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Comparative Study on MATLAB based Joint Photographic Experts Group Image Size Reduction Using Shearlet and Wavelet Transform for X-Ray Images with Potential Hospital Data Storage Application

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Abstract

Aim: *The aim of this paper is to compress the x-ray images using wavelet and shearlet transform and compare the compression ratios to find a better transform.* ***Materials and Methods:*** *The sample size of each group was 30 and the total sample size was 60. Compression ratios (CR) were generated for images based on the transform used for size reduction*. ***Results:*** *Wavelet based CR was seen to be higher mean (6.61) when compared to shearlet (4.025). Hence wavelet transform seems better transform for compressing X-Ray images.* ***Conclusion:*** *We observed that wavelet transform seems to have a better compression ratio compared to shearlet transform (P=0.28, P<0.05, independent sample t-test).*

Key-words: Shearlet, Novel Image Compression Technique, X-ray Images, Artificial Intelligence.

1. Introduction

We tried to compress the X-ray images using both wavelet and shearlet transforms. Until now, the X-ray images were not compressed using wavelet or shearlet transforms. Image compression is important for many applications that involve huge data storage, transmission and retrieval such as for multimedia, documents, video conferencing, and medical imaging (Chouakri, Djaafri, and Taleb-Ahmed 2013) (Mittal et al. 2016); (Bruylants, Munteanu, and Schelkens 2015)

(Chouakri, Djaafri, and Taleb-Ahmed 2013). The objective of image compression technique is to reduce redundancy of image data in order to be able to store and transmit data in an efficient form (Sanchez and Bartrina-Rapesta 2014); (Juliet, Rajsingh, and Ezra 2016) (Nashat and Hussain Hassan 2016). By image compression there won't be any loss in the data and also storage space was saved (Asraf, Akbar, and Jafri 2006) (Al-Jarrah et al. 2015) (Asraf, Akbar, and Jafri 2006). The shearlet is a multiscale structure, which permits productive encoding of anisotropic highlights in multivariate issue classes. Shearlets are regular expansions of wavelets (Easley, Labate, and Colonna 2009). The overall purpose of this paper is to compress the x-ray images using wavelet and shearlet transform and compare the compression ratios to find a better transform.

In 2016, Nashat and team worked on improving spatial resolution, providing compression ratio and PSNR value, better performance quantitatively and visually for images in terms of several metrics (CR=6.45) (Chouakri, Djaafri, and Taleb-Ahmed 2013) (Nashat and Hussain Hassan 2016). The wavelet transform was applied to each vector and some of the high frequency components were suppressed based on threshold criteria ("Website" n.d.; Alarcon-Aquino 2013). Fractal image compression produces high compression ratio with good image quality, but consumes more time for encoding (CR=34.75) (Sridhar, Rajesh Kumar, and Ramanaiah 2014). The visual perception demonstrates the high quality of ECG signal restitution where the different ECG waves are recovered correctly, results obtained are evaluated in terms of compression ratio and mean square error which are, respectively, around 1:8 and 7% (Mittal et al. 2016) (Chouakri, Djaafri, and Taleb-Ahmed 2013) (Al-Jarrah et al. 2015). That was the motivation for researchers to try to present a better transform coding methodology.

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.

We found that none of the literature had evidence of compressing x-ray images with two different transforms. MATLAB© was used for coding. The aim of our study is to compress X-Ray images using Wavelet transform and Shearlet transform and compare them for a better transform.

2. Materials and Methods

The compression of images was done using MATLAB© code. At first we have taken 30 X-ray images for compression using wavelet (haar) transform and 30 images were compressed using shearlet transform. The sample size of each group is 30 and the total sample size was 60. This sample size was determined for G power 80% and alpha 0.05 utilizing clinical.com in reference to (Nashat and Hussain Hassan 2016)(Sophia and Anitha 2017).

For group 1 sample preparation, we resize the images to 512*512 dimensions for wavelet transform and compression was performed. Then in the same way for group 2 sample preparation we resize the images for shearlet transform upto 512*512. After preprocessing the image was compressed. In wavelet transform, the input image undergoes decomposition, then the decomposed image will be compressed finally reconstructed as output. While in shearlet transform the JPEG image was converted to the GIF image by pre-processing. The pre-processed original image was given as input for the transform. Initially the image will be compressed and then restored.

