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Research Article

Machine learning based novel architecture implementation for image processing mechanism

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ABSTRACT
When an image captured in low-light, it gets the low visibility. To overcome the low visibility of the image, some operations are to be performed. But in this paper image enhancement is introduced using illumination mapping. Firstly, R, G, B maximum values in each pixel of the considered image are to be calculated, and then convert it into a grey scale image by applying the formulae. Some filters are used to remove the noise, the choice of filter depends on the type of noise, and then the image is preprocessed. The logarithmic transformation helps to increase the brightness and contrast of the image with a certain amount. Earlier there were some methods to enhance the low-light image, but illumination map existence is chosen. In this illumination, the image will be enhanced with the good quality and efficiency. The illumination technique will be the more efficient and more quality. The illumination corrects the R, G, B values to get the desired image, then Gamma Correction is applied. The Gamma Correction is a non-linear power transform, it helps to increase or decrease the brightness of the desired image, when a low value of gamma is taken, the brightness will be increased and when a high value of gamma is taken, and the brightness will be decreased. The proposed system is implemented using MATLAB software. When different types of images are applied, different contrast and brightness levels that depends on the type of image are observed.

Keywords: Gamma Correction, Illumination Correction, Preprocessing, Transformation.

1 Introduction

An image captured in low light conditions is to be enhanced for a better visibility. Image enhancement plays a vital role in improving the digital image quality. Histogram equalization (HE) in [1] is widely used to adjust the image intensities and to enhance the contrast of the image in a variety of applications due to its simple function and its effectiveness. Contextual and variational contrast enhancement that in [2]-[3] proposes an algorithm that enhances the contrast of input image using inter pixel contextual information. It maps the elements of one histogram to elements of another histogram diagonally. Layered difference representation is used to enhance the image contrast by mapping the input grey levels to the output grey levels. The grey level difference between the adjacent pixels is amplified. Naturalness preserved enhancement algorithm preserves the naturalness of the image by using three methods, they are lightness-order-error measure, bright pass filter and bi-log transformation. These are used for preserving naturalness and also enhances the image. Applications for the above mentioned methods are, these are applied for thresholding, normalization of Magnetic resonance imaging (MRI) images. For comparing two or more images on a particular basis, histograms of the images are to be normalized [2]-[19].

The major drawbacks of existing methods are an increase in the contrast of noise by decreasing the quality of the image. The results are computationally intensive. When we increase the brightness of the image the brighter particles in the image will get brighter. One major drawback observed is with rapid change in technology, techniques that are used in real time applications always keeps on changing less than a decade i.e. digital image processing’s real time products can only survive in the market for a maximum of three to five years only and in this span other technologies arises. The initial cost of the technique is high depending on the type of system [20]-[28].

Proposed work mainly describes input image that is the low light captured image is chosen and is to be enhanced to obtain desired modified image as said in [4]. The file path of the image to be enhanced is considered and is pre-processed, so that noise can be reduced easily. Noise present in the image causes blurrness. These noise or distortions are filtered using pre-processing step. The uneven illumination caused by sensors, default, non-uniform illumination of the scene or orientation of objects can be rectified using illumination correlation. Prospective correlation, retrospective correlation and other using low pass filtering as from [5] is also done using illumination correction [6]. In illumination correction brightness and contrast can be applied to the image where ever required non-linear distribution is done. The grey scale levels between black and white colours are enhanced using gamma correction [7]. Gamma correction also enables us to compare grey levels between the adjacent pixels and stop adjust whichever colour is required. Pixel intensity enhancement has to be carefully adjusting brightness or contrast levels to larger extend may cause irregularities in the image. These pixels enhancement can be applied to both grey and colour scale image. Illumination map estimation is done using RGB channels individually to the input image and then is converted to grey scale image to check the improvements in the image. Enhancement is done until the desired output is obtained. Advantages and applications are also explained in this paper [29]-[34].

