ANALYSIS AND COMPARISON OF EDGE PRESERVING FILTERING USING BILATERAL FILTERING OF IMAGES WITH GAUSSIAN KERNELS AND ANISOTROPIC DIFFUSION FILTERING

Shafinaz filwa S[1], Nithya selvakumari. S[2*]

Article History: Received: 12.12.2022 **Revised:** 29.01.2023 **Accepted:** 15.03.2023

Abstract

Aim: This work aims at developing an artificial intelligence tool which focuses on enhancing the quality of input images. Edge-preserving filter is used for image smoothing and enhancement in image preprocessing stage. Innovative edge preserving filters such as bilateral filtering and anisotropic diffusion filtering design have been attempted in this work.

Materials and Methods: In this research, a bilateral filter for edge preserving in images is proposed and developed for collected images and the proposed work is compared with another innovative edge preserving method called anisotropic diffusion filtering method. Input images (N=20) of both groups were downloaded from standard medical database kaagle.com. The enrolment ratio is obtained as 1 with 95% confidence interval and a threshold value 0.05.

Results: The performance of image enhancement is measured using two parameters namely PSNR and SSIM. These parameters are calculated and evaluated to assess the proposed methods efficacy. High values of PSNR and SSIM indicate better edge preserving filtering. Bilateral filtering provides the mean PSNR (p=0.536) value of 20.247 and mean SSIM (p=0.083) value of 0.9441. Anisotropic diffusion filtering provides the mean PSNR value of 30.423 and mean SSIM value of 0.9079.

Conclusion: Based on the experiments results from MATLAB software and from independent sample t-test results of IBM-SPSS software, edge preserving filtering using bilateral filtering significantly performed better than the anisotropic diffusion filtering.

Keywords: Innovative edge preserving filtering, Bilateral filtering, Anisotropic Diffusion filtering, Peak Signal to Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM), Artificial Intelligence.

[1]Research Scholar, Department of Biomedical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu. India. Pincode: 602105.

[2*]Project Guide, Department of Biomedical Engineering ,Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu. India. Pincode: 602105.

1. Introduction

Edge-preserving image filtering is an essential task in computational photography and imaging. Filtering is the most fundamental operation of image processing and computer vision (Plataniotis and Venetsanopoulos 2013). In the broadest sense of the term "filtering" the value of the filtered image at a given location is a function of the values of the input image in a small neighborhood of the same location (Dejace 1989). Artificial intelligence plays a major role in image filtering. Edge-preserving filters are designed to automatically limit the smoothing at edges in images measured, e.g., by high gradient magnitudes (Jin et al. 2021). Image filtering is done to improve the quality of the image. For example, smoothing an image reduces noise and blurred images can be rectified. There are broadly two types of algorithms, linear and nonlinear (Saha and Xu 2010). One of the most widely used filters to remove the noise while preserving edges is bilateral filter. Averaging filters and gaussian filters work well in applications where the amount of noise is less. However, when the noise is present in high amount, it requires average pixels to remove the noise, the above two filters over-smooth sharp edges and corners (Thiruvikraman 2019; Chen 2008). Artificial intelligence has many applications in image processing. For example, developing computer aided diagnosis systems that help doctors in interpreting images of X-ray and MRI. MATLAB provides artificial intelligence capabilities similar to those of dedicated artificial intelligence tools like Caffe and TensorFlow. MATLAB helps to integrate artificial intelligence into the complete workflow for developing a fully engineered system. The over-smoothing can be avoided using anisotropic diffusion filter, where the amount of smoothing is controlled using the image features (Nie and Unbehauen, n.d.). Bilateral filtering is a technique to smooth images while preserving edges. The use of bilateral filtering has grown rapidly (Bhonsle, Chandra, and Sinha 2012). Bilateral filters can be traced back to 1995 with the work of Aurich and Weule on nonlinear gaussian filters. It was later rediscovered by Smith and Brady in 2017 as part of their SUSAN framework, and Tomasi and Manduchi who gave it its current name.

There are 265 articles in ScienceDirect and 2876 articles in Scopus related to edge preserving filtering using bilateral filtering. Since then, the use of bilateral filtering has grown rapidly and is now ubiquitous in image processing applications. It has been used in various contexts such as denoising, texture editing and relighting, tone management, demosaicing, stylization and optical-flow estimation (Paris et al. 2009). The bilateral filter is a nonlinear filter that does spatial averaging without smoothing edges. It has shown to be an effective image denoising technique. It can also be applied to the blocking artifacts reduction (Aizawa, Sakaue, and Suenaga 2004). An important issue with the application of the bilateral filter is the selection of the filter parameters, which affect the results significantly. Another research interest of bilateral filters is acceleration of the computation speed (Zhang 2009). The anisotropic diffusion filtering was proposed to adaptively remove the noise and to maintain the image edges. Anisotropic diffusion filtering has been successfully employed in the context of image processing to remove high frequency noise while conserving the main edges of existing objects. It was used in the context of medical resonance imaging (Palma et al. 2014).

