Research Journal of Applied Sciences, Engineering and Technology 4(17): 2948-2962, 2012
ISSN: 2040-7467

Submitted: December 23, 2011 Accepted: January 31, 2012 Published: September 01, 2012

Morphological Techniques for Medical Images: A Review

Isma Irum, Mudassar Raza, Muhammad Sharif
Comsats Institute of Information Technology Wah Cantt

Abstract: Image processing is playing a very important role in medical imaging with its versatile applications and features towards the development of computer aided diagnostic systems, automatic detections of abnormalities and enhancement in ultrasonic, computed tomography, magnetic resonance images and lots more applications. Medical images morphology is a field of study where the medical images are observed and processed on basis of geometrical and changing structures. Medical images morphological techniques has been reviewed in this study underlying the some human organ images, the associated diseases and processing techniques to address some anatomical problem detection. Images of Human brain, bone, heart, carotid, iris, lesion, liver and lung have been discussed in this study.

Keywords: Automated clinical methods, CAD systems, disease detection, medical imaging, morphological operations, segmentation

INTRODUCTION

Medical science has achieved great advancement; instrumental technology is very advanced today for measuring and monitoring human health parameters. Ultrasounds, Computed Tomography (CT), X-ray, Magnetic Resonance (MR) are some of common clinical instruments. The medical individuals heavily rely upon the results of images obtained from these sources along their experience in making decisions regarding diagnosis, disease monitoring, prescription, surgery planning etc, but despite of all the advanced techniques there is still a requirement for enhancement of the poor quality images, minor areas identification, computer aid and automatic detection to avoid artifacts and time consuming manual methods. To fulfill this requirement medical images morphology is one of among various image processing techniques to introduce solutions to raising clinical environment problems. A review of various medical image morphology techniques in different domains is presented in this study. Domain division is as given in Fig. 1.

BRAIN IMAGES MORPHOLOGY

Brain images are studied under three domains of Structure-Function, Structure and Function domains (Fig. 2).

Structure-function based brain image morphology: Voxel based morphology and surface based morphology are two methods which are available for analysis procedure of brain morphology, are used to detect the relationship of structure of brain and the points of interest like diagnosis, age, genotype, IQ and severity of disease. Basically there are two statistical procedures involved for the morphometric measures, invoking a statistical model and correction of the conducted multiple tests. New statistical methods are introduced for the above two procedures. For invoking procedure, a statistical model heteroscedastic linear model presented to test the relationships of morphological measurements of each voxel on sub region's surface and points of interest, and testing procedure is resampling based method namely wild bootstrapping (Hongtu *et al*., 2007). Most methods for structure function analysis are statistical based; major disadvantage of those methods is they are unable to locate the regions showing nonlinear relationship with clinical variables. For the analysis of MR brain images a Bayesian method is introduced on the basis of Bayesian network to cope with nonlinear associations (Edward *et al*., 2004).

Structure based brain image morphology: A new form of process in which organs produce minerals called biomineralization in pineal gland is studied. This process generates the crystals of size less than 20 micro m, which are studies through various techniques to study the role of amino acids and heteropolysacchrides in formation of micro crystals and their structural texture (Baconnier and Lang, 2004). A study of influence of genetic and environmental factors upon human brain morphology via structural MRI has been started. These studies are limited to accessing inheritance capability for a single and full anatomical structure. To overcome this limitation a method is developed using nonlinear registration of high dimensional 3D, for the application of field vector of deformation in outer layer of parameter space and accessing the regional density of cortical gray matter on

Corresponding Author: Isma Irum, Comsats Institute of Information Technology Wah Cantt

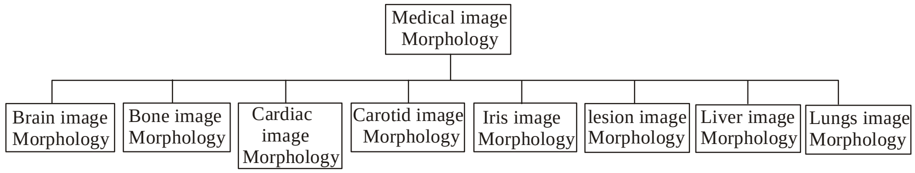

Fig. 1: Types of medical image morphology

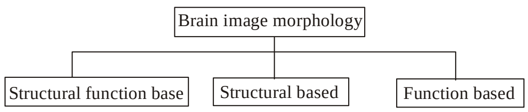

Fig. 2: Types of brain image morphology

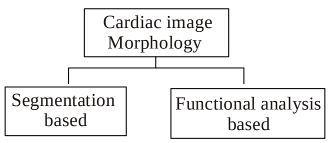

Fig. 3: Types of cardiac image morphology

all outer surface of same genetically and different genetically twins. This method describes that motor cortices and primary sensory parts of brain may have more inheritance capability (Theo *et al*., 2004). The efficient detection of brain tumor is presented in this technique with the help of three step function of enhancement, classification and segmentation (Ahmed *et al*., 2009). Skull stripping is subject to the removal of non cerebral part from the skull during MRI brain imaging applications. The main issue is to segment the non cerebral part and intracranial tissues because of their same intensities. A method is introduced using mathematical morphology based segmentation by using ostu's and double thresholding (Rosniza *et al*., 2010). Monitoring of brain diseases coming into being due to occurrence of structure change for example stroke requires a unique accuracy for expressing the quantity of change at each pixel of computed tomography image display. This study presents a technique that provides a mechanism for quantification of macroscopic anatomical changes (Schormann and Kraemer, 2003). To measure the decrease or loss in size of an organ a method is presented. The method produces the realistic images of tissue loss and provides an exact correspondence between the before and after evaluation of decreases or loss in images (Karaçali and Davatzikos, 2008). The investigation of the preference of use of one organ on another is made using fractal dimension of skeletonized cerebral surface to show that fractal dimension is unprecedented measure of cerebral lack of balances (Jong-Min *et al*., 2004). Statistical analysis of brain surface that uses a method to represent the shape of region of brain with reference to another image of that region using Gaussian random field defined over the whole region surface (Ravi *et al*., 2007). The disease of brain in which periodic loss of consciousness occurs is presurgical investigated through stereo EEG for recording the electric activity of brain by using electrodes. An extended source model is developed for interpretation of stereo EEG signals (Delphine *et al*., 2007). This study presents the segmentation technique of multiple objects preserving the relationships of objects defined by a template. Segmentation of main brain structures using the technique provides the cortical surface with spherical topology (Bazin and Pham, 2007).

Function based brain image morphology: ICA is a technique used to extract components which are statistically independent from a measured signal's set. This technique has various applications of signal analysis in biomedical sciences but the especial is the electromagnetic brain signals. The cause of restrictive standard implementation of independent component analysis is square mixing assumption. The process of signal recording uses the large number of channels and huge number of resulting extracted material that make the analysis procedure lengthy and fatigueous. In the neurophysiological analysis of signals there are many instances which have strong prior information about the signal to be analyzed. The independent component analysis extracts the signal items which are statistically independent other than those which are restricted to have similarity to a signal used as reference that can adjust with such prior information. Temporal constrained independent component analysis is useful to extract errors introduced by humans or signal collecting environments, from multichannel EEG and MEG channels (James and Gibson, 2003). Measuring Intra Cranial Pressure (ICP) is a significant tool in clinical diagnosis of neurosurgical diseases such as accidental head injury. At present only the mean information of ICP is used and continuous information is ignored that is useful for predicting the intracranial changes. This algorithm provides an automated process of observing pulse signals of ICP, and on the basis of this it recognizes the nonartifactual pulses, enhances the signal quality and optimally designs the three subcomponents of the pulse. The experiment is performed on seven hundred hours recording of sixty six intracranial neurosurgical patients (Xiao *et al*., 2009). The reliable template computation of even related potentials

