

## ENHANCED SATELLITE IMAGE CLARITY USING STATIONARY WAVELET TRANSFORM AND SINGULAR VALUE DECOMPOSITION

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### ABSTRACT

Image processing encompasses a wide range of tasks, including compression, feature extraction, and classification. Digital sensors produce a "raw" image, which is essentially a matrix of digital values, where each value indicates the brightness or gray intensity of a pixel. The goal of image enhancement is to reveal hidden details and emphasize key features within an image. Among the critical attributes of any image are resolution and contrast. While resolution defines the clarity of image detail, the human visual system is particularly sensitive to variations in contrast. This paper introduces a technique for contrast and resolution enhancement of satellite images using Stationary Wavelet Transform (SWT) and Singular Value Decomposition (SVD). Satellite imagery finds applications across various fields such as meteorology, oceanography, agriculture, forestry, geology, education, and defense. SWT's translational invariance aids in detecting edge features accurately. The proposed approach decomposes the input image into four frequency sub-bands using Discrete Wavelet Transform (DWT). The high-frequency sub-bands are then refined through interpolation and enhancement using a difference image derived from the input. Additionally, a modified singular value matrix is computed from the LL sub-band of both the histogram-equalized and original images to achieve brightness enhancement. Experimental results demonstrate that the proposed method outperforms traditional and state-of-the-art image enhancement techniques.

**Keywords:** Stationary Wavelet Transform (SWT), Discrete Wavelet Transform (DWT), Singular Value Decomposition (SVD), Satellite Imagery, LL Sub-band, Image Enhancement.

### 1. INTRODUCTION

The fast advance of technologies and the prevalence of imaging devices, billions of digital images are being created every day. Due to undesirable light source, unfavourable weather or failure of the imaging device itself, the contrast and tone of the captured image may not always be satisfactory [1]. Satellite images are used in many applications such as geo-scientific studies, astronomy, and geographical information systems. One of the most important quality factors in satellite image comes from its Contrast. The processing of digital satellite images have different scientific and need based applications in the field of agriculture, geology forestry, biodiversity, construction, regional planning, education, intelligence, warfare etc. Digital satellite images are subject to a wide variety of distortions which may result in visual quality degradations. Therefore, image enhancement is often required for both the aesthetic and pragmatic purposes [2]. The ultimate goal of image enhancement techniques is to improve the visual information of a degraded image in a subjective process.

Image enhancement is among the simplest and most appealing areas of digital image processing. The idea behind enhancement is to bring out the details in the image that are obscured [3] and also to highlight certain features of interest in an image. Image resolution is always a key feature of all kinds of image. Resolution of an image is an important issue in all image and video processing application like, feature extraction, video resolution enhancement and satellite image resolution enhancement. Resolution enhancement is always being associated with interpolation technique. Visual system is more sensitive

to contrast. Contrast of an image is determined by its dynamic range, which is defined as the ratio between brightest and the darkest pixel intensities [4].

Image enhancement divided into two widespread categories one is spatial domain method and another one is frequency domain method. The term spatial domain refers to the image plane itself, which directly deal with the image matrix and in frequency domain processing is done by modifying the Fourier transform of an image. Enhancement techniques based on various combinations of methods from these two categories are not unusual. When an image is processed for visual perception, the viewer is the ultimate judge of how accurate a particular method works, but here along with visual basis paper also check the results on qualitative scale measurements.

While discussing the subparts of the main composed work which is such as, resolution and contrast of an image these two factors are always important issues in many image processing applications. Due to interpolation of an image the number of pixels in a digital image increases and its applications are widely used in many image processing applications, such as image resolution enhancement, multiple description coding and facial reconstruction. Many techniques have

been developed to increases the resolution image enhancement by interpolation. Wavelets are also playing a significant rolein many image processing applications. The 2-D discrete wavelet transform of an image is performed by applying the 1-D discrete wavelet transform (DWT) alongthe rows first, and then along the columns [5]. This operation gives results in fourdecomposed sub band images named aslow-low (LL), low-high (LH), high-low (HL) and highhigh (HH). The frequency components of these sub bands enclose the full frequency spectrum of the original image.