Statistical Analysis

The data of X-Ray images were collected from the Kaggle dataset. For statistical analysis we used SPSS 22 (Statistical Package for the Social Sciences) and the analysis done was an independent sample t-test. From the analysis we observed that wavelet transform has a higher compression ratio compared to the shearlet transform.

3. Results

From Table 1, it was observed that the overall sample size was 60. 30 images were used for wavelet transform and 30 for shearlet transform for compression. The wavelet original image size ranged from 124 kb to 210 kb and for shearlet 121 kb to 211 kb. The compressed images were generated in the range of 23.7 to 26.8 kb with compression ratio in an average of 5.12 to 7.83 for wavelet. For Shearlet, the compressed image sizes ranged from 38.7 to 41.5 kb with compression ratios from 2.7 to 5.3.

Table 1 - Represents the Total Sample Size was 60- Wavelet (30) and Shearlet (30)

SL. No	**Original X-ray image size(KB)**	**Compressed by wavelet**	**Wavelet compression ratio**	**Original X-ray image size(KB)**	**Compressed by shearlet**	**Shearlet compres sion ratio**
1	157	25.4	6.181	193	40.4	4.7
2	150	24	6.25	193	40.8	4.7
3	125	24.4	5.122	134	41.5	3.2
4	144	25	5.76	198	41	4.8
5	167	26.3	6.34	150	40.7	3.6
6	135	23.8	5.67	250	40	4.9
7	193	25.3	7.62	154	39.5	3.8
8	194	25.3	7.66	211	39.5	5.3
9	193	25.5	7.56	139	39	3.5
10	134	23.7	5.65	193	40.2	4.8
11	198	26.1	7.58	134	39.5	3.3
12	134	24.5	5.46	190	39.4	4.8
13	149	24.5	6.08	190	39	4.8
14	135	24.5	5.51	183	40.2	4.5
15	130	24	5.41	180	40.5	4.4
16	124	24	5.16	185	38.7	4.7
17	146	23.7	6.16	185	39.7	4.6
18	194	26	7.46	188	39.1	4.8
19	134	24	5.58	121	40.3	3
20	158	24.2	6.5	179	40.8	4.38
21	196	26	7.53	144	39	3.6
22	190	26.3	7.22	135	39	3.46
23	204	26.3	7.75	125	38.9	3.21
24	197	26.6	7.40	122	39.7	3.07
25	196	26.7	7.34	122	39.9	3.05
26	192	24.5	7.83	211	39.8	5.3
-27	164	23.9	6.86	122	39.5	3.08
28	194	26.3	7.37	110	40.2	2.7
29	210	26.8	7.83	122	40.3	3.02
30	172	26.7	6.44	153	40.4	3.7

Figure 1 represents the wavelet compression of X-ray images. The input image was decomposed using the transform that splits the input image into 8 subunits and finally compressed. The reconstruction of the same lead to output images of reduced sizes. In the same way, Fig. 2 represents the compression of X-ray images using shearlet transform. The input images were pre-processed based on the code and then the compressed images were restored.

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Fig. 1 - Represents Compression of X-ray Images Using Wavelet Transform

