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RESEARCH ARTICLE

Image Restoration Using Lucy Richardson Algorithm for Deblurring Images with Improved PSNR, SSIM, NC in Comparison with Wiener Filter

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ABSTRACT

Aim: Image is the most powerful tool to analyze the information. Sometimes the captured image gets affected with blur and noise in the environment, which degrades the quality of the image. Image restoration is a technique in image processing where the degraded image can be restored or recovered to its nearest original image. **Materials and Methods:** In this research Lucy-Richardson algorithm is used for restoring blurred and noisy images using MATLAB software. And the proposed work is compared with Wiener filter, and the sample size for each group is 30. **Results:** The performance was compared based on three parameters, Power Signal to Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM), Normalized Correlation (NC). High values of PSNR, SSIM and NC indicate the better performance of restoration algorithms. Lucy-Richardson provides a mean PSNR of 10.4086db, mean SSIM of 0.4173%, and NC of 0.7433% and Wiener filter provides a mean PSNR of 6.3979db, SSIM of 0.3016%, NC of 0.3276%. **Conclusion:** Based on the experimental results and statistical analysis using independent sample T test, image restoration using Lucy-Richardson algorithm significantly performs better than Wiener filter on restoring the degraded image with PSNR ($P<0.001$) and SSIM ($P<0.001$).

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Introduction

Image restoration is a technique in image processing which focuses on recovering an image from a degraded version, usually a blurred and noisy image (Reeves 2014). Digital image restoration from the corrupted image has continuously been a major problem. However, imperfections during the capture will degrade the image and reduce the amount of information available. It is very important to recover the degraded image to restore the information captured, so that it would improve the quality of result and the analysis would be better (Kurniawan and Kusumawardhani 2017; Vankawala, Ganatra, and Patel 2015). There are many applications for image restoration like medical imaging, astronomical imaging, law enforcement, digital media restoration etc (Mishra, Mittal, and Khatri 2019a; Murase 2020; Liu, Chen, and Liu 2019; "Website" n.d.).

Some of the studies that relate to the proposed work are discussed next. Mishra.et.al. implemented three techniques, Lucy Richardson, Wiener filter, and Regularized filter for image restoration and they have concluded that Lucy Richardson was one of the best filter on all the parameters assessed like PSNR-29.58, SSIM-0.82, MSE- 71.58 and Lucy Richardson filter was best in removing noise(Mishra, Mittal, and Khatri 2019b). Kurniawan.et.al. used three restoration filters, Lucy Richardson algorithm, Wiener filter and Regularized filters for the restoring images with blur and noise using Matlab software. The performance of the three filters were compared by using parameters such as PSNR, SSIM and Mean square error (MSE). The study concluded that Lucy

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Richardson algorithm was the best algorithm for restoration of degraded images in all parameters with PSNR- 26.31, SSIM – 0.79, MSE- 152.18. And also states that regularization method is not more efficient in removing noise(Kurniawan and Kusumawardhani 2017). Khan.et.al. implemented Inverse filter and Wiener filter for restoring the images and compared the results. They observed that both the filters work well in absence of noise for restoring purpose. But in presence of noise the results show that wiener filter works more better than inverse filter for restoring the degraded images(Khan et al. 2018). Mahapatra.et.al. used wavelet based Lucy Richardson algorithm for image restoration they introduced motion blur and gaussian noise to the image for degradation the results were excellent and they also concluded that even after passing several times through the filter the noise exists in the restored image (Mahapatra, Faruquee, and Kumar 2018). In this experiment, our aim is to further improve the performance of the proposed algorithm and the quality of the restored image.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

From the above studies it is evident that performance of the Lucy Richardson technique needs to be improved. The authors have four years of research experience in the area of image processing and published four research articles in digital image restoration and published two book chapters on this research area. This research focuses on improvement of the performance innovative image restoration technique by Lucy Richardson algorithm and the results are compared with wiener filtering technique.

Materials and Methods

This study was conducted in a simulation lab of Saveetha school of engineering. Ethical approval is not required for this study. In this experiment two filtering techniques are considered as two groups: Lucy Richardson algorithm and wiener filter. The sample size is 30 per group. The sample size calculation is done using clinical cal.com by applying the parameter values from previous literatures(Mahapatra, Faruquee, and Kumar 2018). The value of threshold is set to 0.05 and the confidence interval as 95%.

