CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Angiograms can be analysed using computers to detect the blood vessel boundary as a first step. In the literature, this is performed using the magnitude of the image gradient but this method does not provide sufficient information for locating the boundary of the blood vessel and hence the performance of segmentation becomes complicated. Thus, the quality of the image segmentation can be improved by the use of the proposed histogram equalization technique, rather than the gradient magnitude.

Blood vessel segmentation techniques and algorithms are basically classified into edge detection, pattern based, model based, and neural network and fuzzy logic based.

2.2 EDGE DETECTION TECHNIQUES

Edge detection is done to segment the blood vessels from the angiogram images. Edge detection algorithms are followed by linking and boundary detection procedures. It is used for detecting discontinuities in gray level. First and second order digital derivatives are implemented to detect the edges in an image. The edge is defined as the boundary between two regions with relatively distinct gray-level
properties. An edge is a set of connected pixels that lie on the boundary between two regions.

The complexity of the image is reduced by detecting the edges. They can be used to measure parameters related to blood flow or to locate some patterns in relation to vessels in angiographic images. Thus edge detection is done using first-order derivative (Gradient operator), Second-order derivative (Laplacian operator) and also using the Sobel and Prewitt algorithms.

Marr and Hildeth., (1980) have presented the theory of edge detection. The analysis proceeds in two parts, namely, the first being intensity changes, which occur in a natural image over a wide range of scales, are detected separately at different scales. An appropriate filter for this purpose at a given scale is found to be the second derivative of a Gaussian, and it is shown that, provided some simple conditions are satisfied, these primary filters need not be orientation-dependent. Thus, intensity changes at a given scale are best detected by finding the zero values. The intensity changes thus discovered in each of the channels are then represented by oriented primitives called zero-crossing segments, and evidence is given that this representation is complete. Secondly, intensity changes in images arise from surface discontinuities or from reflectance or illumination boundaries, and these all have the property that they are spatially localized. Because of this, the zero-crossing segments from the different channels are not independent, and rules are deduced for combining them into a description of the image. This description is called the raw primal sketch. The theory explains several basic psychophysical findings, and the operation of forming oriented zero-crossing segments from the output.
Canny, (1986) has developed the edge detection operator and used a multi-stage algorithm to detect a wide range of edges in the images. The researcher proposed the Hysteresis Thresholding method in which two threshold values have to be given. However, its performance was not good enough with respect to detection, localization, and resolution and noise rejection. The percentage of true edges detected is also less as compared to the other algorithms.

The Canny algorithm contains a number of adjustable parameters, which can affect the computation time and effectiveness of the algorithm.

- The size of the Gaussian filter used in the first stage directly affects the results of the canny algorithm. Smaller filters cause reduced blurring, and allow detection of small, sharp lines. A larger filter causes more blurring, smearing out the value of a given pixel over a larger area of the image. Larger blurring radii are more useful for detecting larger, smoother edges, for instance, the edge of a rainbow.

- Thresholds: the use of two thresholds with hysteresis allows more flexibility than in a single threshold approach, but the general problems of thresholding approaches still exist. A threshold set too high can miss important information. On the other hand, a threshold set too low will falsely identify irrelevant information like noise as important. It is difficult to give a generic threshold that works well on all images. No tried and tested approach to this problem yet exists.
Zohaib Hameed and Chunyan Wang., (2011) have stated that edge detection plays a critical role in image processing and the performance of an edge detection algorithm can be affected by serious noise & intensity in homogeneities. The researchers have presented a method aiming at detecting edge of image with varieties of gradient signal degradation is proposed. The method comprises two steps. The first step is to perform adaptive histogram equalization to improve the signal contrast in a discriminative manner. To this end, the histogram of the input image is analysed and the irregularity of image intensity, if there is any, is identified and removed by using a contrast limited adaptive histogram equalization technique. The following step is a gradient modulation filtering process with the modulation factor determined by the local intensity. The simulation results comprising subjective and objective analysis show that the proposed method is applicable and effective to detect edges of low-quality images. But the researchers did not carry any performance evaluation to prove that the algorithm developed is efficient.

2.3 PATTERN BASED TECHNIQUES

Pattern based techniques normally deal with automatic detection and/or classification of features or objects. As far as vessel extraction are concerned, pattern based techniques are used to detect the vessel structures and features automatically. The pattern techniques include differential geometry approach, matching filters approach, mathematical morphology approach, multi-scale approach, skeleton based approach and region growing approach.

Huertas and Medioni., (1986) have presented a system that takes a gray level image as input, locates edges with subpixel accuracy, and links them into lines. Edges are detected by finding zero-crossings in the convolution of the image with
Laplacian-of-Gaussian (LoG) masks. The implementation differs from others in such a way the masks are decomposed exactly into a sum of two separable filters instead of the usual approximation by a difference of two Gaussians (DOG). Subpixel accuracy is obtained through the use of the facet model. Also noted that the zero-crossings obtained from the full resolution image using a space constant for the Gaussian, and those obtained from the $1/n$ resolution image with $1/n$ pixel accuracy and a space constant for the Gaussian, are very similar, but the processing times are very different. Finally, these edges are grouped into lines using the technique described but the results obtained are not very prominent.

Lee et al., (1987) have introduced edge operators based on gray-scale morphologic operations. These operators can be efficiently implemented in near real time machine vision systems which have special hardware support for gray-scale morphologic operations. The simplest morphologic edge detectors are the dilation residue and erosion residue operators. The underlying motivation for these and some of their combinations are discussed and justified. Finally, the blur-minimum morphologic edge operator is defined. Its inherent noise sensitivity is less than the dilation or the erosion residue operators. Some experimental results are provided to show the validity of these morphologic operators. When compared with the enhancement/thresholding edge detectors and the cubic facet second derivative zero-crossing edge operator, the results show that all the edge operators have similar performance when the noise is small. However, as the noise increases, the second derivative zero-crossing edge operator and the blur-minimum morphologic edge operator have much better performance than the rest of the operators. The advantage of the blur-minimum edge operator is that it is less computationally complex than the facet edge operator.
Zhou et al., (1994) have presented an algorithm for the analysis and quantification of the vascular structures of the human retina. Information about retinal blood vessel morphology is used in grading the severity and progression of a number of diseases. These disease processes are typically followed over relatively long time courses, and subjective analysis of the sequential images dictates the appropriate therapy for these patients. In this research, retinal fluorescein angiograms are acquired digitally in a 1024×1024 image format and are processed using an automated vessel tracking program to identify and quantitate stenotic and/or tortuous vessel segments. The algorithm relies on a matched filtering approach coupled with a priori knowledge about retinal vessel properties to automatically detect the vessel boundaries, track the midline of the vessel, and extract useful parameters of clinical interest. By modeling the vessel profile using Gaussian functions, improved estimates of vessel diameters are obtained over previous algorithms. An adaptive densitometric tracking technique based on local neighborhood information is also used to improve computational performance in regions where the vessel is relatively straight.

