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A GRADIENT BASED MORPHOLOGICAL WATERSHED SEGMENTATION APPROACH SUITABLE FOR HUMAN VISUAL SYSTEM

PINAKI PRATIM ACHARJYA[1] & DIBYENDU GHOSHAL[2]

[1]Assistant Professor, Department of CSE, Bengal Institute of Technology and Management, Santiniketan, West Bengal, India

[2]Associate Professor, Department of ECE, National Institute of Technology, Agartala, Tripura, India

ABSTRACT

A 7x7 Laplacian and Gaussian (LOG) filter has been proposed following the structure and behavior of the human brain cells responsible for vision. The conventional 5x5 LOG filter, has been thoroughly modified in dimension and weight of each element to emulate the human visual system (HVS) and this has been achieved by successive approximation method which has utilized the structure of the corresponding brain cells by a mask. The present study has shown that the watershed segmented images obtained by the 7x7 LOG mask appears to be much more clear with sharp and prominent watershed ridges; and the number of segments have been found to much less than those obtained through 5x5 LOG filter. Thus, the proposed method has been found to be able to reduce over segmentation and this would ultimately lead to easier handling by the machine towards higher level of processing at subsequent stages.

KEYWORDS: Image Segmentation, Morphological Gradients, Laplacian of Gaussian Filter, Watershed Algorithm

INTRODUCTION

Image segmentation [1-5] is a very important image analysis process in the field of digital image processing which leads to the fragmentation of the image into regions of statistical co-relation as well as human visual similarity [6-7]. All though image segmentation is done for subsequent perception and processing by the computer, it is also an important aspect that the segmented version of the image should be more susceptible and amenable to human visual system [8-12]. Segmentation algorithms are classified on the basis of the segmentation techniques like edge and contour based techniques, region based techniques, viz-region growing splitting and merging, feature thrash holding, clustering, template merging, etc. All these methods have their own limitations and advantages in terms of suitability, applicability, computer memory space, transmission time of image data, computational cost and overall performance.

A good number of work has already been carried out on watershed segmentation and these are available in the published or online literature [13-22]. It is often found that the contrast of the image is not very high and in these low contrast images gradient images [23-24] are taken instead of the original image for accomplishing watershed segmentation. One disadvantage of the technique is the over segmentation [25-26]. Because the pixel values in the neighbor-hood of a particular pixel changes abruptly and minutely and it is very difficult to have a cluster of pixels having similar intensity over an appreciatable area in the image region.

To avoid this over segmentation generally marker controlled watershed technique [27-29] is followed but the hole process has been found to be a comparatively lengthy process in terms of computation. Thus it is preferred to have an efficient gradient based technique which may yield larger segmented regions and it can be expected that it would reduce the scale of over segmentation and it will be also easier for handling by the machine.

In the present study a gradient based watershed segmentation technique has been carried out following the Laplacian and Gaussian (LOG) filtering approach. The LOG filtering mask although is a 5x5 matrix as proposed by Marr-Hildreth [30], the mask can be extended dimensionally on the basis of the need of the image processing situation. A 7x7 LOG filter mask has been used in this paper to find an edge and contour of a digital image. This filter has been applied in the present study to find the gradient image for three images, obtained from real life and subsequently watershed segmentation has been achieved using the standard MAT LAB command. It has been found from the segmented image that in this case the over segmentation is appreciably less than those obtained by using other edge detecting techniques. It has been already found that the watershed segments are very prominent and the watershed boundaries are also very sharp and this lower scale of over segmentation will enable the computers to process the segmented images more easily and with lower cost.

HUMAN VISUAL SYSTEM

A simple scheme for contour detection may be obtained by three consecutive processing on any image. The first is to compute the gradient map i.e. detection of edge by any standard method with minimum noise. Then this edge information would be assessed based on local context and surround inhibition mechanism. The surround influence would be incorporated on the gradient map using mask operation. Finally the output would have to be processed to binarisation to have the final contour map of the image.