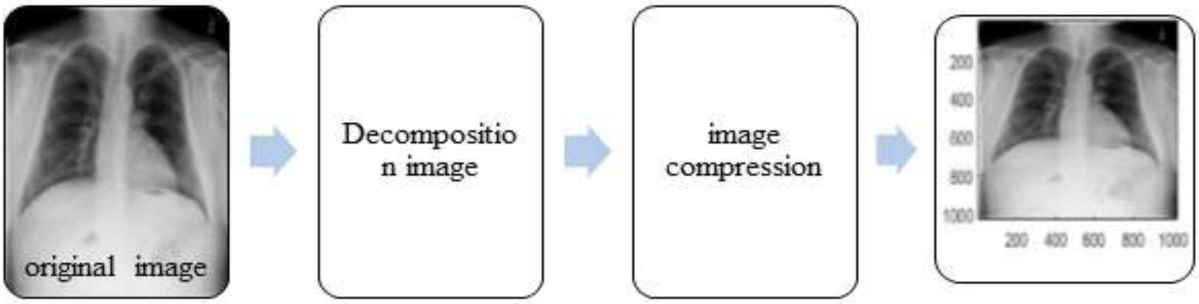
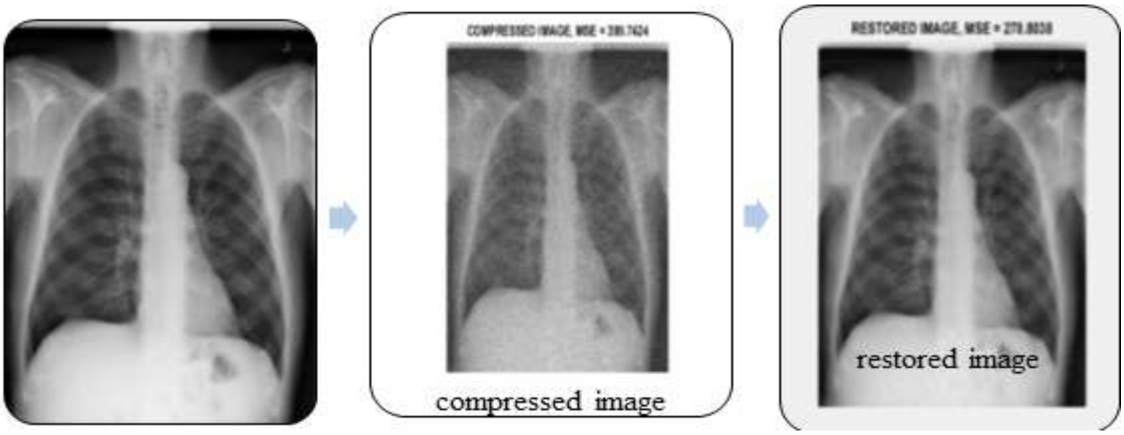


Fig. 2 - Represents the Image Compression Using Shearlet Transform for X-ray Images



From Table 2, we observed the statistical analysis between the compression ratios of the two transforms. Wavelet based CR was seen to be of higher mean (6.61) when compared to shearlet (4.025). Hence wavelet transform is proposed to a better transform for compressing X-Ray images. Table 3 addresses the comparison of wavelet based compression ratio with shearlet transforms based compression ratio for 30 X-ray images there is a statistical insignificance between both the data ($P=0.284$) ($P<0.05$,independent sample t test).

Table 2 - Represents the statistical analysis between the CR generated by wavelet and shearlet transform. Wavelet based compression ratio was higher (6.6146) than the shearlet transforms (4.0257). Hence, proving to be a better compression transform than its counterpart (shearlet)

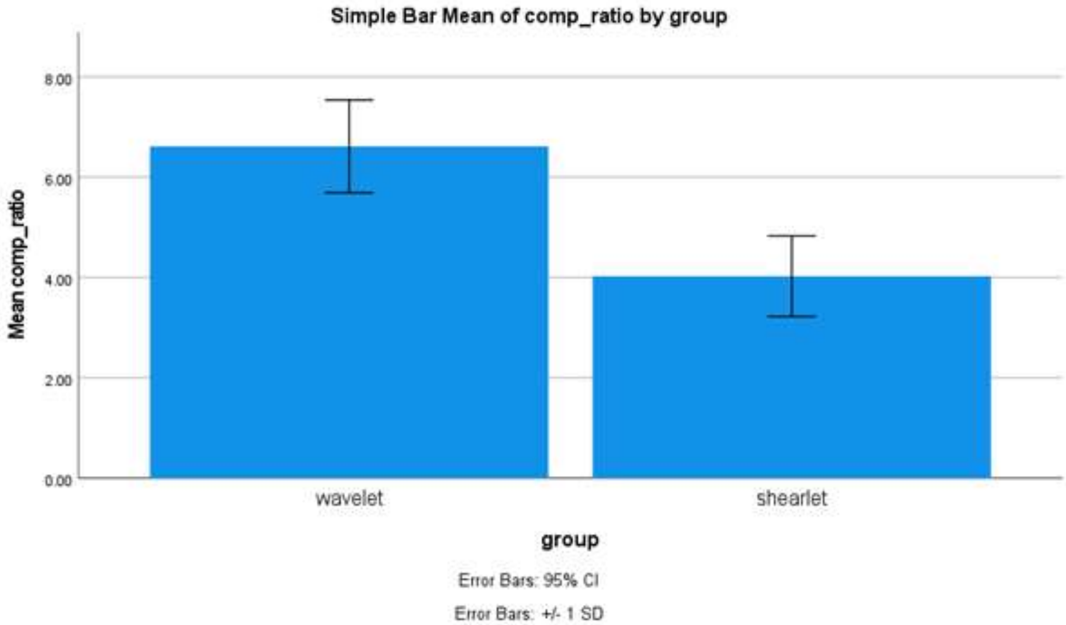
Group Statistics					
	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
comp_ratio	**wavelet**	30	6.6146	.92531	.16894
	shearlet	30	4.0257	.80440	.14686