Changjiang Yan et al., (2000) have proposed the angiography blood vessel detection using fuzzy logic technique implemented using a Laplacian filter to convert the raw image data into a rough image. Intensity Thresholding and fuzzy interference were applied to extract the blood vessel from the angiography image. The blood vessel is extracted from the Willis ring which is in turn obtained from the tissues in edge image generated by Deriche filter and decomposition method based on the Morphological operators.
The Morphological operations involved are expansion and skeletonization to detect the ring structure of the blood vessel. Furthermore, the blood vessels are determined from the ring structure according to the ‘Membership function’ for the blood vessel inferred by the fuzzy system. The Information about the ring structure is obtained using the IF-THEN Fuzzy rule. Finally, Region growing was used to remove the background image from the image obtained by the above process to get the whole image. The existing method was tested with Computer Tomography (CT) angiography images and took 28 minutes to extract the blood vessels from the angiogram images and has high computational complexity involved.

Hernandez-Hoyos, (2000) has dealt with image segmentation applied to three-dimensional (3D) analysis of vascular morphology in magnetic resonance angiography (MRA) images. The researcher has developed a fast and reliable method for stenosis quantification. The first step towards this purpose is the extraction of the vessel axis by an expansible skeleton method. Vessel boundaries are then detected in the planes locally orthogonal to the centerline using an improved active contour. Finally, area measurements based on the resulting contours allowed the calculation of stenosis parameters. The expansible nature of the skeleton associated with a single point initialization of the active contour allowed to overcome some limitations of traditional deformable models. As a result, the algorithm performed well even for severe stenosis and significant vessel curvatures. Experimental results were presented in 3D phantom images as well as in real images of patients, but no statistical analysis was performed.
Nystrom and Smedby, (2000) have proposed a presentation method that uses skeletonization and distance transformations, which visualizes variations in vessel width independent of viewing direction. In the skeletonization, the object is reduced to a surface skeleton and further to a curve skeleton. The skeletal voxels are labeled with their distance to the original background. For the curve skeleton, the distance values correspond to the minimum radius of the object at that point, i.e., half the minimum diameter of the blood vessel at that level. The following image processing steps are performed: resampling to cubic voxels, segmentation of the blood vessels, skeletonization, and reverse distance transformation on the curve skeleton. The reconstructed vessels may be visualized with any projection method. Preliminary results are shown which indicate that locations of possible stenoses may be identified by presenting the vessels as a structure with the minimum radius at each point.

Shi and Malik, (2000) have proposed a novel approach for solving the perceptual grouping problem in vision. Rather than focusing on local features and their consistencies in the image data, the approach aims at extracting the global impression of an image. Image segmentation is treated as a graph partitioning problem and proposed a novel global criterion, the normalized cut, for segmenting the graph. The normalized cut criterion measures both the total dissimilarity between the different groups as well as the total similarity within the groups. It is shown that an efficient computational technique based on a generalized eigenvalue problem can be used to optimize this criterion. Thus this approach is applied in segmenting static images, as well as motion sequences, and found the results to be very encouraging. But no performance evaluation has been carried out.
Susanta Mukhopadhyay and Bhabatosh Chanda., (2000) have presented an automatic segmentation of coronary artery Multiscale morphological approach to local contrast enhancement. The authors have extended the the conventional theoretical concept of local contrast enhancement by modifying the intensity values of the scale specific features of the image using Multiscale tophat Transformations. Then, the locally enhanced features are combined to reconstruct the final image. The algorithm developed have been tested to evaluate its efficiency and also compared with that of the other standard methods.

Chung et al., (2002) have presented a statistical approach by combining the speed information along with the phase information as a priori knowledge in a Markov Random Field (MRF) model which improved the quality of segmentation. Also, a Maxwell-Gaussian mixture density is used to model the background signal distribution and combine it with a uniform distribution for modelling vascular signal to give a Maxwell-Gaussian-Uniform mixture model of image intensity. This algorithm has been tested on aneurysm phantom data set and two clinical data sets, which yields a better quality of segmentation when both speed and phase information are utilised.

Suri et al., (2002) have reviewed MR Vascular image processing algorithms. The researcher also focussed on prefiltering algorithms for MR images, as they are necessary to remove the background non vascular structures.

Jorge Leandro et al., (2003) have described a new framework for automatic analysis of optic fundus nonmydriatic images, focusing on the segmentation of the blood vessels by using pixel classification based on pattern recognition techniques. Each pixel is represented by a feature vector composed of
color information and measurements at different scales taken from the continuous wavelet (Morlet) transform as well as from mean and order filtering applied to the green channel. The major benefit resulting from the wavelet application to the optic fundus images is its multiscale analysing capability in tuning to specific frequencies, thus allowing noise filtering and blood vessel enhancement in a single step. Supervised classifiers are then applied to label each pixel as either a vessel or a nonvessel. Two different strategies to select the training set have been devised: (1) the blood vessels of a sample image are completely drawn by hand, leading to a labeled image (i.e. vessels × nonvessel pixels) which is used to train the classifier, to be applied to other images; (2) the vessels located in a given small portion of the target image are drawn by hand and the remaining fundus image is segmented by a classifier trained using the hand-drawn portion to define the training set. The latter strategy is particularly suitable for the implementation of a semiautomated software to be used by health workers in order to avoid the need of setting imaging parameters such as thresholds. Both strategies have been extensively assessed and several successful experimental results using real-case images have been obtained.

**Susanta Mukhopadhyay and Bhabatosh Chanda., (2003)** have proposed a method of segmenting gray level images using Multiscale morphology. The algorithm proposed by the researcher detects valid segments at each scale using three criteria namely, region growing, merging and saturation. In the final result, the segments extracted at various scales are integrated. First, pre-processing is done and features at various scales are extracted and during second pass potential features responsible for the formation of segments at various scales were detected. Finally the algorithm traced the contours and the results were compared with those of other standard methods.
EllyMatuIlmah et al., (2004) have studied a comparison between the Daubechies wavelet transform, Kernel Principal Component Analysis (PCA), and PCA as feature extractors and classification of arrhythmias have been done using the Support Vector Machines (SVM). The researchers found that better results were obtained when SVM is used with the wavelets as compared to other feature extraction techniques. A 100% accuracy for feature extraction ahhs been obatines using Daubechies wavelet.

CemilKirbas and Francis Quek., (2004) have presented a survey of vessel extraction techniques and algorithms as they are the critical components of the circulatory blood vessel analysis systems. The researcher has mainly targeted the extraction of blood vessels, neurovascular structure in particular, and also reviewed some of the segmentation methods for the tubular objects that show similar characteristics to vessels and also created tables to compare the papers in each category against such criteria as dimensionality, input type, preprocessing, user interaction, and result type.

Mannisieg and Niessen., (2004) have proposed a new segmentation scheme for 3D vascular tree delineation in CTA data sets, which has two essential features. First, the segmentation is carried out locally in a small Volume Of Interest (VOI), second, a global topology estimation is made to initialize a new VOI. The use of local VOI allows that parameter settings for the level set speed function can be optimally set depending on the local image content, which is advantageous especially in vascular tree segmentation where contrast may change significantly, especially in the distal part of the vascular. Moreover, a local approach is significantly faster. A comparison study on five CTA data sets showed that the
proposed method has the potential to segment larger part of the vessel tree compared to a similar global level set based segmentation, and in substantially less computation time. However the researcher did not carry any performance analysis.