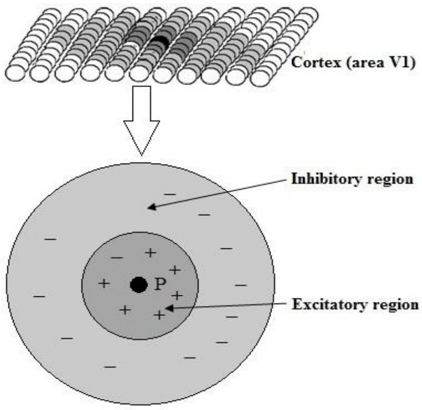


Figure 1: Neighboring Cells Profile of a Cortical Cell in Area V1

Another significant study based on neurophysiology in visual cortex (area VI) of human being has shown that the surround region has an excitatory influence in addition to an inhibitory influence. The result of these can be summarized as follows :-(i) Every cell responses to a stimulus if it is incident on the central region (CRF) . This is shown by the circle P in Fig.2. (ii) Besides the CRF, a neuron has surround region which is made up of two parts , viz. , an inner annular shaped region (shown in dark gray) which is excitatory and an outer annular shaped region (shown in light gray) which is inhibitory . (iii) The surround region which can influence the response of a neuron is limited in extent. The behavior of neurons provides a clue regarding the role of local context in visual perception of a stimulus which is obtained by combining excitatory and inhibitory influences. But the local assessment process in contour detection will not respond sufficiently to edges which belong to texture regions.

MORPHOLOGICAL GRADIENT

In mathematical morphology and digital image processing the gradient of an image is a directional change in the intensity or color in an image and the difference between the dilation and the erosion of a given image forms a morphological gradient. It is an image where typically each non-negative pixel value indicates the contrast intensity in the close neighborhood of that pixel. Image gradients are very much useful to extract different information from images, edge detection of different objects and for several image segmentation applications. It can be defined by

Let, $f: E \rightarrow R$ be a grayscale image, mapping points from a Euclidean space or discrete grid E into the real line. Let $b(x)$ be a grayscale structuring element. An example is given below

$$b(x) = \begin{cases} o, & |x| \leq 1 \\ -\infty, & otherwise \end{cases} \quad (1)$$

Then, the morphological gradient of f is given by:

$$MG(f) = f \oplus b - f \ominus b \quad (2)$$

Where, $\oplus$ and $\ominus$ denote the dilation and the erosion, respectively.

WATERSHED SEGMENTATION TECHNIQUE

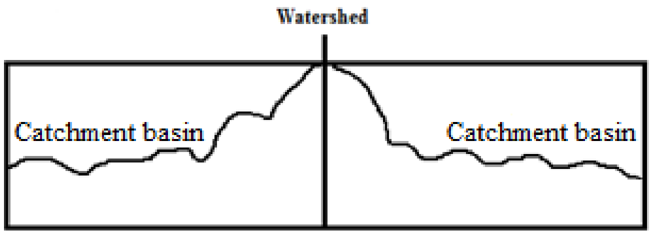


Figure 2: Watershed Segmentation-Local Minima Yield Catchment Basins; Local Maxima Define the Watershed Lines

A gray scale image can be interpreted as the topographic image of landscape. This is accomplished (the image intensity) as an altitude. Using the features of these images, the technique of digital image processing called Watershed Transform. It consists in placing a water source in each regional minimum (catchment basins), to flood the relief from sources, and build barriers when different sources are meeting. The resulting set of barriers constitutes a watershed by flooding, i.e., the set of pixels along which the gray levels changes sharply gives rise to a watershed edge.

