Brain Image Analysis: A Survey

Article *in* World Applied Sciences Journal · January 2012

DOI: 10.5829/idosi.wasj.2012.19.10.3347

World Applied Sciences Journal 19 (10): 1484-1494, 2012
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2012.19.10.3347

Brain Image Analysis: A Survey

Mussarat Yasmin, Sajjad Mohsin, Muhammad Sharif,
Mudassar Raza and Saleha Masood

Department of Computer Sciences,
COMSATS Institute of Information Technology, Wah Cantt, 47040, Pakistan

Abstract: Image analysis is generally a process where digital image processing is utilized to process digital images in order to extract significant statistics or information from the images. The analysis process enables to analyze and visualize medical images of numerous modalities. The paper is basically an overview and discussion of the methods and techniques being proposed and developed in regard of brain image analysis. An image is basically analyzed from the perspective of its segmentation, edge detection, registration and morphology or motion analysis. Here in this paper different brain image types i.e., MRI, CT, PET, EEG/MEG are discussed and presented from the point of operations mentioned above. Each method is discussed and analyzed through its applications, advantages, limitations and results.

Key words: MRI · Segmentation · Brain · Survey · Edge Detection

INTRODUCTION

Image analysis is a process mainly utilized to extract facts confined in the images. This process basically goals at identifying, analyzing and labeling the texture together with the geometry of digital images. The facts, statistics and subsequently the significance of the image are purpose of the procedures used on behalf of its development and achievement. The features by which a digital image is recognized and characterized are of spectral and symmetrical environment. Brain image analysis is a subfield of image analysis and comprises a huge range of applications [1] in detecting, diagnosing and treating brain related issues and diseases. If we talk about brain image analysis, we can see that brain images are analyzed from the perspective of fields described in the figure given below:

Image Segmentation: A vital problematic domain, termed segmentation, is to differentiate substances commencing background or states to the procedure of dividing a digital image into numerous parts. For intensity images, there exist four general methods which are: threshold procedures, edge-based approaches, region- based practices and connectivity-preserving relaxation procedures.

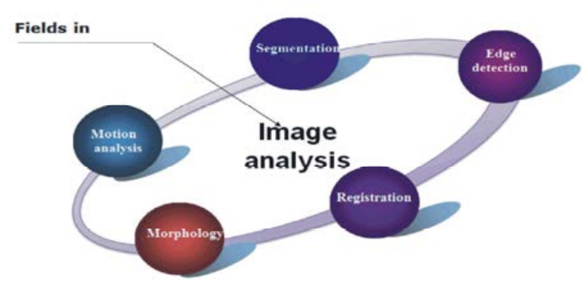

Fig. 1: Image analysis fields

Edge Detection: Edge detection is an essential instrument in image processing, principally in the capacities of feature detection and extraction which target on classifying facts in a digital image at which the image illumination fluctuates suddenly or further has breaks and gaps.

Image Registration: It is the procedure of aligning and arranging two or further images having identical prospect or vision.

Morphology: Morphology is a comprehensive traditional process of image processing procedures that course images centered on shapes. A morphological process utilizes a structuring component to an input image while generating an output image of equal dimension.

Corresponding Author: Muhammad Sharif, Department of Computer Sciences, COMSATS Institute of Information Technology, Wah Cantt., 47040, Pakistan. Cell: +92-300-5188998

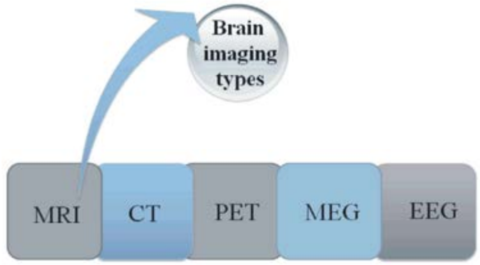

Fig. 2: Brain imaging types

Motion Analysis: Motion analysis is a subject in image processing that lessons approaches and methods in which two or additional successive images from an image arrangement are treated to produce material centered on the deceptive motion in the images.

The categories of papers acknowledged comprise those that shield the progress and execution of procedures and approaches centered on the usage of practical mathematics and physics to resolve the succeeding sorts of difficulties by means of medical image datasets. Now we will discuss and analyze some of these papers in this regard.