RivestJean., (2004) has presented a novel approach to the generalization of mathematical morphology to complex signals and images. This generalization is strongly dependent upon the issue of multivariate order relationships. Although there is no natural way to order multivariate data such as complex numbers, the researcher has outlined the criteria that the order relationship should be met. The researcher has proposed a new order relationship that met certain criteria. Based on this order relationship, the researcher has constructed the basic operators in mathematical morphology using dilations and erosions.

Staal et al., (2004) have proposed Machine learning techniques involving the features of the wavelet transforms and k-nearest neighborhood pixels, are used to detect the pixels inside and outside the vessels. This method took 15 minutes to detect the blood vessels and normally k-means doesn’t provide an optimal solution, as output depends on the initial cluster and the value of k.

Qing Cheng et al., (2004) have evaluated the performance of the Watershed algorithm by analyzing the binary images and comparing them against different distance transforms. The researcher has concluded that the Watershed algorithm is very effective for grey level segmentation of medical images and the chessboard distance transform performed well as against the Euclidean distance.

Chih-Yang Lin et al., (2005) have introduced the extraction of Coronary angiogram blood vessels from the digital angiographic images. The researchers have
used three important steps to segment or extract the Coronary angiogram blood vessel, namely, background elimination done using the temporal Fourier Transform and noise removal using Discrete Wavelet Transform (DWT), blood vessel enhancement using 72 matched filters and blood vessel segmentation based on cluster analysis of the Coronary angiogram image.

In the first stage, the researcher has applied a temporal Fourier transform followed by a high pass temporal filtering, which allows only the low-frequency terms, followed by Inverse Fourier Transform. The transformed image so formed does not have the unwanted background, however contains some spikes or noise, which may be due to isolated noise which cannot be detected and removed by using the Fourier Transform as it is based on the pure frequency domain. Hence to remove the isolated noise, Discrete Wavelet Transform (DWT) is applied. A three level decomposition is employed so that the Low Low Low (LLL) sub-band region will consist of the features pertaining to the blood vessel. Thresholding is applied to preserve the edge information and finally Inverse Discrete Wavelet Transform (IDWT) was applied.

In the second stage, blood vessel enhancement is done using 72 Matched filters and is projected onto the xy plane, followed by blood vessel segmentation, based on clustering analysis using a stencil mask. Further, histogram analysis is carried with Thresholding and 18-adjacency clustering to segment the Coronary Angiogram blood vessel.

The method used is very complicated involving two transforms, 72 Matched filters, masking and Thresholding. Also, the overall execution time was
less than 3 minutes. However, the researcher did not carry any Coronary quantitative or statistical analysis to prove the efficiency of the system.

**Chih-Yang Lin and Yu-Tai Ching, (2005)** have proposed an efficient and robust method for the segmentation of coronary arteries from the cine angiogram. The method has been developed using the Gradient Vector Flow (GVF) snake based algorithm which is signal based image segmentation and vessel feature extraction in order to extract the width of the segmented artery vessels. Initially, 3D Fourier and 3D Wavelets have been employed to reduce the background noises, as it is very challenging to accurately identify the coronary artery due to vessel overlap, poor signal to noise ratio, and superimposition of structures. Then the image is enhanced using a set of matched filters and segmentation is done using clustering & histogram techniques followed by filtering. Finally, GVF is applied to extract the vessel features such as vessel centerline, diameter in order to determine the medial axis, which is used to calculate the vessel boundaries and width. The details of vessel features obtained are accurate and the time taken to execute 30 512 x 512 pixel images took less than three minutes. However, the researcher failed to prove the statistical analysis.

**Scheipers et al., (2005)** have reviewed the application of the Receiver Operating Characteristic (ROC) curve for computer-aided diagnostic systems. A statistical framework is presented and different methods of evaluating the classification performance of computer-aided diagnostic systems, and, in particular, systems for ultrasonic tissue characterization, are derived and summarized that threshold should be chosen. The paper aimed at closing the gap between theoretical works and real-life data.
Ana Maria Mendonca and Aurelio Campilho., (2006) have presented an automated segmentation method to extract the blood vessels of the retinal images. The algorithm starts with the extraction of vessel centerlines using four directional differential operators and the final segmentation is obtained using an iterative region growing method that integrates the contents of several binary images resulting from vessel width dependent morphological filters. The researchers have demonstrated that the algorithm proposed outperforms other solutions and approximates the average accuracy of a human observer without a significant degradation of sensitivity and specificity.

Albert Chung et al., (2006) have proposed a method which uses the multiscale Gabor filtering and the Hessian matrix analysis to enhance the given image and to extract the angio vessels from the original angiographic image. The Hessian matrix is used to obtain the vessel feature map and the vessel direction map from the original angiogram image. The Gabor filter is a linear filter which is used to detect the edges of the vessel and the median filter is used to remove the noise. Thus they are used to obtain an enhanced image. Before segmenting the blood vessels from the angiographic image, it has to be enhanced. Hence as a measure of multiscale detection, the Hessian matrix is used. This is done by convolving the angiographic image with the normalized second order Gaussian derivatives at different scales. Then the filter response is normalized for each scale by selecting the maximum response.

The different type of input parameters such as vessel feature and direction to segment the vessel elements along the same angio vessel were used in the existing method, which is limited in extracting the accurate segmented angio
vessel due to noise, and the width of the extracted angio vessel is not detected at random points.

**Lacoste and Magnin., (2006)** have proposed the use of marked point processes to perform an unsupervised extraction of the coronary tree from 2D X-ray angiography. These processes provide a rigorous framework based on measure theory to describe a scene by an unordered set of objects. Firstly, the thick branches are detected at low resolution using a segment process. Secondly, a polygon tree is derived from this first result at high resolution to represent the main part of the coronary tree. Finally, new branches are extracted using a recursive algorithm based on the modeling of the descendants of a given branch by a polyline process in the neighborhood of this branch. Process optimization is done via simulated annealing using a reversible jump Markov chain Monte Carlo algorithm. Experimental results show the relevance of the object process models, but the researcher failed to evaluate based on statistical datas.

**Li et al., (2006)** have proposed a novel method which includes a multiscale analysis scheme using Gabor fillers and scale production, and an adaptive thresholding scheme using adaptive tracking and morphological filtering. The researcher claimed that the method is good for detecting large and small vessels concurrently and also efficient to denoise and enhance the responses of line filters so that the vessels with low local contrast can be detected. Again, there are no statistical performance analysis performed.

**Nassir Salman., (2006)** has combined K-means clustering, watershed and Difference In Strength (DIS) for segmentation. Although the proposed method overcomes the over segmentation there is no valid performance evaluation done.
Brievaand Ponce, (2007) have evaluated four segmentation algorithms for Coronary Angiogram images. The four algorithms were, namely, Wavelets, Snakes, Level sets and Dynamic Threshold. Here, a Multi-resolution wavelet method was employed which consists of filter banks in turn consisting of one dimensional wavelet functions. A set of five filters is applied and segmented based on Thresholding. The researcher used mean specificity and mean sensitivity for evaluating the performance of the system. However, the researcher have not carried out any other Coronary quantitative or statistical analysis to prove the efficiency of the system nor computed the overall execution time. Thus, the system looks complicated with filter banks and set of five filters.