Our institution is passionate about high quality evidence based research and has excelled in various domains (Vickram et al. 2022; Bharathiraja et al. 2022; Kale et al. 2022; Sumathy et al. 2022; Thanigaivel et al. 2022; Ram et al. 2022; Jothi et al. 2022; Anupong et al. 2022; Yaashikaa, Keerthana Devi, and Senthil Kumar 2022; Palanisamy et al. 2022).Based on the above studies it is found that color images can be enhanced further by improving contrast to enhance the quality of any input images. Artificial intelligence contributes to the improvement of image quality and this research works on two artificial intelligence algorithms. This research aimed at improving the quality of color images using an innovative edge preserving filters called bilateral filtering and anisotropic diffusion filtering.

2. Materials and Methods

This study was carried out in the Saveetha School of Engineering's simulation lab. The study does not require ethical approval. MATLAB software was installed on the computer. The study is divided into two groups. Group one is edge preserving filtering using bilateral filtering of images with gaussian kernels and group two is edge preserving filtering using anisotropic diffusion filtering. Each group has a sample size of 20 (Thiruvikraman 2019). Total 20 images were collected as a collection of 5 medical images, 5 satellite images, 5 nature images and 5 microscopic images in which medical image and microscopic image were collected from standard database website kaagle.com (Pandra 2020). The threshold value is set to 0.05 and the confidence interval is 95% .

Sample preparation for two groups was done by collecting 20 images as a collection of 5 medical images, 5 satellite images, 5 nature images and 5 microscopic images. In this work the proposed

algorithms are innovative edge preserving filtering using bilateral filtering of images with gaussian kernels and anisotropic diffusion filtering. Testing setup was done by installing the MATLAB R2021a software.

First the input images were collected and a MATLAB code was implemented for edge preserving filtering using bilateral filtering of images with gaussian kernels and anisotropic diffusion filtering. Output images were obtained. An additional code was added to the algorithm codingfor both methods to find which algorithm performed significantly better for enhancing images. The steps involved in the bilateral filtering algorithm are shown in Fig. 1 and the steps involved in anisotropic diffusion filtering algorithm are shown in Fig. 2.

PSNR is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed as a logarithmic quantity using the decibel scale. Which is given in equation (1). (Lee 2015)

$$PSNR = 10\ log\ \frac{(L-1)^2}{MSE} \quad \text{- (1)}$$

Here, L is the number of maximum possible intensity levels (minimum intensity level supposed to be 0) in an image. MSE is the mean squared error.

SSIM is used for measuring the similarity between two images. SSIM is a perceptual metric that quantifies image quality degradation caused by pre-processing methods including data compression or by losses in data transmission.It is a metric that requires two images i.e the input image and a processed input image. SSIM is usually used in the video industry, but it has a strong application in photography. SSIM mathematically written as in equation (2). (Bovik 2009)

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)} \quad \text{- (2)}$$

Statistical Analysis

Statistical analysis was used to verify the results of both algorithms using IBM-SPSS software. The independent samples t-test for the two independent variables Peak signal to Noise Ratio (PSNR) and Structural Similarity Index Measure (SSIM) was used because the two algorithms are independent of one another. There is no dependent variable involved in this study.

3. Results

Input images such as medical image, microscopic image, nature image and satellite image are considered and shown in Fig. 3a, Fig. 3c, Fig. 3e and Fig. 3g respectively. The bilateral filtering algorithm is applied to the images and results of medical image, microscopic image, nature image and satellite image for bilateral filtering algorithm are shown in Fig. 3b, Fig. 3d, Fig. 3f and Fig. 3h respectively. The simulation results of anisotropic diffusion filtering for the same input images is shown in Fig. 4. The anisotropic diffusion filter algorithm is applied for input images Fig. 4a, Fig. 4c, Fig. 4e and Fig. 4g and the results are shown in Fig. 4b, Fig. 4d, Fig. 4f and Fig. 4h.

The outcomes such as PSNR and SSIM of both algorithms are tabulated in Table 1 and the values of PSNR and SSIM parameters for medical image, microscopic image, nature image and satellite images for bilateral filtering is higher than anisotropic diffusion filtering. Table 2 shows the mean and standard deviation of PSNR and SSIM values of bilateral filtering algorithm and anisotropic diffusion filtering algorithm. The mean value of bilateral filtering and anisotropic diffusion filtering PSNR is 20.247 and 30.423 respectively. The mean values of bilateral filtering and anisotropic diffusion filtering SSIM is 0.944 and 0.907 respectively. Where the mean value of anisotropic diffusion filtering PSNR is high and the mean value of bilateral filtering SSIM is high. The significance of PSNR and SSIM of both algorithms are tabulated in Table 3. The P values of PSNR is 0.536 and SSIM is 0.083, it is considered insignificant as the values are above 0.05.

Figure 5 consists of a bar chart representing the comparison of mean PSNR of bilateral filtering and anisotropic diffusion filtering. Figure 6 consists of a bar chart representing the comparison of mean SSIM of bilateral filtering and anisotropic diffusion filtering.

4. Discussion

Based on independent sample t-test results, the bilateral filtering method performed better than anisotropic diffusion filtering method with insignificant Peak Signal to Noise Ratio (PSNR) values (P=0.536; P>0.05) and insignificant Structural Similarity Index Measure (SSIM) values (P=0.083; P>0.05).