This paper is well organized as it clearly states step to step process of this project. Image enhancement is the major part as it is a basic need when any image is considered. The drawbacks in previous methods and the possibility to overcome them are discussed in above paragraphs. Reduction of noise as explained in [8]-[9], better version of HE and other steps has been taken. In above mentioned theory it clearly states that what the steps are done from the beginning input image to obtaining the desired output. Section II describes how the input image is taken, reduction of noise, deblurring the blurred image etc., are explained individually. Adjusting the brightness and contrast of the image is done accordingly. Applying different filters individually for the considered input image. Gamma correction enhances the pixel intensity. Gaussian and median filters [10] are used for noise reduction. Recovering the desired image from noise affected or blurred features can also be achieved [11]. In continuation with section II, Section III deals with the simulation results and comparission table of the input and output images.

2 Design methodology and observation

The design methodology briefly describes how image enhancement, pre-processing, transformation, illumination correction and gamma correction are performed on the image which is taken under low-light conditions. The enhanced image is obtained by using the below explained methods [35]-[39].

2.1 Image enhancement

Image enhancement is the process by which the digital images can be adjusted for better quality and for further use. Here the noise can be reduced, the images are sharpened and brighten.

The various methods involved in image enhancement are morphological operations, HE, for removal of noise wiener filter is used, linear contrast adjustment, median filtering, un-sharp mask filtering and decorrelation stretch [1].

Advantages of image enhancement are manipulating the pixel values in the image and it is easy for visual interpretation [2].

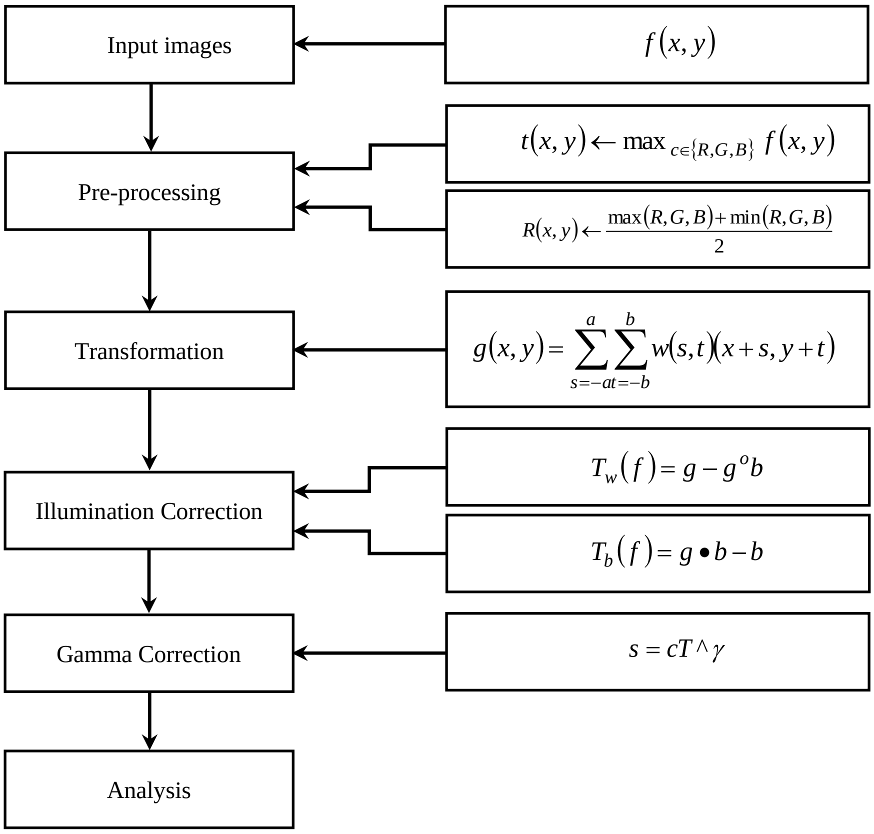


Fig. 1. Flow chart

The flow chart is given in Fig. 1 describes each and every step of the techniques which are used for enhancement of the image. The algorithm shown below gives the information about how an image is taken and processed in a step by step manner. The first is to reduce the noise and enhancing the image by using some of the transforms and at the final step the image contrast levels are increasedby using gamma correction.

