Grenze International Journal of Engineering and Technology, July 2017

New Adaptive Retinex based Spinal Cord Medical Image Enhancement

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***Abstract*—This paper presents a new adaptive retinex scheme in order to enhance Magnetic Resonance Imaging (MRI) spinal cord medical images. The illumination is estimated using cost parameter linked with the luminance function. The estimated illumination is piecewise spatially smoothed that eliminates the hal artifacts in the images. The illumination dynamic correction and details improvement are achieved through edge preserving low pass filter. The proposed method improves the details such that contrast of the spinal cord images is adaptively enhanced and helps the doctors to make the right decisions. It is clear from the experimental results that the presented that the proposed method outperforms and is superior to other researcher's method.**

***Index Terms*— Adaptive retinex, Spinal cord, Illumination estimation, Reflectance.**

I. INTRODUCTION

The interior parts and tasks of the organs of the body are usually invisible to the humans. However, with the use of technology human parts can be pictured with actual structure and details. These images may be adopted by various medical professionals to diagnose abnormal conditions. Among various diseases, cancer also called as neoplasm is a dieseas in which abnormal cell divide without control and can attack nearby tissues with the help of blood and lymph systems. Therefore, cancer needs to be diagnosed at an early stage before it spreads.
As it is evident from the statistics published by the American Cancer Society that in the United States alone have 23,770 (13,350 males and 10,420 females) malignant tumor cases in the year 2015. About 16,050 people (9440 males and 6610 females) die every year from the brain and spinal cord tumors. With reference to men 1 in 140 and females, 1 in 180 have a chance of getting malignant spinal cord tumor in their lifetime.
This paper addresses an approach to ease the identification of spinal cord tumors in an early stage by proposing the new adaptive retinex method in digital image enhancement. A number of researchers have contributed numerous methods for the enhancement of medical images [1] . These techniques can be

Grenze ID: 01.GIJET.3.3.135

classified into several categories: Spatial domain enhancement methods include contrast improvement [2], gray scale transformations, retinex, etc. Transform domain enhancement methods include low pass filter, high pass filter, etc.

II. RELATED WORK

Numerous researchers have contributed for the improvement of retinex algorithm starting from Jobson et al. to Retinex adaptive filter. However most of the retinex versions proposed by other researchers are aimed to improve the quality of aerial, natural, facial, etc. image enhancement. But there are only few retinex versions used to improve the contrast in medical images. The following paragraphs presents the retinex and its relevant schemes used to enhance the quality of medical images.

The X-ray medical image enhancement using improved retinex technique was proposed by Weizhen et al. [3]. The new method presented improves the details in the X-ray images and eases doctor's diagnosis process. The halo artifact problem in the retinex algorithms are effectively addressed in this scheme compared to conventional retinex method. However, this scheme has not used metrics to assess the quality of the image. From the experimental results it was found that there is still room for contrast improvement in x-ray images.

Wang et al. [4] proposed palm vein extraction using single scale retinex method. The asymmetry illumination conditions and non-uniform geometry of the palm leading to robust shadows are eliminated in this scheme. Visual performance of the palm veins are extremely better compared to other image improvement methods. But this scheme offers better results for gray level images instead of 3D medical images.

Simple, efficient, and practical computer tomography (CT) dental image enhancement using histogram weighted retinex was proposed by Tian-yi YangDai and Li Zhang [5]. This scheme reduces increased noise levels and over enhanced artifacts in homogenous regions by retaining the details enhancement of teeth. Although the presented scheme offers contrast improvement of teeth images but the methodology do not provide acceptable outputs for other CT images.

Visual quality improvement and color details in endoscopy images are improved using dynamic color map was proposed by Khan et al. [6]. The vascular and mucosa structures are colorized using low contrast gray scale images. This scheme is used to colorize gray level video frames of wireless capsule endoscopy. The perceptual quality of the reconstructed color pictures are validated by the professionals working in the same domain. But it may be noted that this method lacks with the qualitative metrics.

