www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 6 Issue 8 August 2017, Page No. 22296-22304
Index Copernicus value (2015): 58.10 DOI: 10.18535/ijecs/v6i8.11

An Effective Thresholding Technique for Otsu's Method using Contrast Enhancement

[1]A Sankar Reddy, [2] C Usha Rani, [3] M. Sudhakar
[1] Assistant Professor, [2] Assistant Professor, [3] Research Associate
[1, 2] AITS, JNTUA University, [3] VIT Chennai
[1] sankar551@gmail.com
[2] ch.usha86@gmail.com
[3] malla.sudhakara2015@vit.ac.in

Abstract
Image segmentation is the fundamental approach of digital image processing. Among all the segmentation methods, Otsu method is one of the most successful methods for image thresholding because of its simple calculation. Otsu is an automatic threshold selection region based segmentation method. This paper works based on the principle of binarization of Otsu's method. In addition, various enhancement schemes are used for enhancing an image which includes gray scale manipulation, filtering and Histogram Equalization (HE). Histogram equalization is one of the well-known image enhancement technique. It became a popular technique for contrast enhancement because this method is simple and effective. In the latter case, preserving the input brightness of the image is required to avoid the generation of non-existing artifacts in the output image. Although these methods preserve the input brightness on the output image with a significant contrast enhancement, they may produce images with do not look as natural as the input ones. The proposed work is divided into three stages. Firstly, Histogram Equalization is applied to the low contrast input image. Secondly, we are obtaining the bimodal image by applying Otsu's binarization, Thirdly, Otsu's thresholding technique is applied to get the binary image. The experimental analysis shows that the results are better than the state of the art methods applied. We have shown the comparison results subjectively as well as objectively. Subjective parameters are visual quality and computation time and objective parameters are Peak signal to-noise ratio (PSNR), Mean squared error (MSE and Average Information Content (AIC).

Index Terms: Image Enhancement, Otsu algorithm, Segmentation, Thresholding.

I.Introduction

Image segmentation is one of the most fundamental and difficult problems in image analysis. Image segmentation is an important part of image processing. In computer vision, image segmentation is the process of partitioning an image into meaningful regions or objects. There are various applications of image segmentation like locate tumors or other pathologies, measure tissue volume, computer-guided surgery, treatment planning, study of anatomical structure, locate objects in satellite images and fingerprint recognition etc. Segmentation subdivides an image into its constituent region or object. Image segmentation methods are categorized on the basis of two properties discontinuity and similarity [1].Based on this property image segmentation is categorized as Edged based segmentation and region based segmentation.

The segmentation methods that are based on discontinuity property of pixels are considered as boundary or edges based techniques. Edge based segmentation method attempts to resolve image segmentation by detecting the edges or pixels between different regions that have a rapid transition in intensity and are extracted and linked to form closed object boundaries. The result is a binary image. Based on theory there is two main edge based segmentation methods, gray histogram based and gradient based method [2]. Region based segmentation partitions an image into regions that are similar according to a set of predefined criteria. The region based segmentation is partitioning of an image into similar areas of connected pixels. Each of the pixels in a region is similar with respect to some characteristic or computed property such as color, intensity and/or texture.

Image enhancement plays a significant role in the field of Digital image processing Applications for both human and computer vision. It is mainly used to enhance the apparent visual quality of information contained in an image and makes it easier for visual interpretation, understanding as well as image features process and analysis by computer vision system [3]. The objective of this method is to make an image clearly recognize for a specific application. A Visual Image is rich in information, Confucius said, "A Picture is worth a Thousand words [4]

The histogram is one of the important features which are very related to image enhancement. The histogram does not only gives us a general overview on some useful image statistics (e.g. mode, and dynamic range of an image), but it also can be used to predict the appearance and intensity characteristic of an image. If the histogram is concentrated on the low side of the intensity scale, the image is mostly a dark image. On the other hand, if the histogram is concentrated on the high side of the scale, the image is mostly a bright image. If the histogram has a narrow dynamic range, the image usually is an image with a poor contrast [1]