MATHEMATICAL BACKGROUND OF WATERSHED ALGORITHM

Assume, M_i where $i = 1$ to n be the set of coordinates points in the regional minima (catchment basins), of the image $P(x,y)$ and $C(M_i)$ be the coordinates points of catchment basins associated with the regional minima M_i

$$Tn = \{(s,t) \mid P(s,t) < n\} \quad (3)$$

Where,

$T[n]$ = set of points in $P(x,y)$ which are lying below the plane $p(x,y) = n$

min, max = minimum or maximum gray level value.

n = stage of flooding varies from min + 1 to max + 1

Let $C_n(M_1)$ be the set of points in the catchment basin associated with M_1 that are flooded at stage n.

$$Cn(M1) = \cap \{C(M1), T[n]\} \quad (4)$$

Where,

$$Cn(M_i) = \begin{cases} 1, & if\ (x,y) \in C(M_i) and (x,y) \in T[n] \\ 0, & otherwise \end{cases} \quad (5)$$

C[n] is the union of flooded catchment basin portions at the stage *n*.

Where,

$$C[n] = Cn(m1) \cup Cn(m2) \ldots\ldots Cn(mR) \quad (6)$$

$$C[max + 1] = C(m1) \cup C(m2) \ldots\ldots C(mR) \quad (7)$$

If the algorithm keeps on increasing flooding level then $C_n(M_i)$ and *T[n]* will either remain constant or increase. Algorithm initializes$C[min + 1] = T[min + 1]$, and then precedes recursively by assuming that at step n *C [n - 1]* has been constructed.

Let, *G* is a set of connected components in *T[n]* and for each connected component $g \in G[n]$, there possibilities will arise.

- $g \cap C[n - 1]$ is empty.
- $g \cap C[n - 1]$ contains one connected component of *C[n - 1]*.
- $g \cap C[n - 1]$ contains more than one connected component of *C[n - 1]*.

PROPOSED ALGORITHM

The Laplacian of Gaussian filter (LOG) plays a very important role in image segmentation. It is a convolution filter that is used to detect edges of different objects. This filter first applies a Gaussian blur, then applies the Laplacian filter and finally checks for zero crossings, i.e. when the resulting value goes from negative to positive or from negative to positive. The main objective of this filter is to highlight edges different objects. As a input the LOG operator takes a single gray level image and produces another binary image as output. A 5x5 mask LOG filter has been shown in Figure 3.

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

Figure 3: A Conventional 5x5 LOG Surround Filter

A 7x7 mask has been proposed in the present work. There are two annular regions in this mask, i.e., the inner being excitatory and the outer being inhibitory in nature which surrounds the central pixel where the positive weights (excitatory) are assigned for inner one and negative weights (inhibitory) are assigned for outer one. The influence of a point in the surround on the cell respond depends on its distance from the centre and the nature of variation approximately follows a Gaussian profile and also the excitatory influence is weaker than the inhibitory influence [18], [1]. After large number of trials using masks of larger dimensions, the size of the optimal mask was obtained and found to have 7x7 in dimensions. There is no loss of generality if the weights of individual pixel in the masks are changed slightly, keeping in the mind basic requirement of being isotropic and ability to emulate HVS. The mask has been shown in Figure 4. Where, by sampling a Gaussian profile of standards deviation 1.4 the weights in the outer inhibitory region of the optimal mask were found. If anybody slightly alters the pixel values in the mask which constitute the fuzzy set, there will be no gross deviation from real situation and the sum of the weights inside the mask 0.47 which is sufficient to help enhance a contour pixel.

-5	-6	-5.5	-5	-5.5	-6	-5
-6	-5	-2	0.8	-2	-5	-6
-5.5	-2	0.4	0.4	0.4	-2	-5.5
-5	0.8	0.4	225	0.4	0.8	-5
-5.5	-2	0.4	0.4	0.4	-2	-5.5
-6	-5	-2	0.8	-2	-5	-6
-5	-6	-5.5	-5	-5.5	-6	-5

Figure 4: A 7x7 Laplacian and Gaussian Filter

The flowchart of the proposed algorithm is given below in figure 5. In this approach, for the real life images we have used morphological watershed segmentation with gradients. In the initial step shown in figure 5, three color images from real life is chosen for MAT LAB editor using 'imread' function. The 'imread' function in MAT LAB reads an image which may be grayscale or color image from the specified file. In the next step the color images have been converted into gray level images using 'rgb2gray' function. Watershed algorithm works only on gray scale image because a grey scale image may be considered as a topographic relief. After converting the image into gray scale we compute gradient image using the 7x7 LOG filter. And finally from the gradient images the watershed regions has been computed as a segmented image.