Brain Image Analysis Techniques: Here in this section we will analyze some methods and techniques that have been proposed in the perspective of brain image analysis. The brain image analysis [2] process is discussed from the viewpoint of different brain imaging types which are given in the figure below:

MRI: The first paper in this regard is a MRI brain segmentation method [3]. The procedure presented is for finding brain and contours. Also genuine computation form for EEG and MEG investigation is proposed. The work proposed in [4] is a 3D volume information segmentation centered on 2D image segments. By utilizing the customer presented image mask containing the concerned regions or structural data, the half automatic segmentation method is able to produce segmented fresh volume dataset and regional data. The object centered volume apparition procedure is capable of using this segmented dataset and regional data to carry out structural centered treatment and visualization. The method described in [5] presents the geometric active contour models for detecting the edges and segmentation [6] of MRI and CT images. Method defined is based on feature matrices and then added to the novel snake paradigm. Another automatic brain segmentation of MRI images is addressed in paper [7]; proposed method follows two steps: i) initial model is created first ii) secondly that model deformation to map the precise contour of brain. Automatic segmentation is thus performed by following these two steps. The method described in [8] is the process of registration of brain images. The images are multimodal of MRI and SPECT. This was the big problem because of non availability of any land mark. To overcome this problem, the method uses the anatomic invent brain properties. The method is also presented for missing information i.e., pathological cases. A hybrid method in [9] is introduced for brain segmentation in 3D MRI images. Fuzzy region growing and edge detection is introduced. The proposed technique combines the edge detection method and region growing method. In [10] a novel system is presented to segment automatically from the MRI brain images. Different algorithms are used to extract different types of data. Proposed graph cut atlas based method uses that prior data or information and automatically calculates the atlases and boundares from the image.

Another method of segmenting heads from the MRI images is discussed in [11]; the method is introduced for reconstruction of EEG and MEG model. Brains are detected and contour as well. The method described in [12] is a hybrid method. It is the combination of parametric bias field correction (PABIC), fuzzy connectedness (FC) and atlas registration. Main theme of proposed work is to use full parameters of FC segmentation. Segmented results are then combined with PABIC algorithm to get better results. The method described in [13] is presented to segment the new born brain from MRI brain images. The algorithm is robust for adult and new born brains. The algorithm is automatic and doesn’t require any manual data. The method proposed in [14] is the process of segmentation of brain MRI images [2] by using tree-cutting technique. The method has three steps: i) preprocessing, it gives tree labels which is then used as an input to the tree-metric graph cuts algorithm ii) TM gives the optimal labels and iii) TC algorithm generates mapping by seeing respected labels to tissue classes. The method described in [15] is an automatic algorithm to segment spleen area from the abdominal MRI images. First image enhancement is done. Then in order to split the image water shed and neural network methods are used. Neural network is used to train the spleen feature extraction. In [16] the difficulty is addressed in segmentation and also in estimation of volume because of less difference between the grey matter and white matter. The method used to overcome this problem makes use of purple voxels intensity to separate the blue matter and white matter. Also to determine the intensity of voxel fraction, least squares vector estimator is used. In [17] the semi automatic system of brain head segmentation is introduced. 3D volume data segmentation is extracted from 2D slice of images. In [18] a novel method is introduced for segmentation of brain tissues MRI images. First noise is reduced and then water shed algorithm is used for segmentation. Fuzzy clustering algorithm is used to segment the non-segmented portion of brain. Edge detection in MRI is proposed in [19]. The method makes use of neural network wavelet transform to carry out an edge detection process. The detection result indicates that impressive outcomes are acquired by this method. The edge detection process of MRI using SUSAN and Sobel Edge Detection method is presented in [20]. The method basically analyzes and provides experimental results for the researchers in order to choose between both approaches. Besides, SUSAN method yields superior results as compared to Sobel edge detection process. Another edge detection approach for MRI can be analyzed in [21]. The method combines two processes in order to carry out the edge detection process. The processes are distant dipolar field and intermolecular multiple-quantum coherences. The results showed that method extant abundant evidence about numerous types of edges of object areas and able to detect all types of boundaries. Edge detection of CT images through canny edge detector is presented in [22]. The method makes use of canny detector together with the concept of image fusion. It has been shown through simulations of computer that proposed method can effectively edge-detect MRI images of brain as well as resistant to noise in an environment of spontaneous noise. It can also detect more edges of MRI brain images effectively as well as overcomes the canny algorithm disadvantages. Image registration for MR and CT images can be analyzed in [23]; a half programmed inflexible MR-CT registration process intended for Liver Cancer Surgery for MR images where cancer materials are clotted through ablation of microwave. The experimental results showed that registration of MRI image up to 1.45mm is achieved through the process. Another MRI registration process can be analyzed in [24]. The method is basically centered on optimizing a diffeomorphic demons cost function. Another MR images segmentation and registration method is presented in [25]. The method presents a fuzzy framework in this regard. MRI morphology can be analyzed in [26] and [27]. Table 1 gives a comparison of MRI brain images analysis methods.