Medical image denoising using bilateral filters are proposed and they apply bilateral filtering on medical images which are corrupted by additive white gaussian noise with different values of variances. Artificial intelligence is used in

denoising of images. (Bhonsle, Chandra, and Sinha 2012) demonstrated the efficacy, various performance and quality parameters such as peak signal to noise ratio were evaluated. On conducting the experiment, a high value of peak signal to noise ratio was obtained. Hence it is clear that bilateral filtering gives better performance to remove additive white gaussian noise. (Liu et al. 2018) performed analysis on the performance of bilateral filters in multifocus image fusion. Initially, each input image was decomposed into approximation and detailed images by employing edge preserving techniques. Secondly, approximation and detail images were fused by employing separate fusion rules. Finally, the fused image was reconstructed by combining the final fused approximation and detail images. The results of this study was found to be effective. (Guan et al. 2014) worked on anisotropic diffusion filtering for ultrasound speckle reduction. They implemented the filters in MATLAB and the study has shown that anisotropic diffusion filters can reduce noise effectively while preserving the boundaries of objects without enhancement. This filter increases the signal to noise ratio and contrast to noise ratio and decreases the variance of the image as well, but it was found to have some artifacts.

The quality of a medical image is determined by the imaging method, the characteristics of the equipment and the imaging variables selected by the operator. Image quality can be degraded by factors such as low contrast, high blur, high noise, high artifacts and high distortions. When some algorithms are applied to input images, noise is introduced, images are blurred as a result of incorrect placement of imaging sensors. Artifacts occur when power sources affect interference in image pixels and when processing parameters are not correctly configured for the raw image. These are the limitations and are solved by using suitable preprocessing techniques. As this study involves 20 samples for each group, insignificant results of peak signal to noise ratio and structural similarity index measure may be obtained. The results obtained are insignificant in peak signal to noise ratio and structural similarity index measure because the algorithm is directly to the input images without using any preprocessing methods. In the future, three dimensional images can be used for image enhancement by preserving the edges and also transform based enhancement techniques can be applied to improve the quality of image further.

5. Conclusion

Edge preserving filtering using bilateral filters significantly performed better than anisotropic diffusion filtering by the use of innovative edge preserving techniques.

Declarations

Conflict of interests

No conflict of interest in this manuscript.

Authors Contributions

Author SFS was involved in image collection, algorithm development, image analysis, manuscript writing. Author SN was involved in conceptualization, data validation, and critical review of manuscript.

Acknowledgements

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding

We thank the following organizations for providing financial support that enabled us to complete the study.

1. MBC CapFin Services Pvt.Ltd.,Vijayawada
2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences
4. Saveetha School of Engineering.

6. References

Aizawa, Kiyoharu, Katsuhiko Sakaue, and Yasuhito Suenaga. 2004. *Image Processing Technologies: Algorithms, Sensors, and Applications*. CRC Press.

Anupong, Wongchai, Lin Yi-Chia, Mukta Jagdish, Ravi Kumar, P. D. Selvam, R. Saravanakumar, and Dharmesh Dhabliya. 2022. "Hybrid Distributed Energy Sources Providing Climate Security to the Agriculture Environment and Enhancing the Yield." *Sustainable Energy Technologies and Assessments*. https://doi.org/10.1016/j.seta.2022.102142.

Bharathiraja, B., J. Jayamuthunagai, R. Sreejith, J. Iyyappan, and R. Praveenkumar. 2022. "Techno Economic Analysis of Malic Acid Production Using Crude Glycerol Derived from Waste Cooking Oil." *Bioresource Technology* 351 (May): 126956.

Bhonsle, Devanand, Vivek Chandra, and G. R. Sinha. 2012. "Medical Image Denoising Using Bilateral Filter." *International Journal of Image Graphics and Signal Processing* 4

(6): 36–43.

Bovik, Alan C. 2009. *The Essential Guide to Image Processing*. Academic Press.

Chen, Jia-Xin. 2008. "Watershed Segmentation Algorithm for Medical Image Based on Anisotropic Diffusion Filtering." *Journal of Computer Applications*. https://doi.org/10.3724/sp.j.1087.2008.01527.

Dejace, J. 1989. "Image Processing Techniques: Filtering, Exogenous Data, Geometrical Processing." *Applications of Remote Sensing to Agrometeorology*. https://doi.org/10.1007/978-94-009-2235-8_5.

Guan, Fada, Phuc Ton, Shuaiping Ge, and Lina Zhao. 2014. "Anisotropic Diffusion Filtering for Ultrasound Speckle Reduction." *Science China Technological Sciences*. https://doi.org/10.1007/s11431-014-5483-7.

Jin, Wangyan, Ling Dai, Liuyan Ge, Xuhua Huang, Guanhua Xu, Chunhong Qu, and Jianfei Sun. 2021. "Wavelet Transform Image Enhancement Algorithm-Based Evaluation of Lung Recruitment Effect and Nursing of Acute Respiratory Distress Syndrome by Ultrasound Image." *Journal of Healthcare Engineering* 2021 (September): 8960465.

