ANALYSIS AND COMPARISON OF DECORRELATION STRETCH ALGORITHM FOR IMPROVING THE QUALITY OF COLOR IMAGE OVER CONTRAST STRETCHING ALGORITHM

Farjees Fathima A[1], Nithyaselvakumari. 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**.** Contrast stretching, also called normalization, is a simple image enhancement technique that attempts to improve the contrast in an image by 'stretching' the range of intensity values it contains to span a desired range of values, the full range of pixel values that the image type concerned allows. In order to enhance the quality of color images an innovative decorrelation stretching algorithm technique is developed in this work.
Materials and Methods: In this research, an innovative decorrelation stretching algorithm is proposed and developed for improving the quality of color images and the proposed work is compared with another image enhancement technique called contrast stretching method. Input medical images (N=20) of both groups were downloaded from standard medical databases. The enrollment 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 enhancement. High values of PSNR and SSIM indicate better contrast stretching algorithm. Decorrelation stretching algorithm provides the mean PSNR (p=0.006) value of 19.696 and mean SSIM (p=0.004) value of 0.752. Contrast stretching algorithm provides the mean PSNR (p=0.006) value of 21.572 and mean SSIM (p=0.004) value of 0.968.
Conclusion: Based on the experiments results from MATLAB software and from independent sample t-test results of IBM-SPSS software, the innovative decorrelation stretching algorithm based image enhancement technique significantly performed better than the contrast stretching algorithm based image enhancement technique with Peak Signal to Noise Ratio and Structural Similarity Index Measure.

Keywords: Innovative decorrelation stretching algorithm, Contrast stretching, Normalization, 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

Contrast stretching, also called normalization, is an image enhancement method which attempts to improve an image by stretching the range of intensity values (Sangwine and Horne 2012). Enhancement is used to highlight distinguishing characteristics such as mass and microcalcifications, as well as to draw attention to specific characteristics for early detection and diagnosis (Al-Ameen 2018). In image processing, normalization is a process that changes the range of pixel intensity values. It is a process often used in the preparation of data sets for artificial intelligence. 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. Image enhancement is used in any field where images must be interpreted and analyzed, such as medical image analysis, satellite image analysis (Karvelis and Fotiadis 2008).

There are 2876 articles in ScienceDirect and 131 articles in Scopus. Normalization is the same as histogram stretching. Artificial intelligence has many applications in image processing for developing computer aided diagnosis systems that help doctors in interpreting medical images. The decorrelation stretch originated as an adaptation and extension of two closely related data transformation techniques: the principal component transformation and the Karhunen- Loeve transformation. The Karhunen-Loeve transformation is a linear transformation ("rotation") in multi-dimensional space, with the transformation vectors being defined as the eigenvectors of the covariance matrix of the original data (Poon and Banerjee 2001; Yang and Ruan 2021). The principal component transformation is similar, except that the transformation vectors are derived from the correlation matrix rather than the covariance matrix (Jeon and Incheon National University 2013). When the variances of the individual input variables are the same, the results of these two transformations are identical. The principal component transformation provides a straightforward method of removing the correlation from multispectral image data, and has the added benefit of providing a method of reducing the dimensionality of multispectral images. The decorrelation stretch is a process to enhance the color differences found in a color image by a method that includes the removal of the inter-channel correlation found in the input pixels, hence, the term "decorrelation stretch" (Marques 2011; Reyes-Aldasoro 2015). Use of decorrelation stretch to remove the high correlation commonly found in multispectral data sets and to produce a more colorful color composite image. The decorrelation stretch is proposed as a processing technique to be used for browsing data products at reduced resolution, and also as a standard data product for image analysis (Jeon and Incheon National University 2013). The decorrelation stretch algorithm is best suited to the case where the input data of all three channels have a joint distribution that is gaussian or near gaussian in form. The algorithm produces a color enhanced output, if noise is a major component of the scene variation, the algorithm will enhance those noise differences to produce an output (Arpornsuwan and Arpornsuwan 2020).