Table 3 - Represents the result of an Independent sample t test, for wavelet based compression ratio of X-ray images. There was a statistical significance between wavelet and shearlet data (p=0.284) (p<0.05 Independent sample t test).

Independent Samples Test										
		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Comp_ratio	**Equal variances assumed**	1.16	.28	11.5	58	.000	2.5889	.22385	2.140	3.037
	Equal variances not assumed			11.5	56.8	.000	2.5889	.22385	2.140	3.037

Figure 3 depicts Bar chart representation of the comparison between wavelet and shearlet transform compression ratio for X-ray images. There was a statistical insignificance between the data (P=0.28) (P<0.05, independent sample t test). Wavelet transform which appears to produce higher standard deviation (0.9) when compared with shearlet transform which appears to produce lower results with lower standard deviation (0.8).

Fig. 3 - Comparison between wavelet and Shearlet transform compression ratio for X-ray images. Wavelet transform appears to produce the most consistent results with higher standard deviation (0.92), when compared with shearlet transform which appears to produce lower results with lower standard deviation (0.8). X Axis: Wavelet vs Shearlet transform group Y Axis: Mean value of compression ratio +/- 1 SD.



4. Discussion

In this study we observed that wavelet transform appears to be a better transform compared to shearlet transform based on its compression ratios. This has been depicted in Table 2 and Fig. 3. Improvements in both compression ratio and computational time have been reported (CR=28.85) (Hnesh and Demirel 2016). The results reported good image quality in terms of several metrics ((Reddy et al. 2016)). Experimental results illustrate that the proposed compression algorithm produces high compression ratio and has a good fine detail ((Zuo et al. 2015)). Achieve higher compression ratios than existing standard lossless compression techniques and also meets the legal requirement of medical image archiving ((Asraf, Akbar, and Jafri 2006)). The proposed procedure when applied on Computed Tomography (CT) liver image yields significantly better compression rates without loss in the originality ((Sran, Gupta, and Singh 2013)). Since wavelet transforms are mostly reported as a better compression alternative to conventional methods, we were unable to report any negative citations for the same. From the above data, different transforms are used in image compression but none of them compared the CR of different transforms. So this study helps to find better transforms with better CR. Our paper will be the first of its kind to compare different transforms for X-Ray images. Although the statistical data was insignificant, the experimental data defines that wavelet transform as a better transform for compressing X-Ray images. The use of shearlet as a compression transform for X-ray images is the novelty we have opted for in this 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.

Limitation we faced in our study was that the images had to be preprocessed before the compression based on the code. By optimising the code we can perform compression without any changes in the image.

The code can be enhanced so we can perform compression regardless the size, dimensions of the image and get a better compression ratio.

5. Conclusion

Wavelet transform has better compression ratio compared with shearlet transform. Even though the statistical data was insignificant, the experimental data defines that wavelet transform was better than shearlet transform.

Declarations

Conflict of Interests

No conflict of interest in this manuscript

Authors Contribution

Author GDP was involved in compression of images, data collection and manuscript writing. Author ND was involved in conceptualization, data validation and critical review of manuscript.

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References

Alarcon-Aquino, V. 2013. "Lossy Image Compression Using Discrete Wavelet Transform and Thresholding Techniques." *The Open Cybernetics & Systemics Journal*. https://doi.org/10.2174/1874110x01307010032.