Histogram equalization is one of the well-known image enhancement technique. It became a popular technique for contrast enhancement because this method is simple and effective. In the latter case, preserving the input brightness of the image is required to avoid the generation of non-existing artifacts in the output image. Although these methods preserve the input brightness on the output image with a significant contrast enhancement, they may produce images with do not look as natural as the input. The basic idea of HE method is to re-map the gray levels of an image. HE tends to introduce some annoying artifacts and unnatural enhancement. Histograms can also be taken of color images - either individual histogram of red, green and blue channels can be taken, or a 3-D histogram can be produced, with the three axes representing the red, blue and green channels, and brightness at each point representing the pixel count. The exact output from the operation depends upon the implementation, it may simply be a picture of the required histogram in a suitable image format, or it may be a data file of some sort representing the histogram statistics. Histogram equalization technique is commonly employed for image enhancement because of its simplicity and comparatively better performance on almost all types of images. The operation of HE is performed by remapping the gray levels of the image based on the probability distribution of the input gray levels. It flattens and stretches the dynamic range of the image's histogram and resulting in overall contrast enhancement. Contrast enhancement by histogram equalization is one such technique. A histogram equalized image enhances the hard to perceive details of the original image. Nevertheless, the original image contains useful information. Gray level transformations are the examples of intensity transformations.

GHE also usually causes level saturation (clipping) effects in small but visually important areas [5]. This happens because GHE extremely pushes the intensities towards the right (bright) or the left (dark) side of the histogram. If the input image is dominated by dark intensity pixels, the histogram is pushed to the right side, and thus bright saturation effect will be clearly visible. On the other hand, if the input is dominated by bright intensity pixels, the output normally suffers from dark saturation effect. This saturation effect, not only degrades the appearance of the image but also leads to information loss [14]

II.Literature work

Fang et al. [5] proposed a method to improve the enhancement result with image fusion method with evaluation on sharpness. Image enhancement can improve the perception of information C. Wang and Z. Ye [6] proposed a novel extension of histogram equalization, actually histogram specification, to overcome such drawback as HE (HISTOGRAM EQUALIZATION). To maximize the entropy is the essential idea of HE to make the histogram as flat as possible Mary Kim and Min Gyo Chung[7]Recursively separated and weighted histogram equalization for brightness preservation and contrast enhancement Chen Hee Ooi, Nicholas Sia Pik Kong, and Haidi Ibrahim[8]Bi-Histogram Equalization with a Plateau Limit for Digital Image Enhancement Pei-Chen Wu, Fan-Chieh Cheng, and Yu-Kumg Chen[9]A Weighting Mean-Separated Sub-Histogram Equalization for Contrast Enhancement S. D. Chen and A. Ramli [10-11] proposed a generalization of BBHE referred to as Recursive Mean-Separate Histogram Equalization (RMSHE) to provide not only better but also scalable brightness preservation Y. Wang, Q. Chen [12] presented a novel histogram equalization technique equal area dualistic sub image histogram equalization, is put forward in this paper. First, the image is decomposed into two equal area sub images based on its original probability density function Y. T. Kim [13] proposed a novel extension of histogram equalization to overcome such drawback of the histogram equalization D. Rajan and S. Chaudhuri [14] presented two new techniques of using data fusion, based on the modality of the data generation process, to generate a super resolved image from a sequence of low-resolution image intensity data

III.Related Study

A. Histogram Equalization

Histogram equalization is one of the well-known enhancement techniques. Histogram equalization technique is commonly employed for image enhancement because of its simplicity and comparatively better performance on almost all types of images. In histogram equalization, the dynamic range and contrast of an image are modified by altering the image such that its intensity histogram has the desired shape. This is achieved by using cumulative distribution function as the mapping function. The intensity levels are changed such that the peaks of the histogram are stretched and the troughs are compressed. The histogram of a digital image with gray values r_0, r1…r_{L-1} is the discrete function:

$$p(r_k) = \frac{n_k}{n}$$

Here n_k denotes the number of pixels with gray value r_k , n denotes the number of pixels in the given image. $p(r_k)$ represents the fraction of the total number of pixels with gray value r_k.. The global appearance of the image can be represented by the histogram.

Histogram equalization (HE) results are similar to contrast stretching but offer the advantage of full automation, since HE automatically determines a transformation function to produce a new image with a uniform histogram.

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p_r(r_j)$$

Though this method is simple, it fails in myocardial nuclear images since the gray values are physically far apart from each other in the image. Due to this reason, histogram equalization gives a very poor result for myocardial images.