NingLi et al., (2007) have proposed a novel algorithm which combines the watershed transform and level set method in order to extract the accurate boundary of the vessels. The researcher has demonstrated the cost time which mainly depends on the number of pre segmented regions. However, performance of the system could be improved only if some prior information and distinguishable features are included and the researcher didn't carry any performance evaluation.

Socher et al., (2008) have presented a learning based method for vessel segmentation in angiographic videos, which is automatic, fast and robust towards noise often seen in low radiation X-ray images. Further, it can be easily trained and used for any kind of tubular structure. The researcher has formulated the segmentation task as a hierarchical learning problem over 3 levels: border points, cross-segments and vessel pieces, corresponding to the vessel's position, width and length. Following the marginal space learning paradigm the detection on each level
is performed by a learned classifier. The author has used probabilistic boosting trees with Haar and steerable features. However, not much statistical analysis was done.

Yao et al., (2008) have introduced the Histogram based image segmentation methods which are very efficient as compared and it is computed from all the pixels in the image which in turn determines the peak and valley for clustering. However it is difficult to locate the peak and valley points. The drawback in the existing methods is that the complexity involved and the high computational time as well. The blood vessel detected is also not very accurate.

Ali Atzaz et al., (2009) have presented a method to enhance, locate and segment the blood vessels of a retina using 2D gabor wavelet and sharpening filter to enhance. Edge detection technique and morphological operations have been involved in order to locate and segment the blood vessel accurately. Although the researchers claim that the method segments accurately, failed to demonstrate how accurate using statistical datas and not compared the results with that of the literature.

Ashrafual Amin and Hong Yan., (2009) have stated that detection of blood vessels in a retinal fundus image is the preliminary step to diagnose several retinal diseases. There exist a number of methods to accomplish this task automatically. However, all of these methods suffer from lengthy processing time. The other major use of retina scanning is biometric authentication, for which a real time vessel detection system is required. In this work a method that acquires binary vessel image from a color retinal fundus image in near real time is described. This method first generates the phase congruency image of the green channel of a color retinal image, and then thresholding is applied on the phase congruency image to
obtain the blood vessels. This method is able to acquire the blood vessels from a retinal fundus image within 10 seconds on a PC but not tested for Coronary angiogram images.

**Ghassan Hamarneh and Xiaoxing Li., (2009)** have pointed out that, although Watershed transformation is generally used for segmentation, it is limited due to over segmentation and sensitivity to noise. However, these drawbacks were overcome by enhancing the prior shape and appearance knowledge. The problem of over segmentation was overcome by using clustering namely k-means segmentation and noise is removed or suppressed by computing the mean intensity of each segment. However the researcher didn’t evaluate the performance of the system proposed and it involves complex algorithm.

**Jayadevappa et al., (2009)** have developed a hybrid segmentation model based on Watershed and Gradient Vector flow (GVF) for the detection of the brain tumor. Generally the GVF suffers from a very high computational requirements and sensitive to noise. These are overcome by the integrated method which makes use of the watershed algorithm.

**MarcinRudzki., (2009)** has presented a 3D image processing method that is based on the analysis of Hessian matrix eigen values combined with a Multiscale image analysis approach. The method has been tested on synthetic images containing airway-like structures as well as on real medical images from chest CT scan, but not on Coronary angiogram images.

**Seyed Mostafa Mirhassaniet al., (2009)** have stated that in many of vessel segmentation methods, Hessian Based Vessel Enhancement Filter (HBVEF)
is employed as an efficient step. In this paper, for segmentation of vessels, HBVEF method is the first step of the algorithm. Afterward, a high level threshold is applied to the filtered image to remove non-vessels from the image. As a result of threshold some of weak vessels are removed, recovering of vessels using Hough transform and morphological operations is accomplished. Then, the yielded image is combined with a version of vesselness filtered image which is converted to a binary image using a low level threshold. As a consequence of image combination, most of vessels are detected. In the final step, fine particles are removed from the result according to their size to reduce the false positives. Experiments indicate the promising results which demonstrate the efficiency of the proposed algorithm. Again the researcher failed to perform statistical analysis.

Shoujun Zhou et al., (2009) have used multi-scale Hessian matrix to derive the feature map and direction map of the coronary angiogram blood vessels. The researcher determined the detected artery segment, extracted vessel length and identification ratio, the computational time spent in pre-processing and vessel tracking.

Tsair-Fwu Lee et al., (2009) have proposed a method which combines the 2D discrete periodic wavelet transform with region based and gradient based segmentation methods for quantitative coronary analysis, in order to determine the stenosis minimum and maximum diameter. The results obtained by the combination are good and more accurate as compared to the results yielded individually.

Wenwei Kang et al., (2009) have aimed at the complex background of coronary angiograms, weak contrast between the coronary arteries and the background, and a new segmentation method based on transition region extraction is
proposed. Firstly, the researchers constructed 6 different Gaussian templates that are used to enhance the coronary angiograms. Then the transition region is extracted by using local entropy-based on transition region extraction method. Finally, determined the segmentation threshold and the vessels are obtained. The experiments indicate that the proposed method outperforms the method using morphological operator on the small vessels extraction, connectivity and effectiveness. In addition, the method is indeed valuable for diagnosis and the quantitative analysis of coronary arteries.

**Farsad Zamani Boroujeni et al., (2010)** have presented a new method to detect initial seed points for automatic tracing of the vessel center lines in coronary angiograms. Vessel tracing algorithms are known to be fast and efficient among several feature extraction methods. However, most of them suffer from incomplete results due to inappropriate trade-off between the completeness of seed point detection and computational efficiency. Imposing strict validation rules decreases the number of background traces, but results in more false negatives and more computation time. The researchers have shown that using the geometrical properties of gradient vectors calculated at vessel boundary points as a validation criterion, improves the performance of the seed point detection algorithm. The results illustrated that the proposed method improves upon the prior method in both performance and computation time.

**Rastegar Fatemi et al., (2010)** have proposed a method for segmentation of vessels in angiographic images is addressed. In this method for detecting the vessels in one angiographic frame, whole of angiographic frames in the sequence are utilized. For this purpose, firstly Hessian based vesselness filter is
applied to the angiographic sequence to make discrimination between the vascular structures and the background. Afterward, the angiographic frames and their filtered versions are fused using 2D discrete wavelet transform to make an image to be used for vessel segmentation. In the next step, the fused image with a couple of constant values as coefficient is applied to the vesselness filtered frame as thresholds for detecting the heart vessels. The coefficients are used for adjusting the effect of threshold. As a result, two images containing the detected vessels are obtained. Since the yielded images have some false positives and false negatives, to obtain better segmentation accuracy, morphological operations are used to recover the removed vessels. Finally the result of the approach is prepared by combining the yielded images. Experimental results demonstrate the effectiveness of the proposed method in detecting the heart vessels in X-ray angiographic images.

