

Cloud Based Secure PAC System to Analyze DICOM Images

Roshni Johnson¹, Shangeetha Paktharathshan², Subanemi Sooriyakumaran³, Thirumagal Siluvaithasan⁴, Koliya Pulasinghe⁵, Nethmini Thilakshi. Weerawarna⁶

Sri Lanka Institute of Information Technology, Malabe, Sri Lanka.

1. roshy.jo@gmail.com 2. shangeerb@gmail.com 3. subasooriyakumaran@gmail.com 4. gobisliit@gmail.com

Abstract- Picture archiving and Communication System (PACS) is the backbone of the analysis of medical images as it is well adopt with Digital Imaging and Communications in Medicine(DICOM) standard. In this paper 3D modeling of brain to detect diseases more accurately, content based image retrieval for medical image analysis, brain tumor segmentation for area calculation of tumor and cloud deployment and DICOM image security using Advanced Encryption Standard (AES) encryption for secure remote working have been added to overcome the issues in the existing PAC system implemented by the past students of Sri Lanka Institute of Information Technology (SLIIT).

Keywords- DICOM, Encryption, Decryption, PACS, HL7, MRI, AES

I. INTRODUCTION

A number of studies have been carried out to overcome the storing and retrieval of medical images in Health Information Systems. Even though there are several existing systems available, those systems are not able to be used in Sri Lanka due to the inability to match with Sri Lankan standards and healthcare protocols. Most of the solutions provided were not capable of handling and maintaining those systems in the Sri Lankan Government hospitals due to lack of technical knowledge of staff and as well as requirement of advanced equipment for these systems. Government hospitals in Sri Lanka need more user friendly and easy-to-handle system for their busy daily routine. As a solution for this, the past students of SLIIT developed a PACS system for Sri Lankan government hospitals. The existing system does not completely fulfill the requirements of the radiologists. So the system has been enhanced with additional features.

Enhancements to the system include 3D modeling of series of 2D images from MRI scans to detect diseases more accurately, Deploying system in cloud for radiologists to get access to patient records from anywhere, implementing cloud Security to secure patient information, Segmenting the tumor cells from normal brain cells to calculate the size of mass tumor and to search similar type of medical images to analyze/study about diseases. 3D modeling, content based image retrieval and brain tumor area calculation is implemented using image processing tools and techniques. Cloud security is implemented using image encryption and secure login functionality. AES is a text encryption technique. It's been modified to encrypt DICOM images. Enhancements to the PACS will fill the gap in the existing PACS and it will

have a major impact on the radiology department to ensure the patient satisfaction and reduce workload of radiologists.

II. LITERATURE SURVEY

Table. 1 illustrates the comparison done for the widely used PACS and DICOM viewers worldwide [1] [2].

In earlier days a number of general purpose image search engines have been developed. IBM was the first, who take an initiative by proposing query-by image content (QBIC) [3]. Later most of the image retrieval systems developed was to support random browsing, search by text (including key word or speech). Image Retrieval for Medical applications (IRMA), Automatic Search and Selection Engine with Retrieval Tools (ASSERT) [4] are some existing works related to medical image searching techniques. From [5] a study concludes that a system based on the fuzzy c-means clustering algorithm. All of these systems have their own advantages and disadvantages in their retrieval performance. The proposed system used colour moments [6], Fourier descriptors [7], and wavelet transform [8] for the content based image retrieval.

Rosenthal evaluates how cloud computing could be used for the healthcare industry. Rosenthal also explains that even within a cloud environment, managing the security of data is still the responsibility of organization and is not the responsibility of the cloud service provider [9]. Rijndael is a block cipher algorithm for textual data. The algorithm is flexible in supporting data and key size of 128, 192, and 256 bits. However, AES merely allows a 128 bit data length that can be divided into four basic operation blocks. These blocks operate on array of bytes and organized as a 4x4 matrix that is called the state. For full encryption, the data is passed through N_r rounds ($N_r = 10, 12, 14$) [10].