Table 1: MRI brain images analysis methods comparison

Serial no#	Application	Advantage	Limitation	Results
1	MRI brain segmentation [3]	Has application to MRI as well as to EEG and MEG	-	It has been shown through results that the technique handles MRI segmentation in an effective way
2	MRI volume visualization [4]	Handles both 2D and 3D data	-	The results show that the method gains a powerful ability of structural manipulation and volume visualization
3	Segmentation of MRI images [5]	Feature segmentation of even noisy images	Difficult formulation	Results of this technique show that it is better, fast and accurate as compared to other algorithms
4	Segmentation of MRI medical images [7]	The advantage is that the proposed method is very fast in segmentation and automatic as well	Less accurate with noisy images	Average differences are 1.7% and 2.7%
5	MRI images registration of medical sector [8]	If there is a picture with less information, it will handle it	-	Results show that the proposed method is better for dealing missing information pictures
6	MRI brain segmentation in medical sector [11]	Advantage of this method is that it can segment and detect brain as well as contour	Limitation is that calculation is difficult for contour detection	Proposed method shows better results for contour and brain detection as well as for segmentation
7	MRI brain sector [9]	Advantage is that it is more robust as compared to the individual implemented techniques	Limitation is that data is complex because of 3D images	Improved results are obtained through 3D segmentation of MRI Brain Images
8	MRI brain sector [10]	Advantage of this method is that it is fast and easy to understand	-	The proposed method is tested and compared with ordinary algorithms and it shows better results

Table 1: Continue

Serial no#	Application	Advantage	Limitation	Results
9	Brain images of MRI [12]	Advantage of this method is that it is fast and easy to understand	Limitation is that it has greater tile of computations	The proposed method shows better results as compared to other methods and algorithms
10	Medical MRI brain department [13]	Advantage of the work is that it does not require any manual data	Limitation of this method is that it shows less accurate results on adult brain images	The suggested technique gives more accurate experimental results in comparison with existing methods
11	MRI brain department [14]	It has greater speed and accuracy and it is simple as well	Limitation is not mentioned	Results show that the method proposed is fast and more accurate as compared to algorithms already existing
12	MRI abdominal images department [15]	Advantage is that it is fast	-	The proposed technique gives more precise and reliable results
13	3D segmentation of medical images [16]	This method is very efficient to volume estimation and segmentation	It shows less accuracy if quality of image is low	Experimental results show that novel method is more accurate rather than the ordinary methods
14	Medical sector [17]	Advantage is that it is used for both manual and automatic segmentation	Limitation of this method is that it has very complex calculations	Results show that the segmentation procedure added with the volume visualization has strong ability to segment brain
15	Medical sector [18]	Advantage is that it segments the brain from even noisy images	Limitation is that it involves different algorithms and thus it is complex	The extensive experiments are conducted to validate the results and proposed method shows better results
16	MRI edge detection [19]	Enhances the image features	-	Results indicate that promising outcomes have been achieved by the method
17	MRI edge detection [20]	Provides comparison on two methods	-	Results indicate that SUSAN method yields superior results as compared to Sobel edge detection process
18	MRI-CT image registration [23]	Effective for both MR and CT image registration	-	The experimental results show that registration of MRI image up to 1.45mm is achieved through the process
19	MRI edge detection [21]	Able to detect all sorts of boundary regions	-	The results show that method extants abundant evidence about numerous types of edges of object areas
20	MRI edge detection [22]	Handles both noise and edge detection processes	-	Effective results are obtained
21	MRI registration [24]	-	Computationally complex	-
22	MR images segmentation and registration [25]	Handles both segmentation and registration processes	-	Fast and effective method in regard of MR images segmentation and registration
23	MR image morphology [26]	Fast and accurate morphology method	Computationally a bit complex	Method is robust and effective
24	MRI segmentation [27]	The method does not require any manual connections	Computationally complex	Acceptable segmentation results are achieved

EEG: EEG analysis and segmentation approach is presented in [28]. The method is centered on an adaptive auto correlation Eigen spectrum calculation procedure recognized as APEX in concert with a representation of assortment rule. The conditional R6nyi entropies are centered on time-frequency representation of the signal. It is exposed that: 1) the three times varying complication calculates and accesses account for a *component counting* possession and 2) the immediate numerical measurement is mainly strong to Gaussian white noise. Another approach for EEG segmentation is presented in [29]. In [30] the method introduced is time varying complexity measures. The data is extracted from the born baby. Method shows that it can extract and measure three times varying complexity measures account for a component counting property. A comparison of EEG brain images analysis methods is presented in Table 2.

Table 2: EEG brain images analysis methods comparison

Serial N0#	Application	Advantage	Limitation	Results
1	EEG analysis and segmentation [28]	More robust in noisy measurements	Computationally complex	Effective approach for EEG segmentation
2	EEG segmentation [29]	Less computationally expensive	Incorrect accuracy is a bit high	Results demonstrate that the windowed based NLEO technique was better than the non-windowed based technique and GLR was the better method
3	Medical sector EEG [30]	Advantage of the proposed method is that it can handle large number of data	Limitation is that it is complex to covert 2d slice in to 3d	Investigational analysis of EEG signals has been performed and the time-varying difficulty analysis reveals some appealing insight into the brain task

PET: The proposed method in this paper [31] is to describe sulci on MRI surface. The procedure requires four steps: (i) to segment the anatomical data of MRI to get brain surface, (ii) generating the surface of brain to view ray casting of parallel data, (iii) sulci delineation from the brain surface and (iv) landmarks fusion. The surface of the brain while using the 'Directional Watershed Transform' algorithm automatically segments 3D MRI data to calculate major sulci area. The sulci are then saved for use in the next step. Sulsa landmarks are finally mapped on the volume. The approach presented in this paper [32] is for registration of images like medical images MRI and PET. Related data is first segmented to perform the desired work. The algorithm used for brain segmentation is named as Directional Watershed algorithm. Method used to segment the brain from the PET images is by threshold combining with growing of the region. Shape is then described by generalizing the morphological skeleton. Technique is called possibility shell fitting.