Table 1: Brain image morphology techniques

Reference	Domain	Problem	Methods	Clinical implications
(Hongtu *et al*., 2007)	Structure-function.	Statistical analysis of brain morphology.	Development of heteroscedastic linear model, test procedure called boot strapping based on resampling.	Detection of differences statistically important in morphology of hippocampus over time.
(Edward *et al*., 2004)	Structure-function.	Analysis of MR brain images.	Determine associations among voxel and clinical variables, structure-function of MR images and clinical variables	Identification of voxel wise morphological changes in the case where associations are non linear.
(Baconnier and Lang, 2004)	Structure	Classification of microcrystal in pineal gland of human brain.	Scanning of electron microscopy, spectroscopy by energy dispersion, electron diffraction of selected area,raman spectroscopy using NIR.	Identification of possible exture tof microcrystal and their signific ance.
(Theo *et al*., 2004)	Structure structures.	Studying brain morphology beyond the boundaries of heritability and gross anatomical	High dimensional 3D nonlinear registration, fitting structural equation models.	Heritabilities in primary senor and motor outer layer of gray matter that covers the cerebral hemisphere surface.
(Ahmed *et al*., 2009)	Structure	Detection of tumor in brain MRI images.	Mathematical morphology, wavelet transform, k-means.	To decide the degree of severity of tumor.
(Rosniza *et al*., 2010)	Structure	Separation of cerebral and non cerebral tissues in MRI brain imaging applications.	Mathematical morphology segmentation using double and ostu's thresholding.	To perform skull stripping in an robust and efficient way.
(Schormann and Kraemer, 2003)	Structure	Monitoring the brain diseases occurring as result of morphological change.	Coarse linear alignment, cross correlation, high dimensional multiresolution multigrid, determine volume changes.	Visualizes the blood supply decrease and effect to an organ due to stroke.
(Karaçali and Davatzikos, 2003)	Structure	Measuring the effect decrease in size and other volumetric change on medical images of brain.	Dense warping deformation, energy minimization strategy.	Provides realistic images for tissue loss.
(Jong-Min *et al*., 2004)	Structure	Investigating the cerebral lack of balances.	Skeltonization, fuzzy clustering, calculation of fractal dimension.	Provides fractal dimension as novel measure for cerebral asymmetry.
(Ravi *et al*., 2007)	Structure	Observing the changes in shape of brain due to regeneration and effects of illness.	Reference region, Gaussian random field, Euclidian distance, fluid dynamics.	Application study of healthy and hyperactivity subjects.
(Delphine *et al*., 2007)	Structure	Developing extended source model for depth EEG signals.	Distributed current dipole model, coupled neuronal model.	Links the characteristics of cortical neurons and depth EEG signal.
(Bazin and Pham, 2007)	Structure	Multiple object segmentation preserving the topological properties.	Tissue classification, fast marching, image registration	Provides cortical surfaces with spherical surface during main cerebral structure segmentation..
(James and Gibson, 2003)	Function	Extraction of statistically independent signals from set of measured signals.	Reference signal with some prior information.	Automated extraction of human introduced prediction of disease like errors in EEG and MEG signals.
(Xiao *et al*., 2009)	Function	Automated analysis of continuous ICP signals.	Enhancement of ICP signal, recognizing error free ICP pulses, establishing three sub peaks of ,CP pulse.	Extraction of useful information from ICP pulse morphology from clinical environment.
(Silvia *et al*., 2003)	Function	Computing reliable templates for event related potentials	Dynamic time warping.	Reproducible analysis criteria for ERPs.
(Graben and Frisch, 2004)	Function	To answer the difference of and control condition in ERPs. experimental	Nonlinear data analysis, generalized polarity histogram, the word statistics of symbolic dynamics.	Establishes ERP components on methodological grounds purely.
(Dean *et al*., 2007)	Function	To learn the brain disabilities individuals to control cursor while using the brain computer interface.	Parameterized model, matching filter	-
(Patrick *et al*., 2008)	Function	Noise reduction from signals with repeated patterns and trials.	Wavelet denoising or PCA	Recovery of single event feature in moving low SNR multievent context.

Table 1: Continue

(Patrick *et al*., 2008)	Function	Analysis of brain evoked potentials and fields.	Matching pursuit algorithm, Gabor functions.	Relationship of waveforms with physiologically distinct components.
(Xiao *et al*., 2010)	Function	The importance of ICP in neurosurgical care.	Hypotheses, Testing, morphologicalclustering	Proactive ICP management via accurate forecasts. ICP. analysis

(ERPs) for same groups of subjects and to calculate the quantity of morphological characteristics of ERPs. It suggests that dyslexia involves complex cerebral functions other than the language system (Silvia *et al*., 2003). Distinguishing the conditions be either experimental or control is done on the basis of theoretical grounds in ERPs. If theoretical knowledge does not provide enough and clear informative material for its decision, then the description of ERP is not easy particularly if one considers the both positivity and negativity on basis of pattern morphology and peak latency. Brain computer interface provides non muscular communication to the individuals with severe brain disabilities, to train the individuals for modulation of the specific EEG parts over the sensory motor of cortex and using them for controlling a cursor on computer screen. The method suggests that there is relationship exists between alpha and beta bands and a matched filter can improve performance (Dean *et al*., 2007). To reduce the noise from the signals having repeated patterns or multiple trials an algorithm is presented specifically applications of ERPs (Patrick *et al*., 2008). A new way of analysis of electromagnetic potentials evoked by brain and fields are presented here. Matching pursuit algorithm with multivariate version can perform an iterative and exhaustive search for signal which is fit optimally to those structures of signal which are persistent with respect to phase, frequency, time width and same time of occurrence trials (Patrick *et al*., 2008). For deriving the 24 metrics morphological analysis and clustering of ICP algorithm are used for the characterization of changes in pulses of ICP and testing the hypothetical statement that pre ICP segments can be separated by these metrics defined morphologically over control segments which do not have any association with the elevation of ICP signals or one hour prior to ICP elevation (Xiao *et al*., 2010) (Table. 1).

Bone images morphology: For diagnosis of bone diseases the fractal measurements of x-ray images of bone has achieved great interest. A fractal analysis technique is introduced that is bone X-Ray Tomographic Microscopy (XTM) projections. The purpose of this study is to test the correlation between the changing connecting tissues and two dimensional fractal descriptors (Rachid *et al*., 2001). Bone age description changes from human to human descriptions; therefore an automated method is developed to decide the bone age or skeletal maturity. Bone expert selects images of hand from radio graphs, examines the borders of 15 bones automatically, and describes intrinsic properties of 13 bones. Finally shows the intrinsic bone ages to gruelich pyle and tanner white house bone ages (Hans *et al*., 2009). Magnesium alloys contain the same mechanical properties with bone but they lose their effect within certain span of time. Their ability to be resolved limits their applications; if this resolving rate is decreased they can enjoy wide application in medical field. This technique emphasis to make the calcium coating on magnesium alloys for controlling the losing effect rate (Yang *et al*., 2009). A liquid solution of hydroxyapatite (HA) prepared by very little (nano sized) particles of HA is combined with bone protein gel to control the cell-mediated protein insufficiencies. Combination of HA and protein gels can prevent cell mediated protein gels insufficiencies. The result of HA depends on the ratio of HA to protein gel (Liu and Williams, 2010). MRI is a big source for measuring the loss of connecting bone joints tissues in degenerative joint diseases, but methods used currently are not sufficient for deciding the clinical therapy trials. This method presents statistical models of bone shapes to define different characteristics of bones like dense, anatomical correspondence etc to support the study of connecting tissue in MR of knee. The method gives the advantages of selecting region of interest and propagation through individual to individual; it would be done manually otherwise (Tomos *et al*., 2010). The bone diseases spread occurs when the cancer cells of original tumor takes a place on bones. An automatic computer aided detection method of disease spread cells in thoracolumbar spine is presented in this study. The system involves the detections classification and spinal column segmentation (Jianhua *et al*., 2007). A new technique of 3D segmentation of volumetric skeletal data of CT is presented on the basis of region growing and adaptive thresholds (Yan *et al*., 2003). For solving the registration problem due to the limitation of field view of image devices, a sequence of segmented structures of same shape is rendered; this is called iso-shaping (Punam *et al*., 2004). Voxel structure that represents the correct surface geometrically and topologically and algorithms to find intersection from this structure is discovered as bone and joint surgeries are widely used and various volume manipulation algorithms are presented for virtual bone, bone grafts for surgery simulations (Tsai and Hsieh, 2005). Counting bone marrow's cells of white blood gives tremendous info to surgeons for diagnosis. The very technique investigates whether the nucleus alone provide enough information or not Nipon and Dhompongsa (2007). The relationship of bone morphology and bone intensities can reduce the surface count in generated models (Serge *et al*., 2000)(Table. 2).

Table 2: Bone image morphology techniques

Reference	Problem	Methods	Clinical implications	Accuracy
(Rachid *et al*., 2001)	To find the bone structure.	Mathematical morphology, 2D projections, fractional Brownian motion model.	Useful indicator in early predication of disease like Osteoporosis.	-
(Hans *et al*., 2009)	Assessment of skeletal maturity or bone age.	Computation of intrinsic bone age, transformation to greulich Pyle and tanner white house bone ages.	Replaces an expert to verify the result	.68 %
(Yang *et al*., 2009)	Use of calcium phosphate to avoid degradation of magnesium alloys in bones.	Analysis based procedures to investigate morphology of bones.	Provides bone screws in bone repair	-
(Liu and Williams, 2010)	To cope with cell mediated protein insufficiencies in bones.	-	Helps to control bones weakness	.-
(Tomos *et al*., 2010)	Analysis of knee cartilage.	Statistical shape models, 3D normals.	Osteoarthritis analysis and monitoring.	-
(Jianhua *et al*., 2007)	Developing computerized system for detection of lytic bone metastases.	Hybrid thresholding, mathematical morphology, direct graph search, four part vertebral algorithm, watershed algorithm.	Reporting the location of lesion, identifying organs in chest and abdominal region.	-
(Yan *et al*., 2003)	Bone segmentation in volumetric CT datasets.	3D region growing, local adaptive thresholds.	Applications in CT images of thigh bone, knee and skull	-
(Punam *et al*., 2004)	To guarantee the consistent physical structure extent during different scans.	Iso-shaping	Improvement of diagnosis and treatment of joint diseases.	-
(Tsai and Hsieh, 2005)	Representation of correct surfaces topologically and geometrically.	Voxel structure, intersection computation algorithms.	Real time cutting simulations	-
(Nipon and Dhompongsa, 2007)	Development of automatic system for white blood cell counting.	Segmentation, mathematical morphology,fivefold cross validation baye's classifiers, artificial neural network .	Provides invaluable information to ,doctors for diagnosis purposes	77 %
(Serge *et al*., 2000)	Reducing the polygon counts in surface models.	Polygonal mesh model, segmentation.	3D animation models for educational purposes.	-