- 1) Sub byte transformation
- 2) Shift rows transformation
- 3) Mix columns transformation
- 4) Add round key transformation

P. Radhadevi, P. Kalpana has enhanced the AES encryption proposed by Joan Daemen, Vincent Rijmen to encrypt images [11]. This paper explores DICOM image encryption and decryption technique using AES 128 bit algorithm.

TABLE I. COMPARISON OF EXISTING SYSTEMS

Features System	DICOM Viewer					PAC system						Patient Mgt.
	Image Processing	Annotation	Resolution Mgt	Tiling	3D	Web	Stand-alone	Security	Audio/Video	Attach	Cloud based & Security	
My Free PACS	Moderate	Moderate	No	No	No	No	Yes	Moderate	No	No	No	No
PAC One	Moderate	Moderate	No	No	No	No	Yes	Moderate	No	No	No	No
OsiriX	Low	Low	No	Yes	Yes	Yes	Yes	Low	Yes	No	No	No
RadiAnt	Moderate	Moderate	No	No	Yes	No	No	Low	No	No	No	No
Agnosco Viewer	Moderate	Low	No	No	Yes	No	No	Low	No	No	No	No
Rubo medical Dicom	Moderate	Low	No	No	Yes	No	No	Low	No	No	No	No
Existing HIS PACS	Moderate	High	Yes	No	Yes	No	No	Moderate	Yes	Yes	No	Yes

There are some algorithms and techniques have been used to render 3D model from 2D medical images. Multi planar rendering (MPR) does not require too many calculations, so it is suitable for low configuration computers. Volume Render (VR) method is used to visualize the entire volume of the object. By projecting rays through the volume data cloudiness and color need to be calculated at every voxel [12]. To construct the 3D model of the brain segmentation is necessary. The segmentation of the brain tissue from the brain medical images is a challenging problem. The objects to be segmented are true anatomical structures, which are complex in shape, and exhibit considerable variability from person to person [13]. Mathematical morphology technique is used to segment the brain from the medical image. This technique provides a way to incorporate neighborhood and distance information into algorithms [14]. MATLAB technology and enhanced mathematical morphology technique is used to achieve this task in our system.

Some existing systems are available for Brain Tumor segmentation. M. Karuna and Ankita Joshi proposed a system called “Automatic detection of Brain tumor and analysis using MATLAB” [15]. This system incorporates segmentation through Neuro Fuzzy Classifier but it needs many input images to train an image to the neural network. A.Sivaramakrishnan and Dr.M.Karnan proposed an efficient detection of the brain tumor region from cerebral image was done using Fuzzy C-means clustering and histogram. The histogram equalization was used to calculate the intensity values of the grey level images. The decomposition of images was done using principle component analysis which was used to reduce dimensionality of the wavelet co – efficient [16]. For this system, used K means algorithm for the segmentation of tumor and binary mask is applied to the segmented image using thresholding process [17][18].

III. METHODOLOGY

The system was developed using spring framework, hibernate, codeIgniter. MATLAB has been used for image processing and Amazon EC2 has been used for cloud deployment.

A. Content Based Image Retrieval

In content based image retrieval query image is the input image which that the user want search. User can pick an image and ask the system to retrieve "similar" images. Given a query image, a system first extracts image feature vector for color, shape and texture according to the user selection and then compares it to feature vectors of the images stored the database.

The first step of image retrieval is image pre-processing to ensure the accuracy of the upcoming steps. Noise removal is one of the pre processing steps in this system. When capturing the image noise and other some misalignment will be occur. To overcome this issue image pre processing is required. This pre processing helps to remove the noise from the image as well as increase the image intensity. Here a mat lab program to remove “Salt and Pepper” noise using median filter [19].

