SEGMENTATION OF MAGNETIC RESONANCE BRAIN IMAGES USING WATERSHED ALGORITHM

By

SALEM HAMED ABDURRAHIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Partial Fulfillment of the Requirements for the Degree of Master of Science

May 2004

In the name of God, Most Gracious, Most Merciful

Dedication

To My Parents for Their Endless Support and Encouragement

To My Wife and Kids for Their Patience

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in partial fulfilment of the requirements for the Degree of Master of Science

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Chairman: Associate Professor Abd Rahman Ramli, Ph.D.

Faculty : Engineering

An important area of current research is obtaining more information about brain structure and function. Brain tissue is particularly complex structure and its segmentation is an important step for studies in temporal change, detection of morphology as well as visualization in surgical planning, volume estimation of objects of interest, and more could benefit enormously from segmentation.

Magnetic resonance imaging (MRI) is a noninvasive method for producing tomographic images of the human brain. Its Segmentation is problematic due to radio frequency inhomogeneity, caused by inaccuracies in the magnetic resonance scanner and by movement of the patient which produce intensity variation over the image, and that makes every segmentation method fail.

The aim of this work is the development of a segmentation technique for efficient and accurate segmentation of MR brain images. The proposed

technique based on the watershed algorithm, which is applied to the gradient magnitude of the MRI data. The watershed segmentation algorithm is a very powerful segmentation tool, but it also has difficulty in segmenting MR images due to noise and shading effect present. The known drawback of the watershed algorithm, over-segmentation, is strongly reduced by making the system interactive (semi-automatic), by placing markers manually in the region of interest which is the brain as well as in the background. The background markers are needed to define the external contours of the brain. The final part of the segmentation takes place once the gradient magnitudes of the MRI data are calculated and markers have been obtained from each region. Catchment's basins originate from each of the markers, resulting in a common line of separation between brain and surrounding.

The proposed segmentation technique is tested and evaluated on brain images taken from brainweb. Brainweb is maintained by the Brain Imaging Center at the Montreal Neurological Institute. The images had a combination of noise and intensity non-uniformity (INU). By making the system semi-automatic, a good segmentation result was obtained under all the conditions (different noise levels and intensity non uniformity). It is also proven that the placement of internal and external markers into regions of interest (i.e. making the system interactive) can easily cope with the over-segmentation problem of the watershed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGSEGMENAN PENGIMEJAN RESONANS MAGNETIK BAGI OTAK DENGAN MENGGUNAKAN KAEDAH 'TAKUNGAN AIR' ALGORITMA

Oleh

SALEM HAMED ABDURRAHIM

Mei 2004

Pengerusi: Profesor Madya Abd Rahman Ramli, Ph.D.

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Tujuan utama kajian ini ialah untuk mendapatkan maklumat terperinci berkaitan struktur dan fungsi otak. Tisu otak secara khususnya merupakan satu struktur yang kompleks dan kaedah pengsegmenan merupakan langkah utama dalam proses mengkaji perubahan masa, mengesan morfology, gambaran bagi rancangan pembedahan, jangkaan kekerapan bagi objek yang diperhatikan dan pelbagai faedah lain yang boleh diperolehi daripada proses pengsegmenan.

Pengimejan Resonans Magnetik atau (Magnetic Resonance Imaging (MRI)) merupakan suatu kaedah dalam menghasilkan imej – imej tomografik bagi otak manusia. Namun, proses pengsegmenan tidak dapat dilakukan sekiranya terdapat frekuensi radio yang tidak homogen yang disebabkan oleh ketidakjituan alat pengimbas resonan magnetik (MRI) serta pergerakan pesakit yang boleh menyebabkan pelbagai pergerakan terhasil di dalam imej seterusnya menggagalkan proses pengsegmenan.

Tujuan utama tesis ini antara lain bertujuan untuk membangunkan satu teknik pengsegmenan imej MRI otak agar lebih efisien dan tepat. Teknik yang dicadangkan adalah berdasarkan teknik “takungan air”, di mana ia digunakan untuk magnitud gradien bagi data MR.