Sample preparation for two groups is done by collecting 30 medical images like X-ray-6, CT-6, MRI-6, SPECT-6, PET-6 etc from standard medical database kaggle. Figure 1 shows a basic model of image degradation and restoration procedure. The degradation of the original image in spatial domain can be modelled as:

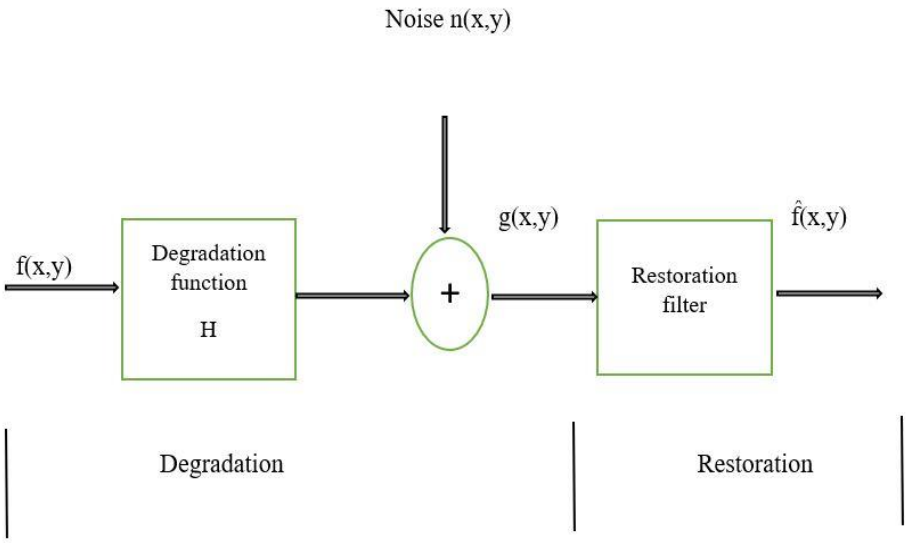

Fig. 1. The fundamental model of image degradation and restoration procedure

$$g(x,y) = h(x,y)*f(x,y) + n(x,y) \quad (1)$$

Where,

(x,y) = detached pixel coordinates of the image frame
f (x,y) = Original image
g (x,y) = Degraded image
h (x,y) = Image degradation function
n (x,y) = Add on noise

Testing setup is done by installing MATLAB R2015a software. The input images were collected and a matlab code is implemented for Lucy Richardson algorithm and wiener filter. The testing procedure for deblurring images using Lucy Richardson algorithm include the following steps, first read the image and simulate a blur and noise then restore the blurred and noisy image, iterate to explore the restoration and control noise amplification by damping, then create a sample image and simulate a blur, provide a weight array and provide a finer sample PSF.

The performance of two filters are measured using PSNR, SSIM, NC values. To validate the results of both the algorithms, statistical analysis was done using IBM-SPSS software. As the two algorithms are independent to each other, Independent sample T test was performed for the three independent variables PSNR, SSIM, NC.

Results

Simulation results of Lucy Richardson algorithm are shown in Fig. 2 and simulation results of Wiener filter are shown in Fig. 3. The performance parameters such as PSNR, SSIM, NC of both algorithms are tabulated in Table1. The PSNR, SSIM, NC values are high for Lucy Richardson algorithm when compared to Wiener filter. These three values should be high for better restoring algorithms. The sample size of both groups are 30 and only 6 results are tabulated for the images given for simulation results which are shown in Table 1.

