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Multilevel Thresholding Technique for Contrast Enhancement in Thermal Images to Facilitate Accurate Image Segmentation

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Abstract

The most challenging task in InfraRed Thermography based condition monitoring of electrical equipment lies in the accurate detection of the anomaly. It necessitates an efficient preprocessing technique for increasing the contrast between the background and the anomaly regions in thermographs. In this paper, an efficient multi-level thresholding based enhancement technique is proposed for highlighting the anomaly region from the background. In contrast to the two levels in binary enhancement, n levels are determined based on the histogram bins. Enhanced intensity is calculated based on the range of the level rather than selecting randomly. Strength of the proposed technique is evident in its ability to detect the true edges corresponding to the anomaly. Also the anomaly region is accurately detected to its true size which in turn resulted in the precise estimation of the real time temperature. The error in temperature is approximately 0.5 at an emissivity of 0.7. The proposed technique can be adapted irrespective of thermal profiling of thermographs. However the intensity range must be chosen appropriately. Relationship between emissivity and error in temperature is also provided at the room temperature

Keywords: Emissivity, Error in Temperature, Histogram, Hotspot, Multiple Threshold

1. Introduction

Infra Red Thermography (IRT) is Non Destructive Testing technique (NDT) used extensively for accessing the quality of welds, health monitoring of structures and condition monitoring of equipment[1,2]. It uses an IR camera that captures the heat pattern and maps into thermograph. A thermograph is two dimensional function f(x ,y) where x,y denotes spatial coordinates f(x,y) is radiance of a thermograph. High intensity region denotes the highest temperature region called hotpot characteristics is the indicator of the anomalies. Hence in order to determine the anomalies or flaws or defects it is necessary to process the thermographs and extract the hotpots. Hotspot extraction is basically performed as Image segmentation technique works well when contrast between the hotspot region and the background is high. Hence it is necessary to preprocess the thermograph in order to highlight the hotspot. Hotspot corresponds to low frequency regions and hence image segmentation is performed to enhance the hotspot image smoothening refers to high lighting low resolution region by blurring and by removing the undesirable high frequency regions. Conventional image smoothening technique involved average filtering weighted average filtering, median filtering, adaptive filtering Butterworth filtering low pass filtering and Gaussian low pass filtering[3,4].

In[5] the authors have proposed an algorithm based on Aaro Mallo (MEAM) for contrast enhancement of IR Images. Dynamic range reduction and contrast enhancement were required to convert the output image of detector with high dynamic range into lower dynamic

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range which was suitable for output display device. In MEAM algorithm, first the image was split into high spatial components and low spatial components. The low spatial frequency component was extracted by applying low pass filter and high spatial components was obtained by subtracting the low spatial components with original image. The summing of both components was done and the final image was extracted from the resultant which was limited to specific range. The author has compared theperformance of MEAM with three other algorithms namely infrared Multi Scale Retinex, Tailless Plateau Equalization (TPE) and Adaptive Plateau Equalization (APE). It was concluded that MEAM algorithm was the best technique for contrast enhancement.

In[6] the authors have proposed a novel method for IR image enhancement using normalization of beta function. The image was acquired and its minimum and maximum intensities were calculated. A constant T was initialized. From input image I_{xy} was derived where $I_{xy =}$ I_{min} + T*(I_{max} –I_{min})*I. The minimum and maximum intensities of I_{xy} were found. Then the input image was normalized using g(x,y) and beta function was applied. After which the image is demoralized. Thus image was enhanced using normalization of beta function. This method had the best results for Far Infrared (FIR) than Near Infrared (NIR).

In[7] the authors have focused on a homomorphic filtering technique which is suitable for identifying the weapon hidden beneath a person clothing application of infrared imaging. The is defined as f(x, y) = i(x, y) * r(x, y) and then natural logarithm was applied on both the sides. Then Fourier Transform is applied to convert the image to its frequency domain. After which a filter function H(u, v) is applied and then inverse Fourier Transform was done to get filtered image. Now Homomorphic filtering is applied which is modified from Gaussian high filter known has Difference of Gaussian (DOG). The author have proved that this most effective method for identifying the hidden weapon.