Jothi, K. Jeeva, K. Jeeva Jothi, S. Balachandran, K. Mohanraj, N. Prakash, A. Subhasri, P. Santhana Gopala Krishnan, and K. Palanivelu. 2022. "Fabrications of Hybrid Polyurethane-Pd Doped ZrO2 Smart Carriers for Self-Healing High Corrosion Protective Coatings." *Environmental Research*. https://doi.org/10.1016/j.envres.2022.113095.

Kale, Vaibhav Namdev, J. Rajesh, T. Maiyalagan, Chang Woo Lee, and R. M. Gnanamuthu. 2022. "Fabrication of Ni–Mg–Ag Alloy Electrodeposited Material on the Aluminium Surface Using Anodizing Technique and Their Enhanced Corrosion Resistance for Engineering Application." *Materials Chemistry and Physics*. https://doi.org/10.1016/j.matchemphys.2022.125900.

Lee, Junhaeng. 2015. "PSNR Analysis of Ultrasound Images for Follow-up of Hepatocellular Carcinoma." *Journal of the Korean Society of Radiology*. https://doi.org/10.7742/jksr.2015.9.5.263.

Liu, Dong, Dongming Zhou, Rencan Nie, and Ruichao Hou. 2018. "Multi-Focus Image Fusion Using Cross Bilateral Filter in NSCT Domain." *Proceedings of the 3rd International Conference on Multimedia and Image Processing - ICMIP 2018*. https://doi.org/10.1145/3195588.3195607.

Nie, X., and R. Unbehauen. n.d. "Edge Preserving Filtering by Combining Nonlinear Mean and Median Filters." *IEEE International Symposium on Circuits and Systems*. https://doi.org/10.1109/iscas.1989.100384.

Palanisamy, Rajkumar, Diwakar Karuppiah, Subadevi Rengapillai, Mozaffar Abdollahifar, Gnanamuthu Ramasamy, Fu-Ming Wang, Wei-Ren Liu, Kumar Ponnuchamy, Joongpyo Shim, and Sivakumar Marimuthu. 2022. "A Reign of Bio-Mass Derived Carbon with the Synergy of Energy Storage and Biomedical Applications." *Journal of Energy Storage*. https://doi.org/10.1016/j.est.2022.104422.

Palma, Caio A., Fábio A. M. Cappabianco, Jaime S. Ide, and Paulo A. V. Miranda. 2014. "Anisotropic Diffusion Filtering Operation and Limitations - Magnetic Resonance Imaging Evaluation." *IFAC Proceedings Volumes*. https://doi.org/10.3182/20140824-6-za-1003.02347.

Pandra, Sushree. 2020. *Analysing of Medical Dataset Using Machine Learning*.

Paris, Sylvain, Pierre Kornprobst, Jack Tumblin, and Frédo Durand. 2009. *Bilateral Filtering: Theory and Applications*. Now Publishers Inc.

Plataniotis, Konstantinos N., and Anastasios N. Venetsanopoulos. 2013. *Color Image Processing and Applications*. Springer Science & Business Media.

Ram, G. Dinesh, G. Dinesh Ram, S. Praveen Kumar, T. Yuvaraj, Thanikanti Sudhakar Babu, and Karthik Balasubramanian. 2022. "Simulation and Investigation of MEMS Bilayer Solar Energy Harvester for Smart Wireless Sensor Applications." *Sustainable Energy Technologies and Assessments*. https://doi.org/10.1016/j.seta.2022.102102.

Saha, Punam K., and Ziyue Xu. 2010. "An Analytic Approach to Tensor Scale with an Efficient Algorithm and Applications to Image Filtering." *2010 International Conference on Digital Image Computing: Techniques and Applications*. https://doi.org/10.1109/dicta.2010.79.

Sumathy, B., Anand Kumar, D. Sungeetha, Arshad Hashmi, Ankur Saxena, Piyush Kumar Shukla, and Stephen Jeswinde Nuagah. 2022. "Machine Learning Technique to Detect and Classify Mental Illness on Social Media Using Lexicon-Based Recommender System." *Computational Intelligence and Neuroscience* 2022 (February): 5906797.

Thanigaivel, Sundaram, Sundaram Vickram, Nibedita Dey, Govindarajan Gulothungan, Ramasamy Subbaiya, Muthusamy Govarthanan, Natchimuthu Karmegam, and

Woong Kim. 2022. "The Urge of Algal Biomass-Based Fuels for Environmental Sustainability against a Steady Tide of Biofuel Conflict Analysis: Is Third-Generation Algal Biorefinery a Boon?" *Fuel*. https://doi.org/10.1016/j.fuel.2022.123494.

Thiruvikraman, P. K. 2019. "Introduction to MATLAB®." *A Course on Digital Image Processing with MATLAB®*. https://doi.org/10.1088/978-0-7503-2604-9ch9.

Vickram, Sundaram, Karunakaran Rohini, Krishnan Anbarasu, Nibedita Dey, Palanivelu Jeyanthi, Sundaram Thanigaivel, Praveen Kumar Issac, and Jesu Arockiaraj. 2022. "Semenogelin, a Coagulum Macromolecule Monitoring Factor Involved in the First Step of Fertilization: A Prospective Review." *International Journal of Biological Macromolecules* 209 (Pt A): 951–62.