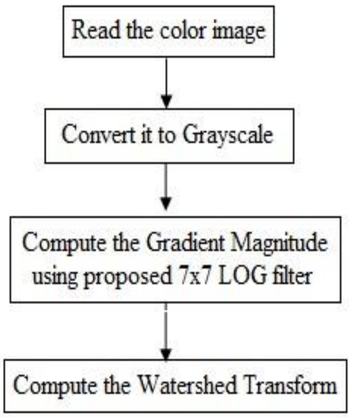


Figure 5: Flowchart of the Proposed Method

RESULTS AND DISCUSSIONS

In the present study three color images has been acquired from the real life. The images are of fruits, car and flower have been shown in figure 6(a), 6(b) and 6(c) respectively. The images are converted to gray level for the execution of the algorithm and follow up running of programs. The gray level images have been shown in figure 7(a), 7(b) and 7(c) respectively. These gray level images have been processed to obtain the corresponding gradient images by using 5x5 LOG filter are shown in figure 8(a), 8(b) and 8(c) respectively. The segmented images obtained by the watershed segmentation algorithm from gradient images by applying 5x5 LOG filter shown are in figure 9(a), 9(b) and 9(c) respectively. And again the gray level images have been converted into gradient images using 7x7 LOG filter which are shown in figure 10(a), 10(b) and 10(c) respectively and the subsequent segmented images using watershed algorithm have been sown in figure 11(a), 11(b) and 11(c) respectively.

(a) (b) (c)

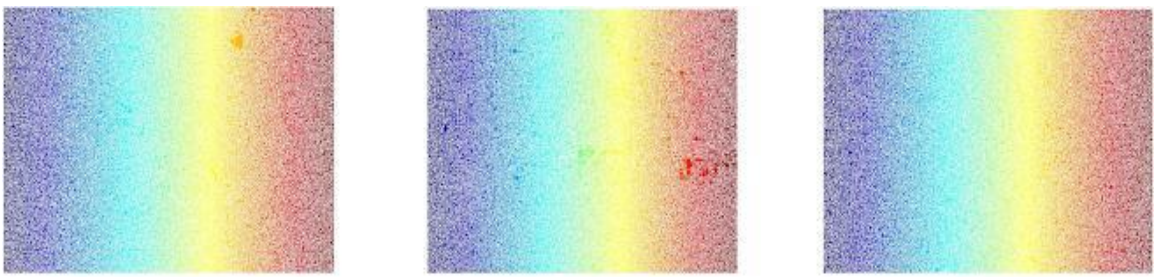
Figure 6: Original Images (a) Image of Fruits (b) Image of Car (c) Image of Flowers

(a) (b) (c)

Figure 7: Gray Level Images (a) Gray Level Image of Fruits (b) Gray Level Image of Car (c) Gray Level Image of Flowers

(a) (b) (c)

Figure 8: Gradient Images by Applying 5x5 LOG Filter (a) Gradient Image of Fruits by Applying 5x5 LOG Filter (b) Gradient Image of Car by Applying 5x5 LOG Filter (c) Gradient Image of Flowers by Applying 5x5 LOG Filter