In [33] the three approaches are independent component analysis (ICA), fuzzy C-means algorithm (FCM) and expectation-maximization algorithm (EM). ICA is less sensitive for noisy images but EM is best for noisy image data. An enhanced version of algorithm of fuzzy C-Means (FCM) is proposed in [34] for segmentation of PET images. Results are different because of image quality. In this method brain tumor is segmented from the images. Image is divided into two parts; background and foreground. In [35] a frame work is introduced which does not require registration to automatic patient images and manual delineation for functional PET images segmentation. MRI atlas images are used as a ground truth. The registration process of PET-MR images is carried out in [36]. The method is a numeric based numerical breathing phantom intended to appraise the recital of registration processes functioned in support of PET and MRI volumes. The method is a non rigid process and according to results obtained higher accuracy in the process of registration as compared to rigid methods. PET images edge detection process is presented in [37]. The method basically makes use of grey scale weighting average technique to compute the centroid by way of the early location of Snake. After this centered on the theory of energy minimal, it extracts the opening of different edges. The results showed that method is more robust, handles the noise factor and clearly indicates the openings within the edges. Table 3 shows a brief comparison of different PET brain images analysis methods.

Medical: In [38] the algorithm is proposed for segmenting the extra ocular muscle EOM. The technique makes use of the fact that extra area is less highlighted than the EOM area in images, so make them more blur to extract the edges of muscles. There is no use of manual extraction. The surrounding area is extracted in less than 12 seconds by this algorithm as compared to manual extraction which takes 1 minute. In [39] the method presented is the thorax organs images segmentation for construction. The model of Geometrical-conductivity is made to simulate the cardiac electrical field. Simulated results are in the form of epicedial maps. Determination of Maps in non-invasive way selects the thorax surface on the basis of Body Surface Potential Maps (BSPM's). The made method is based on the detection of edges and handles X-ray images of chest which are routinely acquired. So the results the proposed model show are more efficient and accurate. In [40] registration of small animals CT and PET images is presented. Registration of animal brains is more difficult as compared to humans. Air algorithm is used to register the f-18 FDG and PET F_10 fluoride; these are respectively the rat's skull and brain images. In [41] the novel multistage method for 3D segmentation from the medical images is introduced. MRE method is used to segment the connected region of interest and the surroundings. The hybrid technique is introduced to fast marking and fast segmentation and at last morphological

Table 3: PET brain images analysis methods comparison

Serial N0#	Application	Advantage	Limitation	Results
1	Sulci Delineation of PET images [31]	Automatic brain sulci segmentation	Complex steps of computation	The technique shows better results as compared to the traditional modality fusion
2	PET and MRI image segmentation and registration [32]	MRI images automatic registration	-	The comparison of the technique shows that automatic registration is better than the manual registration of medical images
3	PET brain data [33]	The method has the advantage of handling noisy images	Limitation of this method is that the processing is slow	Results show that the hybrid technique is more efficient in handling noisy images of PET
4	Medical sector [34]	Advantage of this system is that it is simple and automatic	-	Robust for a lot of diverse data
5	PET brain sector [35]	Advantage of this framework is that it can automatically register the PET segmented images	Limitation of the system is that the algorithm is difficult for types of images	Drastic results for segmentation
6	PET-MRI registration [36]	-	-	The method is a non rigid process and according to results obtained higher accuracy in the process of registration as compared to rigid methods
7	PET edge detection [37]	Handles the noise factor as well	-	Results show that method is more robust, handles the noise factor and clearly indicates the openings within the edges

Table 4: Medical brain images analysis methods comparison

Serial N0#	Application	Advantage	Limitation	Results
1	Muscular automatic edge detection and segmentation [38]	It is much faster than the manual extraction of edges and segmentation	It shows less accuracy in other medical images	The proposed method gives results in comparison of time with manual segmentation
2	Segmentation of medical chest X-ray [39]	The advantage is that it is more accurate and efficient	The model is very difficult to make	It has been shown through results that the method proposed is efficient, more reliable and accurate
3	Animals brain sector [40]	Advantage is that it can handle animal brain and skull images as well as human	Limitation is that it is difficult for human brain images	Results are taken under three types of regular camera images and proposed method shows better results
4	Medical images department [41]	This method has the advantage of being very accurate and easy for the purpose of segmentation	Limitation of this method is that it has greater execution time	The method proposed is more accurate as well as fast as compared with other segmentation methods
5	Medical sector of brain images [42]	Advantage of the proposed system is that it is simple	Limitation is that execution time is greater	The results are compared with three different algorithms and show better segmentation results

recursive dilation is used for recovery of the lost data after first step. In [42] the novel based algorithm is presented for PET-CT images. First train samples are extracted and then atlas of brain is estimated for both PET –CT images. An algorithm works very well on both types of medical images that are PET-CT. A summarized comparison of Medical brain images analysis methods is shown in Table 4.

