regions through enhancing image quality.

2. Material and method

2.1. Related works

This section is dedicated for related denoising filters which are utilize for comparison with the proposed FGA-based noise removal filter.

2.1.1. Poisson noise removal techniques

This kind of noise is generated from nonlinear response of detectors with Poisson distribution. The image information is dependent on detection and recording of the electron random emission in a circuit or the photon in an optical device with Poisson distribution and specified average value. Since in the Poisson distribution, the mean is equal to the variance and the signal containing data is completely dependent on the standard deviation. So, the higher the standard deviation, the more noise is added to the signal [22]. The probability distribution of a Poisson random variable X representing the number of successes occurring in a given time interval or a specified region of space which is given as:

$$f(X) = \frac{e^{-\lambda} \times \lambda^{x}}{x!} \quad (1)$$

where x is the exact number of successes, e equals 2.171828, λ is the mean number of successes in the given time interval or region space and $x!$ is the factorial of x [23]. The model of reduction due to Poisson noise is:

$$u(i,j) = \frac{1}{\lambda} \text{Poisson}(\lambda \times t(i,j)) \quad (2)$$

Please cite this article in press as: Rafati M, et al. Fuzzy genetic-based noise removal filter for digital panoramic X-ray images. Biocybern Biomed Eng (2018), https://doi.org/10.1016/j.bbe.2018.08.005