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Unsharp Masking of Medical Images using Rolling Guidance Filter

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ABSTRACT

Medical Images consists of both high frequency and low frequency information needed by Physician for diagnostics and treatment purpose. Since, human eye is sensitive to high frequency information, the enhancement of high frequency information of medical image is very important. Most image enhancement techniques use the traditional unsharp mask filter to enhance the detail and edge information of medical image. While enhancing the detail and edge information, Gaussian Filter in traditional Unsharp Masking Filter introduces halo effects around edges. To remove this halo effects in enhanced images, this paper proposes a novel image enhancement filter in which Gaussian Filter is replaced by rolling guidance filter. This method provides satisfying results over Traditional Unsharp Mask Filter, Amended Unsharp Mask Filter, Anisotropic Diffusion based Unsharp Mask Filter and Guided Filtering based Unsharp Mask Filter in terms of high frequency information measures like mean gradient, spatial frequency and sharpness.

Keywords – **Gaussian Filter, Guided Filter, Medical Images, Rolling Guidance Filter, Unsharp Masking.**

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I. INTRODUCTION

Medical Images consists of both high frequency and low frequency information needed by Physician for diagnostic and treatment purpose. It is vital to improve the high frequency contents such as edges and details of medical images because the human eye is more sensitive to high frequency detail and edge information than low frequency content. The image may be slightly blurred by the sensors used in medical imaging systems, which lowers the image's visual quality.To increase the perceived quality of the medical images, high frequency information must be enhanced. Image enhancement refers to any image processing algorithm to enhance high frequency contents such as edges and details of an image. Based on the application, image enhancement algorithm modifies one or more attributes of digital image. During this modification process, the choice of attributes and the way of modification are specific to the application. The two basic categories of image enhancement (Spatial domain and Transform domain) are based on the domain in which image attributes are adjusted. Numerous algorithms are described in the literature for both the categories of the spatial domain and the transform domain. Due to its ease of processing and suitability for a variety of image formats, the Traditional Unsharp Mask Filter (TUMF) and its various versions are receiving increased attention from researchers among the existing spatial domain approaches. TUMF enhances the high frequency information like edges in an image by adding overshoot and undershoot which produces halo effects. When applied to an image which is corrupted by noise, TUMF amplifies the noise in low frequency content which degrades the overall quality of the image. To remove these drawbacks in TUMF, many efforts have been devoted and several algorithms including slope restoration have been proposed. Despite of these advancements, still there are some chances to improve the performance of TUMF. This paper proposes a novel image enhancement filter in spatial domain in which Gaussian Filter is replaced by Rolling Guidance Filter (RGF) [13]. The proposed method provides satisfying results over Traditional Unsharp Mask Filter (TUMF), Amended Unsharp Mask Filter (AUMF), Anisotropic Diffusion based Unsharp Mask Filter (ADUMF) and Guided Filtering based Unsharp Mask Filter (GUMF) in terms of high frequency information measures like mean gradient, spatial frequency and sharpness. The following section provides introduction about Rolling Guidance Filter developed by Qi Zhang, Xiaoyong Shen, Li Xu, and Jiaya Jia. Section 3 presents the proposed enhancement methodology. The experimental finding of the proposed enhancement methodology is discussed in Section 4. Summary of the paper and conclusion are presented at the end.

II. ROLLING GUIDANCE FILTER

By employing a Gaussian filter salt and pepper noise in an image is eliminated. But Gaussian Filter blurs the high frequency information present in an image. When the smallest Gaussian of standard deviation σ_s is applied to an image, the structure of size smaller then σ_s disappears. The application of Gaussian filtering to an image is referred as the convolution of Gaussian kernel $G_v(x,y)$ of variance $V = \sigma_s^2$ with the input image I (x,y) and is given by

$$L_v = g_v * I \quad L_v = G_v(x,y) * I(x,y) \tag{1}$$

where $G_v(x,y) = \frac{1}{\sqrt{2\pi V}} e^{-(\frac{x^2+y^2}{2V})}$ and * denotes convolution. L_v is the result of scaling with scale V. The image structure is completely removed from Lv when it is smaller than $\sqrt{V}$. If the image structure is greater than $\sqrt{V}$, smoothing will take place. So, Gaussian filtering removes the edges of structures with scales below the smoothing scale and blurs the large scale structures. The two primary steps of the filtering approach should be small structure removal and edge recovery in order to prevent the blurring caused by the Gaussian filter. Small structure must be removed as a first step. To avoid this blurring by Gaussian filter, filtering method should be composed of two main steps, i.e., small structure removal and edge recovery. The first step is to remove small structures. It is expressed by Gaussian operator in a weighted average form, which takes the input image I and generates outputs image G, which is given by,