Algorithm: Image Enhancement	
Input: The input image is given by $F(x,y)$.	
Initialization:	
	Update the value of $R(x,y)$ using equation (1).
	Update the value of $g(x,y)$ using equation (2).
	Update the value of $T_w(f)$ and $T_b(f)$ using $g(x,y)$.
Output: The solution is s.	

2.2 Pre-processing

Pre-processing is a technique used to suppress the noise and distortion which are present in the image and it enhances the information in the image. The median filter is used in reducing the noise. It is a non-linear digital filtering technique. Reduction of noise is a major solution in pre-processing step for improvement of further use. Fig. 2(b) shows how noise is reduced. By using a median filter, it preserves edges when noise is reduced. The main advantage of pre-processing is to reduce the noise [4].

a) Before filtering b) After filtering

Fig. 2. Removal of noise using a median filter

$$t(x,y) \leftarrow \max_{c\in\{R,G,B\}} f(x,y) \quad (1)$$

$$R(x,y) \leftarrow \frac{\max(R,G,B)+\min(R,G,B)}{2} \quad (2)$$

The two equations (1) and (2) represent the input image and the image converted into grey image. Here represents the input image and is the grey image.

2.3 Transformation

Transformation is a technique used for operations in the image. First the image is transformed into spatial domain then it removes the noise and again convert it into the frequency domain. The image before and after transformation is shown in Fig. 3(a) and 3(b). The mathematical representation of spatial domain is given in equation (3).

$$g(x,y) = \sum_{s=-a}^{a}\sum_{t=-b}^{b} w(s,t)(x+s, y+t) \quad (3)$$

Where $w(s,t)$ is the image which is a pre-processed image, $R(x,y)$ is the grey image and $g(x,y)$ is the transformed image.

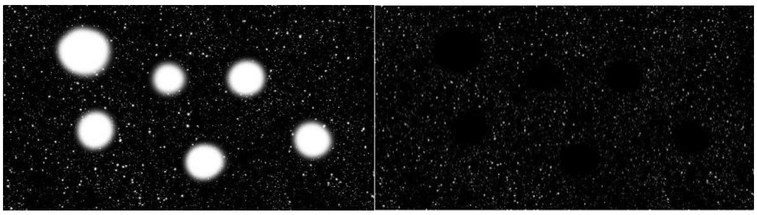
a) Before transformation b) After transformation

Fig. 3. Image after transformation

Advantages of transformation are noise reduction. In the frequency domain, fast convolution is carried out [5].

2.4 Illumination Correction

It is used to adjust the brightness and contrast level of the image. Illumination correction is done by two transforms they are, top-hat and bot-hat transform. Top-hat transform is used in digital image processing and mathematical morphology. It is an operation used for extraction of small elements that are given in Fig. 4.



a) Before transform b) After transform

Fig. 4. Illumination correction

It is also used for extracting the details from the given image. There are two types of top-hat transforms they are 1) white top-hat transform, 2) black top-hat transform. The white top-hat transform is known as the difference between the input image and the structuring element by opening it. White top-hat transform is represented by $T_w(f)$. The black top-hat transform is known as the difference between the closing of structuring element and input image and it is represented by $T_b(f)$. In various applications top-hat transform is used [7].

$T_w(f) = g - g^o b$ (4)

$T_b(f) = g \bullet b - b$ (5)

The above two equations (4) and (5) are top-hat and bot-hat transforms. Where g is transformed image and b is the structuring element.

2.6 Gamma Correction

Gamma correction is also known as power law transformation. The nth power and nth root transformations are two types of power law transformations. These transformations are given by the expression presented in equation (6).