Rubiel Vargas and Panos Liatsis., (2010) have stated that fluorescein angiograms of the human retina are widely used in the diagnosis and treatment of several diseases such as diabetic retinopathy and age relate macular degeneration. They analyze the micro circulation of the retina and choroid. Hence, accurate extraction of the vascular tree network is of crucial importance. Previous approaches to retinal vessel extraction assume either bright vessels on a dark background or dark vessels on a lighter background. The researchers have presented a supervised method to segment retinal blood vessels from fluorescein angiograms images considering that both dark and bright vessels can be seen on an even background within the same image. The proposed approach is based on the eigenvalue decomposition of the Hessian matrix and Fisher’s linear discriminant analisys. This technique has been implemented and tested using retinal fundus images and images from a fluoresceing angiogram in order to evaluate its performance, moreover,
squared error metric, performance and true positive ratio were computed. The approach, in most of the cases, was able to differentiate between dark vessels and bright vessels' edges. But not tested for the Coronary angiogramm images.

Wennwei Kang et al., (2010) have proposed angiogram blood vessel segmentation recently based on a transition region extraction of degree. Although it is a new approach, it used 6 different Gaussian matched filters in order to enhance the coronary arteries and using the method of degree, the transition region was extracted. Finally, the vessels were segmented by histogram Thresholding of the transition region, which out performed the top-hat method. The efficiency of the system performance was analyzed by extracting the total length and comparing with the true length of the vessels. However, the researcher neither didn't carry any Coronary quantitative or statistical analysis to prove the efficiency of the system nor computed the overall execution time.

Zulong Yu et al., (2010) have used contour based segmentation which in turn uses the morphological operations. It is used to detect the edges rather than using the gradient or gray level intensity, whereby the problems due to inhomogeneity is overcome. However, the researcher have not carried out any Coronary quantitative or statistical analysis to prove the efficiency of the system. Segmentation based on Level set and Transition region including contour based don't detect the edges accurately.

Morteza Jalalat Vakilkandi et al., (2011) have proposed a new simple and fast fabrication of Direct Directional filter Bank (DDFB), also called Fast Directional Filter Bank (FDFB), without the necessity of down sampling and resampling employed in DDFB, which is time consuming, especially if the
directions are sizeable. Also, the researcher discussed on parameters of vessel filter in more detail and proposed a proper range for parameters selection to achieve accurate vessel enhancement. A major problem in automatic segmentation is the presence of background non-vessel structures and the researcher used a morphological-based algorithm to remove these, after vessel enhancement. Another problem with DDFB is the ringing artefact; smoothed FDFB unravels the later. The experimental results proved that the proposed FDFB and vessel enhancement framework work well on angiograms. However, there were no statistical anlayisis done.

**Acharjya and Ghoshal, (2012)** have proposed an easy and simple method to overcome over segmentation by using the distance transforms and image smoothing of the Morphological techniques along with watershed for segmentation. A plot with the number of pixels before and after smoothing was done to prove the performance of the system and testing was performed only on color images and not on medical images which is one of the limitations.

**Ishita Maiti et al., (2012)** have proposed a new method for brain tumor segmentation using a watershed and an edge detection algorithm in the Hue Saturation Value (HSV) color model. Initially the Red Green Blue (RGB) image is converted into HSV color image and watershed algorithm is applied to each region after contrast enhancement which is then followed by canny edge detection. Finally all the three images are combined to get the segmented image. However, the performance of the system was not evaluated using any parameter.

**Maiti and Chakraborty., (2012)** have proposed a new method for brain tumor segmentation using watershed and edge detection algorithm in HSV color
model. Initially the RGB image is converted into HSV color image and watershed algorithm is applied to each region after contrast enhancement which is then followed by canny edge detection. Finally all the three images are combined to get the segmented image. However, the performance of the system was not evaluated using any parameter.

Pinaki Pratim Acharjya et al., (2012) have proposed an easy and simple method to overcome over segmentation by using the distance transforms and image smoothing of the Morphological techniques along with watershed for segmentation. Plot with the number of pixels before and after smoothing was done to prove the performance of the system and testing was performed only on color images and not on medical images which is one of the limitations.

Yuganderet et al., (2012) have developed an improved watershed algorithm and modified level set method. The over and under segmentation problems were overcome by using dual tree complex wavelets and modified watershed based on Wasserstein distance. This method was used to extract the fingerprint from the original image and not for segmentation of the blood vessels and the performance of the system was not evaluated. Also, the system involves complex wavelets which itself is complex.

Yangfan Wang et al., (2013) have proposed vessel segmentation using multiwavelet kernels and multiscale hierarchical decomposition. The researcher has proposed that the method does not require pre-processing and training and hence can be used directly on different image sets. The blood vessels have been enhanced using matched filter with multiwavelet kernels which are used to separate the blood vessels from the clutter and bright, localized features. Noise has been removed using
Multiscale hierarchical decomposition of the normalized enhanced image. Finally binary adaptive Thresholding is applied to segment the blood vessel. The drawback is the complexity involved with multiwavelets and multiscale hierarchical decomposition and the method has been tested for retinal images and not for Coronary angiogram images.

2.4 NEURAL NETWORK AND FUZZY LOGIC BASED TECHNIQUES

Medina Rubenet et al., (1997) have described a fuzzy based segmentation algorithm for the estimation of left ventricular contours in angiographic images. The proposed approach proceeds in two stages. Firstly, a fuzzy c-mean classification algorithm is used to provide a fuzzy partition of the image. For that purpose, a membership function is computed for each pixel and allows its classification as belonging to the ventricle or to the image background. The second stage of the method is devoted to a decision process, applying a global analysis followed by a fine segmentation which is only focused on ambiguous points. First results on real images are then presented and discussed but performance analysis has not been carried.

Changjiang Yan et al., (2000) have proposed a method for segmenting the cerebrovascular region from the computed tomography angiography (CTA) images. By segmenting it, the surface shade display can be generated, which is appropriate for evaluating the morphology. The proposed method first derives a rough image by combining a raw image and the difference image. The difference image is obtained by applying a Laplacian filter. For the rough image, the venae and arteries are segmented by fuzzy inference. The method then extracts the Willis ring
contacting the blood vessels based on region growing techniques. The experimental result shows that the method can extract the blood vessels in CTA images with high accuracy but performance evaluation has not been carried.

Rice and Udupa, (2000) have proposed an extension of scale-based fuzzy connected image segmentation. In this method, a strength of fuzzy connectedness is assigned to every pair of the image elements which is in turn done by finding the strongest among all the possible connecting paths between the two elements in each pair. This method has been fully utilized in various medical applications. The effectiveness of the proposed method has been verified by testing in several medical applications and a precision and accuracy of better than 95% has been achieved. This testing has been done on applications using MR brain images but not done for coronary angiogram images.