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 decorrelation stretch algorithm and contrast stretching algorithm.

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 a decorrelation stretch algorithm for improving the quality of color image and group two is a contrast stretching algorithm for improving the quality of color image. Each group has a sample size of 20. 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 kaggle.com (Li and Liu 2021). 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 decorrelation stretch algorithm and contrast stretching algorithm for improving the quality of color image. Testing setup was done by installing the MATLAB R2021a software (Chapman 2015).

First the input images were collected and a MATLAB code was implemented for decorrelation stretch algorithm and contrast stretching algorithm for improving the quality of color image. An additional code was added to the algorithm coding in order to obtain PSNR value and SSIM value. The performance of both algorithms was measured using two parameters namely Peak Signal to Noise Ratio and Structural Similarity Index Measure. These parameters were calculated and evaluated to assess the efficacy and comparison of results were done for both methods to find which algorithm performed significantly better for enhancing images. Steps involved in the decorrelation stretch algorithm are shown in Fig. 1 and the steps involved in contrast stretching algorithm are shown in Fig. 2.

Peak Signal to Noise Ratio (PSNR) is the ratio between the maximum possible power of an image and the power of corrupting noise that affects the quality of its representation. To estimate the Peak Signal to Noise Ratio of an image, it is necessary to compare that image to an ideal clean image with the maximum possible power which is given in equation (1) (Sara, Akter, and Uddin 2019).

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

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.

Structural Similarity Index Measure (SSIM) is a perceptual metric that quantifies image quality degradation caused by processing such as data compression or by losses in data transmission. It is a full reference metric that requires two images from the same image capture a reference image and a processed image. Structural Similarity Index Measure is usually used in the video industry, but it has a strong application in photography. SSIM mathematically written as in equation (2) (Mamun 2019).

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

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

Figure 3 depicts the results of a decorrelation stretch algorithm. 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. These images are applied with an innovative decorrelation stretch algorithm and results of medical image, microscopic image, nature image and satellite image for decorrelation stretch algorithm are shown in Fig. 3b, Fig. 3d, Fig. 3f, Fig. and 3h respectively. The simulation results of a contrast stretching algorithm for the same input images is shown in Fig. 4. The contrast stretching 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 decorrelation stretch algorithm are higher than contrast stretching algorithm. Table 2 gives the mean and standard deviation of PSNR and SSIM values of decorrelation stretch algorithm and contrast stretching algorithm. The significance of PSNR and SSIM of both algorithms are tabulated in Table 3. If the significance of PSNR and SSIM are less than 0.05 then they are considered as significant results.

Figure 5 consists of a bar chart representing the comparison of mean PSNR of decorrelation stretch algorithm and contrast stretching algorithm. Figure 6 consists of a bar chart representing the comparison of mean SSIM decorrelation stretch algorithm and contrast stretching algorithm.

4. Discussion

Based on independent sample t-test results, the innovative decorrelation stretching algorithm performed better than the contrast stretching algorithm for improving the quality of color image with significant Peak Signal to Noise Ratio values

(P=0.006; P<0.05) and significant Structural Similarity Index Measure values (P=0.004; P<0.05).
The decorrelation stretch filter for the reduction of poisson noise that occurs frequently in galaxy images so they proposed a statistical filter (Ferreras 2019). Denoising is carried out for natural and galaxy images with poisson noise using the statistical filters and proposed de-correlation filter. Artificial intelligence is also used in denoising of images. From the results obtained for both natural and galaxy images it has been found that decorrelation stretch provides better results among spatial filters by providing higher PSNR value than any other filter. Uji et al (2019) described the application of the decorrelation stretching method to hyperspectral fundus image processing. The decorrelation stretch is applied to three single-wavelength images with different central wavelengths. It is a remote sensing technique to emphasize image information, reducing or removing the inter-channel correlation. They applied this technique to single-wavelength images of the ocular fundus to separate different tissues such as choroidal and retinal vessels. They concluded that the innovative decorrelation stretching method was successful in enhancing the subtle differences in hue and presented clues for the recognition of the existence and distribution of these diseases. The color image analysis and normalization using histogram equalization is proposed. It is observed from the experimented results that the equalized color image having better contrast than the original image not only enhances the visual quality of the image but also preserves the brightness level (Jeon and Incheon National University 2013).
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, and images are blurred as a result of incorrect placement of imaging sensors (Mitchell 2010). Power sources affect interference in image pixels, resulting in artifacts. These are the limitations and issues can be 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 we applied the algorithm directly to the input images without using any preprocessing methods. In the future, three dimensional images can be used for image enhancement and also transform based enhancement techniques can be applied to improve the quality of image further (Reyes-Aldasoro 2015).