In[8] the authors have proposed method to enhance contrast by transforming 20 minute imaging data into frequency domain and Large Conduit Vessel (LCV) in hand was extracted. First IR image wascaptured for 20 minutes with different temperature fluctuation and then normalized Fast Fourier Transform was applied to divide the whole spectrum into six different frequency ranges. In averaged magnitude image the LCV was identified.

In[9] the authors have proposed an additive wavelet transform for enhancement of IR images. The IR image is first analysed and then decomposed into various band using additive wavelet transform. The illumination and reflectance components of each sub band are extracted using additive wavelet transposition. After enforcement operation reconstruction of separate band was done. Finally Inverse wavelet transform was applied to obtain the effective information for the user.

2. Proposed Methodology

Image enhancement refers to the process of highlighting the Region of Interest in order to facilitate efficient segmentation and characterization. Image enhancement can be performed as point operators or neighbourhood operators[10–12]. Image negative, log transformation, histogram equalization, contrast stretching are the most commonly used point operators. In neighbourhood operations, the mask is placed in such a way that the centre element of the mask is placed on the pixel to be enhanced. Based on the types of masks used, there are two types of enhancement namely image smoothening and image sharpening. Image smoothing refers to blurring the image by removing the high frequency components (noise). Average and weighted average filters are the most commonly used image smoothening filters in spatial domain. On the other hand, image sharpening refers to highlighting the fine details in the image (edges). Gradient and Laplacian operators are the widely used image sharpening filters. Though these filters are widely used for image enhancement, these filters are unsuitable for thermographs. It is because thermographs have distinct temperature profiles and hence gray levels. Hence multi level thresholding is proposed in this paper. In this proposed technique, five set of rules are developed for respective intensity range. In the first case, the output intensity is made as zero and in all the remaining cases, the intensity is decided by the number of intensity bins within the range. Number of bins is equal to th_{max}-th_{min} where th_{max} corresponds to the maximum intensity and th_{min} denotes the minimum intensity. Thresholds are chosen based on the multiple intensity ranges selected from the histogram. Original pseudocolor thermographs, gray scale images and the corresponding histograms are shown from Figures 1-3.

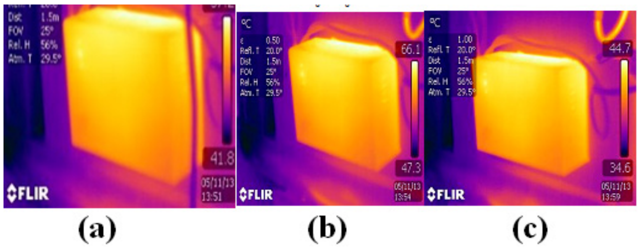


Figure 1. Original image for emissivity. **(a)** 0.64. **(b)** 0.5. **(c)** 1.

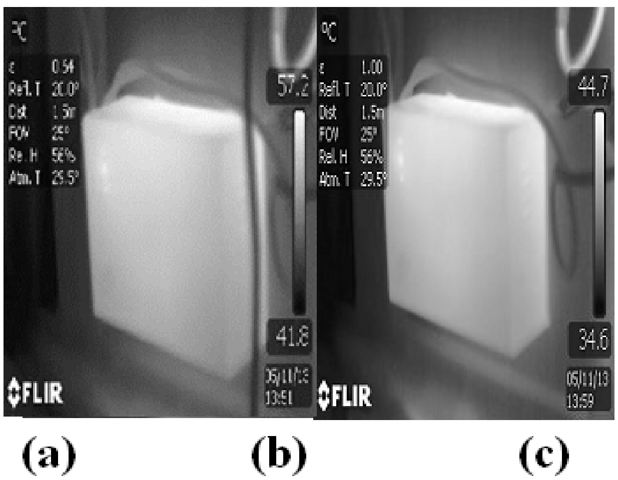


Figure 2. Gray scale image for emissivities. **(a)** 0.64. **(b)** 0.5. **(c)** 1.

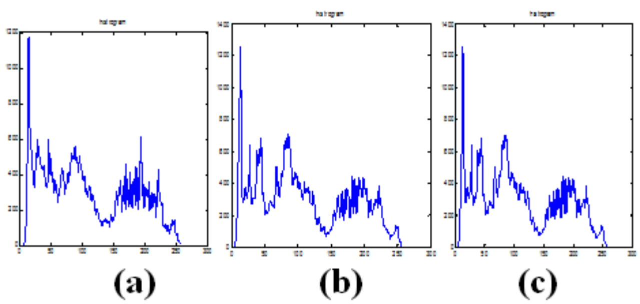


Figure 3. Histogram images for emmisivities. **(a)** 0.64. **(b)** 0.5. **(c)** 1.