$s = cT^\wedge \gamma$ (6)

This γ symbol is called gamma, by reflecting this symbol name, it is also known as gamma transformation. By varying the γ values the image can be enhanced that is shown in Fig. 5. Here c is a color component value ranging from 0 raised to some power γ and T is the image. Different devices or monitors have different display settings, by this the intensity also changes. The advantage of gamma is image can be displayed on CRT and LCD [8].

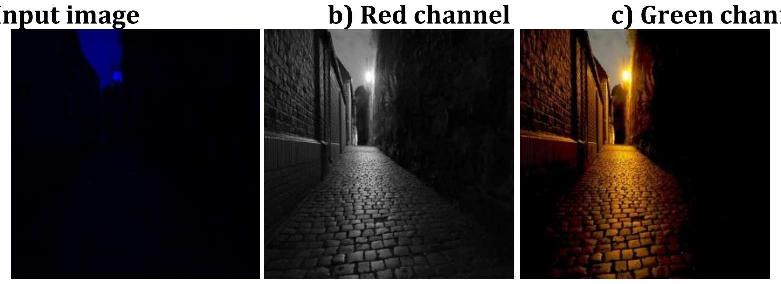
a) Before applying gamma **b) After applying gamma**

Fig. 5. Gamma correction

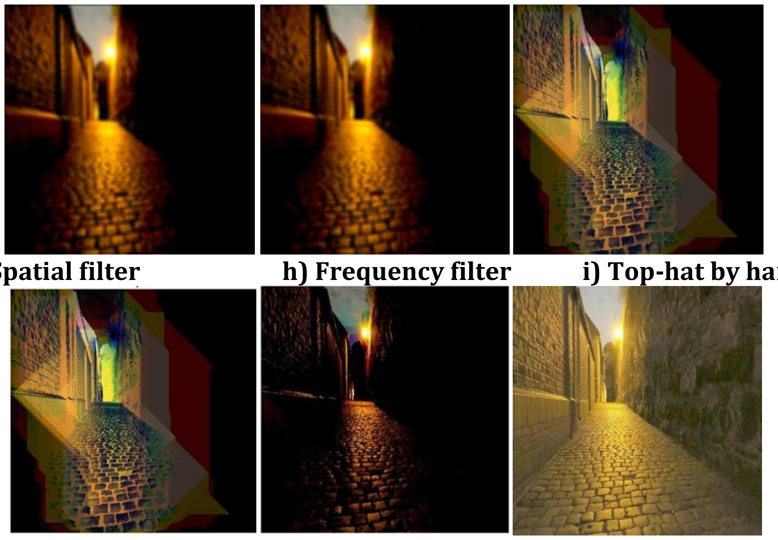
3 Simulation results of the proposed design

The Figs. 6(a)-(l) represent each and every method in the proposed model about how the image is taken and enhanced. First the input image is converted into RGB channels and then converted into a grey image. The grey image is then pre-processed using a median filter and the image is transformed into frequency domain [5]. The image in [7] frequency domain is enhanced by changing the contrast levels using top-hat and bot-hat transform and next to the image is corrected by using gamma correction, in this the image is enhanced by changing the gamma values. Thus, the output image is obtained shown in Fig. 6(l).

a) Input image **b) Red channel** **c) Green channel**



d) Blue channel **e) Grey imageby formula** **f) Grey imagethresholding**



g) Spatial filter h) Frequency filter i) Top-hat by hand

j) Bot-hat by hand k) Top-hat minus bot-hat l) Output image

Fig. 6.Simulation Results

The comparission of different types of images is done by calculating the mean square error (MSE) and signal to noise ratio (SNR). The MSE and SNR of the input image is 1107.9, 0.6948. The MSE and SNR of the output image is 411.90, 1.55, respectively. It is as shown in Table 1.

Table 1. Comparison Table.