B. Thresholding:

Thresholding is an important technique in image segmentation applications. The basic idea of thresholding is to select an optimal gray-level threshold value for separating objects of interest in an image from the background based on their gray-level distribution. While humans can easily differentiable an object from the complex background and image thresholding is a difficult task to separate them. The gray-level histogram of an image is usually considered as efficient tools for development of image thresholding algorithms. Thresholding creates binary images from grey-level ones by turning all pixels below some threshold to zero and all pixels about that threshold to one. If g(x, y) is a threshold version of f(x, y) at some global threshold T, it can be defined as [1],

$$G(x, y) = \begin{cases} = 1 & if\ f(x,y) \geq T \\ = 0 & otherwise \end{cases}$$

Thresholding operation is defined as:

$$T=M\ [x\ ,\ y\ ,p(x,y),\ f(x,y)]$$

In this equation, T stands for the threshold; f (x, y) is the gray value of point (x, y) and p(x, y) denotes some local property of the point such as the average gray value of the neighborhood centered on point (x, y) Based on this, there are two types of thresholding methods. First one is Global thresholding, When T depends only on f (x, y) (in other words, only on gray-level values) and the value of T solely relates to the character of pixels, this thresholding technique is called global thresholding. The second one is Local thresholding if threshold T depends on f (x, y) and p(x, y), this thresholding is called local thresholding. This method divides an original image into several sub regions and chooses various thresholds T for each sub region reasonably [3].

Otsu method is a type of global thresholding in which it depends on only gray value of the image. Otsu method was proposed by Scholar Otsu in 1979. Otsu method is global thresholding selection method, which is widely used because it is simple and effective [4]. The Otsu method requires computing a gray level histogram before running. However, because of the one-dimensional which only consider the gray-level information, it does not give better segmentation result. So, for that two dimensional Otsu algorithms was proposed which works on both gray-level threshold of each pixel as well as its Spatial correlation information within the neighborhood. So Otsu algorithm can obtain satisfactory segmentation results when it is applied to the noisy images [15]. Many techniques thus were proposed to reduce time spent on computation and still maintain reasonable thresholding results. In [16], proposed a fast recursive technique that can efficiently reduce computational time. Otsu's method was one of the better threshold selection methods for general real world images with regard to uniformity and shape measures. However, Otsu's method uses an exhaustive search to evaluate the criterion for maximizing the between-class variance. As the number of classes of image increases, Otsu's method takes too much time to be practical for multilevel threshold selection [17].

C. OTSU'S Method

It works based on the very simple idea that minimizes the weighted **within-clas**s variance. This turns out to be represented same as maximizing the **between-class** variance. Once the histogram is constructed for the given image, it works directly on the gray level histogram. For example, for a gray level image, there is a probability of 256 numbers i.e. P (i), where 'I' denotes the intensity value. Otsu algorithm will consider some assumptions such as the input image is bimodal, uniform illumination etc. The weighted within-class variance is computed as:

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$

The class probabilities q1 and q2 are estimated as:

$$q_1(t) = \sum_{i=1}^{t} P(i)$$

$$q_2(t) = \sum_{i=t+1}^{I} P(i)$$

The class means are computed as:

$$\mu_1(t) = \sum_{i=1}^{t} \frac{iP(i)}{q_1(t)}$$

$$\mu_2(t) = \sum_{i=t+1}^{I} \frac{iP(i)}{q_2(t)}$$

The individual class variances are computed as:

$$\sigma_1^2(t) = \sum_{i=1}^{t} [i - \mu_1(t)]^2 \frac{P(i)}{q_1(t)}$$

$$\sigma_2^2(t) = \sum_{i=t+1}^{I} [i - \mu_2(t)]^2 \frac{P(i)}{q_2(t)}$$

Here we have to select the value which minimizes the range of values between [1,256]. We can compute the results much faster with a recursion relation, a relation between the within-class variance and between-class variance which is shown here:

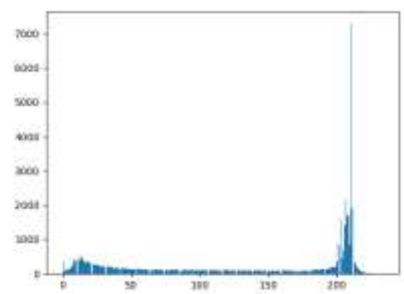
$$\sigma^2 = \sigma_w^2(t) + q_1(t)[1 - q_1(t)][\mu_1(t) - \mu_2(t)]^2$$

Where $\sigma_w^2(t)$ is the within-class variance and $q_1(t)[1 - q_1(t)][\mu_1(t) - \mu_2(t)]^2$ is the between-class variance.