Yaashikaa, P. R., M. Keerthana Devi, and P. Senthil Kumar. 2022. "Algal Biofuels: Technological Perspective on Cultivation, Fuel Extraction and Engineering Genetic Pathway for Enhancing Productivity." *Fuel*. https://doi.org/10.1016/j.fuel.2022.123814.

Zhang, Ming. 2009. *Bilateral Filter in Image Processing*.

Tables and Figures

Table 1. Performance parameters such as PSNR, SSIM of two algorithms namely bilateral filtering and anisotropic diffusion filtering are tabulated. Bilateral filtering provides maximum PSNR (87.1416)dB and SSIM (100)% and anisotropic diffusion filtering provides PSNR (46.1373)dB and SSIM (99.46)%.

INPUT IMAGES	**BILATERAL FILTERING ALGORITHM**		**ANISOTROPIC DIFFUSION FILTERING ALGORITHM**	
	PSNR	**SSIM**	**PSNR**	**SSIM**
Medical Image-1	28.832	86.530	26.169	88.630
Medical Image-2	41.105	94.410	32.914	94.240
Medical Image-3	87.141	100	40.442	97.420
Medical Image-4	27.732	92.410	29.447	93.900
Medical Image-5	32.560	84.410	23.877	78.400
Microscopic Image-1	40.083	99.140	42.633	99.460
Microscopic Image-2	48.087	99.240	46.137	99.100
Microscopic Image-3	40.586	99.820	43.946	99.900

Microscopic Image-4	35.778	98.590	37.919	99.130
Microscopic Image-4	30.300	91.180	29.532	92.370
Satellite Image-1	39.448	99.360	26.279	96.210
Satellite Image-2	32.544	97.460	31.981	98.240
Satellite Image-3	28.240	93.020	26.122	93.160
Satellite Image-4	32.549	97.760	22.476	87.790
Satellite Image-5	32.549	98.760	28.764	93.940
Nature Image-1	28.933	86.520	25.242	88.090
Nature Image-2	27.782	85.820	21.901	61.190
Nature Image-3	32.687	95.720	23.706	78.510
Nature Image-4	34.621	93.620	26.979	83.480
Nature Image-5	23.383	94.330	21.997	92.540

Table 2. Comparison of innovative edge preserving filtering using bilateral filtering of images with gaussian kernels and anisotropic diffusion filtering based on PSNR and SSIM values. The PSNR and SSIM values of the bilateral filtering method are high when compared to the anisotropic diffusion filtering method. The mean value of anisotropic diffusion filtering PSNR is high (30.423) and the mean value of bilateral filtering SSIM is high (0.944). The standard deviation of bilateral filtering PSNR is high (13.348) and the standard deviation of anisotropic diffusion filtering SSIM is high (0.095).

GROUP	**N**	**MEAN**	**STD. DEVIATION**	**STD. ERROR MEAN**

PSNR	BILATERAL FILTERING	20	20.247	13.348	2.984
PSNR	ANISOTROPIC DIFFUSION	20	30.423	7.731	1.728
SSIM	BILATERAL FILTERING	20	0.944	0.051	0.011
SSIM	ANISOTROPIC DIFFUSION	20	0.907	0.095	0.021

Table 3. Independent sample T-test comparison of PSNR, SSIM of edge preserving filtering using bilateral filtering of images with gaussian kernels and anisotropic diffusion filtering. The P values of PSNR is 0.536 and SSIM is 0.083, it is considered insignificant as the values are above 0.05.

Levene's Test for Equality of Variances				**t**	**df**	**Sig(1-sided p)**	**Sig(2-sided p)**	**t-test Equality of Means**		**95% Confidence interval of the Difference**	
		F	**Sig**					**Mean Diff**	**Std.Err Diff**	**Lower**	**Upper**
PSNR	Equal variances assumed	0.390	0.536	1.688	38	0.050	0.100	5.823	3.449	-1.159	12.806
	Equal variances not assumed			1.688	30.450	0.051	0.102	5.823	3.449	-1.216	12.863

SSIM	Equal variances assumed	3.165	0.083	1.495	38	0.072	0.143	0.0362	0.024	-0.0128	0.085
	Equal variances not assumed			1.495	29.240	0.073	0.146	0.036	0.024	-0.013	0.08570