$$G(p)=\frac{1}{K_p}\sum_{q\in N(p)} e^{\left(-\frac{\|p-q\|^2}{2\sigma_s^2}\right)} I(q) \quad (2)$$

where $K_p=\sum_{q\in N(p)} e^{\left(-\frac{\|p-q\|^2}{2\sigma_s^2}\right)}$ and N(p) is the set of neighbouring pixels of p. The small scale structures in the input image are completely removed by this Gaussian filter. If the Gaussian kernel is increased larger, it removes more and more image structures, which is shown in Fig 1. The second step is the edge recovery which is an iterative process. For this edge recovery, RGF uses joint bilateral filter. If $J^1=G(p)$, then J^{t+1} represents t^{th} iteration of J^1 . The value of J^{t+1} is obtained by joint bilateral filtering of $G(p)$. This is given by

$$G(p)=\frac{1}{K_p}\sum_{q\in N(p)} e^{\left(-\frac{\|p-q\|^2}{2\sigma_s^2}-\frac{\|J^t(p)-J^t(q)\|^2}{2\sigma_r^2}\right)} I(q) \quad (3)$$

where $K_p=\sum_{q\in N(p)} e^{\left(-\frac{\|p-q\|^2}{2\sigma_s^2}-\frac{\|J^t(p)-J^t(q)\|^2}{2\sigma_r^2}\right)}$, σ_r and σ_s are weights for range and spatial filters. The aforementioned expression can be thought of as a filter that smoothens the input image I guided by the J^t structure. The guidance image in passes is altered by this operation. As a result, it is named as Rolling Guidance Filter.

III. Proposed Methodology

Image enhancement is the technique of image sharpening by enhancing the high frequency information such as edges and details of the image. Image enhancement often involves combining the original image with high frequency contents such as edges and details. The first step of proposed image enhancement method for improving the visual quality of images involves utilizing RGF to separate the high frequency information like edges and details from the original images. This filter takes three inputs: the input image I, the spatial and range filtering weights (s, r), and the number of iterations N^{iter}. The output of RGF filtered image is the smoothed-out version of the input image. The next step is to extract the high frequency detail and edge information input images by subtraction from the RGF output. The final step is to combine the original image with the high frequency detail and edge information that was retrieved. The proposed method of Image Enhancement is shown in Fig. 2.

Fig 1: Illustration of Gaussian Scale a. Original Image Filtered Image when b. $\sqrt{V}=1$ c. $\sqrt{V}=2$ d. $\sqrt{V}=4$

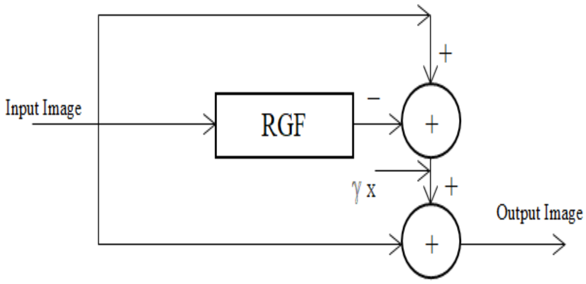


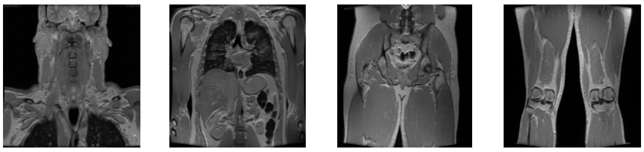
Fig 2: Proposed Method of Image Enhancement

IV. Results

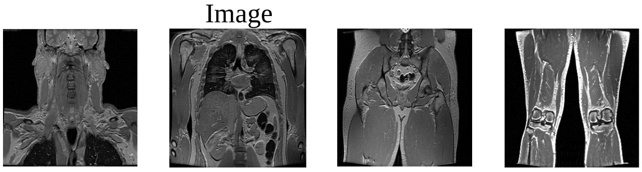
This section presents analysis and experimental findings to determine the effectiveness of the Rolling Guidance Filter in unsharp masking and to develop a practical method for improving medical images. Using MATLAB simulation software, the proposed UMF employing RGF and other image sharpening methods based on TUMF, AUMF, ADUMF, and GUMF were realized. The experiment was run using an Intel Pentium CPU4417U, which is running at 2.3 GHz. Four sets of MRI PD images that were downloaded from the internet were used to test these methods [12]. Spatial Frequency (SF), Mean Gradient, and Sharpness are the factors taken into account for the analysis [9–11]. The comparison results are given in Tab I, and output of various image enhancement methods are shown in Fig 3.