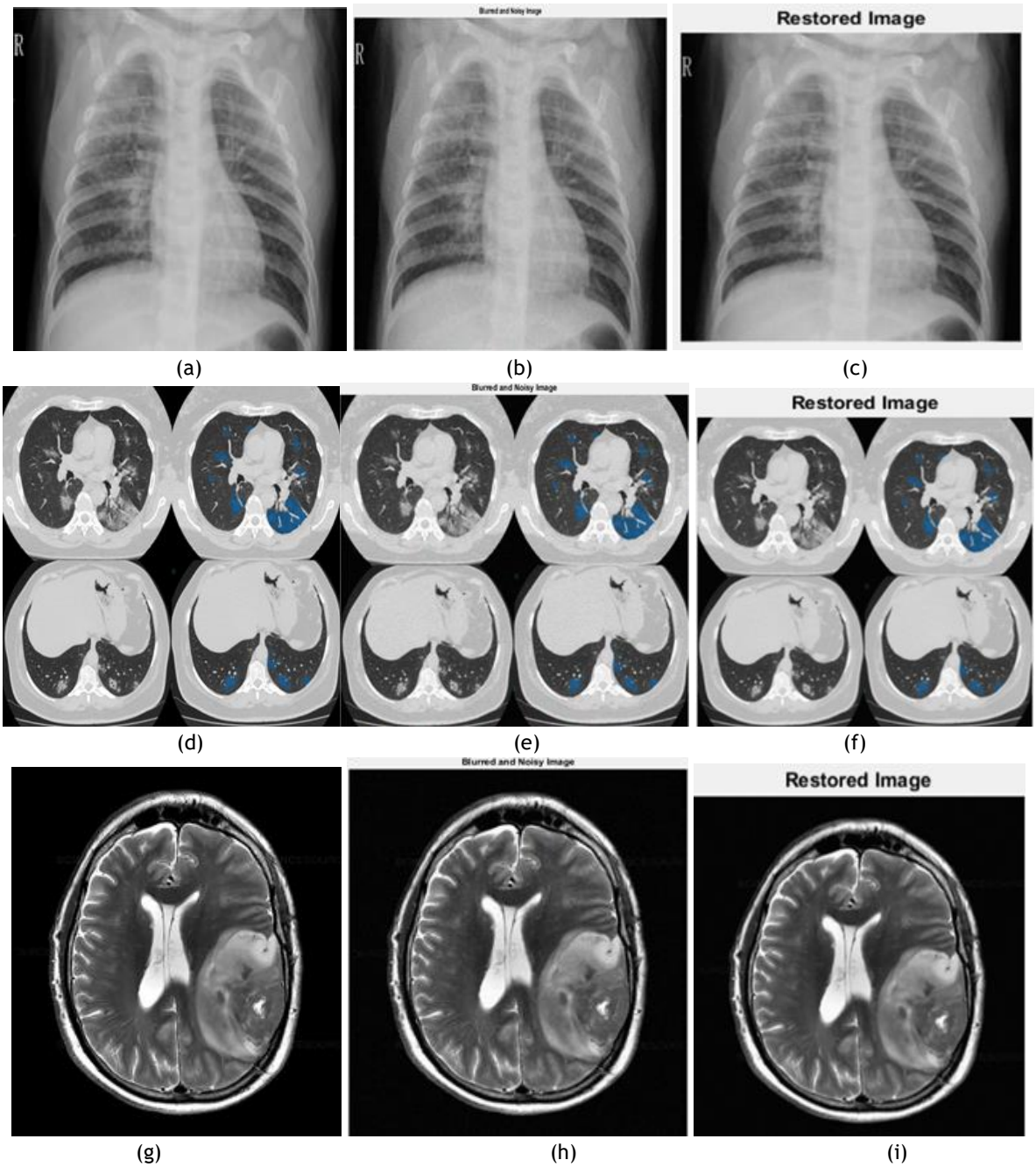

Fig. 2. Simulation results of Lucy Richardson algorithm. (a) Input image (X-ray-chest) (b) Blurred and noisy image (c) Restored X-ray image of chest (d) Input image (CT-lung) (e) Blurred and noisy image (f) Restored CT image of lungs (g) Input image (MRI-brain) (h) Blurred and noisy image (i) Restored MRI image of brain