## 2. LITERATURE SURVEY

Corina Naforntita, Alexandru Isar, TeodorDehelean, et. al.[6] discusses theenhancement of multilooks Synthetic-aperture radar (SAR) images for the purpose of wave detection. The method isbased on improving the contrast in the dualtree complex wavelet domain, whileperforming denoising simultaneously. Wedescribe the particularities of Sentinel-1Strip map multilooks ground rangedetected images with high resolution andpresent the advantages of the proposed SAR image enhancement method.Simulation results and comparisons withstate of the art contrast enhancement anddenoising methods highlight the benefitsof the proposed solution. Wen Zhang,Zhiyuan Zhang, Zhen Huang, et. al. [7]proposes an intelligent extraction methodfor farmland irrigation and drainagesystem based on domestic high resolutionsatellite GF-2 images, which hasconsidered both spectral features andgeometry features of farmland irrigationand drainage system, and could be dividedinto four parts as: image scale converting,spectral model for canal identification,data extraction by spatial features andbreakpoint connecting with morphology.This paper chose the Sanhulianjiangreservoir irrigation area to be experimentalarea, which is located in Hubei's Jiayu County. The comparison shows theaccuracy of this method is credible; itcould satisfy the needs as large-scale, fast extraction for irrigation and drainagesystem, which has huge potential inagriculture and water conservancy fields.

Jun Wang, Xiucheng Yang, Xuebin Qin, Xin Ye, Qiming Qin, et. al. [8] presents a new approach for rapid automatic building extraction from very high resolution (VHR) optical satellite imagery. The proposed method conducts building extraction based on distinctive image

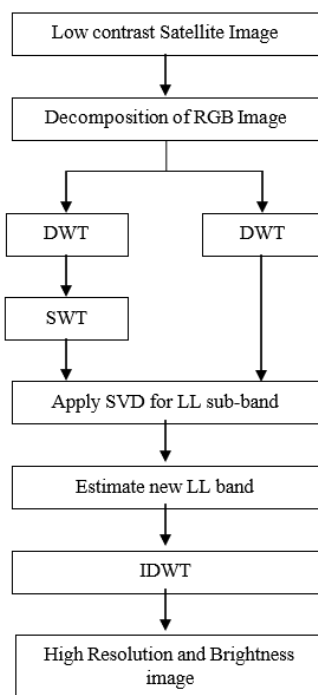
primitives such as lines and line intersections. The optimized framework consists of three stages: First, a developed edge-preserving bilateral filter. Second, a state-of-the-art line segment detector.Finally, we present a graph search-based perceptual grouping approach. Extensiveexperiments performed on VHR optical QuickBird imageries justify the effectiveness and robustness of the proposed linear-time procedure with an overall accuracy of 80.9% andcompleteness of 87.3%.

Vasileios Syrris, Stefano Ferri, Daniele Ehrlich, Martino Pesaresi, et. al. [9] presents Image Enhancement and Feature Extraction Based on Low-Resolution Satellite Data. The purpose ofthis study is to investigate the sensitivity of contrast-based textural measurements and morphological characteristics. In the existence of a low-resolution reference layer, we apply supervised learning thatindirectly reduces the uncertainty and improves the quality of the reference layer.Based on the new class label assignments, the image histogram is adjusted suitablyfor the computation of contrast-based textural/morphological features.Experimental results demonstrate that spectral band combination is the key factor that conditions the contrast of grayscaleimages.

M. Priyadarshini, R. Sasikala, R.Meenakumari, et. al. [10] presents new satellite image resolution and contrast enhancement technique based on DWT (Discrete wavelet transform), Stationary Wavelet Transform (SWT) and BPDHE (Brightness Preserving Dynamic Histogram Equalization) has beenproposed. The BPDHE is used to enhance the contrast of the image. The contrast is enhanced by using Brightness Preserving Dynamic Histogram Equalization. The proposed method enhances the resolution and contrast of the low resolution and contrast image. The quantitative metrics are measured to show that the proposed method is superior to the conventional method.

## 3. CONTRAST AND RESOLUTIONENHANCEMENT FOR SATELLITE IMAGES

The block diagram of Stationary Wavelet Transform (SWT) and Singular ValueDecomposition (SVD) based Contrast and Resolution Enhancement for SatelliteImages is represented in below Fig. 1.



**Fig. 1: BLOCK DIAGRAM OF CONTRAST AND RESOLUTION ENHANCEMENT MODEL**

The purpose of this work is to enhance the resolution and contrast of satellite images using SVD (Singular Value Decomposition) and DWT (Discrete Wavelet Transform). The DWT technique divided the input image into four subband images and different operations performed on different sub bands. Interpolation method is used here for the resolution enhancement of the satellite image whereas the SVD technique enhances the contrast of the satellite image. Then this work gives more refinement in the output image when it is compared with the input image.