Lee at al. [7] proposed adaptive Multiscale retinex method to enhance the contrast of the natural sceneries. Luminance component of the color image is enhanced using single scale retinex and further weights are used to intensify the image. The weights used to improve the quality of the image are computed adaptively based on the input image information. Though this method provides adequate results for natural pictures but could not provide agreeable outputs for medical imageries.

Gradient field reconstruction applied to infrared image detail enhancement and Denoising based on Gaussian Mixture Model (GMM) was proposed by Zhao et al. [8]. The important qualities of infrared images are low signal to noise ratio and low contrast, respectively. To enhance image details and reduce noise Gaussian mixture model based reconstruction was proposed by the authors. This method is capable to produce high quality image with reduced noise but at the cost of increased computation.

The proposed method overcomes the limitations of the other researcher methods in an efficient way. Adaptive retinex scheme presented is capable to improve the details of the MRI image and eases the burden of the doctors in making decisions.

III. PROPOSED METHOD

The proposed method uses RGB to HSV color domain and uses the value channel of HSV color space for spinal cord medical image enhancement.

Illumination Estimation

The proposed scheme uses Shen et al. [9] retinex with robust envelop approach to determine the illumination estimation. The spatial smoothness of the illumination and its closeness to intensity is achieved by the following equation:

$$F\big(L(x,y)\big) = \int(\|\nabla L(x,y)\|^2 + \alpha\|L(x,y) - I(x,y)\|^2)dxdy \qquad (1)$$

where ∇ indicates differential operator of first order and $\| . \|$ indicates the absolute value.

The cost minimization function is employed to gradient descent algorithm and is defined by

$$L_j(x,y) = L_{j-1}(x,y) - \beta.G \quad (2)$$

where $L_j(x,y)$ and $L_{j-1}(x,y)$ indicates the luminance images at step j and j-1; β represents the linear step size, G specifies the gradient function of $F\big(L(x,y)\big)$

Further, the gradient function defined by Kimmel at al. [10] is given by

$$G = -\Delta L + \alpha(L-1) \quad (3)$$

$$G \approx -L(x,y) * K_{lap}(x,y) + \alpha.\big(L(x,y) - I(x,y)\big) \quad (4)$$

where Δ is the Laplacian differential operator of second order which is approximated to the linear convolution with the spatial filter K_{lap}

$$K_{lap} = \begin{pmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

Lastly, we define the expression to determine the illumination

$$L_j(x,y) = \max\{w(\nabla I).I(x,y) + \big(1 - w(\nabla I)\big).L_j(x,y).I(x,y)\} \quad (5)$$

$$w(\nabla I) = \begin{cases} w_0, if\ \nabla I > Th \\ w_0.\left(\frac{\nabla I}{Th}\right)^2, Otherwise \end{cases} \quad (6)$$

$$\nabla I \approx \|I(x,y) * H(x,y)\| + \|I(x,y) * H^T(x,y)\| \quad (7)$$

where Th represents the gradient threshold, H(x, y) signifies the pyramid operator, $H^T(x,y)$ indicates the transpose of H(x, y) that is used to exploit strong edges.

$$H = \frac{1}{34}\begin{pmatrix} 1 & 1 & 1 & 0 & -1 & -1 \\ 1 & 2 & 2 & 0 & -2 & -1 \\ 1 & 2 & 3 & 0 & -3 & -1 \\ 1 & 2 & 3 & 0 & -3 & -1 \\ 1 & 2 & 3 & 0 & -3 & -1 \\ 1 & 2 & 2 & 0 & -2 & -1 \\ 1 & 1 & 1 & 0 & -1 & -1 \end{pmatrix}$$

Reflectance Estimation and Enhancement

The reflection and enhancement in the proposed approach is achieved by the adopting the retinex based enhancement scheme proposed by Saponara et al. [11]. The reflectance is computed by taking the ratio of V channel and estimated illumination. The illumination dynamic correction and detailed enhancement are accomplished through the following Equations.

$$\Gamma(y) = N\left(\frac{L}{N}\right)^{k\left(1+\frac{y}{N}\right)} \quad (8)$$

$$\beta(r) = exp\left(g\left(\frac{1}{1+e^{-b.logr}} - \frac{1}{2}\right)\right) \quad (9)$$

where k ϵ [0, 1], b ϵ [0, 10] and g ϵ [1,10]; N=255.