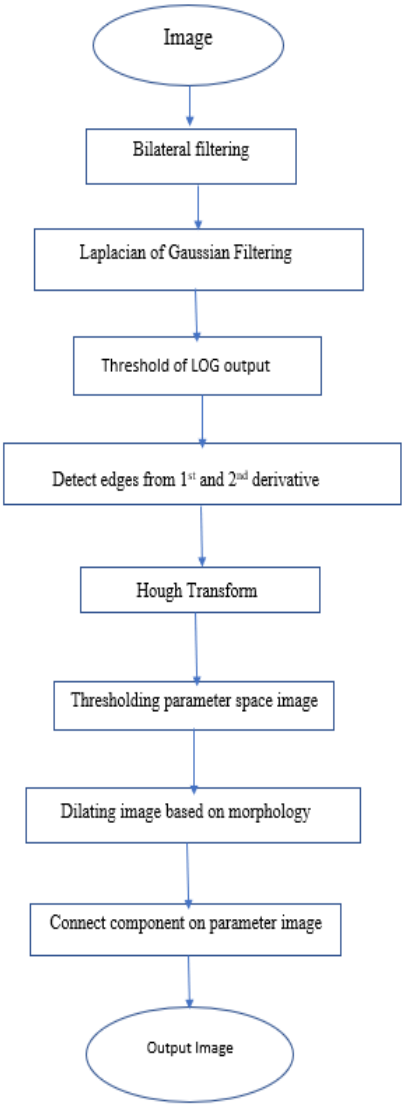


Fig. 1. Steps Involved in Bilateral Filtering Algorithm

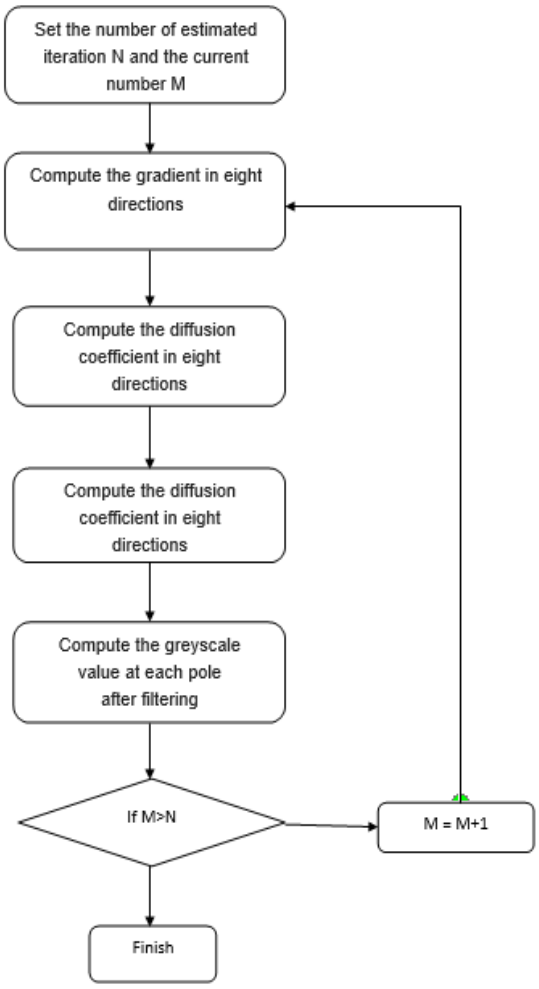
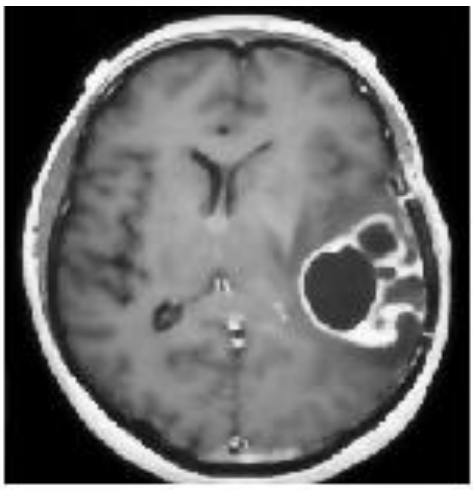
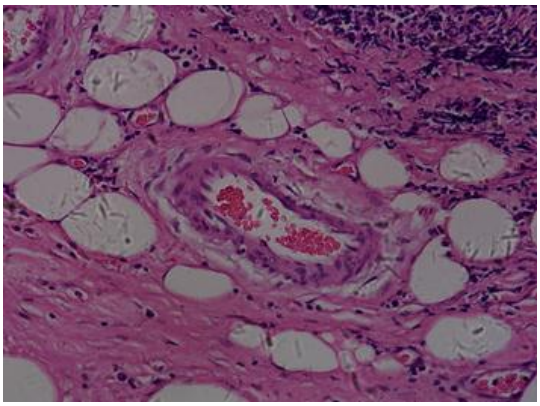


Fig. 2. Steps Involved in Anisotropic Diffusion Filtering algorithm

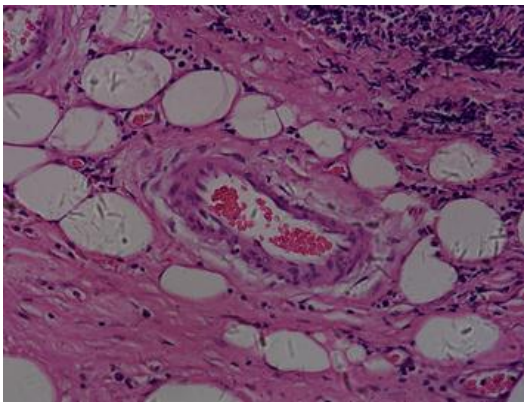
(a)



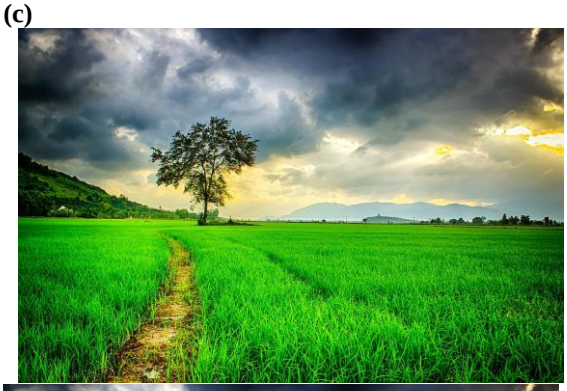
(b)