Down sampling in each of the DWT sub bands causes information loss in the respective sub bands. That is why SWT is employed to minimize this loss. Stationary wavelet transform is translational invariant, which helps to identify the image edge features. The interpolated high frequency sub bands and the SWT high frequency sub bands have the same size which means they can be added with each other. The new corrected high frequency sub bands can be interpolated further for higher enlargement. Also it is known that in the wavelet domain, the low resolution image is obtained by low pass filtering of the high resolution image.

The wavelet decomposition of an image is done row by row and then column by column. DWT provides multi resolution representation of image and can efficiently implemented using digital filters. Image itself is considered as two dimensional signal. Thus in DWT process the image will be subdivided into four sub bands. The four sub images are obtained when the image is by low-pass filtered by rows and then by columns which is named as LL sub band image then the next sub band is obtained by low-pass filtering of the rows and high-pass filtering of the columns is named as LH sub band image. The one which is obtained by high-pass filtering of the rows and low-pass filtering of the columns is named as HL subband image. The sub image which is obtained by high pass filtering of the rows and columns is named as the HH sub band image.

Consider the LL sub band image among the four sub band images of image A and image B then apply SVD on the LL sub band of both the images. The singular value decomposition of an  $a \times b$  real or complex matrix  $M$  is a factorization form. Singular Value Decomposition method can transform matrix  $A$  into  $USV^T$  product which allows us to refactoring of a digital image into three matrices. The using of singular values of such refactoring allows us to represent the image with a smaller set of values, which can preserve useful features of the original image, but use less storage space in the memory.

After that the transformation factor by which new enhanced LL sub band is formed. On the other hand for the need of sharper image because the image is get blurred due to interpolation which get by the frequency sub bands of input image those modified by an intermediate stage in which difference image is added in them, difference image is the image which get by subtracting the input image with interpolated LL sub band image. Then the output is combined by resizing the new SVD enhanced LL sub band to the size of interpolated estimated other three sub bands estimated LH, HL, HH by applying IDWT (Inverse DWT) technique and obtained the final resolution and contrast enhanced image.

#### 4. RESULT ANALYSIS

The proposed technique has been examined on several different satellite images. In order to display the superiority of the proposed method over the conventional techniques visually, we show the result images which we get from different equalization methods such as General Histogram Equalization (GHE), Local Histogram Equalization (LHE), Singular Value Equalization (SVE) and enhanced images obtained by the proposed technique. The superiority of proposed method is estimated by using Peak signal- to-noise ratio (PSNR), root mean square error (RMSE) and mean square error (MSE).

The enhancement is measured in terms of MSE (Mean square error), PSNR (Peak signal to noise ratio) and RMSE (Root mean square error) values of both input and output images. An increase in PSNR value indicates good quality of the images compared to the input image and low value of RMSE, MSE indicates there are fewer errors in the output image as compared to input image. These values are calculated for the qualitative analysis.

##### Mean Square Error (MSE):

MSE is the cumulative squared error between the compressed and the original image. A lower value of MSE means lesser error, and it has the inverse relation with PSNR.

$B^2$

$$\text{PSNR} = 10 \cdot \log_{10} \left( \frac{B^2}{\text{MSE}} \right) \dots \dots (3)$$

Where, B is the maximum fluctuation in the input image.

Table 1 is showing the comparison between the proposed Stationary Wavelet Transform (SWT) and Singular Value Decomposition (SVD) based Contrast and Resolution Enhancement, GHE, LHE and SVE. Fig. 2 shows the Graphical representation of MSE parameter and Fig.

3 shows the graphical representation of PSNR and RMSE values.

**Table 1: COMPARATIVE ANALYSIS OF PERFORMANCE PARAMETERS**

Parameters	GHE	LHE	SVE	SWT & SVD based enhancement
MSE	10156.21	1734.76	9215.46	412.51
PSNR	8.21	16.43	8.99	23.21
RMSE	108.03	41.86	96.11	20.31

M N

1

$$\text{MSE}(i_1, i_2) =$$

$$\sum \sum [i_1(x, y) - i_2(x, y)]^2 \dots \dots (1)$$

NM

$$x=1 \ y=1$$

Where,  $i_1(x, y)$  is the original image and  $i_2(x, y)$  is the reconstructed image and M, N are the dimensions of the image.