5. Conclusion

It is observed from the results that the Contrast stretching algorithm has significantly better performance than Decorrelation stretch algorithm.

Declarations

Conflict of interests

No conflict of interest in this manuscript.

Authors Contributions

Author FFA 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

6. References

Al-Ameen, Zohair. 2018. "CONTRAST ENHANCEMENT FOR COLOR IMAGES USING AN ADJUSTABLE CONTRAST STRETCHING TECHNIQUE." *International Journal of Computing*. https://doi.org/10.47839/ijc.17.2.993.

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.

Arpornsuwan, Manote, and Matinun Arpornsuwan. 2020. "Invisible Facial Flushing in Two Cases of Dengue Infection and Influenza Detected by PC Program and Smartphone App: Decorrelation Stretching and K-Means Clustering." *Case Reports in Infectious Diseases* 2020 (February): 8790130.

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.

Chapman, Stephen J. 2015. *MATLAB Programming for Engineers*. Cengage Learning.

Ferreras, Ignacio. 2019. *Fundamentals of Galaxy Dynamics, Formation and Evolution*. UCL Press.

Jeon, Gwanggil, and Incheon National University. 2013. "Color Image Processing Using Histogram Analysis." *Advances in Multimedia, Communication and Networking*. https://doi.org/10.14257/astl.2013.31.39.

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.

Karvelis, Petros S., and Dimitrios I. Fotiadis. 2008. "A Region Based Decorrelation Stretching Method: Application to Multispectral Chromosome Image Classification." *2008 15th IEEE International Conference on Image Processing*. https://doi.org/10.1109/icip.2008.4712040.

Li, Chuchen, and Huafeng Liu. 2021. "Medical Image Segmentation with Generative Adversarial Semi-Supervised Network." *Physics in Medicine and Biology* 66 (24). https://doi.org/10.1088/1361-6560/ac3d15.

Mamun, Iftekher. 2019. "Image Classification Using SSIM." Towards Data Science. January 16, 2019. https://towardsdatascience.com/image-classification-using-ssim-34e549ec6e12.

Marques, Oge. 2011. *Practical Image and Video Processing Using MATLAB*. John Wiley & Sons.

Mitchell, H. B. 2010. *Image Fusion: Theories, Techniques and Applications*. Springer Science & Business Media.

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.

Poon, T-C, and P. P. Banerjee. 2001. *Contemporary Optical Image Processing with MATLAB*. Elsevier.

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.

Reyes-Aldasoro, Constantino Carlos. 2015. *Biomedical Image Analysis Recipes in MATLAB: For Life Scientists and Engineers*. John Wiley & Sons.

Sangwine, Stephen J., and Robin E. N. Horne. 2012. *The Colour Image Processing Handbook*. Springer Science & Business Media.

Sara, Umme, Morium Akter, and Mohammad Shorif Uddin. 2019. "Image Quality Assessment through FSIM, SSIM, MSE and PSNR—A Comparative Study." *Journal of Computer and Communications* 7 (3): 8–18.

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.

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.