Nyul et al., (2000) have proposed image segmentation techniques using fuzzy connectedness principles. However, one problem with these algorithms has been their excessive computational requirements. The researcher has attempted to substantially speed them up, by studying systematically a host of 18 algorithms under two categories, namely, label correcting and label setting. Extensive testing of these algorithms on a variety of 3D medical images taken from large ongoing applications has demonstrated that a 20 - 360 fold improvement over current speeds is achievable with a combination of algorithms and fast modern PCs. The reliable recognition (assisted by human operators) and the accurate, efficient, and sophisticated delineation (automatically performed by the computer) are effectively incorporated into a single interactive process. But the researcher claimed that if images having intensities with tissue specific meaning (such as CT or standardized
MR images) are utilized, then all parameters for the segmentation method can be fixed once for all, and all intermediate data can be computed before the user interaction is needed, and the user can be provided with more information at the time of interaction. However, the researcher failed to prove his claim with statistical analysis.

Kobashi et al., (2000) have proposed an application of Fuzzy Information Granulation (Fuzzy IG) to medical image segmentation. Fuzzy IG is a derivation of fuzzy granules from information. In the case of medical image segmentation, information and fuzzy granules correspond to an image taken from a medical scanner, and anatomical parts, namely Region Of Interests (ROIs), respectively. The proposed method to granulate information is composed of volume quantization and fuzzy merging. Volume quantization is a gathering of similar neighboring voxels. The generated quanta are selectively merged according to degrees for pre-defined fuzzy models that represent anatomical knowledge of medical images. The proposed method was applied to blood vessel extraction from three-dimensional Time-Of-Flight (TOF) Magnetic Resonance Angiography (MRA) images of the brain. According to the fuzzy IG concept, information correspond to the volume data, fuzzy granules corresponds to the blood vessels and fat. The qualitative evaluation by a physician was done for two- and three-dimensional images generated from the obtained blood vessels. The evaluation showed that the method can segment MRA volume data, and that fuzzy IG is applicable to, and suitable for medical image segmentation.

Deng and Heijmans., (2002) have proposed a method which combines fuzzy logic and morphology in which the basic idea is to use (fuzzy) conjunctions
and implications which are adjoint in the definition of dilations and erosions, respectively. This has given rise to a large class of morphological operators for grey-scale images. It turns out that this class includes the often used grey-scale Minkowski addition and subtraction to segment the blood vessels. The author failed to analyse the performance of the method developed statistically.

Songul Albayrak and Faith Amasyali, (2003) have examined unsupervised clustering methods to develop a medical diagnostic system and Fuzzy C-Means clustering is used to assign patients to the different clusters of thyroid diseases. The results obtained were compared with Hard K Means clustering according to the classification performance. The researcher did not carry out the statistical performance analysis.

Pal et al., (2005) have proposed a new model called Possibilistic-Fuzzy C-Means (PFCM) model. PFCM produces memberships and possibilities simultaneously, along with the usual point prototypes or cluster centers for each cluster. PFCM is a hybridization of Possibilistic C-Means (PCM) and Fuzzy C-Means (FCM) that often avoids various problems of PCM, FCM and FPCM. PFCM solves the noise sensitivity defect of FCM, overcomes the coincident clusters problem of PCM and eliminates the row sum constraints of FPCM. The researcher derived the first-order necessary conditions for extrema of the PFCM objective function, and used them as the basis for a standard alternating optimization approach to finding local minima of the PFCM objective functional. Several numerical examples are given that compare FCM and PCM to PFCM. Since PFCM prototypes are less sensitive to outliers and can avoid coincident clusters, PFCM is a strong candidate for fuzzy rule-based system identification.
Zhou et al., (2006) have presented the Multi-Feature Fuzzy Recognition (MFFR) algorithm to infer the vessel structures, in the context of X-Ray Angiograms (XRA) of the coronary artery. In the modeling, a Multi-Feature Metrics (MFM) was established firstly to describe the local configuration; then the membership degree of MFM-based fuzzy subsets was defined, and the fuzzy recognition operator was constructed. The MFFR algorithm correctly inferred four kinds of vessel structures including vascular ends, segments, bifurcations and crossovers. The results were satisfying on an average 91.1% of the testing vessel lengths in medium quality images are automatically delineated as well as their structures being correctly inferred with point-wise.

Bouchet et al., (2007) have used Fuzzy mathematical Morphology to segment the blood vessels from the angiographic image, although it simple, quick and easier to use, mathematical implementation for these techniques is complex and the researcher have not analyzed the performance of the system in terms of any statistical parameters or computational time required to segment. Few Researchers have evaluated the performance of the system based on parameters like extracted vessel length, total input image area, segmented image area, sensitivity, specificity, ROC Analysis and processing time in the literature.

Wang and Wang., (2008) have stated that image segmentation is often required as a preliminary and indispensable stage in the computer aided medical image process, particularly during the clinical analysis of magnetic resonance (MR) brain image. Fuzzy C-Means (FCM) clustering algorithm has been widely used in many medical image segmentations. However, the conventionally standard FCM algorithm is sensitive to noise because of not taking into account the spatial
information. To overcome the above problem, a modified FCM algorithm (MFCM) for MRI brain image segmentation is presented. The algorithm is realized by incorporating the spatial neighborhood information into the standard FCM algorithm and modifying the membership weighting of each cluster. The proposed algorithm is applied to both artificial synthesized image and real image. Segmentation results not only on synthesized image but also MRI brain image which degraded by Gaussian noise and salt-pepper noise demonstrates that the presented algorithm performs more robust to noise than the standard FCM algorithm. The algorithm proposed has not been tested for Coronary angiogram images.

Zhou et al., (2008) have presented a new approach to the automatic segmentation of coronary artery in X-ray angiograms using the Multi-Feature Fuzzy Recognition (MFFR) algorithm to infer the vessel structures, in the context of X-Ray Angiograms (XRA) of the coronary artery. The results were satisfying on an average 92.7% of the tested vessels were correctly segmented.

Masoomeh Ashoorirad et al., (2009) have introduced a novel Fuzzy Inference System (FIS) to enhance and detect the angiogram blood vessels using morphological operators.

Zhu et al., (2009) have introduced a recent advance of fuzzy clustering called Fuzzy C-Means Clustering with Improved Fuzzy Partitions (IFP-FCM), and a generalized algorithm called GIPF-FCM for more effective clustering. By introducing a novel membership constraint function, a new objective function is constructed, and furthermore, GIPF-FCM clustering is derived. Meanwhile, from the viewpoints of norm distance measure and competitive learning, the robustness and convergence of the proposed algorithm are analyzed. Furthermore, the classical
FCM and IFP-FCM can be taken as two special cases of the proposed algorithm. Several experimental results including its application to noisy image texture segmentation are presented to demonstrate its average advantage over FCM and IFP-FCM in both clustering and robustness capabilities. However, the researcher have carried any performance measures.

Dong Chul Park., (2010) has presented a new model called Intuitive Fuzzy C-Means (IFCM) model is proposed for the segmentation of magnetic resonance image. Fuzzy C-Means (FCM) is one of the most widely used clustering algorithms and assigns memberships to which are inversely related to the relative distance to the point prototypes that are cluster centers in the FCM model. In order to overcome the problem of outliers in data, several models including Possibilistic C-Means (PCM) and Possibilistic-Fuzzy C-Means (PFCM) models have been proposed. In IFCM, a new measurement called intuition level is introduced so that the intuition level helps to alleviate the effect of noise. Several numerical examples are first used for experiments to compare the clustering performance of IFCM with those of FCM, PCM, and PFCM. A practical magnetic resonance image data set is then used for image segmentation experiment. Results show that IFCM compares favorably to several clustering algorithms. Since IFCM produces cluster prototypes less sensitive to outliers and to the selection of involved parameters than the other algorithms, IFCM is a good candidate for data clustering and image segmentation problems.