Al-Jarrah, Omar Y., Paul D. Yoo, Sami Muhaidat, George K. Karagiannidis, and Kamal Taha. 2015. "Efficient Machine Learning for Big Data: A Review." *Big Data Research*. https://doi.org/10.1016/j.bdr.2015.04.001.

Asraf, R., M. Akbar, and N. Jafri. 2006. "Diagnostically Lossless Compression-2 of Medical Images." *1st Transdisciplinary Conference on Distributed Diagnosis and Home Healthcare, 2006. D2H2*. https://doi.org/10.1109/ddhh.2006.1624789.

Bruylants, Tim, Adrian Munteanu, and Peter Schelkens. 2015. "Wavelet Based Volumetric Medical Image Compression." *Signal Processing: Image Communication*. https://doi.org/10.1016/j.image.2014.12.007.

Chouakri, S. A., O. Djaafri, and A. Taleb-Ahmed. 2013. "Wavelet Transform and Huffman Coding Based Electrocardiogram Compression Algorithm: Application to Telecardiology." *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/454/1/012086.

Easley, G. R., D. Labate, and F. Colonna. 2009. "Shearlet-Based Total Variation Diffusion for Denoising." *IEEE Transactions on Image Processing*. https://doi.org/10.1109/tip.2008.2008070.

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.

Hnesh, Allaeldien Mohamed G., and Hasan Demirel. 2016. "DWT-DCT-SVD Based Hybrid Lossy Image Compression Technique." *2016 International Image Processing, Applications and Systems (IPAS)*. https://doi.org/10.1109/ipas.2016.7880068.

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.

Juliet, Sujitha, Elijah Blessing Rajsingh, and Kirubakaran Ezra. 2016. "A Novel Medical Image Compression Using Ripplet Transform." *Journal of Real-Time Image Processing*. https://doi.org/10.1007/s11554-013-0367-9.

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.

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.

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.

Mittal, Anshu, Chinmoy Kundu, Ranjan Bose, and R. K. Shevgaonkar. 2016. “Entropy Based Image Segmentation with Wavelet Compression for Energy Efficient LTE Systems.” *2016 23rd International Conference on Telecommunications (ICT)*. https://doi.org/10.1109/ict.2016.7500430.

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.

Nashat, Ahmed A., and N. M. Hussain Hassan. 2016. “Image Compression Based upon Wavelet Transform and a Statistical Threshold.” *2016 International Conference on Optoelectronics and Image Processing (ICOIP)*. https://doi.org/10.1109/optip.2016.7528492.

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.

Reddy, B. Venkateswara, B. Venkateswara Reddy, P. Bhaskara Reddy, P. Sateesh Kumar, and A. Sateesh Reddy. 2016. “Lossless Compression of Medical Images for Better Diagnosis.” *2016 IEEE 6th International Conference on Advanced Computing (IACC)*. https://doi.org/10.1109/iacc.2016.81.

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.

Sanchez, Victor, and Joan Bartrina-Rapesta. 2014. “Lossless Compression of Medical Images Based on HEVC Intra Coding.” *2014 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*. https://doi.org/10.1109/icassp.2014.6854881.

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.

Sophia, Paul Eben, and Jude Anitha. 2017. “Contextual Medical Image Compression Using Normalized Wavelet-Transform Coefficients and Prediction.” *IETE Journal of Research*. https://doi.org/10.1080/03772063.2017.1309998.

Sran, Paramveer Kaur, Savita Gupta, and Sukhwinder Singh. 2013. “Content Based Medical Image Coding with Fuzzy Level Set Segmentation Algorithm.” *Lecture Notes in Electrical Engineering*. https://doi.org/10.1007/978-81-322-0997-3_15.

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.

Sridhar, S., P. Rajesh Kumar, and K. V. Ramanaiah. 2014. “Wavelet Transform Techniques for Image Compression – An Evaluation.” *International Journal of Image, Graphics and Signal Processing*. https://doi.org/10.5815/ijigsp.2014.02.07.

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 17, 2021.

Zuo, Zhiyong, Xia Lan, Lihua Deng, Shoukui Yao, and Xiaoping Wang. 2015. “An Improved Medical Image Compression Technique with Lossless Region of Interest.” *Optik*. https://doi.org/10.1016/j.ijleo.2015.07.005.