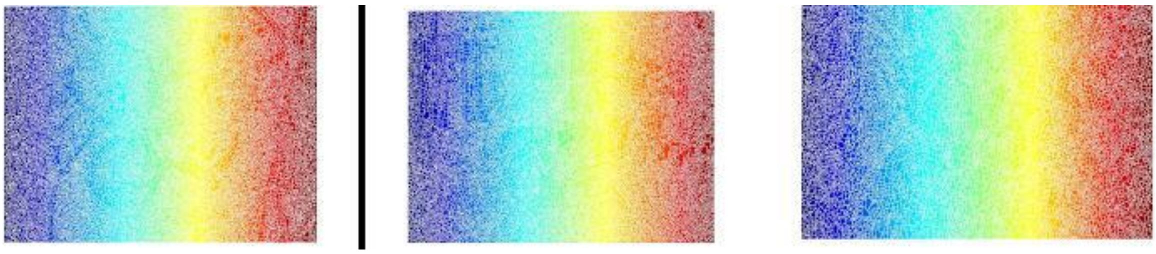


(a) (b) (c)

Figure 9: Segmented Images Obtained by the Watershed Segmentation from Gradient Images by Applying 5x5 LOG Filter (a) Segmented Image of Fruits (b) Segmented Image of Car (c) Segmented Image of Flowers

(a) (b) (c)

Figure 10: Gradient Images by Applying 7x7 LOG Filter (a) Gradient Image of Fruits by Applying 7x7 LOG Filter (b) Gradient Image of Car by Applying 7x7 LOG Filter (c) Gradient Image of Flowers by Applying 7x7 LOG Filter



(a) (b) (c)

Figure 11: Segmented Images Obtained by the Watershed Segmentation from Gradient Images by Applying 7x7 LOG filter (a) Segmented Image of Fruits (b) Segmented Image of Car (c) Segmented Image of Flowers

It has observed that the gradient images for all three images using 5x5 LOG filter have produced a dark shed images, i.e., the gray level of the pixel have been lower down and also the edges in the images are not very sharp. On the other hand the gradient images obtained by 7x7 LOG filter for three figures have given rise to images of more whitish appearance. In these cases the edges and boundaries of the images are also seen to be more prominent and clear with better contrast. The segmented images following the watershed algorithm by using 5x5 LOG filter are seen to yield extremely over segmented images and it is very much difficult to identify the size and area for each segment not only by the human visual system but also it might be a tedious process for the machines to process them at subsequent stages. All though standard LOG 5x5 filters are likely to be, in general more responsive to the ultimate observer, i.e., human beings. Still it is obviously not for practical use for human or computer vision. It have been observed form figure 11(a), 11(b) and 11(c), as obtained by the proposed 7x7 log filter that the each and every segment of the final watershed segmented form of the has occupied an appreciable area and size in the image region and the number of such segmented regions are found to be much more less than those obtained by standard 5x5 LOG filter. It has been further observed that watershed lines are very sharp, thin and prominent in spite of the number of regions are large. These segmented images are expected to create much more response clarity and sharpness of the edges and counters. The entropies of the final segmented images using watershed algorithm through 5x5 log filter and the proposed 7x77 log filter have been calculated and the values have been shown in the table 1. It is apparent that the entropy of the segmented images would rise for the case of segmented images obtained by proposed 7x7 LOG filter as it involves more no of bits.

Table 1: Statistical Measurement

Images Obtained by the Watershed Segmentation	Entropy of the Images Obtained by the Watershed Segmentation from Gradient Images by Applying 5x5 LOG Filter	Entropy of the Images Obtained by the Watershed Segmentation from Gradient Images by Applying 7x7 LOG Filter
Fruits	5.0535	5.3147
Car	5.0847	5.3449
Flowers	5.0860	5.3894

CONCLUSIONS

The conventional watershed algorithm has been applied using 5x5 LOG filter for obtaining the gradient images. The segmented image obtained through 5x5 LOG filter are found to be extremely over segmented and it becomes very much difficult for subsequent computer handling. All though the 5x5 log filter should have been more acceptable to the human visual system, in practice the final image is almost useless for human vision and extremely difficult for the computer vision also. On the contrary the watershed segmented images obtained through proposed 7x7 LOG filter which have been designed by successive approximation method keeping in mind with the structure and behavior of the human visual system have been found to much better result in terms of clarity and sharpness. Furthermore it is apparently pleasing to the human eye during visualization. These segments are expected to provide input data for sub sequent computer vision in most systematic and realistic manner on the number of segmented regions are comparatively less than those obtained by the gradient images through other edge detecting filters.