IV.Results & Discussion

Otsu's binarization technique is very important in the analysis of images, especially in cases in which you want to apply a threshold in the thresholding techniques in an efficient manner. To understand the concept we have to know about the "bimodal images". An image is a set of dots that are defined as **pixels**. Each of these pixels can be represented by a triplet of RGB values in the case of a color image, and a single value if the image is in the gray scale. These values assume all values between 0 and 255. If you take all of the pixels of an image and count how many of these have value 0, how many 1, how many 2, and so on… up to 255, you get a **histogram**. The histogram for the corresponding gray scale image is shown in Figure 1.

a



b

Figure 1: a. gray scale image b. Histogram of (a)

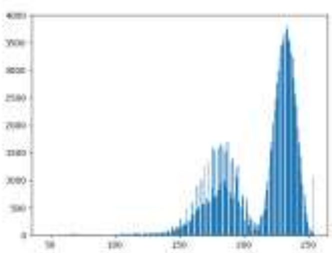
As you can see from the Figure 1, a histogram is nothing more than a way to represent the distribution of the degree of color present in an image. From the figure, for example, you can view the presence of a maximum in the middle. So, in this case, the image is monomodal.

Instead of image bimodal, once represented in the form of a histogram, will present two separate maximum between them (modes). For example, this color image that I have made by adding a bit of background noise is a bimodal example. All the experimental results are executed in OpenCV python. The first image will be loaded in grayscale and then the histogram of the image will be generated. Displaying it immediately after the image via matplotlib you can see that the image chosen is perfectly **bimodal**

Consider the Figure 2. We can observe the image presents two distinct modes among them, dividing into two distinct parts the distribution of pixels in the image. Here we have taken an RGB color image, first, we have converted the RGB Color image to Grayscale image, and then we have constructed the bimodal histogram for the image. Later we have applied the Otsu's binarization, the results are shown in Figure 2(d).


a

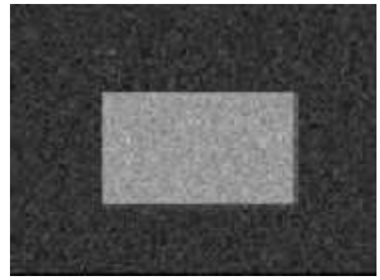

b

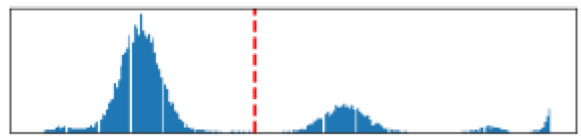

c


d

Figure 2: a. Input image b. Grayscale image of input image c. Bimodal histogram of (b), d. Otsu’s binarization result

As a second example, we have taken another image, with background noise and applied the Otsu’s threshold on the image. Results are shown in Figure 3.


a


b

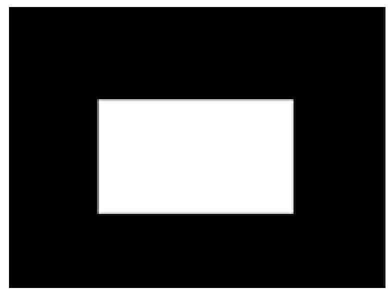

c

Figure 3: (a) Gray Scale Image (b) Histogram after Threshold (c) Otsu’s Thresholding

However. The algorithm fails if the input image is having poor contrast. If the input image is a poor image, then Otsu’s results are also having low in quality. In this sense, we have applied a Global Histogram Equalization on the low contrast image, then we have applied the Otsu’s method on the resultant image. We have observed the good results when compared to the results without applying the Histogram Equalization. The results are shown in Figure 4. The poor contrasted image is shown in Figure 4.a and the result of Histogram Equalization is shown in Figure 4.b. It is clearly shown that the image which is having some background noise our method can effectively apply the threshold and given the better result. Consider a scenario where the given is dark. Any image may be dark because of lighting conditions, illuminations sometimes the object may itself dark. But the algorithm gives the different results.