Type of Image	MSE	SNR
Input image	1107.9	0.6948
Red channel	1223.9	0.8791
Green channel	1242.9	0.8463
Blue channel	1278.3	0.7873
Grey image by formulae	1148.5	1.0286
Grey image threshold	1228.7	0.9052
Spatial filter	1217.4	0.9286
Frequency filter	1215.7	0.9281
Top-hat transform	1211.1	0.9055
Output image	1133.05	1.1090
Input image	1107.9	0.6948

4 Conclusion

In this paper, a low-light image enhancement is proposed. By decomposing a low-light image into the illumination component, it offers a solution to expand illumination and enhances image details separately. Specifically, the illumination component is processed using median image filter in gradient domain, followed by a nonlinear logarithmic transform. Then the illumination component is enhanced by the gamma transform. This leads to enhance the low-light images and effectively reduce the distortions in color image and also reduces noise and image blurring. Then, the final result is analyzed by the output of the enhanced illumination component. Experimental results show that the enhanced images produced by the proposed method are visually clear and more effective by the performance of the proposed method outperforms the existing methods in terms of both HE and Adaptive histogram equalization (AHE) assessments. Moreover, the proposed algorithm is efficient because the computation complexity is not related to filter size. The proposed method has great potential to implement in a real-time low-light video processing.

References

1. Ghitta, O., Ilea, D.E., Whelan, P.F.: Texture Enhanced Histogram Equalization Using TV-L1 Image Decomposition. IEEE Transactions on Image Processing, vol. 22, iss. 8, pp. 3133-3144 (2013).
2. M. Sreevani, S. Lakshmanachari, B. Manvitha, Y.J.N. Pravalika, T.Praveen,V.Vijay, Rajeev Ratna Vallabhuni, “Design of Carry Select Adder Using Logic Optimization Technique,” IEEE 2021 International Conference on Advances in Computing, Communication and Control