Feature extraction is playing important role in image retrieval. Because image retrieval process is highly depend on image features. Transforming an input image into set of features is called feature extraction. It is done by visual content descriptor. The descriptor extracts the low level visual feature such as color, shape, texture and makes the feature vector[6][7][8]. This system automatically extract the visual attributes such as color, shape and texture of each image in the database and stores them separately. Then extract the visual attributes of the input image. The features which are extracted from the image are represented in the form of vector. This

way, it can rank images of the database using the “Euclidean distance” algorithm according to the distance of their feature vector to the query one [20].

B. Cloud Deployment and Data Security

DICOM image encryption was implemented using AES-128 bit algorithm. AES is a text encryption technique. DICOM images are extracted from the DICOM file. Extracted image is transformed into a vector. The image vector is padded with zeroes and passed as an input to the AES encryption method. This encryption method returns an encrypted vector. The encrypted vector is converted to an image. The encrypted image is converted again to a vector and passed as an input to the decryption method. Decrypted vector will be returned by the decryption method. This vector is converted back to image and the original image is produced.

C. Brain Tumor Segmentation and It's Area Calculation

Brain Tumor segmentation and its area calculation has mainly four modules: pre-processing, segmentation, binarization, and area calculation. Pre-processing is done by noise filtering and lossless compression of image. Image segmentation is carried out by Kmeans algorithm. Then binary mask will be applied to the tumor image using Thresholding process. Finally, area calculation will be done to the segmented tumor image.

D. 3D Modeling

There are few steps need to be done for render 3D model of medical image. The stored 2D data slices of DICOM file need to be read and set exactly with the real positions. Then the segmentation of the brain is necessary which aims at extraction of object boundary features. The binary mathematical morphology technique is enhanced to segment the brain. Finally, 3D medical image renders from these processed images.

IV. IMPLEMENTATION

A. Content Based Image Retrieval

There are several noises can be introduced in image. But medical images are mostly affected by Salt and Pepper noise. It appearance is randomly scattered with white and black pixel over the image. Normally each pixel value of gray scale image is 0 (Black) to 255(White). Salt is for white pixel and papers is for black pixel. Noisy pixel takes either slat value or pepper value and it appears black and white spot on the image. Here Median Filtering technique has been used to remove the salt and pepper noise. In this technique the median is calculated by first sorting all the pixel values into ascending order and then replace the pixel being calculated with the middle pixel value.

Three main contents (Features) of the image such as color, texture and shape has been used for retrieving the similar images. The retrieval process will be done according the selected feature. First step is extracting the features of the images in the database. Here, feature vectors are calculated for

all the database images according to the selected feature and stored them in .XLS files. Then extract features of the query image. After that similarity matrix of query image and the image present in the database has been calculated from the .XLS sheet using Euclidean distance method. According to the similarity matrix top 9 similar images are retrieved from the database. Here colour features are extracted using colour moments and shape features are extracted using Fourier descriptors and the texture features are extracted using wavelet transform. Once the retrieval process is over it will show up the Display Images button. By hitting on that button we can view the top 9 similar images which are retrieved from the database.

Euclidean Distance method has been used for similarity matching.

$$D(p,q)=\sqrt{\sum_{i=1}^n(q_i - p_i)^2} \quad (1)$$

Here q is the extracted features of the database images which are saved in excel sheet in form of vector and p is the feature vector of input image and n is the total number of database images. D is the Euclidean Distance between features of input image and all features that has been saved in the excel sheet. Finally similar images will be retrieved which are having the minimum distance to match input image.

B. Cloud Deployment and Data Security

A linux instance which is a virtual server was created in Amazon EC2. The PAC system was hosted on the linux instance which was created. The DICOM image security was handled as below.