CT: In [43] an algorithm is introduced to detect the grey matter and white matter from the brain image of human beings. It follows two steps: i) a reference image is taken which is 2D image ii) the space that the skull encloses is used to determine the ROI (Region of Interest) of the reference image. Same type of work as [44] is done in [38]. The method presented in [45] is a CT image segmentation method using the concept of morphology. The method makes use of morphological filtering, multi resolution decomposition, gradient transform and hit or misses transformations. The results are very robust against the existing approaches of segmentation process. Mathematical morphology is applied on CT images in [46]; the method is CT diffusion obstruct illustration intended for generator discrepancy defense by means of mathematical morphology procedure to precisely notice the time distinction among error incidence and discrepancy present appearance moment. The results being obtained are promising in this regard.

Table 5: CT brain images analysis methods comparison

Serial N0#	Application	Advantage	Limitation	Results
1	CT brain images sector [43]	Advantage of the proposed system is that it can detect and separate the white matter and grey matter, thus easy to detect the brain	Limitation is that it does not work on noisy images	Results are validated with two existing methods, proposed method shows better results
2	CT medical images [44]	Advantage of the proposed system is that it is very accurate and efficient	Limitation is not mentioned	It has been shown through results that the method proposed delivers better and accurate outcomes as compared to other algorithms
3	CT image segmentation [45]	Has a wide range of applications	Mathematical computation	Results show that the method is superior in prospect of segmentation as compared to edge detection and thresholding processes
4	CT image morphology [46]	Simple and accurate method	-	Promising results are obtained in order to notice the time distinction among error incidence and discrepancy present appearance moment
5	CT image edge detection [47]	Can be applied to PET data as well	-	The results indicate that the method effectively outlines the edges of CT as well as PET images
6	CT image registration [50]	No restriction on quality of images	-	Results show that improved registration process is acquired
7	CT images edge detection [48]	Better edge detection method as compared to canny edge detector	Computationally complex	The results are satisfactory in regard of regions distributions through edge detection
8	Edge detection of CT images [49]	-	Computationally expensive	The results prove that the method is robust for various types of edge detection
9	CT image registration [51]	-	-	The method provides better registration method as compared to existing registration methods
10	CT image evaluation [52]	Fast and accurate system	Computationally large system	The method provides acceptable results

Edge detection approach for CT images is proposed in [47]. The method is a three step process. It initially spots edge outlines scheduled on projection statistics. After that the second step being taken in this process is to even or level noisy curves by keeping lesser classified Fourier coefficients and at last converting it to the edge outline on image. Another CT edge detection approach can be analyzed in [48]. The results are satisfactory in regard of regions distributions through edge detection. The method makes use of Least Squares Support Vector Machines process in regard of edge detection process. Similar work can be analyzed in [49]; the method is an edge detection process that initially reconstructs the original image and then carries out the process of edge detection. The edge detection process is carried out through projection data. The results prove that the method is robust for various types of edge detection and is computationally expensive. CT image registration process can be analyzed in [50]; the metod is basically a process to acquire a robust technique of handling registration for ultrasound CT images. The results showed that method is effective and does not apply any conditions on the quality of image.

CT image registration process is described in [51]. The method makes use of intensity information together with geometrical information to carry out the registration process. The method provides better registration process as compared to existing registration methods. The morphology of CT images can be analyzed in [52]. Table 5 presents a comparison of different CT brain images analysis methods.

DISCUSSION AND CONCLUSION

In the above section we discussed different methods and approaches presented in the prospect of image analysis i.e., image segmentation, edge detection, registration and motion analysis. From the above analysis we can say that huge work has been done in regard of medical image segmentation and edge detection but not much effort is carried out in the prospect of brain image registration and motion analysis. Another point to be considered is that NIRS and MEG brain types do not encompass much work in this regard. Comparison table demonstrates the effectiveness and efficiency of different methods in this prospect. It can be observed that effective and acceptable compression results are obtained by different techniques.

This paper is based on short discussion and description of various brain image analysis methods from the perspective of brain image segmentation, brain images edge detection, brain images registration, brain images morphology and brain images motion analysis. Each method or technique is discussed through its application area, advantages, limitations and overall results. The discussion showed that huge methods are working effectively and accurately in regard of brain image analysis but still there exists need for more effective and precise work.