Cardiac images morphology: Cardiac images morphology methods are divided into two domains segmentation based and functional analysis based as given in Fig. 3. There is a huge amount of images included in dynamic short axes MR examination, normally two to three hundred images, therefore segmenting these structures robustly and automatically is essential for analyzing cardiac MRI images quantitatively. Automatic approach for left and right ventricles segmentation is presented (Steven *et al*., 2001). The segmentation of right and left ventricles of normal and tetralogy of fallot hearts is done by Active Shape Model (ASM) and Active Appearance Model (AAM) on 4D MR images (Zhang *et al*., 2010). A 3D method for coronary arteries tracking in images of biplane X-ray angiography temporary sequences is discussed based on reconstruction of 3D centerline model of biplane image pair at one time frame and its motion tracking on coarse-to-fine hierarchy of motion models (Guy *et al*., 2003). Cine MR Image acquisition is made on three orthogonal view of the heart; an active contour model is proposed to propagate in cine MR images automatically (Gilion *et al*., 2006). The information taken from MRI is important to for development of advanced clinical applications and guidance and planning the cardiac interfered changing procedures. To get rid of inter and intra observer variations of manual descriptions it is very demanding to design an automated method for the segmentation method of whole heart for MRI images. A fully automated method for whole heart segmentation and two new algorithms for registration are presented in this study (Xiahai *et al*., 2010). To visualize local radial strain of arteries intravascular ultrasound elastography is used in so called elastograms for the detection of rupture prone plaques. However, these elastograms can not be described directly as material and morphology compositing image due to arterial stress distribution. To address this problem, a method is suggested to reconstruct young's modulus image from an available elastograms. Specifically, this procedure is suitable for a plaque with media region having lipid pool and cap covered. Minimization algorithm is used for reconstruction; the geometry parameters reconstruct the lipid pool, cap and plaque media regions with a circle (Radj *et al*., 2005). Noise heavily affects the ECG signal during recording; ECG signals are heterogeneous having variations of amplitude of beats. For automatic heartbeat detection a wavelet based detection technique is used to detect the precise ECG points and a local beat classifier is used to profile each patient's cardiac behavior (Miad *et al*., 2010). Ultrasonic strain and strain rate has been presented to assess regional myocardial function quantitatively (Jan *et al*., 2002). For identification of changes of heartbeat and detection of R-wave events an orthogonal approach is

Table 3 :Comparison between segmentation based morphology of cardiac images

Reference	Sample space	Test space	Mean error	Accuracy	Regression coefficient (P)	Correlation coefficient (R)
(Steven *et al*., 2001)	102	60	0.3 mm	-	<0.001	0.96,0.96,0.90
(Zhang *et al*., 2010)	50	50	<0.3 (normal), <0.5 (TOF)	90-100%	0.27-0.97 (normal) <0.05-0.89 (TOF)	0.96-0.98 (normal), 0.92-0.99 (TOF)
(Guy *et al*., 2003)	58	58	0.69 mm	93%	3	-
(Gilion *et al*., 2006)	107	69	5.6±6.7	24.3%	<0.005	-
(Xiahai *et al*., 2010)	37	37	4.31 mm	95%	0.068,0.057,0.95	0.93,0.94,0.98

Table 4: Cardiac image morphology techniques

Reference	Core problem	Methods	Clinical implications
(Steven *et al*., 2001)	Automatic segmentation of left and right ventricles.	Active shape models, active appearance models.	Fully automatic quantitative analysis of left and right ventricles.
(Zhang *et al*., 2010)	Segmentation of normal and tetralogy of fallot hearts.	Active shape models, active appearance models.	Can be used as disease progression indicator.
(Guy *et al*., 2003)	Tracking the cardiac arteries in clinical angiograms.	3D centerline model, coarse-to-fine hierarchical motion models.	Diagnosis of myocardial infarcts and diffuse coronary artery disease.
(Gilion *et al*., 2006)	Automatic contour propagation in cine cardiac MR images.	Active contour model, matching gray values.	Determination of stroke volume and ejection fraction.
(Xiahai *et al*., 2010)	Whole heart segmentation of cardiac MR images automatically.	The locally affine Registration method (ALRM), The free-form deformation with adaptive control point status (ACPS FFDs)	Computing stroke volume, ejection fraction, myocardium mass.
(Radj *et al*., 2005)	Assessment of vulnerable plaque composition in arteries.	Reconstruction of young's modulus image, minimization algorithm, parametric finite element model (PFEM), testing.	Tissue characterization, monitoring atherosclerosis, investigation and explanation of strain artifacts in elastograms, quantifying the amount of stiffening of arterial plaque.
(Miad *et al*., 2010)	Automation in signal processing, ECG and heart beat classification.	Wavelet based beat detection, local ECG beat classifier.	Diagnoses purposes for example arrhythmia.
(Jan *et al*., 2002)	Assessment of regional myocardial function.	Ultrasonic strain, strain rate, images.	To study the acute blockage of blood in coronary arteries.
(Kleydis *et al*., 2007)	Identification of heartbeat changes and detection of R-wave events.	Geometric matching, polynomial expansion model, algebraic fitting distance,genetic algorithm.	Identification of heart behavior and diagnosis of various cardiac diseases.

described in ECG frame work. The approach is based on evaluation by decision function of geometrical matching in procedure of movement of local window (Kleydis *et al*., 2007)(Table. 3 and 4).

Carotid images morphology: The aerial morphology, lumen diameter (LD), Intima Media Thickness (IMT) and the existence of plaque can be guaranteed discovered by B type ultra sound. For the measurement of any of carotid parameters it is essential to find the lumen intima and media adventitia. An automatic technique of measuring the LD and IMT is presented based on the active contour technique and improved by analysis of multiresolution (Gutierrez *et al*., 2009). The major cause of ischemic stroke is atherosclerosis at carotid bifurcation resulting in the cerebral emboli. The strokes due to carotid atherosclerosis can be prevented if detected early in checking the carotid plaque changes by changing lifestyle, eating habits and medicine treatments. For this purpose it is necessary to take images of three dimensional ultra sounds for the monitoring of changing plaque conditions at different time intervals. This method of registration must not be rigid as different head places create torsion and bending in the neck during acquisition process. The given model is none rigidly monitors the neck movements and calculates the mean error of registration between the target image and segmented vessel surface image (Seabra *et al*., 2009; Nuwan *et al*., 2008). The high resolution images of carotid plaque have shown their predictive implementations. The purpose of this study is to build computerized system to provide ease of classification of characteristics of carotid plaques to identify the persons with no symptom of disease of carotid contraction but at risk of stroke (Christodoulou *et al*., 2003). Segmentation of inner space of carotid is an important step towards the evaluation of disease severity. This approach uses only single seed point for initializing the deformable carotid cross sections (Mao *et al*., 2000). The 3D vessel boundaries can be extracted by using edge preserving and direction sensitive filter on B-mode ultrasound images. These obtained boundaries are more distinct than the conventional gradient calculation methods (Dionisiol *et al*., 2004). A Bayesian algorithm that determines the estimate of the size of the plaque inside the carotid

Table 5: Comparison between segmentation of carotid images morphology techniques

Reference	Population	Comparison entities	Mean	Standard deviation	Confidence interval	Regression coefficient (P)
(Gutierrez *et al*., 2009)	30	Automatic & manual methods	7.85,6.81,0.72 & 7.78,6.77,0.63	1.01,1.06,0.14 & 1.01,1.05,0.12	-	0.99,0.99,0.90
(Seabra *et al*., 2009)	60	3D method	32.19	90.77	-	-
(Nuwan *et al*., 2008)	26093	Rigid & non rigid registration errors	1.06 & 0.79	0.60 & 0.51 0.78-0.80	1.05-1.07 &	<0.05
(Christodoulou *et al*., 2003)	230	SOM classifier & KNN classifier	68.8 & 6.97	2.2 & 2.3	-	-
(Mao *et al*., 2000)	7	Computerized human contour & circle matching initialization	2.979 & 6.2	3.794 & 5.339	-	0.0228
(Dionisiol *et al*., 2004)	-	Intra & inter observer	-0.006,0.007 ,-0.013 &0.095, 0.025,0.070	-	0.0274,0.234, 0.043 & 0.368, 0.288,0.08	00.003 & 0.002
(Seabra *et al*., 2007)	50	2D medical & 3D estimated	44.29 & 49.31	27.83 & 25.78	-	-
(Danijela *et al*., 2009)	40	Vessel segmentation & plaque segmentation	86,85,89 & 73,68,74	2,3,1 & 8,7,7	-	0.92 & 0.86