AES-128 encryption technique has been modified to encrypt DICOM images. The image embedded in DICOM file is extracted using the function ‘dicomread’ in MATLAB. The function ‘dicomread’ reads the image data from the compliant Digital Imaging and Communications in Medicine (DICOM) file filename. For single-frame grayscale images, the output is an M-by-N array. For single-frame true-color images, output is an M-by-N-by-3 array. Multi frame images are always 4-D arrays [18].The array is passed into the function ‘uint8’ to converts the elements of an array into unsigned 8-bit (1-byte) integers. This array is converted into one dimensional double vector. The length of the double byte vector should be a multiple of 16. The ‘mod’ function in MATLAB returns the remainder after division by 16, where the length of the double byte vector is the dividend and 16 is the divisor. The mod function returns how much to be padded. So the double byte vector is padded accordingly with zeroes. This padded double byte vector is passed to the AES encryption function for encryption. Cipher Block Chaining (CBC) mode has been used to break the large byte vector into blocks of 128 bits. The double byte vector passed as an input to the AES encryption function will go through many transformations [10]. AES encryption method returns a byte vector which is now encrypted. The padded values are removed from the encrypted byte vector, converted into a 3D array and it is stored as an encrypted image

Byte vector returned by AES encryption function can be passed as an input to the decryption function. As same as the AES encryption function, AES decryption function also returns byte vector. So the decrypted image can be stored as same as the encrypted image was stored.

C. Brain Tumor Segmentation and It's Area Calculation

Image pre-processing steps like RGB to grey conversion, denoising and image compression had been done to increase the quality of images. Used Median Filter to denoise the image, for the better understanding of median filter, salt and pepper noise is added to the image artificially and removed using median filter. Haar wavelet transformation is used to compress the image.

Tumor cells are segmented from normal brain cells using K mean algorithm [17]. In K means algorithm same characteristics pixels have been group together. Below steps will describe the flow of K means algorithm.

- 1) Given n pixels, initialize k cluster centers.
- 2) Assign each pixel to its closest cluster center.
- 3) Update the center for each cluster.
- 4) Repeat 2 and 3 until no change.

After segmenting the tumor cells from the normal brain cells, binary mask is applied to the tumor image using Thresholding method [18]. It makes the dark pixel become darker and white become brighter.

Total number of white pixels is taken from the binary image to calculate the size of tumor. DICOM images have metadata embedded in them [21]. Using the pixel spacing value in the metadata of DICOM image, one pixel area can be calculated.

$$Per_pixel_area = x * y \quad (2)$$

Where

- x= Row spacing in mm,
- y= Column spacing in mm.

Finally, using the total number of white pixels and the area of one pixel, total area of tumor can be calculated.

$$Tumor\ area = no_of_white\ pixels * Per_pixel_area \quad (3)$$

D. 3D Modeling

The enhanced binary morphology technique is used for segment the medical image. There are some steps in this technique. The technique enhanced by removing high and low intensity pixels from the gray scale image.

- 1) *Removing high and low intensity pixels.*

Intensity distribution of the brain image has only a less amount of high and low intensity pixels. 99% values of

dataset distribution are less than three standard deviations away from the mean [22]. Therefore 1% pixels of the intensity distribution can be removed by calculating the mean μ and three standard deviation sd . 99% values of dataset distribution interval is denoted by [22].

$$\mu \pm 3sd \quad (4)$$

- 2) *Convert gray scale image to binary image.*

A binary image is a digital image that has only two possible values for each pixel. Typically, the two colors used for a binary image are black and white. The graythresh(I) function on image I computes the global threshold and the result are used to convert intensity images to the binary images [18].

- 3) *Erode image*

Thick edges can be removed from the binary images using erosion method. The erosion operator takes two pieces of data as inputs. The first is the image which is to be eroded. The second is a set of coordinate points known as a structuring element. This element determines the precise effect of the erosion of the input image [18]. Let $F(x, y)$ denotes a gray-scale two dimensional image, B denote structuring element. Erosion of a grayscale image $F(x, y)$ by a grayscale structuring element $B(s, t)$ is denoted by [23].

$$(F \ominus B)(x, y) = \min \{F(x+s, y+t) - B(s, t)\} \quad (5)$$

- 4) *Get largest connected component.*

Bwlabeln(I) function is used to label all the connected components in the eroded image. Then find largest connected components in the eroded image.