REFERENCES

1. Christoph M. Michel and Micah M. Murray, 2011. Towards the utilization of EEG as a brain imaging tool, NeuroImage, Available online 28 December 2011, ISSN 1053-8119, 10.1016/j.neuroimage.2011.12.039.
2. Subramanyam Rallabandi, V.P. and Prasun Kumar Roy, 2010. Magnetic resonance image enhancement using stochastic resonance in Fourier domain, Magnetic Resonance Imaging, Volume 28, Issue 9, November 2010, Pages 1361-1373, ISSN 0730-725X, 10.1016/j.mri.2010.06.014.
3. Shijuan He, Xueqin Shen, Yamei Yang, Renjie He and Weili Yan, 2001. Research on MRI Brain Segmentation Algorithm with the Application in Model –Based EEG/MEG", Ieee Transactions on Magnetics, 37(5).
4. Zhen Zheng and Xie Mei, 2008. MRI Head Space-based Segmentation for Object Based Volume Visualization, Computer Science and Information Technology, 2008 ICCSIT '08 International Conference on, pp: 691-694, Aug. 29 2008-Sept. 2 2008.
5. Yezzi A. Jr., S. Kichenassamy, A. Kumar, P. Olver and A. Tannenbaum, 1997. A geometric snake model for segmentation of medical imagery, Medical Imaging, IEEE Transactions on, vol.16, no.2, pp.199-209, April 1997 doi: 10.1109/42.563665
6. David D. Sha and Jeffrey P. Sutton, 2001. Towards automated enhancement, segmentation and classification of digital brain images using networks of networks, Information Sciences, Volume 138, Issues 1–4, October 2001, Pages 45-77, ISSN 0020-0255, 10.1016/S0020-0255(01)00130-X
7. Georges B. Aboutanos, 1999. Member, IEEE, Jyrki Nikanne, Nancy Watkins and Benoit M. Dawant, Member, IEEE 'Model Creation and Deformation for the Automatic Segmentation of the Brain in MR Images' IEEE Transactions on Biomedical Engineering, 46(11):.
8. Cormier, S., N. Boujemaa, F. Tranquart and L. Pourcelot, 1999. Multimodal brain images registration with severe pathological information missing, [Engineering in Medicine and Biology, 1999. 21st Annual Conf. and the 1999 Annual Fall Meeting of the Biomedical Engineering Soc.] BMES/EMBS Conference 1999 Proceedings of the First Joint, 2(1154):
9. Zhang Xiang, Zhang Dazhi, Tian Jinwen and Liu Jian, 2002. A hybrid method for 3D segmentation of MRI brain images, Signal Processing, 2002 6th International Conference on, vol.1, no., pp: 608- 611 vol.1, 26-30 Aug. 2002
10. Zhuang Song, Nicholas Tustison, Brian Avants and James Gee, 2006. Adaptive Graph Cuts with Tissue Priors for Brain Mri Segmentation, 0-7803-9577-8/06/$20.00 ©2006 IEEE
11. Shijuan He, Xueqin Shen, Yamei Yang, Renjie He, Weili Yan, 2001. Research on MRI brain segmentation algorithm with the application in model-based EEG/MEG, Magnetics, IEEE Transactions on, 37(5): 3741-3744.
12. Yongxin Zhou and Jing Bai, 2007. Atlas-Based Fuzzy Connectedness Segmentation and Intensity Non uniformity Correction Applied to Brain MRI, Biomedical Engineering, IEEE Transactions on, 54(1); 122-129.
13. Laura Gui1, Radoslaw Lisowski2, 3, Tamara Faundez2, Petra S. H¨uppi2, Franc¸ois Lazeyras3 and Michel Kocher4, 2011. Automatic Segmentation of Newborn Brain Mri Using Mathematicalmorphology' 978-1-4244-4128-0/11/$25.00 ©2011 IEEE
14. Ruogu Fang, Y.J. Chen, R. Zabih and Tsuhan Chen, 2010. Tree-metrics graph cuts for brain MRI segmentation with tree cutting, Image Processing Workshop (WNYIPW), 2010 Western New York, vol., no., pp: 10-13, 5-5 Nov. 2010
15. Alireza Behrad and Hassan Masoumi, 2010. Automatic Spleen Segmentation in MRI Images using a Combined Neural Network and Recursive Watershed Transform, 978-1-4244-8820-9/10/$26.00 ©2010 IEEE