Table 6: Carotid images morphology techniques

Reference	Core problem	Methods	Clinical implications
(Gutierrez *et al*., 2009)	Measurement of arterial changes parameters like lumen diameter, intima media thickness of far wall.	Artery boundary enhancement, contour modeling, dynamic force formulation.	Determination of plaque presence in arteries.
(Seabra *et al*., 2009)	Development of 3D free hand ultrasound.	3D reconstruction, labeling procedure, graph cuts	Achievement of clinically significant parameters
(Nuwan *et al*., 2008)	Modeling of neck movements for non rigid registration.	Rigid & Non rigid registration, twisting & bending models.	Reduction of non linear changes in images taken in different time by 3D carotid ultrasound.
(Christodoulou *et al*., 2003)	Carotid plaques characterization.	Preprocessing, feature extraction, plaque classification.	Hybrid diagnostic system can combine risk factors, stroke related laboratory & clinical data.
(Mao *et al*., 2000)	Segmentation of lumen cross sections of carotid artery.	Segmentation, initialization.	Management & assessment of stroke risk.
(Dionisiol *et al*., 2004)	Getting the vessels boundaries of 3D edge fields.	Vessel morphology estimation, vessel strain and motion estimation.	Discovering the potential of 3D carotid ultrasound imaging.
(Seabra *et al*., 2007)	Volume reconstruction and characterization of carotid plaques.	Filling of non observed region, noise removal, filtering, data interpolation.	Determination of level of plaque volume & stenosis.
(Danijela *et al*., 2009)	Segmentation of plaque through a semi-automatic, slice based method and carotid arteries quantification in CTA.	Segmentation, classification.	Assessment of risk of stroke.
(Ali and El-Sakka, 2004)	Segmentation of carotid artery in B-mode ultrasound images.	Histogram equalization, edge detection, boundary extraction, image composition.	Replacement of time consuming manual segmentation methods of practitioner.
(Abdel-Dayem and El-Sakka, 2004)	Contour extraction of carotid artery.	Preprocessing, quantization, contour extraction, contour enhancement.	Detection and monitoring of plaque precipitation on carotid artery walls.
(Abdel-Dayem *et al*., 2005)	Segmentation of carotid ultrasound images.	Preprocessing, watershed segmentation, region merging, boundary extraction.	Computer aided diagnostic tool for detection of carotid plaques.

through the filter and distortion of data for the purpose of removing speckle noise and filling of areas unobserved, respectively. It uses more of this quantity for analyzing the echo morphology of the plaque (Seabra *et al*., 2007). Novel, slice-based, semi-automatic method for segmenting and quantifying plaque in the carotid artery CTA is introduced. Method begins with semi-automatic; level set through the lumen segmentation is initialized with three points (Danijela *et al*., 2009). A segmentation technique is presented in this study to be applied on noisy B mode ultra sound images. The aim is to reduce noise and human introduced errors (Ali and El-Sakka, 2004). Noninvasive imaging of Carotid coated with the layer of cholesterol provides the opportunities to develop the analysis methods for plaque having a high rate of risk stroke. Many methods of analyzing plaque images that have been introduced in past years are discussed here Efthyvoulos *et al*. (2010). Ultrasound images are used to detect the existence of carotid artery plaques but due to poor quality of ultrasound images it takes a lot of effort of radiologist to extract the contours and manually detection methods are not reproducible therefore an automatic contour extraction scheme is proposed (Abdel-Dayem and El-Sakka, 2004; Abdel-Dayem *et al*., 2005). Table. 5

compares segmentation of carotid images with statistical measures and Table 6 gives a general comparison of carotid images morphological techniques.

Iris images morphology: Displaying the organic material on video devices is challenging task. Human eye has a significant place in communication of gestures and expression; needs special modeling and displaying techniques. A method based on images for estimation of both iris morphology and dispersed properties for generating visually appealing images of virtual eyes is discussed here Guillaume *et al.* (2009). Redeye is a problem appearing in photographs when we take photographs in flash light. When the light passes through the dark circular aperture in the center of iris it reflects the blood vessel and arrives at camera length. This makes the red eye in photographs. An algorithm for the removal of red eye from photographs on the basis of reconstruction lost and deteriorated part and eye metric information is introduced in Yoo and Park (2009). In process of iris recognition segmentation takes the most time Alberto *et al.* (2009), Nitin and Nandita (2009). Therefore a technique is introduced that is based on the fuzzy and neural network for separation of iris reliably and accurately is discussed in Alberto *et al.* (2009). Morphological operations and area computations are combinely used with other segmentation techniques in order to speed up the preprocessing techniques (Nitin and Nandita, 2009). Iris recognition system involves key design issues of iris liveliness detection, iris imaging, and iris recognition and quality assessment of iris image. The very algorithm focused on assessment of image quality and iris recognition targeting the speed and accuracy of segmentation (Kahlil and Abou-Chadi, 2010). Iris can also be used for detecting the individuals; this can be done by segmentation and analysis of iris. The obtained features are used to uniquely describe the iris, for proper extraction of features an algorithm is also presented to produce the skeletal of iris with unique paths at end points (Demira and Mayer, 2003). This study suggests operators of Mathematical morphology to perform a geometric transformation of an image. As a consequence of this process, conversion, image processing with field elements of the regular construction work with the elements of the original representation is equivalent to the deformed structure (Oroz and Angulo, 2009). A new method on the basis of operators of morphology for biometric identification of individuals' applications, analysis and segmentation of the iris is presented. Algorithms are developed on basis of operators of morphology to divide the region of the iris image, as well as to shed light on the patterns of the iris has been chosen (Demira and Mayer, 2003). Iris recognition has proven to be very precise for the identification of human. In this article, a technique is developed to extract the iris pattern to take advantage of the least significant bit plane: the least significant bit of each pixel in the image (Bradford *et al*., 2004). This study achieves a new approach to locate the pupil (internal) and limbic (outer) limits of the iris, the two binary shapes and the "center of mass" of technical limits of the pupil and approaches the limits of local statistics of the limbic (Kennell *et al*., 2006). Iris localization is one of the primary methods in the system of iris recognition. After analysis principle, the strengths and short of some of the methods commonly used in iris localization, proposed a theory of formal and morphological based algorithm in this study (Gui and Qiwei, 2008). In this study, the morphological techniques used for purification treatment of the pupil's binary image, this strategy allows precise localization of the pupil distinguish between Iris on the interior, as well as his assessment of the pupil center, which gives us about an Iris (Imene *et al*., 2009). A new algorithm presented here for localization, which, unlike earlier works, not an assumption for the shape of the boundary is assumed. Inner boundary is localized using coarse to fine strategy (Hamed *et al*., 2010). This study proposes multi-structure and multi-level algorithm to adapt on the basis of morphological integration of images that could be considered reasonable to reduce noise and maintain detailed information on the edge (Chao *et al*., 2010). Based on the morphology of the obstruction and a method for the detection of refining mask is suggested. Compared with traditional methods based on the order in which the eyelid-eyelash and lash alone distinguish the detection threshold (Youbo and Xia, 2010). A general comparison of Iris images morphology is given in Table.7

Lesion images morphology: A statistical model supports an approach to improve the segmentation and isolation of effected areas in mammographic images. In this study, derivation of a type of morphological operation is made for increment of incidence of suspected mass clean-up related to background noise, and model-based image segmentation is carried out on localization of suspicious mass areas using labeling scheme of stochastic relaxation (Huai *et al*., 2001). Assessment of Volumetric growth for pulmonary lesions and lung cancer screening and monitoring of oncologic therapy is very important. The base of study is morphological processing and suited to both small and large lesions; rapid, automatic segmentation method is available (Jan-Martin *et al*., 2006). The ultimate objective of this study is Computer Aided Diagnosis (CAD) system for providing a system of detection for melanoma skin lesion images automatically (Khaled *et al*., 2006). Nuclear shape and structure visualization, from the microscopic pathology images can produce some benign and malignant lesions of the important diagnostic clues. The method to describe and

Table 7: Iris images morphology techniques

Reference	Core problem	Methods	Clinical implications
(Guillaume *et al*., 2009)	Realistic organic materials rendering.	Estimation of iris morphology, scattering features, human iris. modeling	Assessment of pigment concentration and iridal thickness.
(Yoo and Park, 2009)	Correction and detection of red eye in photographs.	Face region detection, red eye regions segmentation, region growing.	-
(Alberto *et al*., 2009)	Segmentation of iris.	Iris segmentation, pupil detection, iris detection.	Extension to other biometric segmentation procedures.
(Nitin and Nandita, 2009)	Segmentation of iris.	Edge detection, circular Hough transform, parabolic curve fitting, binary image.	- REF
(Kahlil and Abou-Chadi, 2010)	Assessing iris image quality & iris recognition.	Hough transform, polynomial fitting, segmentation, ID log gabor filter	-
(Demira and Mayer, 2003)	Identifying the persons via iris analysis and segmentation.	Segmentation, skeltonization, morphological operators.	-
(Oroz and Angulo, 2009)	Application of morphology operations in geometric transformati on of image.	Structuring elements, polar logarithmic coordinates conversion.	Application to biometric iris identification.
(Demira and Mayer, 2003)	Identifying the persons via iris analysis and segmentation.	Morphological operators, segmentation, skeltonization.	Application to biometric iris identification.
(Bradford *et al*., 2004)	Identifying the persons via iris analysis and segmentation.	Bit planes, binary morphology, limbic boundary.	Application to biometric iris identification.
(Kennell *et al*., 2006)	Iris recognition (segementation).	Binary morphology, limbic boundary, center of mass technique.	Biometric application.
(Gui and Qiwei, 2008)	Iris localizatin.	Euclidian space, morphology operations, preprocessing, gauss filter.	Physiology of eye description.
(Imene *et al*., 2009)	Locating the pupil.	Histogram thresholding, morphological cleaning, hough transform.	An emerging biometric technology.
(Hamed *et al*., 2010)	Improving the precision of localizing the iris.	Morphology operations, canny edge detection, hough transform.	-
(Chao *et al*., 2010)	Edge detection considering the noise.	Morphological adaptive algorithm, image fusion.	Application like robot vision system.
(Youbo *et al*., 2010)	Reliable iris detection.	Segmentation, region growing, thresholding.	Modality of biometric field.