- 5) *Dilate connected component.*

The dilation operation is restoring the boundaries of the brain component that were distorted in the erosion step [14]. It reduces the free space between components. The dilation operator takes two pieces of data as inputs. The first is the image which is to be dilated. The second is a structuring element which is used in erosion method. Dilation of a grayscale image $F(x, y)$ by a grayscale structuring element $B(s, t)$ is denoted by [23]

$$(F \oplus B)(x, y) = \max \{F(x-s, y-t) + B(s, t)\} \quad (6)$$

V. RESULTS

This interface is used to view the output similar images. Below Figure is the query result for Image the input is the query image. The images listed in the Under "Retrieved Similar Images" are the top nine images returned by the query. These images are displayed based on their ranks.

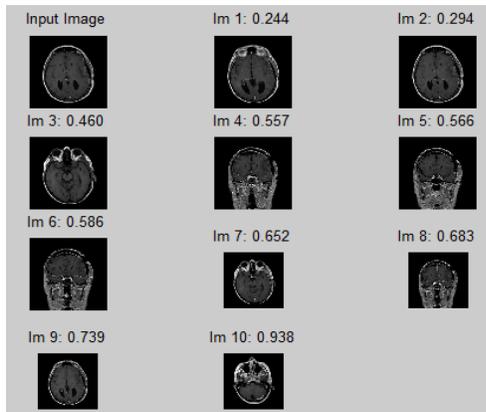


Fig. 1. Retrieved Similar Images

The outcome of DICOM image encryption and decryption using AES is shown in Fig. 2.

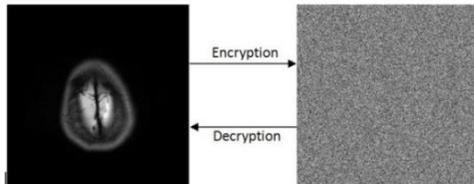


Fig. 2. Encrypted and decrypted images

System takes about three minutes to render the 3D model of brain, which makes the method attractive to clinicians.

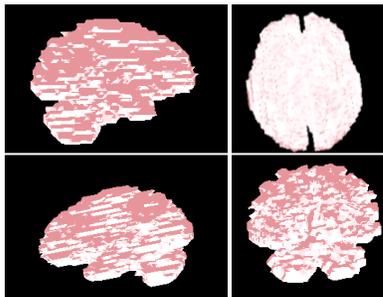


Fig. 3. 3D model of the brain

Fig. 4 shows the Brain tumor segmentation and its area calculation in mm^2 .

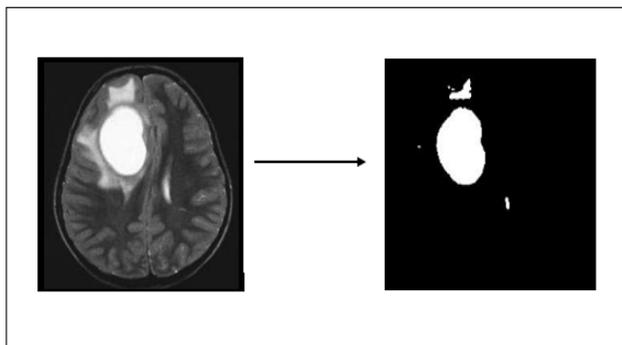
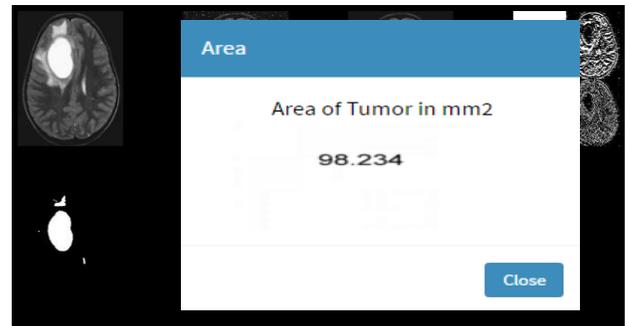


Fig. 4. Output Image of Segmented Tumor

Fig. 5. Output Image of Tumor area



VI. DISCUSSION

The histograms of the original image in Fig. 5 and the histogram of the decrypted image are similar. This shows that the quality of the original DICOM image has not degraded during the encryption and decryption process.