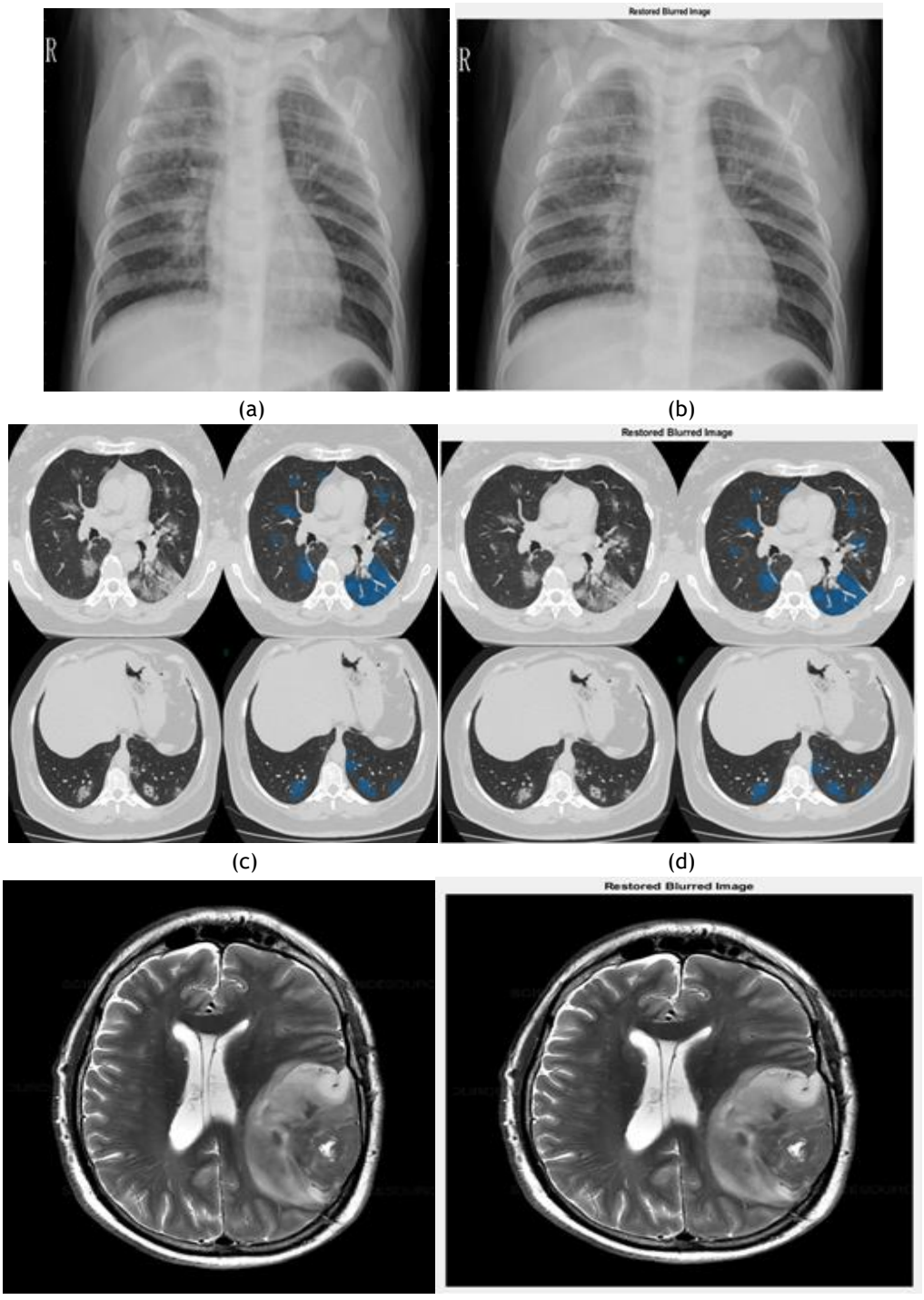

Fig. 3. Simulation results of Wiener filter. (a) Input image (X-ray-chest) (b) Restored blurred X-ray image of chest (c) Input image (CT-lung) (d) Restored blurred CT image of lung (e) Input image (MRI-brain) (f) Restored blurred MRI image of brain

Table 1. Comparison of performance parameters of blur and noisy image after restoration using Lucy Richardson algorithm and Wiener filter.

S.no	Medical images	Lucy Richardson algorithm			Wiener filter		
		PSNR (db)	SSIM (%)	NC (%)	PSNR (db)	SSIM (%)	NC (%)
1	SET 1	7.4675	0.2173	0.5338	5.8559	0.0515	0.1505
2	SET 2	8.2478	0.2000	0.5130	7.0104	0.0467	0.0263
3	SET 3	8.9938	0.0934	0.7557	6.5764	0.4156	0.1121

In order to validate the results independent sample T test was performed. Group statistics of both algorithms for PSNR, SSIM, NC parameters are tabulated in Table 2, it shows that PSNR of Lucy Richardson algorithm is having high mean (10.4086), SSIM of Wiener filter is having low mean (0.3016). PSNR of Lucy Richardson algorithm is having high standard deviation (2.72138), NC of Lucy Richardson algorithm is having low standard deviation (0.15855).

Table 2. Group statistics comparison of PSNR, SSIM, NC of image restoration algorithms using Lucy Richardson algorithm and Wiener filter algorithms.

	Group	N	Mean	Std. Deviation	Std. Error mean
PSNR	Lucy Richardson	30	10.4086	2.72138	.49685
	Wiener filter	30	6.3979	1.97763	.36106
SSIM	Lucy Richardson	30	.4173	.27629	.5044
	Wiener filter	30	.3016	.25904	.4729
NC	Lucy Richardson	30	.7433	.15855	.02895
	Wiener filter	30	.3276	.21384	.3904

Independent sample T test results for Lucy- Richardson algorithm and Wiener filter are given in Table 3, it shows that there appears to be no significant difference in SSIM (P=0.1) and there is a significant difference in PSNR and NC (P<0.001).

Table 3. Independent sample test comparison of the PSNR, SSIM, NC of image restoration using Lucy Richardson algorithm and Wiener filter algorithms

	Levene's test for equality of variances			t-test for equality of means					95%confidence interval of the difference	
		F	SIG	t	df	Sig (2-tailed)	Mean diff	Std. error diff	Lower	Upper
PSNR	Equal variances assumed	5.648	.021	6.530	58	<.001	4.01067	.61419	2.78123	5.24011
	Equal variances Not assumed			6.530	52.950	<0.001	4.01607	.61419	2.78123	5.24011
SSIM	Equal variances assumed	.182	.671	1.672	58	.100	.11564	.06915	-.02278	.25405
	Equal variances Not assumed			1.672	57.761	.100	.11564	.06915	-.02279	.25405
NC	Equal variances assumed	.821	.369	8.553	58	<.001	.41571	.04860	.31842	.51300
	Equal variances Not assumed			8.553	53.486	<.001	.41571	.04860	.31824	.51317