V. Conclusion

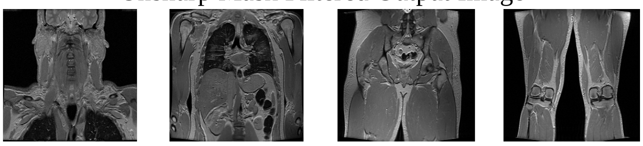
This research introduces a new technique to enhance medical images based on rolling guidance filter in unsharp masking. The proposed approach significantly enhances the high frequency information such as edges and details in MRI PD images while preventing overshoot effect. TUMF, AUMF, ADUMF, and GUMF are compared with the proposed technique. The proposed technique improves the contrast and edge details of MRI PD pictures. Three well-known metrics—SF, Mean Gradient, and Sharpness—are also used to quantitatively assess the accuracy of the obtained results. As can be observed from the results, the proposed rolling guidance filter based enhancement approach produced satisfactory results and outperformed other UMFs in terms of qualitative and quantitative evaluation.



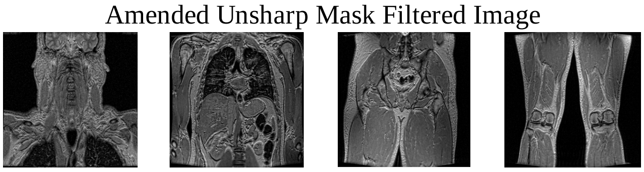
Thorax PD Input Image | Abdomen PD Input Image | Pelvis PD Input Image | Thigh PD Input mage



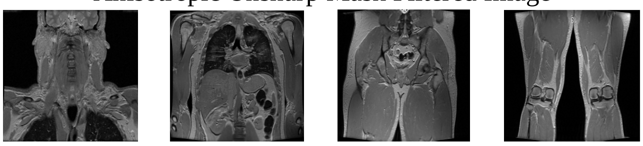
Unsharp Mask Filtered Output Image



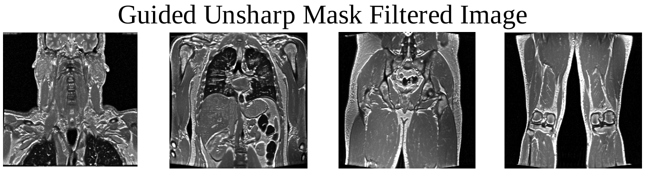
Amended Unsharp Mask Filtered Image



Anisotropic Unsharp Mask Filtered Image



Guided Unsharp Mask Filtered Image



Proposed Filtered Output Image

Fig 3 : Results of Image Enhancement

TABLE 1

RESULTS OF IMAGE ENHANCEMENT

Metrics	Throax PD Image					
	Original	UMF	AUMF	ADUMF	GUMF	Proposed
SF	15.3905	22.5162	20.3571	26.9503	56.3801	39.2728
Gradient	10.3543	15.2805	13.9804	20.9066	42.38	24.4679
Sharpness	8.2756	11.4709	10.3833	15.0085	31.1427	19.3487
Abdomen PD Image						
SF	19.1055	28.0799	25.3461	36.605	39.036	47.8743
Gradient	13.0478	19.3497	17.502	27.8541	26.905	30.6226
Sharpness	10.446	14.5273	13.0539	20.335	20.2169	24.2588
Pelvis PD Image						
SF	16.807	24.2375	22.0889	28.5289	33.5784	38.8438
Gradient	9.727	14.2861	13.0173	19.8507	19.7842	21.8899
Sharpness	7.8652	10.8217	9.7893	14.5381	14.9451	17.3835
Thigh PD Image						
SF	18.6035	25.8226	24.0939	25.4184	33.3953	40.5859
Gradient	9.7279	13.7889	12.8833	16.9821	18.6271	23.3899
Sharpness	7.8932	10.4691	9.6644	12.3556	13.9128	16.4621

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