Table 8: Comparison of segmentation results of lesion image morphology techniques

Reference	Population	Structuring element properties	Error Type	Error Value	Mean	Standard deviation
(Huai *et al*., 2001)	200	Res: 400 µm, 7 pixels diameter	Classification, segmentation error	0.7935%, 0.1578%	3	4
(Jan-Martin *et al*., 2006)	700	Fixed size	Median error	10.2%	30%	2 mm
(Khaled *et al*., 2006)	62	Disc	-	-	89.5,91.65,95.8	90
(Wei *et al*., 2006)	1550	Nuclei	Classification error	0	0.66, 0.68	
(Omid *et al*., 2010)	80	-	Border error	<6%	-	-
(Ronald *et al*., 2001)	8	-	-	-	2.2,1.2	1.2,0.6
(William *et al*., 2003)	50	3.96, 3.20mm diameter	rmserror	2%	-	5.4

compare different tissue distribution of nuclear structure in the class (normal, benign, cancer, etc.) is presented (Wei *et al*., 2011). Dermoscopy is among the main mirror imaging for diagnosing of skin damage, such as melanoma and other pigmented lesions. A new method for border detection of skin lesions mirror image is proposed in Omid *et al.* (2010). In von Hippel-Lindau disease setting, the accurate quantification of kidney disease is an important genetic research. A semi-automated quantification of these renal lesions is developed (Ronald *et al*., 2001). Small lung nodules is a common X-ray showed a significant diagnosis of lung nodules contemporary medicine. While main challenge is the imaging of lung cancer indicators, which may also be a sign of benign conditions. For isotropic anisotropic CT data resampling method is discussed (William *et al*., 2003). Table.8 compares statistical measures of segmentation results of lesion images morphology methods.

Liver images morphology: Liver surgical planning, structure and morphology of hemangiomas and their relationship is important interests. In order to achieve rapid and optimal amount of visual information and the strong assistance of the vascular system, a geometric and structural analysis is proposed (Dirk *et al*., 2002). A method for automatic identification of abdominal organs such as kidney, spleen, stomach, seaweed from the computed tomography scan (CT) images for three-dimensional morphology is described (Toyohisa *et al*., 2000). This article describes the automatic separation of overlapping based on mathematical morphology object, which is located a link from their point of transformation and expansion based algorithms (Liu *et al*., 2002). In this

Table 9: Liver image morphology techniques

Reference	Core problem	Methods	Clinical implications
(Dirk *et al*., 2002)	Structural and geometrical analysis of vessel system.	Preprocessing, skeltonization.	Provides assistance to decision making in liver surgical planning.
(Toyohisa *et al*., 2000)	Recognizing the abdominal organs automatically.	Conditional dilation, recursive erosion, differential tip hats.	Applied to extract regions of candidate organ from CT data.
(Liu *et al*., 2002)	Separation of overlapping objects automatically.	Distance transform, dilation.	To separate the liver cells in hepatitis pathology images.
(Hazem *et al*., 2003) `	Developing an automatic cell counting process.	Segmentation, local adaptive conditioning, mathematical morphology.	Counting the dead and live liver cells.
(Yi *et al*., 2005)	Analysis of liver vessel system.	Vessel tree, vessel surface model.	Provides assistance to decision making in liver surgical planning.
(Ma and Yang, 2007)	Segmentation of liver tissues.	Initial segmentation, refinement, Gaussian distribution, EM algorithm.	Suitable for medical image segmentation tasks.
(Wenfeng *et al*., 2008)	Segmentation of liver.	Texture classification, morphology filters, morphological multiscale gradient.	Provides accurate liver boundaries.
(Jiang and Cheng, 2009)	Segmentation of liver in noisy CT image.	Threshold segmentation, morphology image processing, active contour model.	Provides accurate and automatic liver structure.
(Yussof and Burkhardt, 2009)	Identifying the liver region.	Morphological based, histogram based, region based.	Computer aided diagnosis of liver.
(Jiang *et al*., 2010)	Automatic segmentation of liver.	Multi threshold, morphological methods, voting mechanism.	Provides support for computer aided diagnoses of liver.
(Ali *et al*., 2009)	Automatic liver segmentation.	Preprocessing, liver extraction algorithm, mathematical morphology, watershed algorithm.	Automatic diagnosis of liver pathologies.

study, dead and live liver cells in culture from the microscopic images (liver cells) to explain some of the current research activities of the count. Job requirements, fast, has achieved a high level of precision and has developed a cell count counting process is automatically simple (Hazem *et al*., 2003). Hepatic vascular system is the body's vascular system in one of the most complex. Liver surgery planning, shape and topology analysis of the liver vascular system is our vital interests. A new method for the analyses of the hepatic vascular system is proposed in Yi *et al*. (2005). CT images of liver tissue segmentation is particularly challenging because the complexity of anatomy. A comprehensive model based on statistical learning and morphological operations is presented in this study, to simplify procedures and liver segmentation results, while achieving compliance (Ma and Yang, 2007). Snakes, or active contour, are commonly used in segmentation of medical image. Automatic generation of the initial snake curve and improve the performance of the snake is still open under the edge of the liver partition fuzzy challenges. In this study, texture classification and morphological filtering to generate the initial snake points are discussed (Wenfeng *et al*., 2008). This study presents a complex algorithm, based on active contour automatically extracted abdominal CT images of the liver region (Jiang and Cheng, 2009). For computer-aided diagnosis of liver CT scan identified the first step in the liver area. In order to solve the multi-slice spiral CT scan, automatic liver segmentation is required. A combination of form-based, region based and histogram-based techniques to separate the liver and CT volumetric data segmentation using hybrid technology is introduced Yussof and Burkhardt (2009). Liver segmentation has been difficult in the CAD (computer aided diagnosis). In particular, in the liver CT images at different levels may have two or more regions, adding a more difficult problem, liver segmentation. To solve this problem, a new multi-regional liver CT image of the automatic segmentation method proposed here Jiang *et al*. (2010). Automatic diagnosis of liver disease is among the current interests in medical image processing field. The very basic step in these studies is the liver segmentation automatically. A new automated system, liver abdominal MRI image segmentation is presented in Ali *et al*. (2009). Table.9 compares liver images morphology in general.

Lungs images morphology: This article describes the research work of the stimulation of innovation for medical applications: computer-assisted bronchial biopsy. This project includes the registration, in the absence of an external positioning device, preoperative three-dimensional (3-D) Computed Tomography (CT) scan chest (show a tumor, you need to biopsy), and two-dimensional endoscopic surgery (2-D) image sequence, to provide help to cancer Bronchial biopsy (Ivan *et al*., 1998). A quantitative analysis of aspects of building your own vessel size standard of the local probability density map for the size of the spatial distribution of vessels pulmonary is made. The three dimensional multi-core action Morphological opening is applied to determination of blood vessel size (Yoshitaka *et al*., 2000). Spiral CT angiography is a totally automatic procedure for automatic detection of pulmonary embolism has been developed on