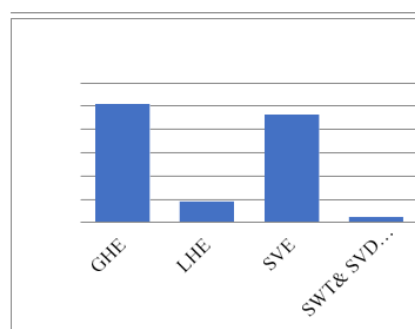
**Root mean square error (RMSE):** Clearly, RMSE is the square root of MSE, hence it can be calculated by the following:

M N

1

$$\text{RMSE} = \sqrt{\text{MSE}}$$

MSE



**Fig. 2: COMPARATIVE ANALYSIS INTERMS OF MSE**

$$\sum \sum [i_1(x, y) - i_2(x, y)]^2 \dots (2)$$

NM

x=1 y=1

12000

10000

8000

6000

**Peak Signal-to-Noise Ratio (PSNR):** PSNR is used to measure the quality of compression images. It is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

4000

2000

0

### Techniques

This ratio is often used as a quality measurement between the original and compressed image. The higher PSNR gives better quality of the compressed or reconstructed image.

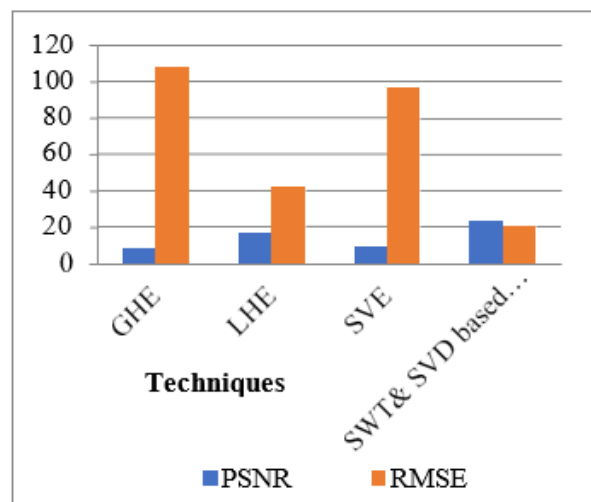


Fig. 3: COMPARATIVE ANALYSIS INTERMS OF PSNR AND RMSE

If we are taking the input image cameraman in Fig. 4 image as some noise should be occur. Similarly Fig. 5 is the final resolution and contrast enhanced image.

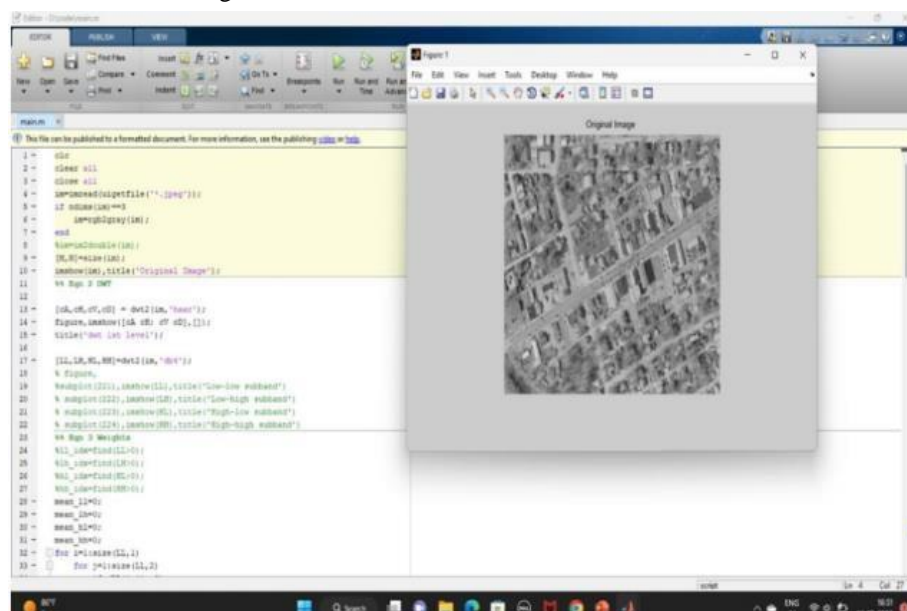
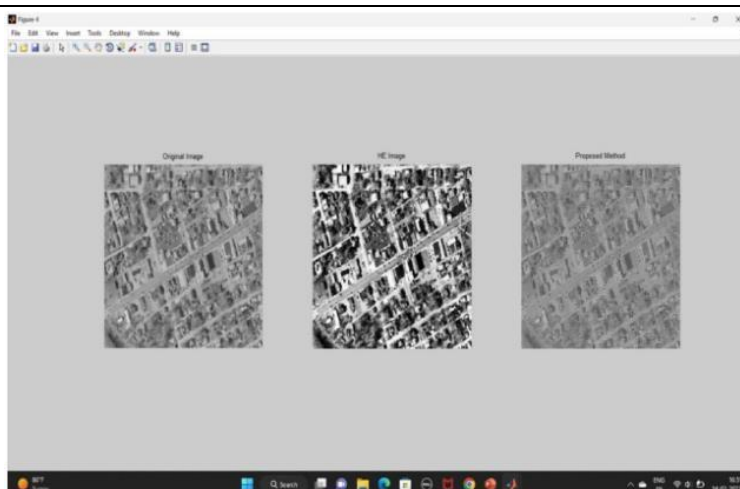


Fig. 4: INPUT IMAGE





**Fig. 5: OUTPUT IMAGE**

It is clear that the enhanced image using proposed technique is sharper and brighter than the other techniques.