Santhiyakumari and Madheswaran., (2010) have proposed a method to categorize the carotid artery subjects into normal and diseased subjects namely, cerebro vascular and cardiovascular diseases. For each and every preperecessed
ultrasound carotid artery image, contours are extracted using contour extraction techniques. Multilayer Back Propagation Network (MBPN) system have been developed for categorizing the carotid artery subjects. The obtained results showed that MBPN system provides higher classification efficiency, with minimum training and testing time.

Mohammed Aslam et al., (2011) have introduced a novel Fuzzy Inference System (FIS) to enhance and detect the angiogram blood vessels using morphological operators to cancel the noise present. The method involved four major steps namely, Pre-processing, Fuzzy Inference System (FIS), Thresholding and Morphological Filtering. The researchers used four linear filters for pre-processing consisting of two Sobel operators, one high pass and one Gaussian filter in order to remove noise. This is followed by the Fuzzy Inference System, with nine fuzzy rules and finally the Mamdani method was used for defuzzification, where all the inference rules were applied on each and every input image and their results were joined together using the AND function. The system output is then computed as the centroid of the resulted membership function.

Thus, the edges of the vessels are segmented using the FIS, but the output obtained contained noise. Hence, the researchers have applied the basic morphological operators such as dilation and erosion to detect the edges more appropriately and remove the noise. The algorithm proposed by the researchers proved to be more efficient than the Canny Edge detector method but failed to justify the efficiency of the system developed in terms of the performance analysis and the computational time for processing. However, the output image still seemed to contain noise and could have detected the edges much more accurately.
Tara Saikumar et al., (2012) have proposed an image segmentation method which combines the adaptive threshold algorithm with the watershed transform, Fuzzy C-means and level set method. Here watershed was used to presegment the image and fuzzy C-means were used to generate an initial contour curve and finally the boundaries of the objects were detected using the edge indicator function. The accuracy and efficiency of the system were demonstrated by the experiments but the system implemented was complex and time consuming.

Sidahmed et al., (2013) have proposed an algorithm to produce a 85.5% classification accuracy in the diagnosis of CAD, in which Genetic Algoirthm (GA) generates in each iteration a subset of attributes that will be evaluated using the Bayes Naïve (BN) based feature selection in the second step of the selection procedure. Thus, the assest of the algorithm is then compared with the Support Vector Machine (SVM), Multi-Layer Perceptron (MLP) and C4.5 decision tree algorithm. The result of classification accuracy for those algorthm are 83.5%, 83.16% and 80.85% respectively.

2.5 MODEL BASED TECHNIQUES

Model based techniques generally apply the explicit vessel models in order to extract the vasculature structures. It includes the deformable models, generalized cylinders, parametric models and template matching.

Klien and Amin., (1997) have stated that although the current edge-following schemes can be very efficient in determining coronary boundaries, they may fail when the feature to be followed is disconnected (and the scheme is unable to bridge the discontinuity) or branch points exist where the best path to follow is
indeterminate. The researchers presented new deformable spline algorithms for determining vessel boundaries, and enhancing their centerline features. A bank of even and odd S-Gabor filter pairs of different orientations are convolved with vascular images in order to create an external snake energy field. Each filter pair will give maximum response to the segment of vessel having the same orientation as the filters. The resulting responses across filters of different orientations are combined to create an external energy field for snake optimization. Vessels are represented by B-Spline snakes, and are optimized on filter outputs with dynamic programming. The points of minimal constriction and the percent-diameter stenosis are determined from a computed vessel centerline. The system has been statistically validated using fixed stenosis and flexible-tube phantoms. It has also been validated on 20 coronary lesions with two independent operators, and has been tested for interoperator and intraoperator variability and reproducibility. The system has been found to be specially robust in complex images involving vessel branchings and incomplete contrast filling.

Chan et al., (2000) have presented a novel diameter estimator which reduces both magnitude and variability of measurement error. They have used a parametric nonlinear imaging model for X-ray cine angiography and estimate unknown model parameters directly from the image data. The authors' technique allowed them to exploit additional diameter information contained within the intensity profile amplitude, a feature which is overlooked by existing methods. This method has used a two-step procedure: the first step estimates the imaging model parameters directly from the angiographic frame and the second step uses these measurements to estimate the diameter of vessels in the same image. In Monte-Carlo simulation over a range of imaging conditions, the authors' approach consistently
produced lower estimation error and variability than conventional methods. With actual X-ray images, the authors' estimator was also better than existing methods for the diameters examined (0.4–4.0 mm). These improvements were significant in the range of narrow vessel widths associated with severe coronary artery disease.

**Krissian et al., (2000)** have presented a new approach for centerline detection and reconstruction of 3D tubular structures. Several models of vessels are introduced for estimating the sensitivity of the image second-order derivatives according to elliptical cross section, to curvature of the axis, or to partial volume effects. The approach uses a multiscale analysis for extracting vessels of different sizes according to the scale. For a given model of vessel, an analytic expression of the relationship between the radius of the structure and the scale at which it is detected is derived. The algorithm gives both centerline extraction and radius estimation of the vessels allowing their reconstruction. The method has been tested on synthetic images, an image of a phantom, and real images, with encouraging results. But performance analysis is not done.

**Lorigo et al., (2001)** have stated that the direct visualization of images acquired with current imaging modalities, cannot provide a spatial representation of small vessels. This paper addresses the problem of automatic segmentation of complicated curvilinear structures in three-dimensional imagery, with the primary application of segmenting vasculature in magnetic resonance angiography (MRA) images. The method presented is based on recent curve and surface evolution work in the computer vision community which models the object boundary as a manifold that evolves iteratively to minimize an energy criterion. This energy criterion is based both on intensity values in the image and on local smoothness properties of
the object boundary, which is the vessel wall in this application. In particular, the method handles curves evolving in 3D, in contrast with previous work that has dealt with curves in 2D and surfaces in 3D. Results are presented on cerebral and aortic MRA data as well as lung computed tomography (CT) data but no statistical analysis have been done and not done for coronary angiogram images.

Čhanand Vese., (2001) have proposed a new model for active contours to detect objects in a given image, based on techniques of curve evolution, Mumford-Shah functional for segmentation and level sets. The model proposed detects objects whose boundaries are not necessarily defined by the gradient and a numerical algorithm using finite differences has been developed. Finally, various experimental results were presented and in particular some examples for which the classical snakes methods based on the gradient are not applicable. Also, the initial curve can be anywhere in the image, and interior contours are automatically detected.