Barchart comparison of mean PSNR value for both groups is shown in Fig. 4, it shows that Lucy Richardson appears to produce most variable results with its standard deviation ranging from the lower 7 to the upper 13. Wiener filter appears to produce consistent results with minimal Standard deviation. Bar chart comparison of mean SSIM value for both groups is shown in Fig. 5, it shows that Lucy Richardson appears to produce most variable results with its standard deviation ranging from the lower 0.15 to the upper 0.7. Wiener filter appears to produce consistent results with minimal Standard deviation. Barchart comparison of mean NC value for both the groups is shown in Fig. 6, it shows that Lucy Richardson appears to produce most variable results with its standard deviation ranging from the lower 0.58 to the upper 0.9. Wiener filter appears to produce consistent results with minimal Standard deviation.

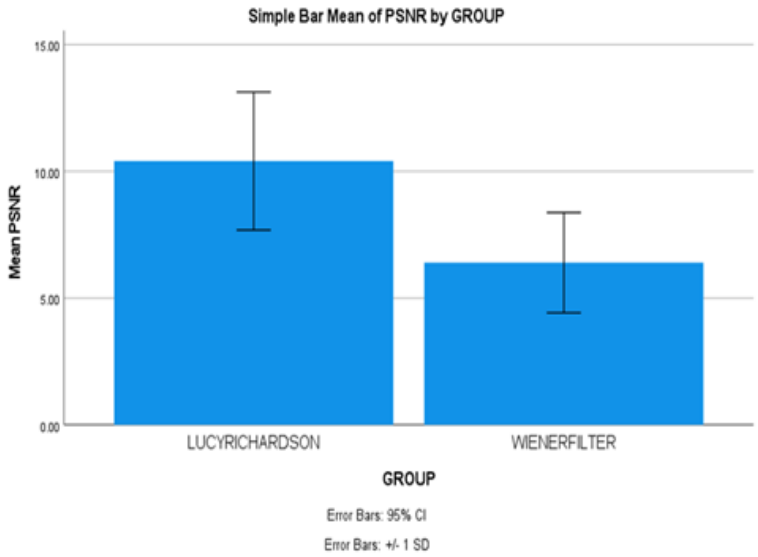

Fig. 4. Bar chart representing the comparison of Mean PSNR (+/−1SD) of Lucy Richardson algorithm and Wiener filter. X Axis: Lucy Richardson vs Wiener filter Algorithms, Y Axis: Mean Peak Signal to Noise Ratio.

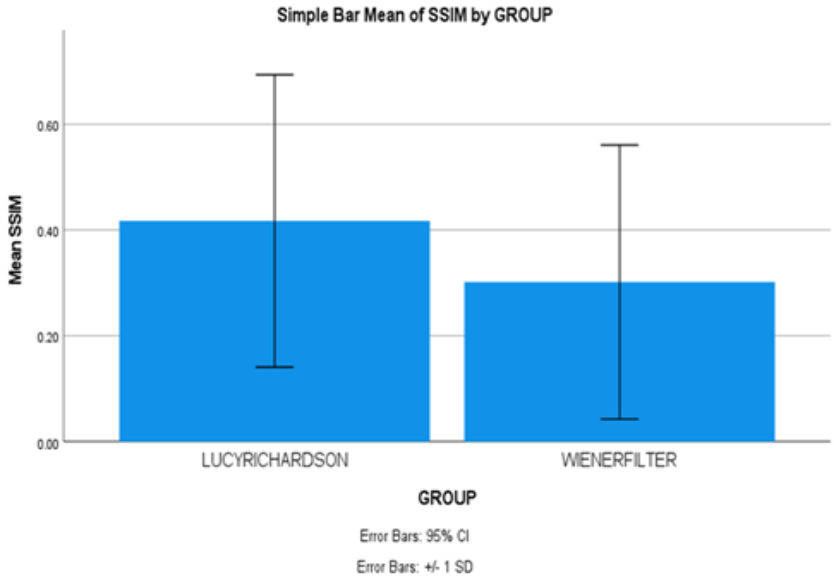

Fig. 5. Bar chart representing the comparison of Mean SSIM(+/−1SD) of Lucy Richardson algorithm and Wiener filter. X Axis: Lucy Richardson vs Wiener filter Algorithms, Y Axis: Mean Structural Similarity Index Measure