DOI: 10.18535/ijecs/v6i8.11

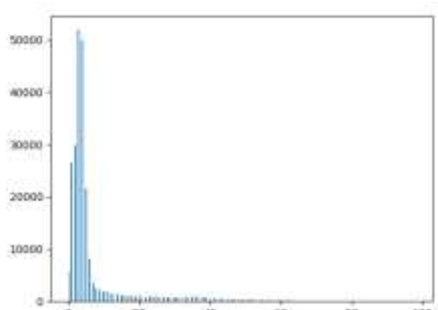
We have worked in this case of low contrast images and produced the good results.

a

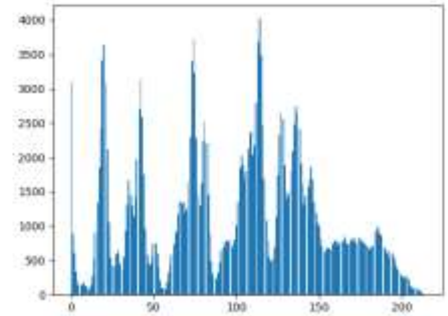
b

Figure 4: (a) Poor contrast Image, (b) Result of Global Histogram Equalization of (a)

The histograms of Figure 4(a) and 4(b) are shown in Figure 5(a) and Figure 5(b) respectively.



a



b

Figure 5: (a) Histogram of Figure 4(a), (b) Histogram of Figure 4(b)

Here we can observe the subjective comparison of Otsu's results. Figure 6(a) shows the resultant image of Otsu binarization without increasing the contrast in the image. After applying the Histogram Equalization the result is as shown in Figure 6(b).

a

b

Figure 6: (a) Otsu's Result (b) Our result

Quality Measurements:

The comparison of various image enhancement techniques based on histogram equalization is carried out in an objective manner for gray scale images. Quantitative performance measures are very important in com-paring different image enhancement algorithms. Besides the visual results and computational time, our evaluation includes Entropy or Average Information Contents (AIC). We have computed the Mean Square Error and Peak Signal Noise ratio and Entropy for the image to show our result objectively.

The Mean Square Error can be computed as:

$$\text{MSE} = \frac{1}{NXM} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} [X(i,j) - Y(i,j)]^2$$

The value of the MSE should be always minimum and PSNR should be maximum for the better results. Entropy or Average Information Content is used to measure the total information in the image. The higher value of Entropy indicates the richness of the details in the output image. A Higher value of the Entropy indicates that more information is brought out from the images and it can be computed as:

$$\text{AIC} = - \sum_{k=0}^{L-1} P(k) \ \log P\ (k)$$

The computed values are MSE=41321.02 and PSNR= 1.96 and entropy values before and after applying the method are 11.61 and 20.21 respectively.

V.Conclusion

Image segmentation is the fundamental approach of digital image processing. Among all the segmentation methods, Otsu method is one of the most successful methods for image thresholding because of its simple calculation. Otsu is an automatic threshold selection region based segmentation method. We have proposed an efficient algorithm which consists of three steps. In the initial stage, contrast enhancement algorithm is applied to produce a quality image. Next, we have constructed a bimodal image for the resultant image. Finally, we have applied the Otsu's binarization on the resultant image. The comparison results show the better results than the existing method. In this paper, we have considered the Histogram Equalization for the contrast enhancement. There are other variations of Histogram equalization methods are also applied to get the better results, which is considered as a future work.

References

[1]. Rafael C. Gonzalez, Richard E. Woods, “Digital Image Processing”, 2nd ed., Beijing: Publishing House of Electronics Industry, 2007.

[2] W. X. Kang, Q. Q. Yang, R. R. Liang ,“The Comparative Research on Image Segmentation Algorithms”, IEEE Conference on ETCS, pp. 703-707, 2009

[3]. Rafael C, Gonzalez, Richard E, Woods & Steven L. Eddins, 2004, ‘Digital Image Processing Using MATLAB’, Pearson Prentice Hall.

[4]. S. Lau, 1994, “Global image enhancement using local information,” Electronics Letters, vol. 30, pp. 122–123.