Irrespective of the thermal images, the threshold ranges for the five different cases are found as f(x,y)<=75, 76<=f(x,y)<=175, 176<=f(x,y)<=240 and f(x,y)>=255. Hence these values were chosen for performing contrast enhancement. The flowchart depicting the proposed technique is shown in Figure 4.

After performing image enhancement, the hotspot is isolated through edge detection and morphological image processing. After extracting the hotspot, the average intensity is determined from which the real temperature is calculated.

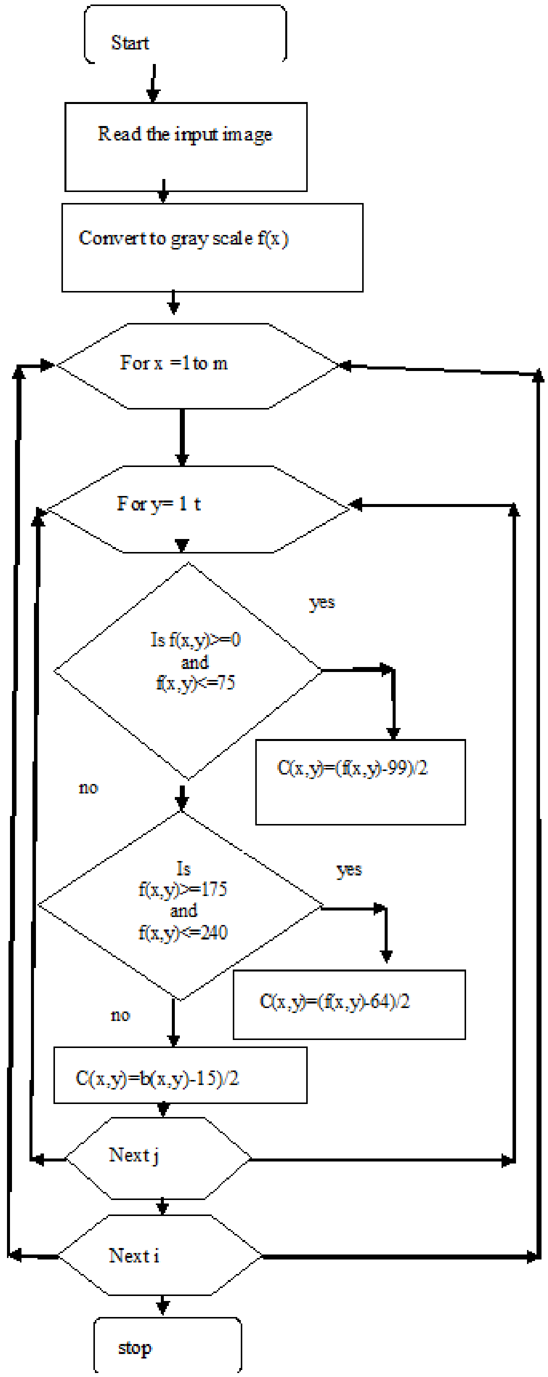
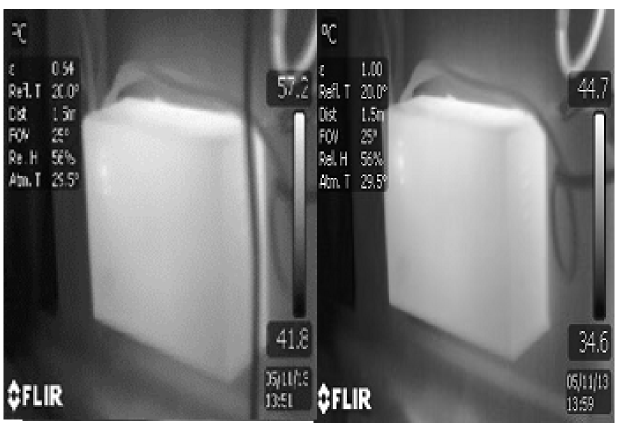


Figure 4. Flowchart.