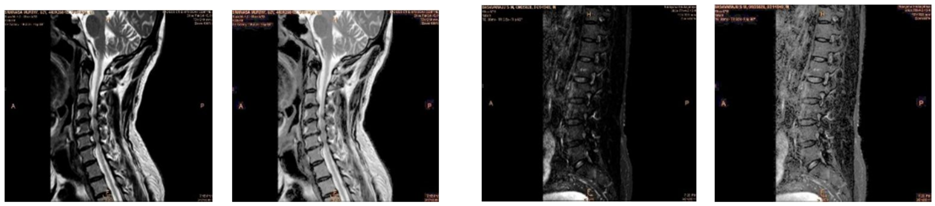
The proposed algorithm not only works for MRI spine images but also provides satisfactory results for natural images. This is validated by using natural images downloaded from the NASA database.

IV. Experimental Results

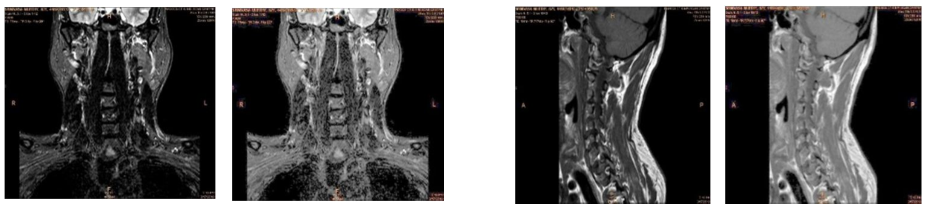
The proposed method is validated using MRI spinal cord images obtained from the local hospital. Algorithm is validated using Matlab (Ver. 2015b) with over a dozens of sample images. It was found from the experimental results that the proposed method is capable of producing images that are of high quality. This scheme not only improves the quality of spinal cord images but helps the doctors in arriving at decisions.

Figure 1 shows the spinal cord images with each set consisting of original and enhanced images. Although the elaborated experiments are conducted on over a dozens of spinal cord images but as an example six sets are presented here.

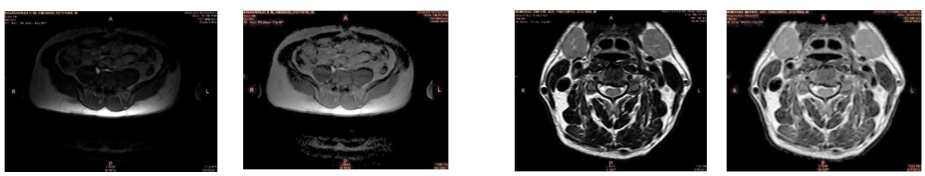
Figure 2 shows the algorithm validated for natural images downloaded from the NASA database. The reconstructed images are shown to the doctors for validation. Also, the Peak Signal to Noise Ratio (PSNR) is used to qualitative evaluation of enhanced images. The subjective and objective evaluation of the enhanced images are found to be satisfactory. Finally, it may be concluded that the proposed method outperforms and produces the images with high visual quality



(a) PSNR: 37.34 dB **(b) PSNR: 31.08 dB**



(c) PSNR: 35.05 dB **(d) PSNR: 36.73 dB**



(d) PSNR: 31.27 dB **(e) PSNR: 37.72 dB**

Figure 1. Original and Enhanced Spinal Cord Images

Figure 2. Original and Enhanced Natural Images

V. Conclusion

This paper presents the adaptive retinex method to enhance the spinal cord images. The illumination estimation is accomplished by embedding the cost function into the luminance. Estimated illumination is piecewise spatially smooth to eliminate the halo artifacts of the retinex algorithm. The reflectance and enhancement of the image is carried out as a second step that improves the contrast of the spinal cord images to a larger extent. The proposed method helps the doctors in making correct decisions during the diagnosis process. As is evident from the experimental results presented that the proposed method outperforms compared to other methods.

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