Hassouna et al., (2003) have presented an automatic statistical intensity based-approach for extracting the 3D cerebrovascular system from Time-Of-Flight (TOF) magnetic resonance angiography (MRA) data. The voxels of the dataset are classified as either background tissues, which are modeled by a finite mixture of one Rayleigh and two normal distributions, or blood vessels, which are modeled by one normal distribution. The researcher has proposed models that fit the clinical data properly and result in fewer misclassified vessel voxels and estimated the parameters of each distribution using the Expectation Maximization (EM) algorithm. Since the convergence of the EM is sensitive to the initial estimate of the parameters, a novel method for parameter initialization, based on histogram analysis, was provided.
A new geometrical phantom motivated by a statistical analysis was designed to validate the accuracy of the method. The algorithm was also tested on 20 in-vivo datasets. The results showed that the proposed approach provides accurate segmentation, especially those blood vessels of small sizes but there are no significant proof of how accurate was the results.

Nain et al., (2004) have presented a segmentation method for vessels using an implicit deformable model with a soft shape prior. Blood vessels are challenging structures to segment due to their branching and thinning geometry as well as the decrease in image contrast from the root of the vessel to its thin branches. Using image intensity alone to deform a model for the task of segmentation often results in leakages at areas where the image information is ambiguous. In order to address this problem, the researcher combined image statistics and shape information to derive a region-based active contour that segments tubular structures and penalizes leakages. Results were present on synthetic and real 2D and 3D datasets.

Yan and Kassim., (2005) have developed a specific segmentation scheme for accurate extraction of vasculature from MRA images. The proposed algorithm, called the Capillary Active Contour (CAC), models capillary action where liquid can climb along the boundaries of thin tubes. The CAC, which is implemented based on level sets, is able to segment thin vessels and has been applied for verification on synthetic volumetric images and real 3D MRA images. Although the researcher claims that the segmented blood vessels are accurate but there are no statistical analysis done.
Wong and Chung., (2005) have stated that, in the segmentation of flat shaded, nontextured objects in real-world images, objects are usually assumed to be piecewise homogeneous. This assumption, however, is not always valid with images such as medical images. As a result, any technique based on this assumption may produce less-than-satisfactory image segmentation. By assuming that the intensity nonuniformity is smooth in the imaged objects, a novel algorithm that exploits the coherence in the intensity profile to segment objects was proposed. The algorithm uses a novel smoothness prior to improve the quality of image segmentation. The formulation of the prior is based on the coherence of the local structural orientation in the image. The segmentation process was performed in a Bayesian framework. Local structural orientation estimation was obtained with an orientation tensor. Comparisons between the conventional Hessian matrix and the orientation tensor have been conducted. The experimental results on the synthetic images and the real-world images have indicated that their novel segmentation algorithm produces better segmentations than both the global thresholding with the maximum likelihood estimation and the algorithm with the multilevel logistic model.

Lo Kwee-Seong and Albert Chung., (2006) have presented that local phase coherence, local iso-intensity structural orientation and weighted local variances are extracted as features to identify and quantify vascular abnormalities such as stenotic, atherosclerotic, fusiform and saccular form the segmented vasculatures. Segmentation methods such as binary segmentation using the Bayesian framework and using Active Contour Model has been implemented. There are no statistical analysis performed and could have been implemented using direct segmentation methods.
Sarry and Boire, (2006) have proposed a new method for coronary artery tracking in biplane digital subtraction. The dynamic tracking of nonrigid objects from two views has been achieved using a generalization of parametrically deformable models. Three-dimensional (3-D) Fourier descriptors used for shape representation are obtained from the two-dimensional (2-D) descriptors of the projections. A new constraint inferred from epipolar geometry is applied to the contour model. Direct 3-D tracking is compared with the classical approach in two steps: independent 2-D tracking in each of the two projection planes; 3-D reconstruction using the epipolar constraint. Convergence quality and accuracy of the 3-D reconstruction are analyzed for several sequences showing different displacement amplitudes, deformation rates and image contrasts.

Pascal Fallavollita and Farida Cheriet, (2006) have introduced the four step filter to enhance the vessel contours in the angiogram images, but however during segmentation, some of the smaller arteries were lost or were unseen, and suffered from more filter parameters.

Law and Chung, (2006) have stated that performing segmentation of vasculature with blurry and low contrast boundaries in noisy images are really challenging jobs, hence have presented a novel approach to segment blood vessels using weighted local variances and an active contour model. In this method, the vessel boundary orientation is estimated locally based on the orientation that minimizes the weighted local variance. Such estimation was less sensitive to noise compared with other common approaches. The edge clearness was measured by the ratio of weighted local variances obtained along different orientations. It is independent of the edge intensity contrast and capable of locating weak boundaries.
Integrating the orientation and clearness of edges, an active contour model is employed to align contours that match the contour tangent direction and edge orientation. The proposed method was validated by two synthetic images and two real cases. It was experimentally shown that the proposed method was suitable for dealing with noisy images which consist of structures having blurry and low contrast boundaries, such as blood vessels.

Jean Stawiaski et al., (2008) have used the application of minimal surfaces and Markov random fields as models and applied to the region adjacency graph of the watershed transform to segment the liver tumors. The researcher attempted to segment the relevant tumors from the liver image. Although the researcher does not segment the blood vessels of the angiogram image, but it is understood that unsupervised watershed transform along with Markov model is applied.

Lizhe Xie et al., (2010) have proposed a Maximum a Posteriori (MAP) method which combined Markov Random Field (MRF) and the feature of vessel-like feature of the angiograms. As considering the advantages from both, the proposed method is sensitive to the vessel-like structures in the angiograms and robust to noise. Hence, it is able to extract the details of the vessels while at the same time reducing the noises. The proposed method is applied to clinic angiograms, the experiment results of the experiment on real angiograms concluded that this segmentation method is suitable for the segmentation of coronary angiography and is available for further accurate analyze to coronary angiography.

Weili et al., (2010) have proposed a new robust corner detection method for detecting and localizing corners of planar curves. First, edges are extracted using
a canny detector. Then, a local inedetector is developed, and edge-pixels are labeled on the basis of the information provided by the localline detector. After edge labeling, the approximate location of the corners are determined. Finally, the minimum moments of the phase congruency information was used at a local window to determine the accurate location of corners. The advantage of the proposed method was that it does not involve calculation of the curvature and the threshold value. Experimental results demonstrated that it is particularly effective for natural images, and possesses a high detection rate than the present methods.

Kaiqiong Sun et al., (2012) have used shape or contour model to detect the blood vessels considering the intensity gradient and later considered the orientation of the tubular structures of the blood vessel using the CUREV algorithm, along with the use of capillary force and flux in a multi-scale fashion, for detecting the blood vessels in a low-contrast and thin vascular region.

2.6 SUMMARY

Segmenting the blood vessels from the medical images is very important in the present scenario of imaging systems. Extracting the blood vessels from the angiography images is again challenging to the researchers in terms of accuracy which may be due to weak contrast and noise during imaging. However, there is always a need for the performance improvement and gap for enhancement.

- It is summarized that the edges of the vessels segmented still contains noise.

- Although researchers developed various algorithms and claimed to be efficient but failed to justify the efficiency of the system
developed in terms of the performance analysis in terms of sensitivity and specificity and the computational time for processing.

- Thus, the output image still seemed to contain noise and could have detected the edges much more accurately.

- Hence, the researcher are yet to combine the different image features to develop a unified image segmentation framework.