(ICAC3'21) 7th Edition (3rd and 4th December 2021), Mumbai, Maharashtra, India, December 03-04, 2021, pp. 1-6.
3. M. Saritha, Chelle Radhika, M. Narendra Reddy, M. lavanya, A. Karthik, Vallabhuni Vijay, Rajeev Ratna Vallabhuni, "Pipelined Distributive Arithmetic-based FIR Filter Using Carry Save and Ripple Carry Adder," Second IEEE International Conference on Communication, Computing and Industry 4.0 (C2I4-2021), Bengaluru, Karnataka, India, December 16-17, 2021, pp. 1-6.
4. Vijay, Vallabhuni, Chandra S. Pittala, A. Usha Rani, Sadulla Shaik, M. V. Saranya, B. Vinod Kumar, RES Praveen Kumar, and Rajeev R. Vallabhuni, "Implementation of Fundamental Modules Using Quantum Dot Cellular Automata," Journal of VLSI circuits and systems, vol. 4, no. 01, 2022, pp. 12-19.
5. Gollamandala Udaykiran Bhargava, Vasujadevi Midasala, and Vallabhuni Rajeev Ratna, "FPGA implementation of hybrid recursive reversable box filter-based fast adaptive bilateral filter for image denoising," Microprocessors and Microsystems, vol. 90, 2022, 104520.
6. Chandra Shaker Pittala, Rajeev Ratna Vallabhuni, Vallabhuni Vijay, Usha Rani Anam, Kancharapu Chaitanya, "Numerical analysis of various plasmonic MIM/MDM slot waveguide structures," International Journal of System Assurance Engineering and Management, 2022.
7. Chandra Shaker Pittala, Vallabhuni Vijay, B. Naresh Kumar Reddy, "1-Bit FinFET Carry Cells for Low Voltage High-Speed Digital Signal Processing Applications," Silicon, 2022. https://doi.org/10.1007/s12633-022-02016-8.
8. M. Saritha, M. Lavanya, G. Ajitha, Mulinti Narendra Reddy, P. Annapurna, M. Sreevani, S. Swathi, S. Sushma, Vallabhuni Vijay, "A VLSI design of clock gated technique based ADC lock-in amplifier," International Journal of System Assurance Engineering and Management, 2022, pp. 1-8. https://doi.org/10.1007/s13198-022-01747-6
9. B. M. S. Rani, Vallabhuni Rajeev Ratna, V. Prasanna Srinivasan, S. Thenmalar, and R. Kanimozhi, "Disease prediction based retinal segmentation using bi-directional ConvLSTMU-Net," Journal of Ambient Intelligence and Humanized Computing, 2021, pp. 1-10. https://doi.org/10.1007/s12652-021-03017-y
10. Vallabhuni Vijay, C. V. Sai Kumar Reddy, Chandra Shaker Pittala, Rajeev Ratna Vallabhuni, M. Saritha, M. Lavanya, S. China Venkateswarlu and M. Sreevani, "ECG Performance Validation Using Operational Transconductance Amplifier with Bias Current," International Journal of System Assurance Engineering and Management, vol. 12, iss. 6, 2021, pp. 1173-1179.
11. Sravana, J., K. S. Indrani, M. Saranya, P. Sai Kiran, C. Reshma, and Vallabhuni Vijay, "Realısatıon of Performance Optımısed 32-Bıt Vedıc Multıplıer," Journal of VLSI circuits and systems, vol. 4, no. 2, 2022, pp. 14-21.
12. V. Vijay, J. Prathiba, S. Niranjan Reddy, V. Raghavendra Rao, "Energy efficient CMOS Full-Adder Designed with TSMC 0.18μm Technology," International Conference on Technology and Management (ICTM-2011), Hyderabad, India, June 8-10, 2011, pp. 356-361.
13. Ch. Srivalli, S. Niranjan reddy, V. Vijay, J. Pratibha, "Optimal design of VLSI implemented Viterbi decoding," National conference on Recent Advances in Communications & Energy Systems, (RACES-2011), Vadlamudi, India, December 5, 2011, pp. 67-71.
14. Ch. Srivalli, S. Niranjan reddy, V. Vijay, J. Pratibha, "Low power based optimal design for FPGA implemented VMFU with equipped SPST technique," National Conference on Emerging Trends in Engineering Application (NCETEA-2011), India, June 18, 2011, pp. 224-227.
15. S. Swathi, S. Sushma, V. Bindusree, L Babitha, Sukesh Goud. K, S. Chinavenkateswarlu, V. Vijay, Rajeev Ratna Vallabhuni, "Implementation of An Energy-Efficient Binary Square Rooter Using Reversible Logic By Applying The Non-Restoring Algorithm," Second IEEE International Conference on Communication, Computing and Industry 4.0 (C2I4-2021), Bengaluru, Karnataka, India, December 16-17, 2021, pp. 1-6.
16. Kiran, K. Uday, Gowtham Mamidisetti, Chandra shaker Pittala, V. Vijay, and Rajeev Ratna Vallabhuni, "A PCCN-Based Centered Deep Learning Process for Segmentation of Spine and Heart: Image Deep Learning," In Handbook of Research on Technologies and Systems for E-Collaboration During Global Crises, pp. 15-26. IGI Global, 2022.
17. Vallabhuni Vijay, V.R. Seshagiri Rao, Kancharapu Chaitanya, S. China Venkateshwarlu, Chandra Shaker Pittala, Rajeev Ratna Vallabhuni, "High-Performance IIR Filter Implementation Using FPGA," 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST-2021), Jamshedpur, India, February 11-12, 2022, pp. 1-5.
18. Jujavarapu Sravana, S.K. Hima Bindhu, K. Sharvani, P. Sai Preethi, Saptarshi Sanyal, Vallabhuni Vijay, Rajeev Ratna Vallabhuni, "Implementation of Spurious Power Suppression based Radix-4 Booth Multiplier using Parallel Prefix Adders," 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST-2021), Jamshedpur, India, February 11-12, 2022, pp. 1-6.
19. Chandra Shaker Pittala, Vallabhuni Vijay, A. Usha Rani, R. Kameshwari, A. Manjula, D.Haritha, Rajeev Ratna Vallabhuni, "Design