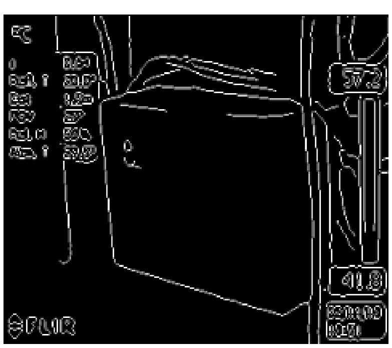
3. Results and Discussion

The gray scale image and the corresponding edge detected images for thermographs IR_1411, IR_1417, and IR_1431 are shown in Figures 5-6. From the images, it is found that the edges corresponding to the hotspot are not visible which hence makes it practically impossible to determine the hotspot by edge detection based segmentation. The enhanced image and the edge detected images are shown in Figures 7-8. From the Figure 8, it is found that the edges corresponding to the hotspot are visible in the output images. In order to extract the hotspot it is necessary to region fill the hotspot images. The region filled thermographs are shown in Figure 9. From Figure 9, it is found that the undesirable regions are also visible in the hotspot. In order to isolate the hotspot the region corresponding to the maximum area is chosen. The output images are shown in Figure 10. From the Figure, it is found that the original size of the hotspot is obtained which is in contrast to image erosion where the size of the hotspot is also reduced while removing the undesirable regions.

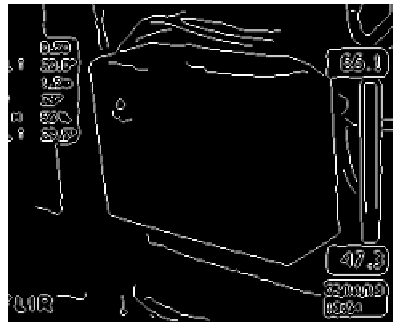


(a) (b) (c)

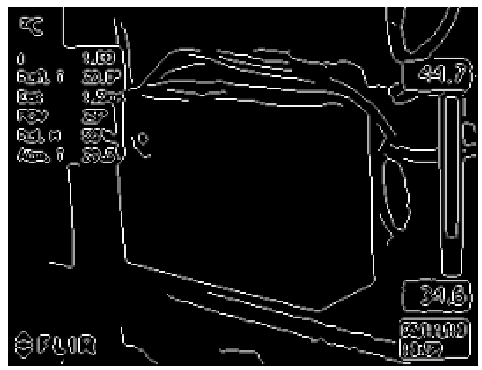
Figure 5. Gray scale image for emissivities. **(a)** 0.64. **(b)** 0.5. **(c)** 1.



(a)

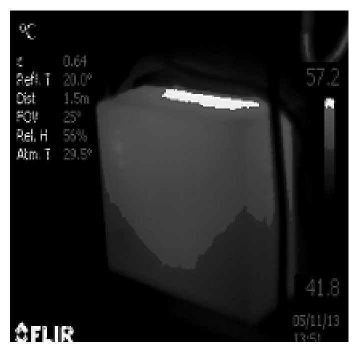


(b)

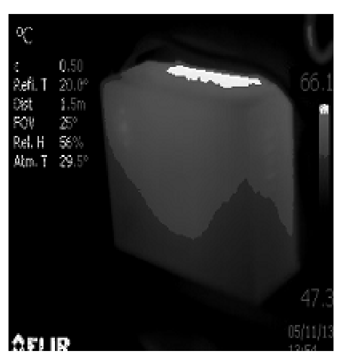


(c)

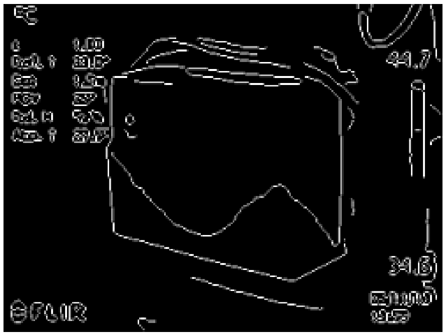
Figure 6. Edge detection images of emmisivity. **(a)** 0.64. **(b)** 0.5. **(c)** 1.