16. Jacob M. Agrlsl12, 1991. Student IEEE, Ruidefigueiredd, Fellow IEEE, Gilbert R. Hillmah3~1a,n d Thomas A. Kent4 'A NOVEL METHOD FOR 3D SEGMENTATION AND VOLUME ESTIMATION OF BRAIN COMPARTMENTS FROM MRI' Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Vol. 13. No. 1, 1991 CH3068-4/91/0000-006$80 1.00 6 1991 IEEE
17. Zhen Zheng and Xie Mei, 2008. MRI Head Space-based Segmentation for Object Based Volume Visualization, Computer Science and Information Technology, 2008 ICCSIT '08 International Conference on, vol., no., pp: 691-694, Aug. 29 2008-Sept. 2 2008
18. Jun Kong, Jianzhong Wang, Yinghua Lu, Jingdan Zhang, Yongli Li and Baoxue Zhang, 2006. A novel approach for segmentation of MRI brain images, Electro technical Conference, 2006. MELECON 2006 IEEE Mediterranean, vol., no., pp.525-528, 16-19 May 2006doi: 10.1109/MELCON.2006.1653154
19. Karras', D.A. and B.G. Mertzios', 2003. On Edge Detection in Mri Using the Wavelet Transform and Unsupervised Neural Networks, EC-VIP-MC 2003. 4th EURASIP Conference focused on Video I Image Processing and Multimedia Communications, 2-5 July 2003, Zagreb, Croatia
20. Rezai-Rad, G. and M. Aghababaie, 2006. Comparison of SUSAN and Sobel Edge Detection in MRI Images for Feature Extraction, Information and Communication Technologies, 2006. ICTTA '06.2nd, vol.1, no., pp.1103-1107, 0-0 0
21. Huijun Sun, Tao Lin Song Chen and Zhong Chen, 2008. Numerical Simulations of Edge Detection Effect Due to Chemical Shift Variation in Intermolecular Multiple-Quantum Coherence MRI, Proceedings of 2008 IEEE International Symposium on IT in Medicine and Education.
22. Agaian, S. and A. Almuntashri, 2009. Noise-resilient edge detection algorithm for brain MRI images, Engineering in Medicine and Biology Society, 2009. EMBC 2009 Annual International Conference of the IEEE, vol., no., pp.3689-3692, 3-6 Sept. 2009.
23. Chen, Y.W., R. Xu, S.Y Tang4, S. Morikawa and Y. Kurumi, 2007. Non-rigid MR-CT Image Registration for MR-Guided Liver Cancer Surgery, 2007 IEEE
24. Xiujuan Geng, T.J. Ross, Hong Gu, Wanyong Shin, Wang Zhan, Yi-Ping Chao, Ching-Po Lin, N. Schuff and Yihong Yang, 2011. Diffeomorphic Image Registration of Diffusion MRI Using Spherical Harmonics, Medical Imaging, IEEE Transactions on, vol. 30, no. 3, pp; 747-758, March 2011.
25. Moumen El-Melegy and Hashim Mokhtar, 2010. Fuzzy Framework for Joint Segmentation and Registration of Brain MRI with Prior Information, 78-1-4244-7042-6/10/$26.00 ©2010 IEEE
26. Rosniza Roslan, Nursuriati Jamil and Rozi Mahmud, 201. Skull Stripping of MRI Brain Images using Mathematical Morphology, IEEE 2010
27. Automatic segmentation of newborn MRI using mathematical morphology, 978-1-4244-4128-0/11/$25.00 ©2011 IEEE
28. Celka, P. and P. Colditz, 2001. Time-varying statistical complexity measures with application to EEG analysis and segmentation, Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2(1919-1922): 2.
29. Lisa Wong Waleed Abdulla, 2006. Time-frequency evaluation of segmentation methods for neonatal EEG signals, IEEE.
30. Celka, P. and P. Colditz, 2001. Time-varying statistical complexity measures with application to EEG analysis and segmentation, Engineering in Medicine and Biology Society, 2001. Proceedings of the 23rd Annual International Conference of the IEEE, 2: 1919-1922.
31. Michel, C., M. Sibomana, J.M. Bodart, C. Grandin, A. Coppens, A. Bol, A. De Volder, V. Warscotte, J.P. Thiran and B. Macq, 1995. Interactive delineation of brain sulci and their merging into functional PET images," Nuclear Science Symposium and Medical Imaging Conference Record, 1995., 1995 IEEE, vol.3, no., pp.1480-1484 vol.3, 21-28 Oct 1995 doi: 10.1109/NSSMIC.1995.500306
32. Thiran, J.P., B. Macq and C. Michel, 1996. Morphological registration of 3D medical images, Image Processing, 1996. Proceedings, International Conference on, vol.1, no., pp.253-256 vol.2, 16-19 Sep 1996 doi: 10.1109/ICIP.1996.560764
33. Koivistoinen, H., J. Tohka and U. Ruotsalainen, 2004. Comparison of pattern classification methods in segmentation of dynamic PET brain images, Signal Processing Symposium, 2004. NORSIG 2004 Proceedings of the 6th Nordic, pp: 73-76.