Table 10: Lungs image morphology techniques

Reference	Core problem	Methods	Clinical implication
(Ivan *et al.*, 1998)	Registration thoracic image without external localization device.	Segmentation, registration, 3D reconstruction.	Computer assisted transbronchial biopsy.
(Yoshitaka *et al.*, 2000)	Analysis of size of pulmonary vessels.	3D grayscale opening.	Provides quantitative representation for anatomical knowledge.
(Yoshitaka *et al.*, 2002)	Computer aided pulmonary embolism detection.	Segmentation, mathematical morphology, geometric features, second derivatives.	Provides fully automated pulmonary embolism detection. Automatic detection of airway branch.
(Deniz *et al.*, 2003)	Identification of airway lumen in CT images.	Grayscale morphological reconstruction, segmentation.	
(Gady *et al.*, 2005)	Vessel tree detection.	Morphological operations, correlation based enhancement filters.	Accommodates vessel discontinuities and bifurcation, nodule detection.
(Hye-Suk *et al.*, 2007)	Segmentation of lung.	Morphological operation, anisotropic diffusion, binary image.	Computer aided diagnostic system for identification of lung.
(Arfan *et al.*, 2009)	Detection of lung nodule from CT images.	Fuzzy C-mean, morphological operations, ROI extraction.	Automatic lungs segmentation.
(Arfan *et al.*, 2008)	Segmentation of lung.	Genetic algorithm, Morphological images processing techniques.	Fully automated computer aided diagnostic system.
(Taher and Sammouda, 2010)	Early detection of lung cancer.	Region detection, feature extraction.	CAD system for early detection of lung cancer.
(William *et al.*, 2003)	Measuring the nodule growth over time.	Morphology based and 3D segmentation algorithms, anisotropic sampling.	Clinical use of distinguishing the malignant and non malignant pulmonary nodules.

bases of volumetric image analysis (Yoshitaka *et al.*, 2002). Pulmonary airlines are used for exchange of air between lung and the external environment. Computed tomography (CT) scan can be used to achieve detailed anatomical images of the lung, with the airlines too. A fully automated segmentation technique to three-dimensional airway tree (3-D) of the CT images of the chest is described (Deniz *et al.*, 2003). Reconstruction of vessels in the tree data are necessary prerequisites for a variety of medical imaging applications. In this study, a new way to the application of vascular tree reconstruction and chest CT scan detected nodules is related to increased use of filters and development of a fuzzy shape representation of the data (Gady *et al.*, 2005). A new segmentation technique on bases of anisotropic diffusion and morphological lung operation, fast and accurately is presented (Hye-Suk *et al.*, 2007). A method from lung computed tomography (CT) scan, using the Fuzzy C-means (FCM) and morphological techniques image nodule detection is introduced (Arfan *et al.*, 2009). A segmentation method for lung cancer Genetic Algorithm (GA) and morphological image processing technology as the foundation is described (Arfan *et al.*, 2008). Lung cancer is a serious disease mainly presumptive diagnosis is based on control. In addition to clinical suspicion, the diagnosis of lung cancer was diagnosed sputum in order to form a general rule specimen. In smears should be done through a specific order, the shape of cell nuclei is determined in sputum. A method for feature extraction and detection methods of the area is presented (Taher and Sammouda, 2010). A small lung nodule is a common X-ray film that presents a major challenge of modern medical diagnosis. Although the main indicators of lung nodules imaging of lung cancer, they may also be a sign of benign conditions. Over time, the rate of nodule growth measurement has proved to be malignant in differentiating malignant lung nodules most promising tools. The segmentation of three-dimensional (3-D) methods and characterization of lung nodules using Computer Imaging Tomography (CT) is discussed here William *et al.* (2003). Table.10 gives a general comparison of lungs images morphological techniques.

CONCLUSION

A number of techniques have been introduced in the field of medical image morphology. Each technique addresses a specific problem but it can be concluded on the basis of this review that segmentation is a key technique in morphological operations of medical images. Most of the techniques use segmentation as key step in whole process. The segmentation is done using morphological structures, operations, techniques and various features like edge detection, region growing, boundary extraction etc. These techniques are combined to with other techniques to present various solutions to problems. In this way the effected area is extracted for example extraction of lung from chest CT image and observed under specific parameters to detect specific problem. A number of morphological techniques associated images are presented in this study which includes images of brain, bone, heart, iris, carotid, liver and lungs.

REFERENCES

Abdel-Dayem, A.R. and M.R. El-Sakka, 2004. A novel morphological-based carotid artery contour extraction. Canadian Conference on Electrical and Computer Engineering, 2-5 May, Dept. of Comput. Sci., Univ. of Western Ontario, London, Ont., Canada, 4: 1873-1876.

Abdel-Dayem, A.R., M.R. EI-Sakka and A. Fenster, 2005. Watershed segmentation for carotid artery ultrasound images. The 3rd ACS/IEEE International Conference on Computer Systems and Applications, 2005.

Arfan Jaffar, M., A. Hussain and M.M. Anwar, 2009. Lungs Nodule Detection by Using Fuzzy Morphology from Ct Scan Images. Singapore, April 17-20, ISBN: 978-0-7695-3653-8.

Bonney, B., R. Ives, D. Etter and Y. Du, 2004. Iris pattern extraction using bit planes and standard deviations. Conference on Signals, Systems and Computers, Conference Record of the Thirty-Eighth Asilomar, 7-10 Nov., Dept. of Electr. Eng., US Naval Acad., Annapolis, MD, USA, 1: 582-586.

Baconnier, S. and S.B. Lang, 2004. Calcite microcrystals in the pineal gland of the human brain: Second harmonic generators and possible piezoelectric transducers. IEEE T. Dielect. Elect. Insulat., 11(2).

Bazin, P.L. and D.L. Pham, 2007. Topology-preserving tissue classification of magnetic resonance brain images. IEEE Transact. Med. Imag., 26(4).

Christodoulou, C.I., C.S. Pattichis, M. Pantziaris and A. Nicolaides, 2003. Texture-based classification of atherosclerotic carotid plaques. IEEE Transact. Med. Imag., 22(7).

Chao, L., L. Zhao and S. Sun, 2010. An adaptive morphological edge detection algorithm based on image fusion. 3rd International Congress on Image and Signal Processing (CISP), 16-18 Oct., Inst. of Syst. Eng., Southeast Univ., Nanjing, China, 3: 1072-1076.

Dionisiol, K., R. Chan, L.W. Campbell, J. Connellyl, W.C. Karl and R.S. Lees, 2004. Three-dimensional characterization of carotid plaque structure' and deformation with non-invasive ultrasound imaging. Comput. Cardiol., 31: 237-240.

Demira Jr., J. and J. Mayer, 2003. Image feature extraction for application of biometric identification of iris-a morphological approach. Proceedings of the XVI Brazilian Symposium on Computer Graphics and Image Processing (SIBGRAPI'03) IEEE, pp: 1530-1834.

De Santos Sierra, A., J.G. Casanova, C.S. Avila and V.J. Vera, 2009. Iris segmentation based on fuzzy mathematical morphology, neural networks and ontologies. Security Technology, Conference on 43rd Annual 2009 International Carnahan, 5-8 Oct. 2009, Grupo de Biometria y, Tratamiento Numerico de la Informacion, Centro de Domotica Integral (CeDInt), Madrid, Spain, pp: 355-360.

Dean, J.K., G. Schalk, D.J. Mcfarland and J.R. Wolpaw, 2007. A rhythm matched filter for continuous control of a brain-computer interface. IEEE Transact. Biomed. Eng., 54(2).

Delphine, C.R., B. Jean-Michel, C. Patrick and W. Fabrice, 2007. A physiologically plausible spatio-temporal model for EEG signals recorded with intracerebral electrodes in human partial epilepsy. IEEE Transact. Biomed. Eng., 54(3).

Deniz, A., E.A. Hoffman, G. Mclennan and J.M. Reinhardt, 2003. Segmentation and analysis of the human airway tree from three-dimensional X-Ray CT images. IEEE Transact. Med. Imag., 22(8).

Dirk, S., P. Bernhard, S. Andrea and P. Heinz-Otto, 2002. Analysis of vasculature for liver surgical planning. IEEE Trans. Med. Imag., 21(11).

Edward, H.H., P. Hanchuan and D. Christos, 2004. A bayesian morphometry algorithm. IEEE Trans. Med. Imag., 23(6).

Efthyvoulos, C.K., P. Constantinos, P. Marios, L. Christos, C. Christodoulos, K.K. Stavros and N. Andrew, 2010. A review of noninvasive ultrasound image processing methods in the analysis of carotid plaque morphology for the assessment of stroke risk. IEEE T. Inf. Technol. Biomed., 14(4).

Gui, F. and L. Qiwei, 2008. Iris localization scheme based on morphology and gaussian filtering. Third International IEEE Conference on Signal-Image Technologies and Internet-Based System, SITIS '07, 16-18 Dec., Dept. of Electron. Commun., HuaQiao Univ., Quanzhou, pp: 798-803.

Gady, A., S.G. Armato and C. Wuvessel, 2005. Tree reconstruction in thoracic ct scanswith application to nodule detection. IEEE Trans. Med. Imag., 24(4).

Gilion, H., L. Steven, B. Marcel and G. Frans, 2006. Automatic contour propagation in cine cardiac magnetic resonance images. IEEE Trans. Med. Imag., 25(11).

Gutierrez, M.A., P.E. Pilon, S.G. Lage, L. Kopel, R.T. Carvalho and S.S. Furuie, 2009. Automatic measurement of carotid diameter and wall thickness in ultrasound images automatic measurement of carotid diameter and wall thickness in ultrasound images, computers in cardiology. IEEE Trans. Biomed. Eng., 56(5).

Guillaume, F., P. Gautron, G. Breton and K. Bouatouch, 2009. Image-based modeling of the human eye. IEEE Trans. Visualizat. Comput. Graphics, 15(5).