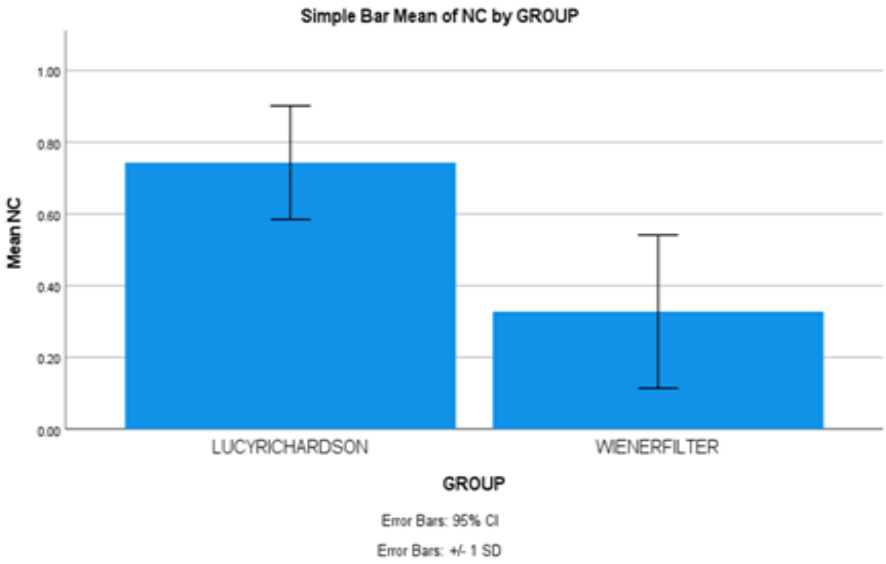

Fig. 6. Bar chart representing the comparison of Mean NC(+/−1SD) of Lucy Richardson algorithm and Wiener filter. X Axis: Lucy Richardson vs Wiener filter Algorithms, Y Axis: Mean Normalised Correlation.

Discussion

In this study we observed that Lucy Richardson algorithm performance is better than Wiener filter with significant PSNR and NC values (P<0.001; P<0.005).

The research conducted by Mishra et.al (2019) on comparison of image restoration algorithms by measuring the performance of the algorithm based on PSNR, SSIM and MSE is similar to our research. The values of PSNR value (9.428) of Lucy Richardson are higher than wiener filter PSNR value (4.164). The research done by Kurniawan.et.al. (2017) on comparing three filters for image restoration. The performance of the three filters were compared by using parameters such as PSNR, SSIM and (MSE). The study concluded that Lucy Richardson algorithm was the best algorithm for restoration of degraded images in all parameters with PSNR- 26.31, SSIM - 0.79, MSE-152.18.(Kurniawan and Kusumawardhani 2017). Both the study findings are most convincing with our study. There are no research papers available that contradict the findings of our study.

Our institution is passionate about high quality evidence based research and has excelled in various fields ((Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019; Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

The proposed algorithm takes more time in processing and may have noise amplification problem. High blur, high artifacts, high distortions, high noise, low contrast are the possible factors that affect the outcome. As the input images were not preprocessed which may yield insignificant results

and this can be avoided by applying proper filtering techniques before applying algorithms. The future scope of the study is to design a technique which consumes less time during processing and removes both blur and noise more efficiently.

Conclusion

Lucy-Richardson algorithm appears to perform better than Wiener filter for deblurring images.

Declarations

Conflict of Interest

No conflict of interest in this manuscript.

Author's Contributions

Author GSR was involved in data collection, algorithm development, data analysis, and manuscript writing. Author NR was involved in conceptualization and data validation. Author GP was also involved in conceptualization, data critical review of manuscript.

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References

Ezhilarasan, Devaraj, Velluru S. Apoorva, and Nandhigam Ashok Vardhan. 2019. "Syzygium Cumini Extract Induced Reactive Oxygen Species-Mediated Apoptosis in Human Oral Squamous Carcinoma Cells." *Journal of Oral Pathology & Medicine: Official Publication of the International Association of Oral Pathologists and the American Academy of Oral Pathology* 48 (2): 115–21.

Gheena, S., and D. Ezhilarasan. 2019. "Syringic Acid Triggers Reactive Oxygen Species-Mediated Cytotoxicity in HepG2 Cells." *Human & Experimental Toxicology* 38 (6): 694–702.

Jose, Jerry, Ajitha, and Haripriya Subbaiyan. 2020. "Different Treatment Modalities Followed by Dental Practitioners for Ellis Class 2 Fracture – A Questionnaire-Based Survey." *The Open Dentistry Journal* 14 (1): 59–65.

Ke, Yang, Mohammed Saleh Al Aboody, Wael Alturaiki, Suliman A. Alsagaby, Faiz Abdulaziz Alfaiz, Vishnu Priya Veeraraghavan, and Suresh Mickymaray. 2019. "Photosynthesized Gold Nanoparticles from Catharanthus Roseus Induces Caspase-Mediated Apoptosis in Cervical Cancer Cells (HeLa)." *Artificial Cells, Nanomedicine, and Biotechnology* 47 (1): 1938–46.