## 5. CONCLUSION

This paper presents a contrast and resolution enhancement method for satellite images, leveraging Stationary Wavelet Transform (SWT) and Singular Value Decomposition (SVD). In image processing, resolution and **contrast** are crucial attributes. While resolution captures the level of detail in an image, the human visual system is particularly responsive to contrast. The Discrete Wavelet Transform (DWT) offers a multi-resolution image representation and can be efficiently executed using digital filters. SWT, which maintains translational invariance, is particularly effective in detecting image edge features. The SVD method improves image contrast by adjusting the singular values in the transformed image domain. In this approach, DWT decomposes the input image into frequency sub-bands: the LL sub-band (representing low-frequency components) and the HL, LH, and HH sub-bands (representing high-frequency components). Resolution enhancement focuses on refining the high-frequency sub-bands (HL, LH, HH), while contrast enhancement targets the LL sub-band. The proposed method was evaluated on multiple test images, and the results—measured in terms of PSNR, MSE, RMSE, and visual quality—demonstrated its superiority over conventional and contemporary techniques. The enhanced images produced by this method are noticeably sharper and brighter, confirming the effectiveness of the approach.

## 6. REFERENCES

- [1] Thommandru, R. (2024). Quantum Key Distribution for Securing 6G Networks: Shaping the Future of Mobile Communication. MJARET, 4(5), 16-20.
- [2] Thommandru, R., & Saravanakumar, R. (2022). Survey on MIMO Antenna for 5G Applications. Mathematical Statistician and Engineering Applications, 71(3), 2181-2191.
- [3] Reddy, V., Sk, K. B., Roja, D., Purimetla, N. R., Vellela, S. S., & Kumar, K. K. (2023, November). Detection of DDoS Attack in IoT Networks Using Sample elected RNN-ELM. In 2023 International Conference on Recent Advances in Science and Engineering Technology (ICRASET) (pp. 1-7). IEEE.
- [4] Sai Srinivas Vellela, M Venkateswara Rao, Srihari Varma Mantena, M V Jagannatha Reddy, Ramesh Vatambeti, Syed Ziaur Rahman, "Evaluation of Tennis Teaching Effect Using Optimized DL Model with Cloud Computing System", International Journal of Modern Education and Computer Science(IJMECS), Vol.16, No.2, pp. 16-28, 2024. DOI:10.5815/ijmeecs.2024.02.02
- [5] Vullam, N., Roja, D., Rao, N., Vellela, S. S., Vuyyuru, L. R., & Kumar, K. K. (2023, November). Enhancing Intrusion Detection Systems for Secure ECommerce Communication Networks. In 2023 International Conference on the Confluence of Advancements in Robotics, Vision and Interdisciplinary Technology Management (IC-RVITM) (pp. 1-7). IEEE.
- [6] Vullam, N., Roja, D., Rao, N., Vellela, S. S., Vuyyuru, L. R., & Kumar, K. K. (2023, December). An Enhancing Network Security: A Stacked Ensemble Intrusion Detection System for Effective Threat Mitigation. In 2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA) (pp. 1314-1321). IEEE.
- [7] Basha, S. K., Purimetla, N. R., Roja, D., Vullam, N., Dalavai, L., & Vellela, S. S. (2023, December). A Cloud-based Auto-Scaling System for Virtual Resources to Back Ubiquitous, Mobile, Real-Time Healthcare