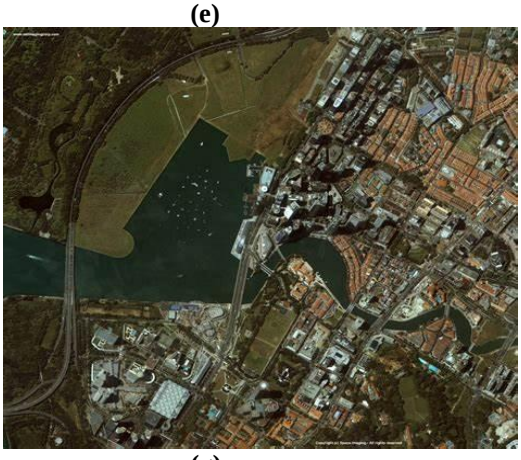
(c)



(d)



(e) **(f)**



(g) **(h)**

Fig. 3. Simulation results of innovative edge preserving filtering using bilateral filtering method. (a) Input image (medical image) (b) enhanced image of (medical image) (c) Input image (microscopic image) (d) enhanced image of (microscopic image) (e) Input image (nature image) (f) enhanced image of (nature image) (g) Input image (satellite image) and (h) enhanced image of (satellite image)

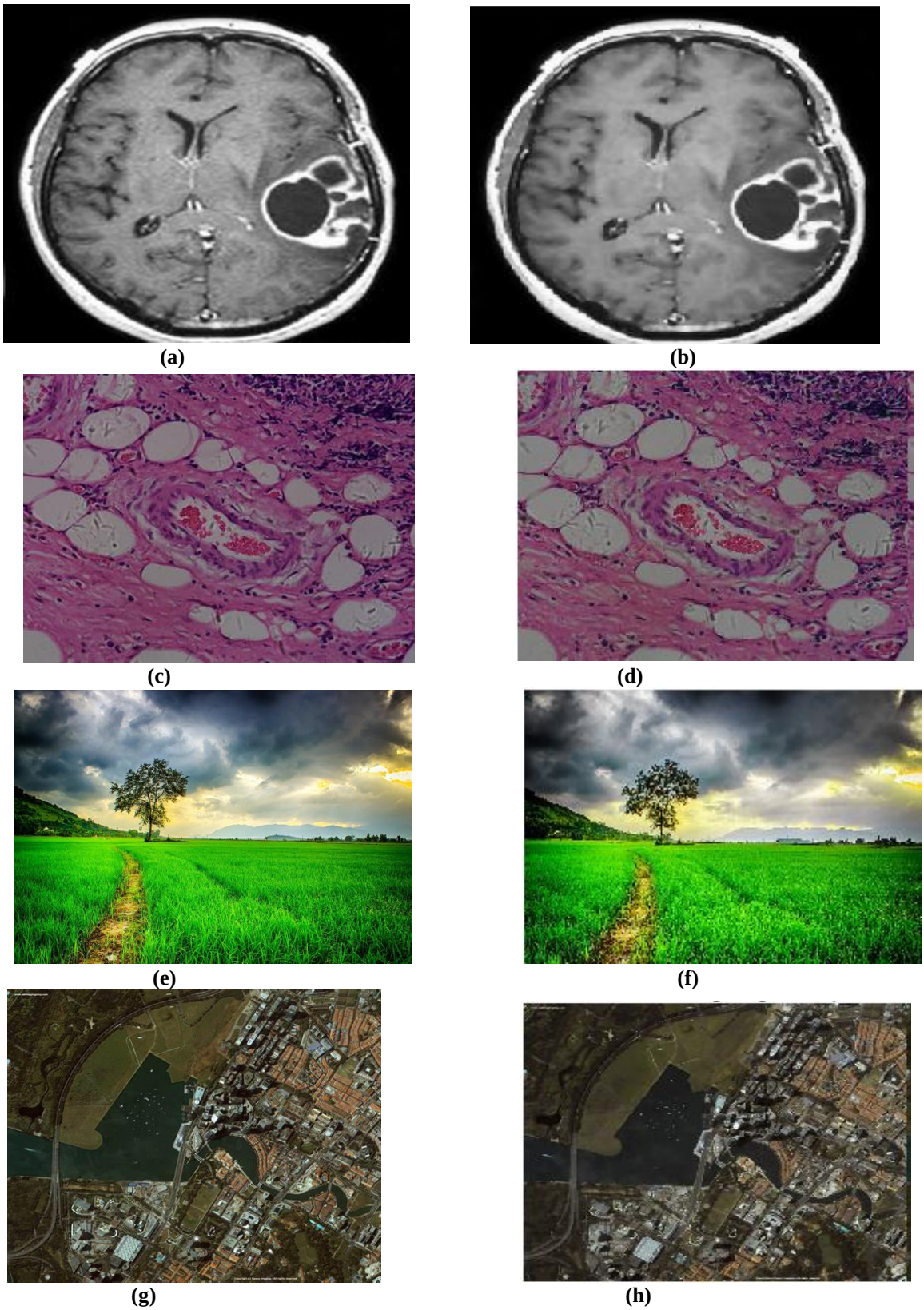


Fig. 4. Simulation results of innovative edge preserving filtering using anisotropic diffusion filtering method. (a) Input image (medical image) (b) enhanced image of (medical image) (c) Input image (microscopic image) (d) enhanced image of (microscopic image) (e) Input image (nature image) (f) enhanced image of (nature image) image (g) Input image (satellite image) and (h) enhanced image of (satellite image).