Yang, Gaoyi, and Litao Ruan. 2021. "Imaging Findings of Prostate Tuberculosis by Transrectal Contrast-Enhanced Ultrasound and Comparison with 2D Ultrasound and Pathology." *The British Journal of Radiology*, September, 20210713.

Table and Figures

Table 1. Performance parameters such as PSNR, SSIM of two algorithms namely Decorrelation stretch algorithm and Contrast stretching algorithm are tabulated. Contrast stretching algorithm provides maximum PSNR (48.130) dB and SSIM (100)%

INPUT IMAGES	**DECORRELATION STRETCHING ALGORITHM**		**CONTRAST STRETCHING ALGORITHM**	
	PSNR	**SSIM**	**PSNR**	**SSIM**
Medical Image-1	20.408	100	18.999	100
Medical Image-2	19.786	100	16.089	52.350
Medical Image-3	18.654	100	17.563	100
Medical Image-4	17.2416	60.870	15.876	100
Medical Image-5	23.709	100	13.158	100
Microscopic Image-1	27.309	81.040	11.708	86.780
Microscopic Image-2	16.865	81.420	23.709	1.00
Microscopic Image-3	16.609	77.08	48.130	1.000
Microscopic Image-4	24.900	92.72	34.789	100
Microscopic Image-4	18.206	56.32	30.306	100

Satellite Image-1	21.212	78.23	27.987	100
Satellite Image-2	20.328	69.23	25.673	100
Satellite Image-3	19.389	64.78	23.521	97.66
Satellite Image-4	21.760	47.34	22.564	100
Satellite Image-5	16.837	53.94	21.987	100
Nature Image-1	17.407	74.81	19.652	100
Nature Image-2	19.077	71.40	18.561	100
Nature Image-3	15.345	40.57	15.098	100
Nature Image-4	22.124	90.29	13.305	100
Nature Image-5	16.753	64.32	12.763	100

Table 2. Comparison of decorrelation stretch algorithm for improving the quality of color image over contrast stretching algorithm based on PSNR and SSIM values. The PSNR and SSIM values of the contrast stretching algorithm are high when compared to the decorrelation stretch algorithm. The mean value is high for the contrast stretching algorithm PSNR (21.572) and SSIM (0.968). The standard deviation is high for contrast stretching algorithm PSNR (8.819) and decorrelation stretch algorithm SSIM (0.182).

GROUP		**N**	**MEAN**	**STD. DEVIATION**	**STD. ERROR MEAN**
PSNR	DECORRELATION STRETCHING	20	19.696	3.102	0.693
PSNR	CONTRAST STRETCHING	20	21.572	8.819	1.972
SSIM	DECORRELATION STRETCHING	20	0.752	0.182	0.040
SSIM	CONTRAST STRETCHING	20	0.968	0.108	0.243

Table 3. Independent sample t-test comparison of PSNR, SSIM of decorrelation stretch algorithm and Contrast stretching algorithm.The P values of PSNR 0.006 and SSIM 0.004, it is considered significant as the values mentioned above are lesser than 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	8.669	0.006	-0.897	38	0.188	0.375	-1.875	2.090	-6.107	2.360
	Equal variances not assumed			-0.897	23.631	0.189	0.379	-1.875	2.090	-6.193	2.442
SSIM	Equal variances assumed	9.373	0.004	-4.546	38	<0.001	<0.001	-0.216	0.047	-0.312	-0.119
	Equal variances not assumed			-4.546	30.972	<0.001	<0.001	-0.216	0.047	-0.313	-0.119