- Applications. In 2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA) (pp. 1223-1230). IEEE.
- [8] Rao, A. S., Dalavai, L., Tata, V., Vellela, S. S., Polanki, K., Kumar, K. K., & Andra, R. (2024, February). A Secured Cloud Architecture for Storing Image Data using Steganography. In 2024 2nd International Conference on Computer, Communication and Control (IC4) (pp. 1-6). IEEE.
- [9] Reddy, B. V., Sk, K. B., Polanki, K., Vellela, S. S., Dalavai, L., Vuyyuru, L. R., & Kumar, K. K. (2024, February). Smarter Way to Monitor and Detect Intrusions in Cloud Infrastructure using Sensor-Driven Edge Computing. In 2024 IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT) (Vol. 5, pp. 918-922). IEEE.
- [10] Biyyapu, N., Veerapaneni, E. J., Surapaneni, P. P., Vellela, S. S., & Vatambeti, R. (2024). Designing a modified feature aggregation model with hybrid sampling techniques for network intrusion detection. Cluster Computing, 1-19.
- [11] Reddy, N. V. R. S., Chitteti, C., Yesupadam, S., Desanamukula, V. S., Vellela, S. S., & Bommagani, N. J. (2023). Enhanced speckle noise reduction in breast cancer ultrasound imagery using a hybrid deep learning model. Ingénierie des Systèmes d'Information, 28(4), 1063-1071.
- [12] Vellela, S. S., Vuyyuru, L. R., MalleswaraRaoPurimetla, N., Dalavai, L., & Rao, M. V. (2023, September). A Novel Approach to Optimize Prediction Method for Chronic Kidney Disease with the Help of Machine Learning Algorithm. In 2023 6th International Conference on Contemporary Computing and Informatics (IC3I) (Vol. 6, pp. 1677-1681). IEEE.
- [13] Davuluri, S., Kilaru, S., Boppana, V., Rao, M. V., Rao, K. N., & Vellela, S. S. (2023, September). A Novel Approach to Human Iris Recognition And Verification Framework Using Machine Learning Algorithm. In 2023 6th International Conference on Contemporary Computing and Informatics (IC3I) (Vol. 6, pp. 2447-2453). IEEE.
- [14] Vellela, S. S., Roja, D., Sowjanya, C., SK, K. B., Dalavai, L., & Kumar, K. K. (2023, September). Multi-Class Skin Diseases Classification with Color and Texture Features Using Convolution Neural Network. In 2023 6th International Conference on Contemporary Computing and Informatics (IC3I) (Vol. 6, pp. 1682-1687). IEEE.
- [15] Praveen, S. P., Nakka, R., Chokka, A., Thatha, V. N., Vellela, S. S., & Sirisha, U. (2023). A Novel Classification Approach for Grape Leaf Disease Detection Based on Different Attention Deep Learning Techniques. International Journal of Advanced Computer Science and Applications (IJACSA), 14(6).
- [16] Vellela, S. S., Reddy, V. L., Roja, D., Rao, G. R., Sk, K. B., & Kumar, K. K. (2023, August). A Cloud-Based Smart IoT Platform for Personalized Healthcare Data Gathering and Monitoring System. In 2023 3rd Asian Conference on Innovation in Technology (ASIANCON) (pp. 1-5). IEEE.
- [17] Vellela, S. S., & Balamanigandan, R. (2023). An intelligent sleep-awake energy management system for wireless sensor network. Peer-to-Peer Networking and Applications, 16(6), 2714-2731.
- [18] Vullam, N., Yakubreddy, K., Vellela, S. S., Sk, K. B., Reddy, V., & Priya, S. S. (2023, June). Prediction And Analysis Using A Hybrid Model For Stock Market. In 2023 3rd International Conference on Intelligent Technologies (CONIT) (pp. 1-5). IEEE.
- [19] Rao, K. N., Gandhi, B. R., Rao, M. V., Javvadi, S., Vellela, S. S., & Basha, S. K. (2023, June). Prediction and Classification of Alzheimer's Disease using Machine Learning Techniques in 3D MR Images. In 2023 International Conference on Sustainable Computing and Smart Systems (ICSCSS) (pp. 85-90). IEEE.
- [20] Vellela, S. S., Vullum, N. R., Thommandru, R., Rao, T. S., Sowjanya, C., Roja, D., & Kumar, K. K. (2024, May). Improving Network Security Using Intelligent Ensemble Techniques: An Integrated System for Detecting and Managing Intrusions in Computer Networks. In 2024 International Conference on Advances in Modern Age Technologies for Health and Engineering Science (AMATHE) (pp. 1-7). IEEE.
- [21] Vullam, N., Vellela, S. S., Reddy, V., Rao, M. V., SK, K. B., & Roja, D. (2023, May). Multi-Agent Personalized Recommendation System in ECommerce based on User. In 2023 2nd International Conference on Applied Artificial Intelligence and Computing (ICAIC) (pp. 1194-1199). IEEE.
- [22] Praveen, S. P., Sarala, P., Kumar, T. K. M., Manuri, S. G., Srinivas, V. S., & Swapna, D. (2022, November). An Adaptive Load Balancing Technique for Multi SDN Controllers. In 2022 International Conference on Augmented Intelligence and Sustainable Systems (ICAISS) (pp. 1403-1409). IEEE.
- [23] Vellela, S. S., & Balamanigandan, R. (2022, December). Design of Hybrid Authentication Protocol for High Secure Applications in Cloud Environments. In 2022 International Conference on Automation, Computing and