Structures Using Cell Interaction Based XOR in Quantum Dot Cellular Automata," 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST-2021), Jamshedpur, India, February 11-12, 2022, pp. 1-5.
20. Ratna, Vallabhuni Rajeev, and Ramya Mariserla. "Design and Implementation of Low Power 32-bit Comparator." (2021).
21. Vallabhuni Vijay, Kancharapu Chaitanya, T. Sai Jaideep, D. Radha Krishna Koushik, B. Sai Venumadhav, Rajeev Ratna Vallabhuni, "Design of Optimum Multiplexer In Quantum-Dot Cellular Automata," International Conference on Innovative Computing, Intelligent Communication and Smart Electrical systems (ICSES -2021), Chennai, India, September 24-25, 2021.
22. S. Sushma, S. Swathi, V. Bindusree, Sri Indrani Kotamraju, A. Ashish Kumar, Vallabhuni Vijay, Rajeev Ratna Vallabhuni, "QCA Based Universal Shift Register using 2 to 1 Mux and D flip-flop," IEEE 2021 International Conference on Advances in Computing, Communication and Control (ICAC3'21) 7th Edition (3rd and 4th December 2021), Mumbai, Maharashtra, India, December 03-04, 2021, pp. 1-6.
23. S. China Venkateshwarlu, Mohammad khadir, V. Vijay, Chandra Shaker Pittala, Rajeev Ratna Vallabhuni, "Optimized Design of Power Efficient FIR Filter Using Modified Booth Multiplier," 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST-2021), Jamshedpur, India, February 11-12, 2022, pp. 1-5.
24. G. Naveen, V.R Seshagiri Rao, Nirmala. N, Pavan kalyan. L, Vallabhuni Vijay, S. China Venkateswarlu, Rajeev Ratna Vallabhuni, "Design of High-Performance Full Adder Using 20nm CNTFET Technology," 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST-2021), Jamshedpur, India, February 11-12, 2022, pp. 1-5.
25. Mohammad khadir, S. Shakthi, S. Lakshmanachari, Vallabhuni Vijay, S. China Venkateswarlu, P. Saritha, Rajeev Ratna Vallabhuni, "QCA Based Optimized Arithmetic Models," 4th International Conference on Recent Trends in Computer Science and Technology (ICRTCST-2021), Jamshedpur, India, February 11-12, 2022, pp. 1-5.
26. P. Ashok Babu, P. Sridhar, and Rajeev Ratna Vallabhuni, "Fake Currency Recognition System Using Edge Detection," 2022 Interdisciplinary Research in Technology and Management (IRTM), Kolkata, India, February 24-26, 2022, pp. 1-5.
27. Koteshwaramma, K. C., Vallabhuni Vijay, V. Bindusree, Sri Indrani Kotamraju, Yasala Spandhana, B. Vasu D. Reddy, Ashala S. Charan, Chandra S. Pittala, and Rajeev R. Vallabhuni, "ASIC Implementation of An Effective Reversible R2B Fft for 5G Technology Using Reversible Logic," Journal of VLSI circuits and systems, vol. 4, no. 2, 2022, pp. 5-13.
28. Vijay, Vallabhuni, Kancharapu Chaitanya, Chandra Shaker Pittala, S. Susri Susmitha, J. Tanusha, S. China Venkateshwarlu, and Rajeev Ratna Vallabhuni, "Physically Unclonable Functions Using Two-Level Finite State Machine," Journal of VLSI circuits and systems, vol. 4, no. 01, 2022, pp. 33-41.
29. Vijay, Vallabhuni, M. Sreevani, E. Mani Rekha, K. Moses, Chandra S. Pittala, KA Sadulla Shaik, C. Koteshwaramma, R. Jashwanth Sai, and Rajeev R. Vallabhuni, "A Review On N-Bit Ripple-Carry Adder, Carry-Select Adder And Carry-Skip Adder," Journal of VLSI circuits and systems, vol. 4, no. 01, 2022, pp. 27-32.
30. Vallabhuni Vijay, and Avireni Srinivasulu, "A Novel Square Wave Generator Using Second Generation Differential Current Conveyor," Arabian Journal for Science and Engineering, vol. 42, iss. 12, 2017, pp. 4983–4990.
31. Vallabhuni Vijay, Pittala Chandra shekar, Shaik Sadulla, Putta Manoja, Rallabhandy Abhinaya, Merugu rachana, and Nakka nikhil, "Design and performance evaluation of energy efficient 8-bit ALU at ultra low supply voltages using FinFET with 20nm Technology," VLSI Architecture for Signal, Speech, and Image Processing, edited by Durgesh Nandan, Basant Kumar Mohanty, Sanjeev Kumar, Rajeev Kumar Arya, CRC press, 2021.
32. S. Swathi, S. Sushma, C. Devi Supraja, V. Bindusree, L. Babitha and Vallabhuni Vijay, "A Hierarchical Image Matting Model for Blood Vessel Segmentation in Retinal Images," International journal of system assurance engineering and management, vol. 13, iss. 3, 2022, pp. 1093-1101.
33. Bandi Mary Sowbhagya Rani, Vasumathi Devi Majety, Chandra Shaker Pittala, Vallabhuni Vijay, Kanumalli Satya Sandeep, Siripuri Kiran, "Road Identification Through Efficient Edge Segmentation Based on Morphological Operations," Traitement du Signal, vol. 38, no. 5, Oct. 2021, pp. 1503-1508.
34. M. Lavanya, Malla Jyothsna Priya, Ponukumatla Janet, Kavuluri Pavan Kalyan, and Vijay Vallabhuni, "Advanced 18nm FinFET Node Based Energy Efficient and High-Speed Data Comparator using SR Latch," International Conference On Advances In Signal Processing And Communication Engineering (ICASPACE 2021), Hyderabad, India, July 29-31, 2021.
35. J. Sravana, K.S. Indrani, Sankeerth Mahurkar, M. Pranathi, D. Rakesh Reddy, and Vijay Vallabhuni, "Optimised VLSI Design of Squaring Multiplier using Yavadunam Sutra through Deficiency Bits