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DEDICATIONS

One of the others (Dibyendu Ghoshal) dedicates the entire study to the loveliest and loving memory of his only one and younger sister Kumari Sumita Ghoshal who herself was a gem of the scholars, a symbol of wisdom and art, peerless beauty and simplicity, unfathomable knowledge and generosity.

REFERENCES

1. C. Gonzalez, Richard E. Woods, Digital Image Processing, 2nd Edition, Addison Wesley Pub. Co, 2002.
2. A.K.Jain, Fundamentals of digital image processing, Second Edition, Prentice Hall, 2002.
3. L. Vincent and P. Soille, “Watersheds in digital spaces: an efficient algorithm based on immersion simulations,” IEEE Trans. Pattern Anal. Mach. Intell., vol. 13, no. 6, pp. 583-598, Jun. 1991.
4. S. Beucher, “Watersheds of functions and picture segmentation,” in Proc. IEEE Int. Conf. Acoustic, Speech, Signal Processing, pp. 1982-`931, 1982.
5. Gonzalez & Woods, Digital Image Processing, 3rd edition, Prentice Hall India, 2008.
6. J. Cavanaugh, W. Bair and J. Movshon, “.Nature and interaction of signals from the receptive field center and surround in macaque VI neurons”, In Journal of Neurophysiology, vol. 9, no. 4, pp. 569-577, April 2006.
7. S. Yen and L. Finkel, “Extraction of perceptually salient contours by striate cortical networks”, in Vision Research, vol. 38, no. 5, pp. 719-741, .1998
8. Dobbins ,S. W. Zucker and M. S. Cynader, “Endstopped neurons in the visual cortex as a substrate for calculating curvature”, .in nature, vol. 329, pp. 438-441, 1987.
9. R. Baumann, R. van der Zwan and E. Peterhans, “Figure-ground segregation at contours: a neural mechanism in the visual cortex of the alert monkey”, in European Journal of Neuroscience, vol. 9, no. 1, pp. 129-1303, 1997.

10. Von der Heydt R, Peterhans E, Dürsteler MR, "Grating cells in monkey visual cortex: coding texture? In: Channels in the Visual Nervous System: Neurophysiology", Psychophysics and Models (Blum B, ed), pp 53-73, London: Freund, 1991.

11. J Knierim and D van Essen (1992). Neuronal responses to static texture patterns in area v1 of the alert macaque monkey.In journal of Neurophysiology, vol. 67, no.4, pp. 961-80, April 1992.

12. M.C. Morrone and D.C. Burr, "Feature detection in human vision : A phase-dependent energy model", in Proceedings of the Royal Society,London series B, vol. 235, no. 1280, pp. 221-245, December 1988.

13. S. Beucher, "Watershed, hierarchical segmentation and water fall algorithm," in Mathematical Morphology and Its Applications to Image Processing, Dordrecht, The Netherlands: Kluwer, 1994, pp. 69–76.

14. Beucher, S., and Meyer, F. The morphological approach to segmentation: the watershed transformation. In Mathematical Morphology in Image Processing, E. R. Dougherty, Ed. Marcel Dekker, New York, ch. 12, pp. 433-481, 1993.

15. Beucher, S., and Lantuejoul, C, "Use of watersheds in contour detection", In Proc. International Work-shop on Image Processing, Real-Time Edge and Motion Detection/Estimation, Rennes, pp.17-21, France, September 1979.

16. Vicent L. Solille P, Watershed in digital spaces, "An efficient algorithm based immersion simulations," IEEE Transections PAMI,vol. 13.no6. pp. 538-598, 1991.

17. M. Couprie and G. Bertrand, "Topological grayscale watershed transformation," in Proc. SPIE Vision Geometry V, vol. 3168, pp. 136-146, 1997.