Khan, Mohammad Mahmudur Rahman, Shadman Sakib, Rezoana Bente Arif, and Md Abu Bakr Siddique. 2018. "Digital Image Restoration in Matlab: A Case Study on Inverse and Wiener Filtering." *In 2018 International Conference on Innovation in Engineering and Technology (ICIET). IEEE*. https://doi.org/10.1109/ciet.2018.8660797.

Krishnaswamy, Haribabu, Sivaprakash Muthukrishnan, Sathish Thanikodi, Godwin Arockiaraj Antony, and Vijayan Venkatraman. 2020. "Investigation of Air Conditioning Temperature Variation by Modifying the Structure of Passenger Car Using Computational Fluid Dynamics." *Thermal Science* 24 (1 Part B): 495–98.

Kurniawan, Muhammad, and Apriani Kusumawardhani. 2017. "Analysis and Comparison of Image Restoration Algorithms Using MATLAB." https://doi.org/10.13140/RG.2.2.22236.90246.

Liu, Di, Xiyuan Chen, and Xiao Liu. 2019. "An Improved Richardson-Lucy Algorithm for Star Image Deblurring." *2019 IEEE International Instrumentation and Measurement Technology Conference (I2MTC)*. https://doi.org/10.1109/i2mtc.2019.8826905.

Mahapatra, Abhilash, Muddasir Ahamad Faruquee, and Pranaw Kumar. 2018. "Restoration of Motion Blurred Image Using Lucy Richardson Algorithm." *2018 International Conference on Communication, Computing and Internet of Things (IC3IoT)*. https://doi.org/10.1109/ic3iot.2018.8668143.

Malli Sureshbabu, Nivedhitha, Kathiravan Selvarasu, Jayanth Kumar V, Mahalakshmi Nandakumar, and Deepak Selvam. 2019. "Concentrated Growth Factors as an Ingenious Biomaterial in Regeneration of Bony Defects after Periapical Surgery: A Report of Two Cases." *Case Reports in Dentistry* 2019 (January): 7046203.

Mathew, M. G., S. R. Samuel, A. J. Soni, and K. B. Roopa. 2020. "Evaluation of Adhesion of Streptococcus Mutans, Plaque Accumulation on Zirconia and Stainless Steel Crowns, and Surrounding Gingival Inflammation in Primary …." *Clinical Oral Investigations*. https://link.springer.com/article/10.1007/s00784-020-03204-9.

Mehta, Meenu, Deeksha, Devesh Tewari, Gaurav Gupta, Rajendra Awasthi, Harjeet Singh, Parijat Pandey, et al. 2019. "Oligonucleotide Therapy: An Emerging Focus Area for Drug Delivery in Chronic Inflammatory Respiratory Diseases." *Chemico-Biological Interactions* 308 (August): 206–15.

Mishra, Reeturaj, Neetu Mittal, and Sunil Kumar Khatri. 2019a. "Digital Image Restoration Using Image Filtering Techniques." *2019 International Conference on Automation, Computational and Technology Management (ICACTM)*. https://doi.org/10.1109/icactm.2019.8776813.

2019b. "Digital Image Restoration Using Image Filtering Techniques." *2019 International Conference on Automation, Computational and Technology Management (ICACTM)*. https://doi.org/10.1109/icactm.2019.8776813.

Murase, Kenya. 2020. "New Image-Restoration Method Using a Simultaneous Algebraic Reconstruction Technique: Comparison with the Richardson-Lucy Algorithm." *Radiological Physics and Technology* 13 (4): 365–77.

Muthukrishnan, Sivaprakash, Haribabu Krishnaswamy, Sathish Thanikodi, Dinesh Sundaresan, and Vijayan Venkatraman. 2020. "Support Vector Machine for Modelling and Simulation of Heat Exchangers." *Thermal Science* 24 (1 Part B): 499–503.

Pc, J., T. Marimuthu, and P. Devadoss. 2018. "Prevalence and Measurement of Anterior Loop of the Mandibular Canal Using CBCT: A Cross Sectional Study." *Clinical Implant Dentistry and Related Research*. https://europepmc.org/article/med/29624863.

Ramadurai, Neeraja, Deepa Gurunathan, A. Victor Samuel, Emg Subramanian, and Steven J. L. Rodrigues. 2019. "Effectiveness of 2% Articaine as an Anesthetic Agent in Children: Randomized Controlled Trial." *Clinical Oral Investigations* 23 (9): 3543–50.

Ramesh, Asha, Sheeja Varghese, Nadathur D. Jayakumar, and Sankari Malaiappan. 2018. "Comparative Estimation of Sulfiredoxin Levels between Chronic Periodontitis and Healthy Patients - A Case-Control Study." *Journal of Periodontology* 89 (10): 1241–48.