Kaedah pembiasan takungan air merupakan kaedah pembiasan yang paling berjaya. Namun ianya juga mempunyai kelemahan, antaranya kesukaran dalam membuat pengsegmenan imej MR jika terdapat bunyi bising dan kehadiran bayangan. Halangan lain yang dikenalpasti dihadapi oleh kaedah takungan air ialah lebihan proses pengsegmenan Lebihan yang berlaku dapat diatasi dengan mengurangkan lebihan tersebut menggunakan sistem interaktif separa automatik di mana penanda diletakkan di kawasan yang berkaitan di belakang kepala .

Teknik pengimejan yang dicadangkan dalam tesis ini telah diuji dan dinilai ke atas imej otak dan teknik ini juga boleh didapati dari laman web “ brainweb”. “Brainweb” dihasilkan oleh Pusat Pengimejan Otak “Brain Imaging Center” di Institut Neurological Montreal (Montreal Neurological Institute). Sesuatu imej yang diperolehi tidak seratus peratus jelas dan terdapat sedikit bintik dan paparan imej yang tidak seragam (Intensity Non–Uniformity). Ianya juga membuktikan bahawa penetapan penanda dalaman dan luaran pada titik tumpuan menggunakan teknik sistem interaktif boleh mengatasi dengan mudah masalah pengimejan berlebihan yang berlaku dalam proses “takungan air”.

ACKNOWLEGMENTS

First of all I would like to express my utmost thanks and gratitude to Almighty Allah S.W.T for giving me the ability to finish this thesis successfully.

I would like to take this opportunity to express my gratitude and thanks to my supervisor and chairman of the supervisory committee Dr. Abd Rahman Ramli. He has helped me at every stage of this work and he gave me the motivation and inspiration at all times. He has always been very understanding, compassionate, encouraging and helpful to me and always keeping me focused.

I am also thankful to Puan Roslizah and Mr. Syed Abdul Rahman for helping me in all ways that a student could be helped to complete the work. I am grateful to all the Faculty members of the department of Computer and Communication Systems for helping me have a better understanding of various subjects of computer engineering.

And in this occasion, if I do not express my thankfulness to my family, that would be doing the greatest injustice to them. They kept giving me their blessings, encouragement, and endless patience when it was most needed.

And obviously I would like to thank all my Multimedia and Imaging Laboratory colleagues for being very supportive and helpful.

I certify that an Examination Committee met on 20th May 2004 to conduct the final examination of Salem Hamed Abdurrahim on his Master of Science thesis entitled "Segmentation of Magnetic Resonance Brain Images using Watershed Algorithm" in accordance with universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for the quotation and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

SALEM HAMED ABDURRAHIM

Date:

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LIST OF ABBREVIATIONS

2D	**:**	Two Dimension
3D	**:**	Three Dimension
CAT	**:**	Computerized Axial Tomography
CT	**:**	Computed Tomography
CB	**:**	Catchments Basin
CCL	**:**	Connected Component Labeling
INU	**:**	Intensity Non Uniformity
MM	**:**	Mathematical Morphology
MS	**:**	Multiple Sclerosis
MRI	**:**	Magnetic Resonance Imaging
NEX	**:**	Number of Excitations
PET	**:**	Positron Emission Tomography
PVE	**:**	Partial Volume Effect
RF	**:**	Radio Frequency
ROI	**:**	Region of Interest
SE	**:**	Shading Effect

CHAPTER 1

INTRODUCTION

1.1 Background

Segmentation is to partition an image into a number of non-overlapping regions that form a complete tessellation of the image plane. A wide range of work has been undertaken to achieve this aim and segmentation has found a diverse applications ranging from medical to military uses. In many image-processing tasks, segmentation is an important step toward the analysis phase. It allows quantification and visualization of object of interest.

The segmentation of medical images in 2D, slice by slice, or directly in the 3D voxel dataset, has many useful applications for the medical professional: visualization and volume estimation of objects of interest, detection of abnormalities (e.g. tumours, polyps, etc.), tissue quantification and classification, and more. Also, technical advantages can result from segmenting (or isolating) anatomical structures; for example the optimization of the rendering process for virtual colonoscopy by segmenting the colon from the original dataset. It is also used to improve visualization of medical imagery and allow quantitative measurements of image structures, segmentations are also valuable in building anatomical atlases, researching shapes of anatomical structures, and tracking anatomical changes over time.