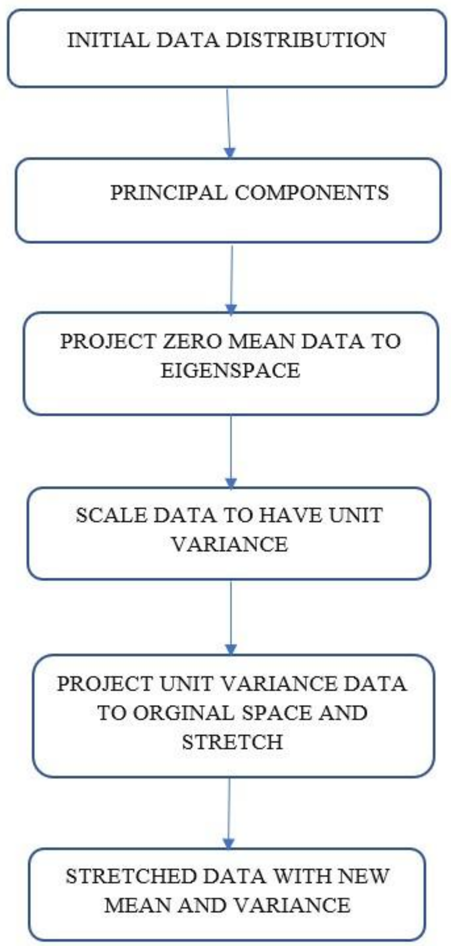


Fig.1 . Steps Involved in Decorrelation Stretch Algorithm

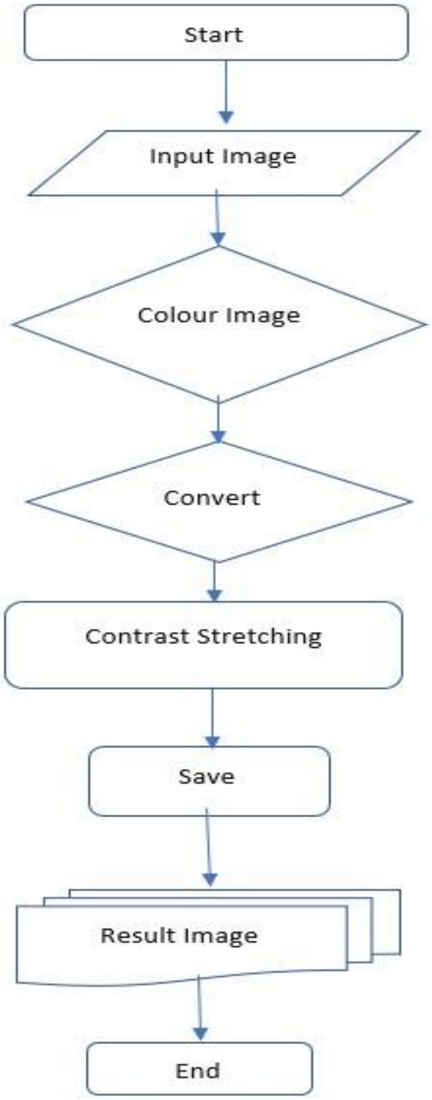
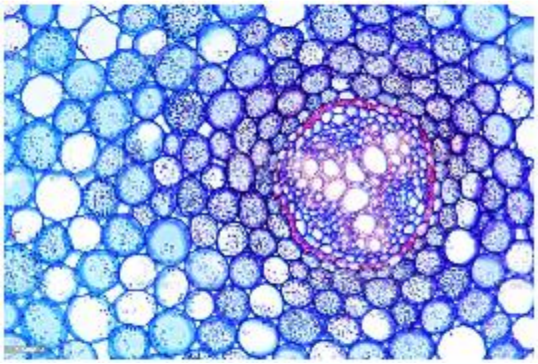


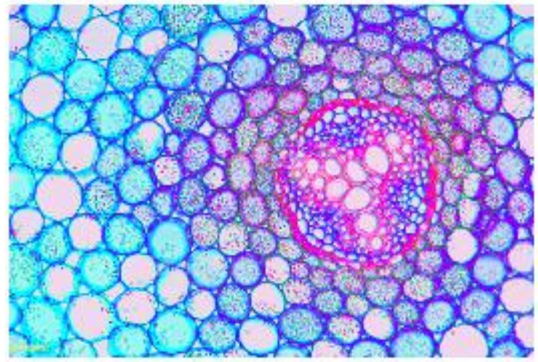
Fig. 2. Steps Involved in Contrast Stretching Algorithm