[5] Xiaoying Fang, Jingao Liu, Wenquan Gu, Yiwen Tang, “A Method to Improve the Image Enhancement Result based on Image Fusion”, International Conference on Multimedia Technology, 2011, pp. 55-58

[6] Y. Wang, Q. Chen, B. Zhang, “Image enhancement based on equal area dualistic sub-image histogram equalization method,” IEEE Trans. on Consumer Electronics, vol. 45, no. 1, pp. 68-75, Feb. 1999.

[7] Mary Kim and Min Gyo Chung, “Recursively separated and weighted histogram equalization for brightness preservation and contrast enhancement”, IEEE Trans. Consumer Electronics, vol. 54, no. 3, pp.1389 - 1397, August 2008.

[8] Chen Hee Ooi, Nicholas Sia Pik Kong, and Haidi Ibrahim, “Bi-Histogram Equalization with a Plateau Limit for Digital Image Enhancement”, IEEE Trans. Consumer Electronics, Vol. 55, No. 4, NOVEMBER 2009.

[9] Pei-Chen Wu, Fan-Chieh Cheng, and Yu-Kumg Chen, “A Weighting Mean-Separated Sub-Histogram Equalization for Contrast

DOI: 10.18535/ijecs/v6i8.11

Enhancement", IEEE Trans. Biomedical Engineering and Computer Science, 2010.
[10] S.-D. Chen, A. Ramli, "Contrast enhancement using recursive mean-separate histogram equalization for scalable brightness preservation," IEEE Trans. On Consumer Electronics, vol. 49, no. 4, pp. 1301-1309, Nov.2003.
[11] Y.-T. Kim,"Contrast enhancement using brightness preserving bi - histogram equalization," IEEE Trans. On Consumer electronics, vol. 43, no. 1, pp. 1-8, Feb. 1997.
[12] Iyad Jafar , and Hao Ying," Multilevel Component-Based Histogram Equalization for Enhancing the Quality of Grayscale Images", IEEE EIT, pp. 563-568, 2007.
[13] Nymlkhagva Sengee, and Heung Kook Choi, "Brightness preserving weight clustering histogram equalization", IEEE Trans. Consumer Electronics, vol. 54, no. 3, pp. 1329 - 1337, August 2008.
[14] Gyu-Hee Park, Hwa-Hyun Cho, and Myung-Ryul Choi, "A contrast enhancement method using dynamic range separate histogram equalization", IEEE Trans. Consumer Electronics, vol. 54, no. 4, pp. 1981 - 1987, November 2008.
[15] LIU Jian-zhuang, Li Wen-qing, "The Automatic threshold of gray level pictures via Two-dimentional Otsu Method", Acta Automatic Sinica,1993.
[16] J. Gong, L. Li, and W. Chen, "Fast recursive algorithms for two-dimensional thresholding," Pattern Recognition,vol. 31, no. 3, pp. 295–300, 1998.
[17] P. K. Sahoo, S. Soltani, A. K. C. Wong, and Y. Chen, "A survey of thresholding techniques," Computer Vision Graphics Image Processing, Vol. 41, 1988, pp. 233-260

Authors Profile:

Mr. A. Sankar Reddy is currently working as Assistant Professor at the school of Computer Science and Engineering in AITS, JNTUA. He received his master's degree from JNTUA University in 2014 and Bachelor's degree from JNTUA in 2007. He has 4 years of teaching experience and taught various subjects in computer science stream and organized various national conferences and workshops in the organization. His research interests are cloud computing, computer vision and Computer Graphics and knowledge engineering.

Mrs. C. Usha Rani is currently working as Assistant Professor at the school of Computer Science and Engineering in AITS, JNTUA. She received her master's degree from JNTUA University in the year of 2010 and Bachelor's degree from JNTUH University in the year of 2006. She has 7 years of teaching experience and taught various subjects in computer science stream and organized various national conferences and workshops in the organization. Her research interests are machine learning, Virtualization in the cloud, big data analytics and knowledge engineering.

Mr. M.Sudhakar, currently working as Research Associate at VIT University, Chennai Campus. He received his master's degree at the school of SCSE from JNTUA University in the year 2012. He received his Bachelor's degree in computer science and engineering in 2010. He has published various national and international journals. His research interests are image analytics, and image enhancement and recommender systems.