Guy, S., F. Devernay, E. Coste-Manière, A. Quyyumi and E.R. Mcveigh, 2003. Three-dimensional motion tracking of coronary arteries in biplane cineangiograms. IEEE Trans. Med. Imag., 22(4).

Ghodrati, H., M.J. Dehghani and M. Sadegh, 2010. Localization of noncircular iris boundaries using morphology and aarched hough transform. 2nd International Conference on Image Processing Theory Tools and Applications (IPTA), 7-10 July, Dept. of Electr. Eng., Shiraz Univ. of Technol. (sutech), Shiraz, Iran, pp: 458-463.

Hamou, A.K. and M.R. El-Sakka, 2004. A novel segmentation technique for carotid ultrasound images. IEEE International Conference on Acoustics, Speech and Signal Processing, Proceedings (ICASSP '04), 17-21 May, Dept. of Comput. Sci., Univ. of Western Ontario, London, Ont., Canada, 3: 521-524.

Hans, H.T., S. Kreiborg, A. Juul and K.D. Pedersen, 2009. The bonexpert method for automated determination of skeletal maturity. IEEE Trans. Med. Imag., 28(1).

Hye-Suk, K., Y. Hyo-Sun, T. Kien Nguyen and G.S. Lee, 2007. Automatic lung segmentation in Ct images using anisotropic diffusion and morphology operation. 7th IEEE International Conference on Computer and Information Technology, (CIT 2007), 16-19 Oct., Chonnam Nat. Univ., Gwangju, pp: 557-561.

Hongtu, Z., J.G. Ibrahim, N. Tang, D.B. Rowe, X. Hao, R. Bansal and B.S. Peterson, 2007. A statistical analysis of brain morphology using wild bootstrapping. IEEE Trans. Med. Imag., 26(7).

Huai, L., W. Yue, K.J. Ray Liu, B.L. Shih-Chung and M.T. Freedman, 2001. Computerized radiographic mass detection-part I: Lesion site selection by morphological enhancement and contextual segmentation. IEEE Trans. Med. Imag., 20(4).

Imene, K.K., S.M. Dorra and D. Nabil, 2009. Fast pupil location for better iris detection. 6th International Multi-Conference on Systems, Signals and Devices (SSD '09), 23-26 March, Res. Unit Ciels, Nat. Eng. Sch. Sfax, Sfax, pp: 1-6.

Ivan, B., F. Gilbert and C. Philippe, 1998. Registration of real and CT-derived virtual bronchoscopic images to assist transbronchial biopsy. IEEE Trans. Med. Imag., 17(5): 703-703.

James, C.J. and O.J. Gibson, 2003. Temporally Constrained ICA: An application to artifact rejection in electromagnetic brain signal analysis. IEEE Trans. Biomed. Eng., 50(9).

Jiang, H. and Q. Cheng, 2009. Automatic 3d segmentation of ct images based on active contour models. 11th IEEE International Conference on Computer-Aided Design and Computer Graphics, (CAD/Graphics '09), 19-21 Aug., Software Coll., Northeastern Univ., Shenyang, China, pp: 540-543.

Jiang, H., Y. Zhang and Q. Cheng, 2010. Vertebra location-based multi-regional segmentation of liver CT image. International Conference on Biomedical Engineering and Computer Science (ICBECS), 23-25 April, Software Coll., Northeastern Univ., Shenyang, China, pp: 1-3.

Jaffar, M.A., A. Hussain, M. Nazir, A.M. Mirza and A. Chaudhry, 2008. GA and morphology based automated segmentation of lungs from Ct scan images. International Conference on Computational Intelligence for Modelling Control and Automation, 10-12 Dec., Dept. of Comput. Sci., FAST Nat. Univ. of Comput. Emerging Sci., Islamabad, Pakistan, pp: 265-270.

Jan, D., B. Bart, T. Jan, F. Van De Werf, G.R. Sutherland and P. Suetens, 2002. Echocardiographic strain and strain-rate imaging: A new tool to study regional myocardial function. IEEE Transact. Med. Imag., 21(9).

Jan-Martin, K., D. Volker, B. Lars, B. Annemarie, W. Dag, K. Stefan and P. Heinz-Otto, 2006. Morphological segmentation and partial volume analysis for volumetry of solid pulmonary lesions in thoracic CT scans. IEEE Trans. Med. Imag., 25(4).

Jianhua, Y., S.D. O'Connor1 and R.M. Summers, 2007. Computer aided detection of lytic bone metastases in the spine using routine CT images. 4th IEEE International Symposium on Biomedical Imaging: From Nano to Macro, (ISBI 2007), 12-15 April, Department of Diagnostic Radiol., Nat. Inst. Health, Bethesda, MD, pp: 512-515.

Jong-Min, L., U. Yoon, J.J. Kim, Y. Kim, D.S. Lee, J.S. Kwon and S.I. Kim, 2004. Analysis of the hemispheric asymmetry using fractal dimension of a skeletonized cerebral surface. IEEE Trans. Biomed. Eng., 51(8).

Kahlil, A.T., F.E.M. Abou-Chadi, 2010. Generation of iris codes using 1d log-gabor filter. International Conference on Computer Engineering and Systems (ICCES), Nov. 30-2 Dec., Electron. Commun. Eng. Dept., MET Higher Inst. Eng. Technol., Mansoura, Egypt, pp: 329-336.

Karaçali, B. and C. Davatzikos, 2006. Simulation of tissue atrophy using a topology preserving transformation model. IEEE Trans. Med. Imag., 25(5).

Khaled, T. and N.B. Romdhane, 2006. Automatic segmentation and classification of skin lesion images. The 2nd International Conference on Distributed Frameworks for Multimedia Applications, Sci. Technol. Image Telecommun., Higher Inst. Biotechnol., Sfax, pp: 1-12.

Kharrat, A., N. Benamrane, M. Ben Messaoud and M. Abid, 2009. Detection of brain tumor in medical images. 3rd International Conference on Signals, Circuits and Systems (SCS), 6-8 Nov. 2009, Comput. Embedded Syst. Lab. (CES), Nat. Eng. Sch. of Sfax, Sfax, Tunisia, pp: 1-6.

Kleydis, V.S., J.C. Silva, Y. Berthoumieu, P. Gomis and M. Najim, 2007. ECG beat detection using a geometrical matching approach. IEEE Trans. Biomed. Eng., 54(4).

Kennell, L.R., R.W. Ives and R.M. Gaunt, 2006. Binary morphology and local statistics applied to iris segmentation for recognition. IEEE International Conference on Image Processing, 8-11 Oct., Dept. of Electr. Eng., US Naval Acad., Annapolis, MD, pp: 293-296.

Liu, Y. and D.J. Williams, 2010. Incorporation of hydroxyapatite sol into collagen gel to regulate the contraction mediated by humanbone marrow-derived stromal cells. IEEE Trans. Nanobiosci., 9(1).

Liu, B., X. Fang, W. Wang and Z. Zheng, 2002. Automatic separation of overlapping objects. Proceedings of the 4th World Congress on Intelligent Control and Automation, Shanghai, P.R. China.

Ma, L. and L. Yang, 2007. Liver segmentation based on expectation maximization and morphological filters in CT images. IEEE,

Mao, J.G., D. Downey and A. Fenster, 2000. Segmentation of carotid artery in ultrasound images. Proceedings of the 22nd Annual EMBS International Conference, Chicago IL.

Miad, F., A. Saeed, S.C. Bulusu, M. Nouran, H. Minn and L. Tamil, 2010. A patient-adaptive profiling scheme for ECG beat classification. IEEE Transact. Informat. Technol. Biomed., 14(5).

Nipon, T.U. and S. Dhompongsa, 2007. Morphological granulometric features of nucleus in automatic bone marrow white blood cell classification. IEEE Transact. Informat. Technol. Biomed., 11(3).

Nitin, K.M. and N. Bhattacharjee, 2009. An efficient and accurate iris segmentation technique, digital image computing: Techniques and applications. Digital Image Computing: Techniques and Applications, (DICTA '09), Fac. of Inf. Technol., Monash Univ., Clayton, VIC, Australia, pp: 347-352.

Nuwan, D.N., C. Bernard, S. Abbas, J.D. Spence, J. Samarabandu and A. Fenster, 2008. A "Twisting and Bending" model-based nonrigid image registration technique for 3-D ultrasound carotid images. IEEE Trans. Med. Imag., 27(10).

Omid, S., M.H. Miran Baygi and P. Ghassemi, 2010. Skin lesion detection in dermoscopy images usingwavelet transform and morphology operations. Proceedings of the 17th Iranian Conference of Biomedical Engineering (ICBME2010).

Patrick, C., K.N. Le and T.R.H. Cutmore, 2008. Noise reduction in rhythmic and multitrial biosignals with applications to event-related potentials. IEEE Transact. Biomed. Eng., 55(7).

Punam, K.S., Member, J.K. Udupa, A.X. Falcao, B.E. Hirsch and S. Siegler, 2004. Iso-shaping rigid bodies for estimating their motion from image sequences. IEEE Transact. Med. Imag., 23(1).