(a)

(b)



(c)

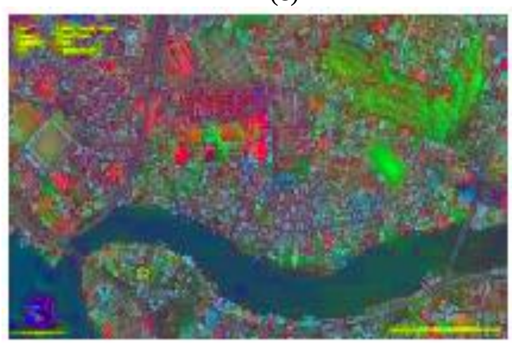


(d)

(f)

(e)

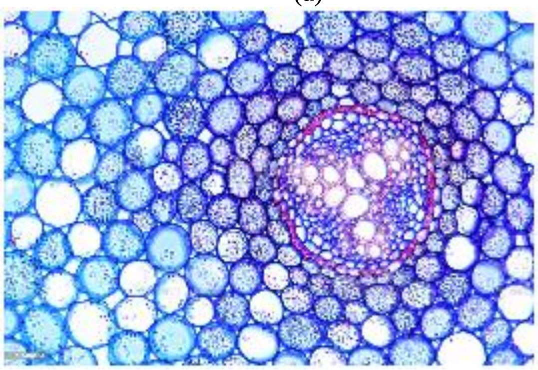
(g)

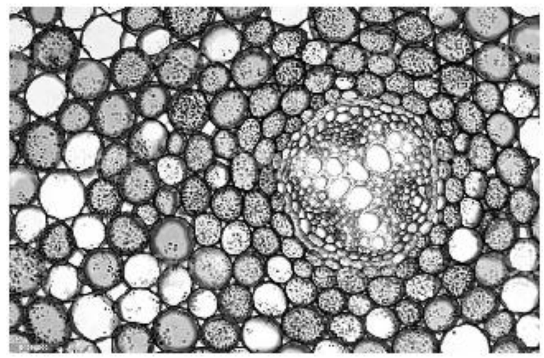


(h)

Fig. 3. Simulation results of decorrelation stretch 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)

(a) (b)





(c) (d)

(f) (e)

(h)

(g)

Fig. 4. Simulation results of contrast stretching algorithm (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).