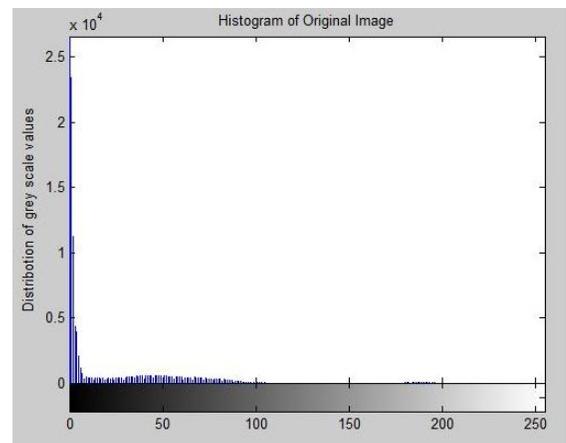


Fig.5. Histogram of original image extracted from DICOM file

PACS system provides 3D modeling images automatically without manual segmentations. Segmented images have been compared with manual segmentation for validating results. There are only few differences between manual and automated segmentation images.

In Content Base Image Retrieval the system automatically extract the visual attributes such as color, shape and texture of each image in the database and stores them separately. The retrieval algorithms color moments, Fourier descriptors, wavelet transformers which are used in feature extraction mainly increase the user interaction and reduce the processing time.

VII. CONCLUSION

The enhanced PAC system has great potential to improve clinical work practices by automating the manual processes carried out by the radiologists and clinical staff. The radiologists can render the 3D model of brain and calculate the area of brain tumor using brain tumor segmentation without critically examining medical images. The content based image retrieval for diagnostic purposes is important because the historical images of different patients in medical centers have valuable information for the upcoming diagnosis with a system which retrieves similar cases, make more accurate diagnosis and decide on appropriate treatment. Cloud

based PAC system allows remote working for radiologists with patient data security.

VIII. FUTURE WORK

Content based image retrieval has rich potential and high scope in medical applications. In future filtering techniques can be added to categorize the images to increase the retrieval speed and accuracy.

One patient study consists of many DICOM files. So the DICOM image encryption and decryption process is time consuming. The proposed DICOM image encryption technique can be extended to reduce the time consumed for encryption and decryption processes.

Developed system can render only 3D images of brain. Rendering 3D model of other body structure and anatomies such as heart, tumor can be developed in future.

Accurate detection of malignant tumor can be developed using 3D modeling of brain images.