(a)

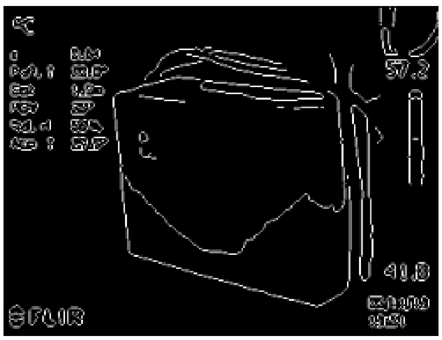


(b)

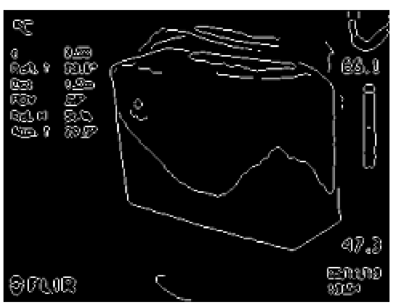


(c)

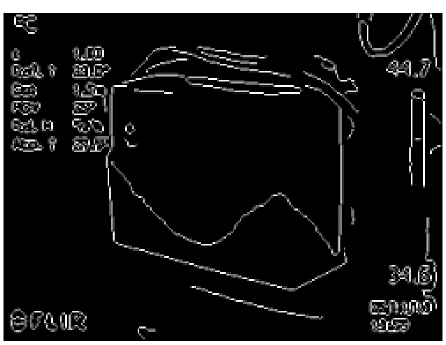
Figure 7. Multi Level Enchancement images of emmisivity. **(a)** 0.64. **(b)** 0.5. **(c)** 1.



(a)

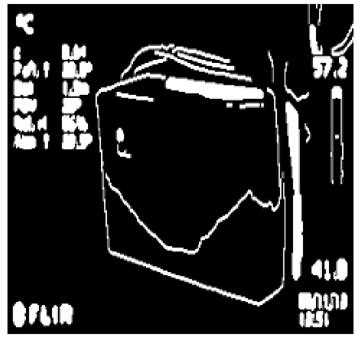


(b)

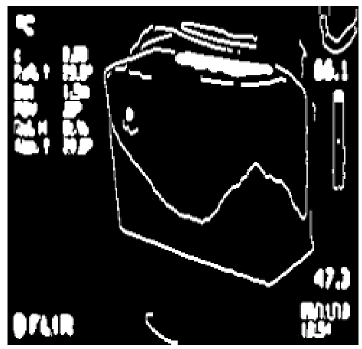


(c)

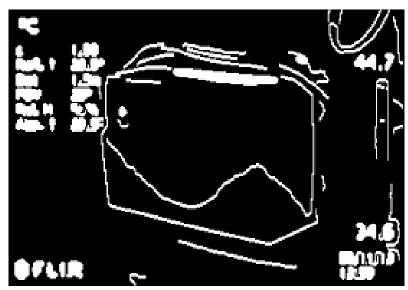
Figure 8. Edge detection on enhanced images of emmisivity. **(a)** 0.64. **(b)** 0.5. **(c)** 1.



(a)



(b)

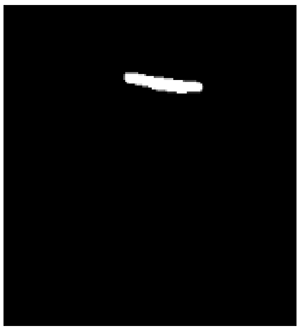


(c)

Figure 9. Edge detection on of emmisivity. **(a)** 0.64. **(b)** 0.5. **(c)** 1.

(a)

(b)



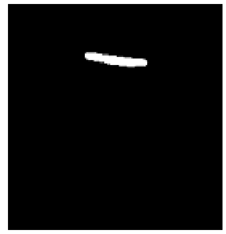
(c)

Figure 10. Output images of emmisivity. **(a)** 0.64. **(b)** 0.5. **(c)** 1.

However in order to calculate the original intensity the gray scale image corresponding to the hotspot regions are then recovered. The recovered hotspot regions are shown in Figure 11. From the Figure 11, it is found that the actual gray scale values are retained. The real temperature calculated from the average intensity of the hotspot is shown in Table 1.

(a)

(b)



(c)

Figure 11. Recovered hotspot region of emmisivity. **(a)** 0.64. **(b)** 0.5. **(c)** 1.