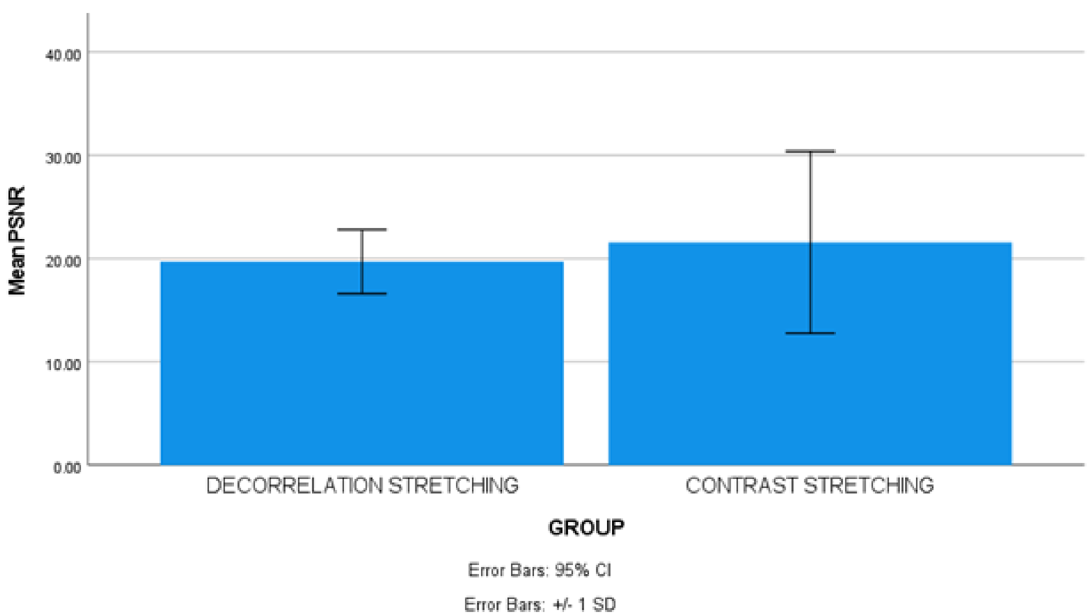


Fig. 5. Bar chart representing the comparison of mean PSNR (+/-1 SD) of decorrelation stretching and contrast stretching algorithm. Contrast stretching algorithm appears to produce most variable results with its standard deviation ranging from the lower 17.00 to the upper 30.00 and decorrelation stretching algorithm appears to produce consistent results with minimal standard deviation. X-axis represents groups decorrelation stretching algorithm vs contrast stretching algorithm and Y-axis represents Mean PSNR with +/-1 SD.

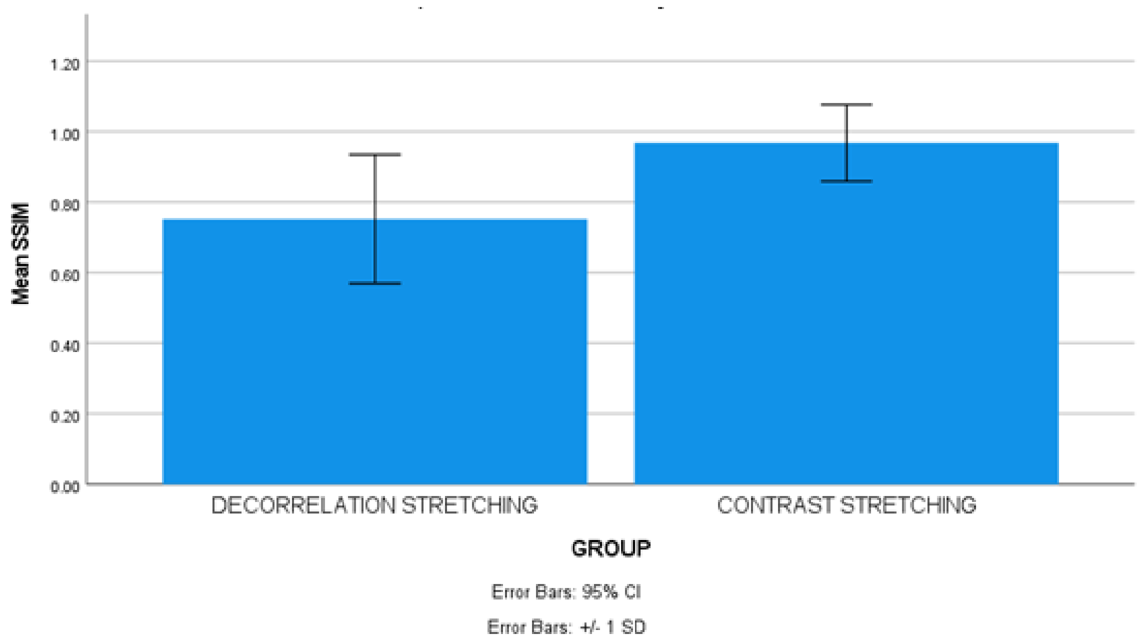


Fig. 6. Bar chart representing the comparison of mean SSIM (+/-1 SD) of decorrelation stretching and contrast stretching algorithm. Innovative decorrelation stretching algorithm appears to produce most variable results with its standard deviation ranging from the lower 0.58 to the upper 0.95 and contrast stretching algorithm appears to produce consistent results with minimal standard deviation. X-axis represents groups decorrelation stretching algorithm vs Contrast stretching algorithm and Y-axis represents Mean SSIM with +/-1 SD.