18. C. Riddell, p. Brigger, R. E. Carson and S. L. Bacharach, "The watershed algorithm: a method to segment noisy PET transmission images," IEEE Trans. Nucl. Sci., vol. 46, no. 3, pp. 713-719, Mar, 1999.

19. M. W. Hansen and W. E. Higgins, "Watershed-based maximum-homogeneity filtering," IEEE Trans. Image Process., vol. 8, no. 7, pp. 982-988, jul. 1999.

20. K. Haris,"Hybrid image segmentation using watersheds and fast region merging," IEEE Trans Image Processing, vol. 7, no. 12, pp. 1684-1699, 1998.

21. F. Meyer, S. Beucher, "Morphological Segmentation," Journal of Visual Communication and Image Representation,vol. 1, pp. 21-46, 1990.

22. D. Wang, "Unsupervised video segmentation based on waterseds and temporal traking," IEEE Trans. Circuits Syst. VideoTechnol., vol. 8, no. 5, pp. 539-546, May 1998.

23. P. Jackway, "Gradient watersheds in morphological scalespace," IEEE Trans. Image Processing vol. l5, pp. 913–921, June, 1996.

24. Rafael C. Gonzalez, Richard E. Woods, Steven L. Eddins, "Digital Image Processing Using MATLAB," Second Edition, Gatesmark Publishing, 2009.

25. S. Thilagamani, N.Shanthi, "A Novel Recursive Clustering Algorithm for Image Oversegmentation", European Journal of Scientific Research, Vol.52, No.3, pp.430-436, 2011.

26. Peter Eggleston, "Understanding Oversegmentation and Region Merging", Vision Systems Design, December 1, 1998.

27. Chen Pan, Congxun Zheng, Hao-Jun Wang “Robust Color Image Segmentation Based On Mean Shift And Marker-controlled Watershed Algorithm”, Second International Conference on Machine Learning and Cybernetics, Wan, ,pp 2752-2756, 2-5 November 2003.

28. Chi Zhang, Ning Zhang, Chengjun Li, Guoping Wang, "Marker-Controlled Perception-Based Mesh Segmentation," Third International Conference on Image and Graphics (ICIG'04), icig, pp.390-393, 2004.

29. K. Parvati, B. S. Prakasa Rao and M. Mariya Das, “Image Segmentation Using Gray-Scale Morphology and Marker-ControlledWatershed Transformation”, Discrete Dynamics in Nature and Society,vol. 2008, pp. 1-8, 2008.

30. D Marr and E Hildreth, “Theory of edge detection”, in proceedings of the Royal Society, vol. 207, pp. 187-217, London, 1980.

AUTHOR’S DETAILS

Dibyendu Ghoshal received his B.Sc. degree in physics (Hons), B.Tech degree in Radio Physics and Electronics, M.Tech degree in Radio Physics and Electronics and the Ph.D. degree in Engineering, in 1981, 1984, 1986 and in 1997 respectively from University Of Calcutta. He was awarded Senior Research Fellowship by Council of Scientific and Industrial Research (CSIR) on the basis of all-India selection in 1992, and Awarded Research Associate ship by Council of Scientific and Industrial Research (CSIR) on the basis of all-India selection in 1996 and got Post Doctoral Associate ship from Council of Scientific and Industrial Research (CSIR) in 2007.

He is presently working as Associate Professor from 2010 in the Department of Electronics and Communication Engineering at National Institute of Technology, Agartala. His research interests include Microwave, Digital Image Processing and Digital Signal Processing.

Pinaki Pratim Acharjya received his B.Tech degree in Information Technology, M.Tech degree in Computer Science and Engineering in 2007 and 2009 respectively from West Bengal University of Technology. He is doing his research works in National Institute of Technology, Agartala. Presently he is working in Bengal Institute of technology and Management, Santiniketan. He joined the institute in 2009 as a lecturer and now working as Assistant Professor in the Department of Computerscience and Engineering. His research interests include Digital Image Processing.