Table 1. The real temperature and error in temperature for various emissivity

Emissivity	Min Temp ^{0}c	Max Temp ^{0}c	Real Temp ^{0}c	Error In Temp ^{0}c
0.64	41.8	57.2	41.9639	0.9639
0.6	43.3	59.4	43.46	2.46
0.55	45.5	62.5	45.833	4.833
0.5	47.3	66.1	47.4955	6.4955
0.7	40.2	54.4	40.455	-0.545
0.75	39	52.4	39.1329	-1.8671
0.8	38.2	50.4	38.3449	-2.6551
0.85	37.3	48.7	37.554	-3.446
0.9	35.8	46.9	35.948	-5.052
0.95	35.5	45.7	35.589	-5.411
0.1	34.6	44.7	34.6897	-6.3103

After calculating the error in temperature, the next task is to determine the relationship between the emissivity and error in temperature. The relation is shown in Equation (1)

Error in temperature = (p1*x^2 + p2*x + p3) / (x + q1) (1)

Where x is emissivity

p1 = - 14.25 (-18.41, -10.08).

p2 = 9.158 (5.059, 13.26).

p3 = 0.4119 (-0.3238, 1.148).

q1 = - 0.2877 (-0.3443, - 0.2311).

The SSE is 0.6582 while RMSE is 0.3312.

4. Conclusion

In this paper, an efficient image enchantment technique based on multilevel thresholds is proposed. Thresholds are chosen based on bins in histograms. The proposed technique enhances the image effectively such that the hotspot regions are visible after edge detection.

Undesirable regions are removed using morphological image processing. Though the hotspot is isolated the actual size of the hotspots is compromised in certain images. Also the structuring elements play a major role in the efficiency of the segmentation technique. Curve fitting toolbox is also used to obtain the relationship between the input and the error in temperature.

5. References

1. Sudha S. Group theory- A tool to analyse infrared and raman spectra. Indian Journal of Science and technology. 2014; 7(s3). DOI: 10.17485/ijst/2014/v7i3S/49292.
2. Zave RJ. Determining pavement layers thickness and moduli according to non-destructive testing and back analysis (Case Study: Azadegan Freeway-Tehran). Indian Journal of Science and Technology. 2015 Aug; 8(18). DOI: 10.17485/ijst/2015/v8i19/75989.
3. Selvarasu N, Nachiappan A, Nandhitha NM. Effective representation of non-uniformity and asymmetry in breast thermographs using statistical parameters on histograms of wavelet coefficients for cancer detection. European Journal of Scientific Research. 2012.
4. Selvarasu N, Vivek S, Nandhitha N. M. Performance evaluation of image processing algorithms for automatic detection and quantification of abnormality in medical thermograms. Proceedings International Conference on Computational Intelligence and Multimedia Applications, ICCIMA; 2007 Dec 13-15. p. 388–93.
5. Glushko S, Salvaggio C. Quantitative analysis of infrared contrast enhancement algorithms. Infrared imaging systems: design, analysis, modeling, and testing. 18, Holst GC, editor. Proc of SPIE; 2007 Apr 9. 6543, 65430S1-11.
6. Bindu NC. Infrared image enhancement using normalization and beta function. International Journal of Engineering and Science. 2013 Aug; 3(6):19–22.
7. Upadhyay EM, Rana NK. Effect of homomorphic filter on infrared images for exposure fusion. International Journal of Emerging Technologies in Computational and Applied Sciences. 2013; 28–37.
8. Yang YG, Yang WC, Liu YC, Liu WM. A contrast enhancement method for skin vasculature extraction under thermal infrared imaging. Symposium on Engineering Medicine and Biology Applications; 2013.
9. Sahu A, Shandilya V. Infrared image enhancement using wavelet transform. Computer Engineering and Intelligent Systems. 2012; 3(3):40–7.
10. Sujatha P, Sudha KK. Performance analysis of different edge detection techniques for image segmentation. Indian Journal of Science and Technology. 2015 Jul; 8(14). DOI: 10.17485/ijst/2015/v8i14/72946.
11. Janani P, Premaladha J, Ravichandran KS. Image enhancement techniques: A study. Indian Journal of Science and Technology. 2015 Sep; 8(22). DOI: 10.17485/ijst/2015/v8i22/79318.
12. Mahalakshmi S, Velmurugan T. Detection of brain tumor by particle swarm optimization using image segmentation. Indian Journal of Science and Technology. 2015 Sep; 8(22). DOI: 10.17485/ijst/2015/v8i22/79092.