- 
- Renewable Systems (ICACRS) (pp. 408-414). IEEE.
- [24] Vellela, S. S., & Balamanigandan, R. (2024). Optimized clustering routing framework to maintain the optimal energy status in the wsn mobile cloud environment. *Multimedia Tools and Applications*, 83(3), 7919-7938.
- [25] VenkateswaraRao, M., Vellela, S., Reddy, V., Vullam, N., Sk, K. B., & Roja, D. (2023, March). Credit Investigation and Comprehensive Risk Management System based Big Data Analytics in Commercial Banking. In 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS) (Vol. 1, pp. 2387-2391). IEEE.
- [26] Vellela, S. S., Reddy, B. V., Chaitanya, K. K., & Rao, M. V. (2023, January). An integrated approach to improve e-healthcare system using dynamic cloud computing platform. In 2023 5th International Conference on Smart Systems and Inventive Technology (ICSSIT) (pp. 776-782). IEEE.
- [27] Kumar, K. K., Rao, T. S., Vullam, N., Vellela, S. S., Jyosthna, B., Farjana, S., & Javvadi, S. (2024, March). An Exploration of Federated Learning for Privacy-Preserving Machine Learning. In 2024 5th International Conference on Innovative Trends in Information Technology (ICITIIT) (pp. 1-6). IEEE.
- [28] SrinivasVellela, S., Praveen, S. P., Roja, D., Krishna, A. R., Purimetla, N., Rao, T., & Kumar, K. K. (2024, April). Fusion-Infused Hypnocare: Unveiling Real-Time Instantaneous Heart Rates for Remote Diagnosis of Sleep Apnea. In 2024 International Conference on Knowledge Engineering and Communication Systems (ICKECS) (Vol. 1, pp. 1-5). IEEE.
- [29] Vellela, S. S., KOMMINENI, K. K., Rao, D. M. V., & Sk, K. B. (2024). An Identification of Plant Leaf Disease Detection Using Hybrid Ann and Knn. Sai Srinivas Vellela, Dr K Kiran Kumar, Dr. M Venkateswara Rao, Venkateswara Reddy B, Khader Basha Sk, Roja D, AN IDENTIFICATION OF PLANT LEAF DISEASE DETECTION USING HYBRID ANN AND KNN, *Futuristic Trends in Artificial Intelligence*, e.
- [30] Polasi, P. K., Vellela, S. S., Narayana, J. L., Simon, J., Kapileswar, N., Prabhu, R. T., & Rashed, A. N. Z. (2024). Data rates transmission, operation performance speed and figure of merit signature for various quadrature light sources under spectral and thermal effects. *Journal of Optics*, 1-11.
- [31] Thommandru, R., Krishna, C. M., Suguna, N., Sathish, M., & Kiran, K. (2024, January). Millimetre Wave Self-Isolated MIMO Antenna with High Isolation and Radiation Efficiency. In 2024 2nd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT) (pp. 191-196). IEEE.
- [32] Thommandru, R., Krishna, C. M., Suguna, N., Sathish, M., & Kiran, K. (2024, January). Millimetre Wave Self-Isolated MIMO Antenna with High Isolation and Radiation Efficiency. In 2024 2nd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT) (pp. 191-196). IEEE.
- [33] Vellela, S. S., & Balamanigandan, R. (2024). Optimized clustering routing framework to maintain the optimal energy status in the wsn mobile cloud environment. *Multimedia Tools and Applications*, 83(3), 7919-7938.
- [34] Vuyyuru, L. R., Purimetla, N. R., Reddy, K. Y., Vellela, S. S., Basha, S. K., & Vatambeti, R. (2024). Advancing automated street crime detection: a drone-based system integrating CNN models and enhanced feature selection techniques. *International Journal of Machine Learning and Cybernetics*, 1-23.
- [35] Krishna, C. V. M., Krishna, G. G., Vellela, S. S., Rao, M. V., Sivannarayana, G., & Javvadi, S. (2023, December). A Computational Data Science Based Detection of Road Traffic Anomalies. In 2023 Global Conference on Information Technologies and Communications (GCITC) (pp. 1-6). IEEE.
- [36] Vellela, S. S., & Balamanigandan, R. (2024). An efficient attack detection and prevention approach for secure WSN mobile cloud environment. *Soft Computing*, 1-15.