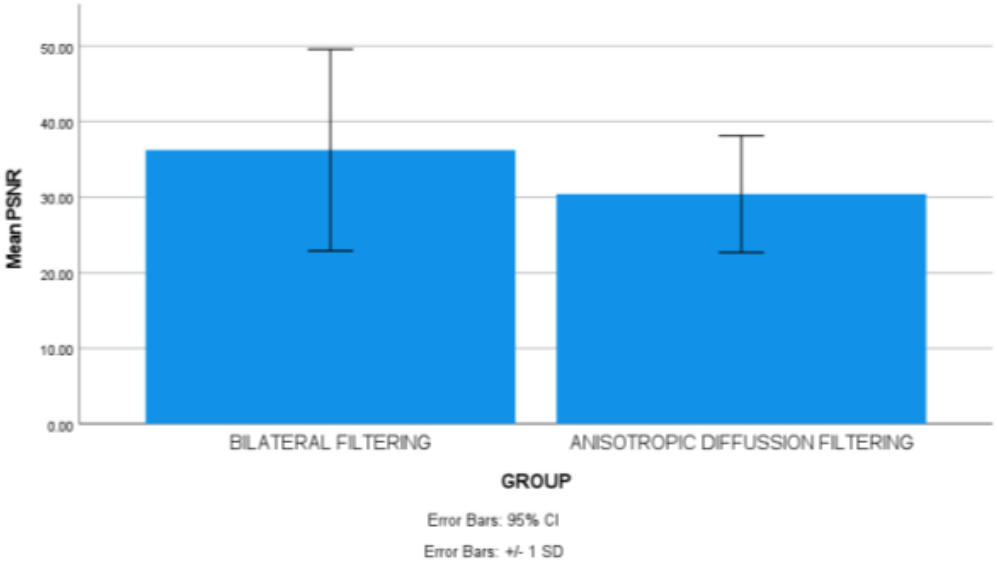


Fig. 5. Bar chart representing the comparison of mean PSNR (+/-1 SD) of bilateral filtering and anisotropic diffusion filtering. Bilateral appears to produce most variable results with its standard deviation ranging from the lower 22.00 to the upper 50.00 and anisotropic diffusion filter appears to produce consistent results with minimal standard deviation. X-axis represents groups bilateral filtering vs anisotropic diffusion filtering and Y-axis represents Mean PSNR with +/-1 SD.

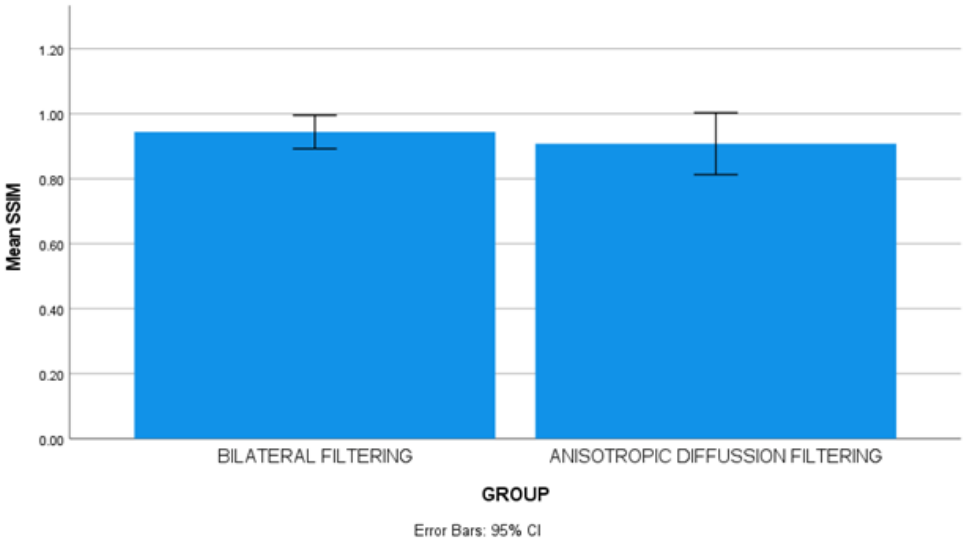


Fig. 6. Bar chart representing the comparison of mean SSIM (+/-1 SD) of bilateral filtering and anisotropic diffusion filtering. Anisotropic diffusion filtering appears to produce most variable results with its standard deviation ranging from the lower 0.80 to the upper 1.00 and bilateral filtering appears to produce consistent results with minimal standard deviation. X-axis represents groups bilateral filtering vs anisotropic diffusion filtering and Y-axis represents Mean SSIM with +/-1 SD.