Reduction," International Conference On Advances In Signal Processing And Communication Engineering (ICASPACE 2021), Hyderabad, India, July 29-31, 2021.

36. L. Babitha, U. Somanaidu, CH. Poojitha, K. Niharika, V. Mahesh, and Vallabhuni Vijay, "An Efficient Implementation of Programmable IIR Filter for FPGA," 1st International Conference on Innovations in Signal Processing and Embedded systems (ICISPES-2021), Hyderabad, India, October 22-23, 2021.
37. K. C. Koteswaramma, Ande Shreya, N. Harsha Vardhan, Kantem Tarun, S. China Venkateswarlu, and Vallabhuni Vijay, "ASIC Implementation of division circuit using reversible logic gates applicable in ALUs," 1st International Conference on Innovations in Signal Processing and Embedded systems (ICISPES-2021), Hyderabad, India, October 22-23, 2021.
38. Vallabhuni Vijay, J. Sravana, K.S. Indrani, G. Ajitha, A. Prashanth, K. Nagaraja, K.C. Koteswaramma, C. Radhika, M. Hima Bindu, N. Manjula, "A SYSTEM FOR CONTROLLING POSITIONING ACCORDING TO MOVEMENT OF TERMINAL IN WIRELESS COMMUNICATION BASED ON AI INTERFACE," The Patent Office Journal No. 50/2021, India. Application No. 202141055995 A.
39. Dr. L.V. Narasimha Prasad, Dr. Vijay Vallabhuni, Dr. S. China Venkateswarlu, Dr. V. Vhandra Jagan Mohan, Ms. P. Sruthilaya, Mr. K. Tarun Kumar, Mr. B. Raju, Mr. P. Ravinder, "Garbage Collector with Smart Segregation and Method of Segregation Thereof," The Patent Office Journal No. 04/2022, India. Application No. 202141062270 A.