Rachid, J., W.J. Ohley, S. Majumdar and G. Lemineur, 2001. Fractal analysis of bone X-Ray tomographic microscopy projections. IEEE Trans. Med. Imag., 20(5).

Radj, A.B., J.A. Schaar, F. Mastik, C.W.J. Oomens and A.F.W. Van Der Steen, 2005. Assessment of vulnerable plaque composition by matching the deformation of a parametric plaque model to measured plaque deformation. IEEE Transact. Med. Imag., 24(4).

Rafiee, A., H. Masoumi and A. Roosta, 2009. Using neural network for liver detection in abdominal MRI Images. IEEE International Conference on Signal and Image Processing Applications (ICSIPA), 18-19 Nov., Kazeroun Branch, Electr. Dept., Islamic Azad Univ., Kazeroun, Iran, pp: 21-26.

Ravi, B., L.H. Staib, D. Xu, H. Zhu and B.S. Peterson, 2007. Statistical analyses of brain surfaces using gaussian random fields on 2-D manifolds. IEEE Transact. Med. Imag., 26(1).

Refai, H., L. Li, T.K. Teague and R. Naukom, 2003. Automatic count of hepatocytes 1n microscopic images. International Conference on Image Processing, ICIP 2003, Proceedings, 2003, 14-17 Sept., Electr. Comput. Eng. Dept., Oklahoma Univ., Tulsa, OK, USA, 2: 1101-1104.

Ronald, M.S., C.M.L. Agcaoili, M.J. Mcaulifle, S.S. Dalal, P.J. Yim, P.L. Choyke, M.M. Walther and W.M. Linehan, 2001. Helical Ct of von hippel-lindau: Semi-automated segmentation of renal lesions. Proceedings International Conference on Image Processing, 7-10 Oct., Nat. Cancer Inst., Nat. Inst. of Health, Bethesda, MD, 2: 293-296.

Rosniza, R., N. Jamil and R. Mahmud, 2010. Skull stripping of MRI brain images using mathematical morphology. Proceedings of the IEEE EMBS Conference on Biomedical Engineering and Sciences, Kuala Lumpur, Malaysia.

Seabra, J.C., J.M. Sanches, L.M. Pedro and J.F.E Fernandes, 2007. Carotid plaque 3D compound imaging and echo-morphology analysis: A bayesian approach. Proceedings of the 29th Annual International Conference of the IEEE EMBS Cité Internationale, Lyon, France.

Seabra, J.C.R., L.M. Pedro, J. Fernandes and J.M. Sanches, 2009. A 3-D ultrasound-based framework to characterize the echo morphology of carotid plaques. IEEE Transact. Biomed. Eng., 56(5).

Serge, L.V.S.J., G.J. Clapwortliy and M. Rooze, 2000. Morphology-based data elimination from medical image data. IEEE Computer Graphics and Applications, Dept. of Anatomy, Univ. of Brussels, 20(2): 46-52.

Silvia, C., A.M. Bianchi, S. Cerutti and G.A. Chiarenza, 2003. Dynamic time warping in the analysis of event-related potentials. IEEE Engineering in Medicine and Biology Magazine, Milan Polytech Univ., Italy, 24(1): 68-77.

Steven, C.M., B.P.F. Lelieveldt, R.J. Van Der Geest, H.G. Bosch, J.H.C. Reiber, and M. Sonka, 2001. Multistage hybrid active appearance model matching: Segmentation of left and right ventricles in cardiac MR images. IEEE Trans. Med. Imag., 20(5): 415-415.

Schormann, T. and M. Kraemer, 2003. Voxel-Guided Morphometry (“VGM”) and application to stroke. IEEE Transact. Med. Imag., 22(1).

Taher, F. and R. Sammouda, 2010. Morphology analysis of sputum color images for early lung cancer diagnosis. Proceedings of the 10th International Conference on Information Science, Signal Processing and Their Applications (ISSPA 2010).

Tsai, M.D. and M.S. Hsieh, 2005. Volume manipulations for simulating bone and joint surgery. IEEE Trans. Inf. Technol. Biomed., 9(1).

Theo, G.M., V. Erp, T.D. Cannon, H.L. Tran, A.D. Wobbekind, M. Huttunen, J. Lonnqvist, J. Kaprio, O. Salonen, L. Valanne, V.P. Poutanen, C.G. Standertskjöld-Nordenstam, A.W. Toga and P.M. Thompson, 2004. Genetic influences on human brain morphology. IEEE International Symposium on Biomedical Imaging: Nano to Macro, 15-18 April, Dept. Psychol., UCLA, Los Angeles, CA, USA, 1: 583-586.

Tomos, G.W., A.P. Holmes, J.C. Waterton, R.A. Maciewicz, C.E. Hutchinson, R.J. Moots, A.F.P. Nash and C.J. Taylor, 2010. Anatomically corresponded regional analysis of cartilage in asymptomatic and osteoarthritic knees by statistical shape modelling of the bone. IEEE Transact. Med. Imag., 29(8).

Toyohisa, K., L. Gu and H. Fujimoto, 2000. Abdominal organ recognition using 3D mathematical morphology. 15th International Conference on Pattern Recognition, Proceedings, Toyohashi Univ. Technol., 2: 263-266.

Vukadinovic, D., T. Van Walsum, S. Rozie, T. De Weert, R. Manniesing, A. Van Der Lugt and W. Niessen, 2009. Carotid artery segmentation and plaque quantification in cta, carotid artery segmentation and plaque quantification in cta. IEEE International Symposium on Biomedical Imaging: From Nano to Macro, ISBI '09, June 28-July 1, Biomed. Imaging Group, Univ. Med. Center Rotterdam, Rotterdam, Netherlands, pp: 835-838.

Wei, W., J.A. Ozolek, D. SlepCev, A.B. Lee, C. Chen and G.K. Rohde, 2011. An optimal transportation approach for nuclear structure-based pathology. IEEE Transact. Med. Imag., 30(3).

Wenfeng, W., L. Ma and L. Yang, 2008. Liver contour extraction using modified snake with morphological multiscale gradients. International Conference on Computer Science and Software Engineering, 12-14 Dec., Sch. Autom., Hangzhou Dianzi Univ., Hangzhou, 6: 117-120.

William, J.K., A.P. Reeves, D.F. Yankelevitz and C.I. Henschke, 2003. Three-dimensional segmentation and growth-rate estimation of small pulmonary nodules in helical Ct images. IEEE Trans. Med. Imag., 22(10).

Xiahai, Z., K.S. Rhode, R.S. Razavi, D.J. Hawkes and S. Ourselin, 2010. A registration-based propagation framework for automatic whole heart segmentation of cardiac MRI. IEEE Trans. Med. Imag., 29(9).

Xiao, H., P. Xu, F. Scalzo, P. Vespa and M.arvin Bergsneider, 2009. morphological clustering and analysis of continuous intracranial pressure. IEEE Transact. Biomed. Eng., 56(3).

Xiao, H., P. Xu, S. Asgari, P. Vespa and M. Bergsneider, 2010. Forecasting ICP elevation based on prescient changes of intracranial pressure waveform morphology. IEEE Trans. Biomed. Eng., 57(5).

Yoo, S. and R.H. Park, 2009. Red-eye detection and correction using inpainting in digital photographs. IEEE Transact. Consumer Elect., 55(3).

Yan, K., K. Engelke and W.A. Kalender, 2003. A new accurate and precise 3-D segmentation method for skeletal structures in volumetric CT data. IEEE Transact. Med. Imag., 22(5).

Yi, S., B. Wang, Y. Ju, J. Xie and X. Huang, 2005. Interaction techniques for the exploration of hepatic vessel structure. Proceedings Of The IEEE Engineering In Medicine And Biology 27th Annual Conference Shanghai, China.

Yoshitaka, M., H. Macmahon' and K. Doi', 2000. Quantitative analysis on spatial distribution of vascular sizes in lung using three-dimensional greyscale morphology. Proceedings of the 22nd Annual EMBS International Conference, Chicago IL.

Yang, J.X., F.Z. Cui, Q.S. Yin, Y. Zhang, T. Zhang and X.M. Wang, 2009. haracterization and degradation study of calcium phosphate coating on magnesium alloy bone implant in vitro. IEEE Transact. Plasma Sci., 37(7).

Yoshitaka, M., H. Macmahon and K. Doi, 2002. Computerized detection of pulmonary embolism in spiral CT angiography based on volumetric image analysis. IEEE Trans. Med. Imag., 21(12): 1517-1517.

Youbo, Y. and M. Xie, 2010. Eyelid and eyelash detection method based on morphology. The 2nd International Conference on Computer and Automation Engineering (ICCAE), 26-28 Feb., Coll. of Electron. Eng., Univ. Electron. Sci. Technol. of China, Chengdu, China, 1: 678-681.

Zhang, H., A. Wahle, R.K. Johnson, T.D. Scholz and M. Sonka, 2010. 4-D cardiac MR image analysis: Left and right ventricular morphology and function. IEEE Transact. Med. Imag., 29(2).