34. Wanlin Zhu and Tianzi Jiang, 2003. Automation segmentation of PET image for brain tumors, Nuclear Science Symposium Conference Record, 2003 IEEE, vol.4, no., pp. 2627- 2629 Vol.4, 19-25 Oct. 2003
35. Jinman Kim1,2, 2004. Student Member, IEEE, Weidong Cai1, Member, IEEE, David Feng1,2, Fellow, IEEE, Stefan Eberl1,3 Member, IEEE 'An Objective Evaluation Framework forSegmentation Techniques of Functional Positron Emission Tomography Studies'0-7803-8700-7/04/$20.00 (C) 2004 IEEE
36. Pollari, M., J. Lotjonen, T. Makela, N. Pauna, A. Reilhac and P. Clarysse, 2004. Evaluation of cardiac PET-MRI registration methods using a numerical breathing phantom, Biomedical Imaging: Nano to Macro, 2004. IEEE International Symposium on, vol., no., pp. 1447- 1450 Vol. 2, 15-18 April 2004
37. Wang Xiao, Mi Hong and Wang Wei, 2010. Inner edge detection of PET bottle opening based on the Balloon Snake, Advanced Computer Control (ICACC), 2010 2nd International Conference on, vol.4, no., pp; 56-59, 27-29 March 2010.
38. Souza, A.S.A. and E.E.S. Ruiz, 2000. Fast and accurate detection of extra ocular muscle borders using mathematical morphology, Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE, 3: 1779-1782 vol.3, 2000
39. Czerwinska, A., M. Doros and K. Kolebska, 2000. Method of segmentation of thorax organs images applied to modelling the cardiac electrical field, Engineering in Medicine and Biology Society, 2000. Proceedings of the 22nd Annual International Conference of the IEEE, 1: 402-405.
40. Vaquero, J.J., M. Desco, J. Pascau, A. Santos, I.J. Lee, J. Seidel and M.V. Green, 2000. PET and CT image registration of the rat brain and skull using the AIR algorithm, Nuclear Science Symposium Conference Record, 2000 IEEE, 3: 16/22-16/23.
41. Lixu Gu, Jianfeng Xu and T.M. Peters, 2006. Novel Multistage Three-Dimensional Medical Image Segmentation: Methodology and Validation, Information Technology in Biomedicine, IEEE Transactions on, vol.10, no.4, pp.740-748, Oct. 2006
42. Yong Xia, S. Eberl and Dagan Feng, 2010. Dual-modality 3D brain PET-CT image segmentation based on probabilistic brain atlas and classification fusion," Image Processing (ICIP), 2010 17th IEEE International Conference on, vol., no., pp: 2557-2560, 26-29 Sept. 2010
43. Qingmao Hu, Guoyu Qian, A. Aziz and W.L. Nowinski, 2006. Segmentation of brain from computed tomography head images, Engineering in Medicine and Biology Society, 2005 IEEE-EMBS 2005 27th Annual International Conference of the, vol., no., pp.3375-3378, 17-18 Jan. 2006
44. Yongjie Hu and Mei Xie, 2007. Automatic Segmentation of Brain CT Image Based on Multiplicate Features and Decision Tree, Communications, Circuits and Systems, 2007. ICCCAS 2007 International Conference on, vol., no., pp.837-840, 11-13 July 2007
45. Wei Li, V. Haese-Coat and J. Ronsin, 1996. Region segmentation of CT images using mathematical morphology, Engineering in Medicine and Biology Society, 1996. Bridging Disciplines for Biomedicine Proceedings of the 18th Annual International Conference of the IEEE, vol.3, no., pp: 1059-1061 vol.3, 31 Oct-3 Nov 1996
46. Chao Zhang, Xiangning Lin, Z. Chen, Z.Q. Bo and M.A. Redfern, 2004. A novel mathematical morphology based anti-CT saturation criterion for generator differential protection, Universities Power Engineering Conference, 2004. UPEC 2004 39th International, vol.2, no., pp. 763- 767 vol. 1, 6-8 Sept. 2004
47. Tomitani, Takehiro, 1987. An Edge Detection Algorithm for Attenuation Correction in Emission CT, Nuclear Science, IEEE Transactions on, vol.34, no.1, pp.309-312, Feb. 1987
48. Jing-Hong Liu, Yao-Dong Jiang, Yi-Xin Zhao, Jie Zhu and Yin Wang, 2009. Crack edge detection of coal CT images based on LS-SVM, Machine Learning and Cybernetics, 2009 International Conference on , vol.4, no., pp: 2398-2403, 12-15 July 2009
49. Sastry, C.S., Amit K. Mishra and Agnivesh Singh, 2009. Detection of edges in CTi mages directly from projection data, 2009 International Conference on Advances in Recent Technologies in Communication and Computing.
50. Peterhans, M., H. Talib, M.G. Linguraru, M. Styner and M.A.G. Ballester, 2008. A method for frame-by-frame us to CT registration in a joint calibration and registration framework," Biomedical Imaging: From Nano to Macro, 2008. ISBI 2008 5th IEEE International Symposium on, vol., no., pp.1131-1134, 14-17 May 2008

51. Gorbunova, V., S. Durrleman, Pechin Lo, X. Pennec and M. De Bruijne, 2010. Lung CT registration combining intensity, curves and surfaces, Biomedical Imaging: From Nano to Macro, 2010 IEEE International Symposium on, vol., no., pp: 340-343, 14-17 April 2010.

52. Blechschmidt, R.A., R. Werthschutzky and U. Lorcher, 2001. Automated CT image evaluation of the lung: a morphology-based concept, Medical Imaging, IEEE Transactions on, vol. 20, no. 5, pp: 434-442, May 2001