IX. REFERENCES

- [1] MyFreePacs A Free Web Based Radiology Image Storage and Viewing Tool, [Online], Available: <http://www.pacssoft.com/index.php?page=myfreepacs>
- [2] *PacsOne Server Solution*, [Online] Available: <http://www.pacsone.net/solutions.htm> [Accessed: 16-January-2016].
- [3] Dzulkipli Mohamad, N.A. Ismail Hui Hui Wang, "Approaches, challenges and future direction of image retrieval," *Journal of Computing*, vol. 2, no. 6, pp. ISSN 2151-9617, June 2010.
- [4] K.R.Chandran B.Ramamurthy, "Content based image retrieval for medical images using canny edge detection algorithm," *International Journal of Computer Applications*, vol. Volume 17- No.6, March 2011.
- [5] Fuzzy Logic [Online] Available: <https://www.scribd.com/book/145718199/Fuzzy-Logic-with-Engineering-Applications> [Accessed: 16-September-2016].
- [6] N. J. Janwe P. B. Thawari, "CBIR based on color and texture," *International Journal of Information Technology and Knowledge Management*, vol. 4, pp. 129-132, January - June 2011.
- [7] M.A. Balafar Y. Fanid Fathabad, "Application of content based image retrieval in diagnosis brain disease," *International Journal on Technical and Physical Problems of Engineering*, vol. 4, no. 13, pp. 133-138, December 2012.
- [8] Nelwin Raj N R Manjusha S, "Content based image retrieval using wavelet transform feedback algorithm," *International Conference On Innovations & Advances In Science, Engineering*, vol. 3, no. 5, July 2014.
- [9] A. Rosenthal, P. Mork, M. H. Li, J. Stanford, D. Koester and P. Reynolds "Cloud computing: A new business paradigm for biomedical information sharing," *Methodological Review*, August 2009.
- [10] J. Daemen, V. Rijmen, "The block cipher rijndael", *Proceedings of the Third International Conference on smart card Research and Applications*, CARDIS'98, Lecture Notes in computer Science, vol. 1820, Springer, Berlin, 2000, pp. 277_284.
- [11] P. Radhadevi and P. Kalpana, "Secure image encryption using AES," *International Journal of Research in Engineering and Technology*, vol. 1, no. 2, pp. 115-117, October 2012. [Online serial]. Available: <http://esatjournals.net/ijret/2012v01/i02/>. [Accessed May, 2016].
- [12] R. M. Sherekar and Anand Pawar, "A MATLAB Image processing approach for reconstruction of DICOM Images for Manufacturing of customized anatomical implants by using rapid prototyping," *American Journal of Mechanical Engineering and Automation*, vol. 1, no. 5, pp. 48-53, 2014.
- [13] Challenges in brain segmentation [Online] Available: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4402572/>. [Accessed: 28-March-2016]
- [14] T. Kapur, W. Grimson, W. Wells III and R. Kikinis, "Segmentation of brain tissue from magnetic resonance images", *Medical Image Analysis*, vol. 1, no. 2, pp. 109-127, 1996.
- [15] M. Karuna and Ankita Joshi, "Automatic detection and severity analysis of brain tumors using GUI in MATLAB," *International Journal of Research in Engineering and Technology*, vol. 02, no. 10, 2013.
- [16] A. Sivaramakrishnan and Dr. M. Karnan, "A novel based approach for extraction of brain tumor in MRI images using soft computing techniques," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 2, no. 4, 2013.
- [17] "Data Clustering Algorithms," [Online]. Available: <https://sites.google.com/site/dataclusteringalgorithms/k-means-clustering-algorithm>. [Accessed 17 09 2016].
- [18] "MathWorks," [Online]. Available: <http://in.mathworks.com/>. [Accessed 2016 09 17].
- [19] Saurabh Kumar Mishra, Pallavi Asthana, G. R. Mishra Chanchal Srivastava, "Performance comparison of various filters and wavelet transform for image de-noising," *IOSR Journal of Computer Engineering (IOSR-JCE)*, vol. 10, no. 1, pp. 55 - 63, April 2013.
- [20] "Euclidean Distance," [Online]. Available: https://en.wikipedia.org/wiki/Euclidean_distance. [Accessed 2016 09 17].
- [21] Digital Imaging and Communications in Medicine (DICOM), Virginia 22209 USA : National Electrical Manufacturers Association, 2011
- [22] "Measures of variability," [Online]. Available: <http://www2.le.ac.uk/offices/ld/resources/numerical-data/variability>. [Accessed: 20-March-2016]
- [23] N. Senthilkumar and C. Kirubakaran, "A case study on mathematical morphology segmentation for MRI brain image", *International Journal of Computer Science and Information Technologies*, vol. 54, no. 0975-9646, pp. 5336-5340, 2014.