Reeves, Stanley J. 2014. "Image Restoration: Fundamentals of Image Restoration." *Academic Press Library in Signal Processing: Volume 4 - Image, Video Processing and Analysis, Hardware, Audio, Acoustic and Speech Processing*. https://doi.org/10.1016/b978-0-12-396501-1.00006-6.

Samuel, Melvin S., Jayanta Bhattacharya, Sankalp Raj, Needhidasan Santhanam, Hemant Singh, and N. D. Pradeep Singh. 2019. "Efficient Removal of Chromium(VI) from Aqueous Solution Using Chitosan Grafted Graphene Oxide (CS-GO) Nanocomposite." *International Journal of Biological Macromolecules* 121 (January): 285–92.

Samuel, Srinivasan Raj, Shashidhar Acharya, and Jeevika Chandrasekar Rao. 2020. "School Interventions-Based Prevention of Early-Childhood Caries among 3-5-Year-Old Children from Very Low Socioeconomic Status: Two-Year Randomized Trial." *Journal of Public Health Dentistry* 80 (1): 51–60.

Sathish, T., and S. Karthick. 2020. "Wear Behaviour Analysis on Aluminium Alloy 7050 with Reinforced SiC through Taguchi Approach." *Journal of Japan Research Institute for Advanced Copper-Base Materials and Technologies* 9 (3): 3481–87.

Sharma, Parvarish, Meenu Mehta, Daljeet Singh Dhanjal, Simran Kaur, Gaurav Gupta, Harjeet Singh, Lakshmi Thangavelu, et al. 2019. "Emerging Trends in the Novel Drug Delivery Approaches for the Treatment of Lung Cancer." *Chemico-Biological Interactions* 309 (August): 108720.

Sridharan, Gokul, Pratibha Ramani, Sangeeta Patankar, and Rajagopalan Vijayaraghavan. 2019. "Evaluation of Salivary Metabolomics in Oral Leukoplakia and Oral Squamous Cell Carcinoma." *Journal of Oral Pathology & Medicine: Official Publication of the International Association of Oral Pathologists and the American Academy of Oral Pathology* 48 (4): 299–306.

Vankawala, Fagun, Amit Ganatra, and Amit Patel. 2015. "A Survey on Different Image Deblurring Techniques." *International Journal of Computer Applications*. https://doi.org/10.5120/20396-2697.

Varghese, Sheeja Saji, Asha Ramesh, and Deepak Nallaswamy Veeraiyan. 2019. "Blended Module-Based Teaching in Biostatistics and Research Methodology: A Retrospective Study with Postgraduate Dental Students." *Journal of Dental Education* 83 (4): 445–50.

Venu, Harish, V. Dhana Raju, and Lingesan Subramani. 2019. "Combined Effect of Influence of Nano Additives, Combustion Chamber Geometry and Injection Timing in a DI Diesel Engine Fuelled with Ternary (diesel-Biodiesel-Ethanol) Blends." *Energy* 174 (May): 386–406.

Venu, Harish, Lingesan Subramani, and V. Dhana Raju. 2019. "Emission Reduction in a DI Diesel Engine Using Exhaust Gas Recirculation (EGR) of Palm Biodiesel Blended with TiO2 Nano Additives." *Renewable Energy* 140 (September): 245–63.

Vignesh, R., Ditto Sharmin, C. Vishnu Rekha, Sankar Annamalai, and Parisa Norouzi Baghkomeh. 2019. "Management of Complicated Crown-Root Fracture by Extra-Oral Fragment Reattachment and Intentional Reimplantation with 2 Years Review." *Contemporary Clinical Dentistry* 10 (2): 397–401.

Vijayakumar Jain, S., M. R. Muthusekhar, M. F. Baig, P. Senthilnathan, S. Loganathan, P. U. Abdul Wahab, M. Madhulakshmi, and Yogaen Vohra. 2019. "Evaluation of Three-Dimensional Changes in Pharyngeal Airway Following Isolated Lefort One Osteotomy for the Correction of Vertical Maxillary Excess: A Prospective Study." *Journal of Maxillofacial and Oral Surgery* 18 (1): 139–46.

Vijayashree Priyadharsini, Jayaseelan. 2019. "In Silico Validation of the Non-Antibiotic Drugs Acetaminophen and Ibuprofen as Antibacterial Agents against Red Complex Pathogens." *Journal of Periodontology* 90 (12): 1441–48.

"Website." n.d. Accessed March 18, 2021. Panfilova, Kristina, and Sergey Umnyashkin. 2019. "Correlation-Based Quality Measure for Blind Deconvolution Restoration of Blurred Images Based on Lucy-Richardson Method." *In 2019 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus). IEEE*. https://doi.org/10.1109/eiconrus.2019.8657324.