Many segmentation methods have been proposed in literature but no one has been widely accepted in order to be used as a general method in clinics

Thresholding (Sahoo ,et al.,1988) techniques are based on the postulate that all pixels whose value lie within a certain range belongs to one class, such methods neglect all of the spatial information of the image and this causes it to be sensitive to noise and intensity inhomogenities which occur in MRI, both these artifacts essentially corrupt the histogram of the image making separation more difficult (Zheng, et al, 2000; Dzung, et al, 1998; O'Donnell L., 2001).

Boundary based methods are sometimes called edge detection because they assume that pixel values change rapidly at boundaries between two regions the high values of this filter provide candidates for region boundaries which must then be modified to produce close curves representing the boundaries between regions (Dzung, et al, 1998; O'Donnell L., 2001)

Region based segmentation algorithms postulate that neighboring pixels within the same region have similar intensity values of which the split and merge (Horowitz and Pavlidis, 1974) technique is probably the most known. In general procedure is to compare a pixel with its immediate surrounding neighbors if a criterion of homogeneity is satisfied, the pixel can be classified into the same class as one or more of its neighbors. The choice of homogeneity criterion is therefore critical to the success of the segmentation. Region growing can also be sensitive to noise causing extracted regions to have holes or even become disconnected. Conversely, partial volume effects can cause separate regions to become disconnected (Dzung, et al, 1998).

The watershed is guaranteed to produce close boundaries even if the transitions between regions are of variable strength or sharpness. However, it encounters difficulties with images in which regions are both noisy and have blurred or indistinct boundaries (Dzung, et al, 1998).

1.2. Problem statement

Image segmentation methods were extensively reviewed by many researchers in the field (Clarke et al, 1995). They concluded that segmentation is a difficult task and still a subject of on going investigation and cannot be conclusively stated that the segmentation problem has been solved. Also fully automatic segmentation of medical images procedure is far from satisfying in many realistic situations. Merely when the intensity or structure of the object differs significantly from the surroundings, segmentation is obvious in all other situations, manual tracing of the object boundaries by an expert seems to be the only ‘valid truth’, but it is undoubtedly a very time-consuming task and it is difficult to receive reproducible results due to operator fatigue (Kuhne et al, 1996).

Magnetic resonance imaging (MRI) is a noninvasive method for producing tomographic images of the human body. Segmentation of MRI is problematic due to radio frequency inhomogeneity (image intensity variation) caused by inaccuracies in the magnetic resonance scanner and by movement of the patient.

The watershed transform is the method of choice for image segmentation (Vincent and Soille, 1991). Any gray scale image can be thought of as a topographic relief, the grayscale value of a pixels being the altitude at that particular point.

This method is powerful in simple situations, but generally fail in real life complicated images. This is due to the fact that, even after regularization, the number of local minima is generally larger than the number of objects (or number of regions), resulting in an over-segmentation problem which remains difficult to solve.

The method that is adapted in this thesis was suggested by researchers in the field of medical image processing: it consists in renouncing fully automatic image segmentation in favor of semi-automatic image segmentation, with a very limited amount of user interaction (Zijdenbos and Dawant, 1995; Cabral, 1993).

1.3. Research objective

- To identify of key problems with traditional image segmentation algorithms in general, as well as specifically for medical applications.
- To develop a semi-automatic segmentation technique for efficient and accurate segmentation of magnetic resonance images (MRI) of the human brain
- To overcome the drawback of the watershed segmentation algorithm. Which is over-segmentation

The goals of the development of automated segmentation of MRI more practical by placing manual outlining without a measurable effect on results, reducing operator time, and improve reproducibility.

MRI is most of the time full of noise and shading effect, which reduces the performance of every segmentation algorithm. The aim were to devise a system in which the user would be able to specify the desired segment class through the intuitive visual initialization, for the purpose of placing the seed, followed by an automatic segmentation process requiring no further interaction.

1.4. Thesis organization

This chapter provides an introduction, motivation for the research project described in this thesis and describe how the theses is organized