- [37] Saravanakumar, R., Raja, A., Narayan, P., Rajesh, G., Vinoth, M., & Thommandru, R. (2024, September). Dual-Band Performance Enhancement of Square Wheel Antennas with FR4 Substrate for Sub 7GHz Applications. In 2024 International Conference on Advances in Computing Research on Science Engineering and Technology (ACROSET) (pp. 1-7). IEEE.
- [38] Thommandru, R., Krishna, C. M., Suguna, N., Sathish, M., & Kiran, K. (2024, January). Millimetre Wave Self-Isolated MIMO Antenna with High Isolation and Radiation Efficiency. In 2024 2nd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT) (pp. 191-196). IEEE.
- [39] Saravanakumar, R., Thommandru, R., Kumar, E. K., Al Ansari, M. S., Manage, P. S., & Muthuvel, S. K. (2024, April). Cross Scoop Fractal Antenna Design with Notch at 15 Degree for Emerging Applications at 5.2 GHz. In 2024 International Conference on Recent Advances in Electrical, Electronics, Ubiquitous Communication, and Computational Intelligence (RAEEUCCI) (pp. 1-7). IEEE.
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- [40] Saravanakumar, R., Ponnappalli, V. P., Thommandru, R., Khatak, S., Manohara, H. T. P., & Thenmozhi, A. (2024, March). Analysis Circular Wave Guide Antenna for 5G Mid-Band Applications. In 2024 10th International Conference on Advanced Computing and Communication Systems (ICACCS) (Vol. 1, pp. 560-566). IEEE.
- [41] Thommandru, R., Krishna, C. M., Suguna, N., Sathish, M., & Kiran, K. (2024, January). Millimetre Wave Self-Isolated MIMO Antenna with High Isolation and Radiation Efficiency. In 2024 2nd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT) (pp. 191-196). IEEE.
- [42] Thommandru, R., & Saravanakumar, R. (2022). Survey on MIMO Antenna for 5G Applications. Mathematical Statistician and Engineering Applications, 71(3), 2181-2191.
- [43] Madhuri, A., Jyothi, V. E., Praveen, S. P., Sindhura, S., Srinivas, V. S., & Kumar, D. L. S. (2024). A new multi-level semi-supervised learning approach for network intrusion detection system based on the 'goa'. Journal of Interconnection Networks, 24(supp01), 2143047.
- [44] Thommandru, R., Kalyani, K., Rani, B. S., Karunakar, K., Sai, A. V., & Guptha, P. IoT Based Automatic Vehicle Accident Detection and Rescue System.
- [45] Madhuri, A., Praveen, S. P., Kumar, D. L. S., Sindhura, S., & Vellela, S. S. (2021). Challenges and issues of data analytics in emerging scenarios for big data, cloud and image mining. Annals of the Romanian Society for Cell Biology, 412-423.
- [46] Vellela, S. S., Balamanigandan, R., & Praveen, S. P. (2022). Strategic Survey on Security and Privacy Methods of Cloud Computing Environment. Journal of Next Generation Technology, 2(1).
- [47] Sk, K. B., Roja, D., Priya, S. S., Dalavi, L., Vellela, S. S., & Reddy, V. (2023, March). Coronary Heart Disease Prediction and Classification using Hybrid Machine Learning Algorithms. In 2023 International Conference on Innovative Data Communication Technologies and Application (ICIDCA) (pp. 1-7). IEEE.
- [48] Vellela, S. S., & Krishna, A. M. (2020). On Board Artificial Intelligence With Service Aggregation for Edge Computing in Industrial Applications. Journal of Critical Reviews, 7(07).
- [49] Kumar, E. R., Chandolu, S. B., Kumar, K. P. V., Rao, M. V., Muralidhar, V., Nagarjuna, K., & Vellela, S. S. (2023, November). UAVC: Unmanned Aerial Vehicle Communication Using a Coot Optimization-Based Energy Efficient Routing Protocol. In 2023 International Conference on Recent Advances in Science and Engineering Technology (ICRASET) (pp. 1-5). IEEE.
- [50] Vellela, S. S., Sowjanya, C., Vullam, N., Srinivas, B. R., Durga, M. L., Jyosthna, B., & Kumar, K. K. (2024, March). An Examination of Machine Learning Applications in the Field of Cybersecurity Approaches for Detecting and Mitigating Threats. In 2024 Third International Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS) (pp. 1-6). IEEE.