UNIVERSITI PUTRA MALAYSIA

TUMOR EXTRACTION FOR BRAIN MAGNETIC RESONANCE IMAGING USING MODIFIED GAUSSIAN DISTRIBUTION

QUSSAY ABBAS SALIH AL-BADRI.

TUMOR EXTRACTION FOR BRAIN MAGNETIC RESONANCE IMAGING USING MODIFIED GAUSSIAN DISTRIBUTION

By

QUSSAY ABBAS SALIH AL-BADRI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

January 2006

DEDICATION

In the name of God, Most Gracious, Most Merciful

Dedication to

This thesis is dedicated to my parents, and my brothers who have always been with me all the time, for all the sacrifices they made to help me reach this point.

My Parents,

Professor Dr. Abbas Salih Al-Badri

Professor Dr. Layla Abd Al-Wahab

My Brothers,

Oday, Ghaith, Meis, and the rest of my family

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

TUMOR EXTRACTION FOR BRAIN MAGNETIC RESONANCE IMAGING USING MODIFIED GAUSSIAN DISTRIBUTION

By

QUSSAY ABBAS SALIH AL-BADRI

January 2006

Chairman: Associate Professor Abdul Rahman Ramli, PhD

Faculty : Engineering

Magnetic Resonance Imaging (MRI) is extensively used in the study of brain. Segmentation of MR brain images is necessary for a number of clinical investigations of various complexity, change detection, cortical labeling, and visualization in surgical planning. The volume of enhancing lesions, following the administration of paramagnetic contrast agent is an important indicator of pathology in multiple sclerosis (MS). Manual estimation of enhancing lesion volumes introduces significant errors, and operator bias, besides being time consuming and subjective. Therefore, there is a need for automatic identification and estimation of volumes of the present MS lesions specially by dealing with a large number of images that are typically acquired in multi-center clinical trials.

In the developed techniques, 150 T1- and T2-weighted spin echo images were taken from the routine scans of Kuala Lumpur General Hospital.

Multiple sclerosis lesions visualized by morphological MRI are classified through a feature map technique on T1 weighted MRI tissue. Gray level morphology methods are used to make tissue types in the images more homogenous and minimize difficulties with connections to outside tissue. A method for fuzzy connectedness and combinations of the different segmentation techniques were experimented. A gain-based correction method; probability density function model are used to cluster white and gray matters, cerebrospinal fluid, and meninges. Results of segmentation have been validated by a group of neuro-radiologists.

3D visualization has been implemented for the segmented regions as well as brain lesion. The visualization of the segmented structures uses a combination of volume rendering and surface rendering.

The mutual information algorithms used in this work has been developed and experimented in the system and has proven to yield more accurate and stable results than other algorithms.

Currently testing the validation of the proposed segmentation in a validation study that compares resulting MS lesion as well as gray and white matter tissue structures with Neural Network expert segmentation system. The proposed method versus Neural Network rater validation showed an average validation score of overlap ratio of >85% for gray and white matters tissue segmentation and for MS lesion the rater validation showed an average overlap ratio of > 87%.

Abstrak tesis yang dikemukakan Senat Universisti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor of Falsafah

PENYARIAN TUMUR UNTUK RESONANS MAGNETIK PENGIMEJAN OTAK PENGUBAHSUAIAN DENGAN TABURAN GAUSSIAN

Oleh

QUSSAY ABBAS SALIH AL-BADRI

Januari 2006

Pengerusi: Profesor Madya Abdul Rahman Ramli, PhD

Fakulti : Kejuruteraan

Kaedah Pengimejan Resonans Magnetik atau (MRI) digunakan secara meluas di dalam bidang kajian otak. Segmentasi imej otak MR diperlukan untuk siasatan klinikal bagi pelbagai kerumitan, dan pengesanan pertukaran, pelabelan kortikal, dan visualisasi perancangan pembedahan. Jumlah pertambahan *lesion*, berikutan pentadbiran ejen kontras paramagnetic merupakan petunjuk penting bagi patologi berbilang sklerosis (MS). Jumlah *lesion* yang bertambah yang dianggarkan secara manual memperlihatkan ralat yang ketara, kecenderungan operator, mengambil masa serta subjektif. Oleh itu, identifikasi secara automatik dan anggaran jumlah pertambahan *lesion* dalam MS adalah perlu terutamanya apabila menguruskan sejumlah besar imej yang lazimnya diambil dalam percubaan klinikal di pelbagai tempat.

Dalam teknik yang dibangunkan ini, lebih daripada 150 imej *T1-and-T2-weighted spin echo* diambil dari imbas rutin di Hospital Besar Kuala Lumpur.

Penambahan bukan-*lesion* menerusi pemetaan kebarangkalian fungsi ketumpatan yang digambarkan oleh morfologikal MRI, diklasifikasikan menerusi teknik pemetaan sifat, dan ke atas tisu berpemberat *T1* MRI. Kaedah morfologi tahap kelabu digunakan supaya jenis tisu lebih seragam, selain mengurangkan kesulitan dengan tisu luar. Kombinasi kaedah penambahan tersebut dengan teknik segmentasi berbeza dieksperimentasi. Kaedah perolehan berdasarkan pembetulan dipilih; model fungsi kebarangkalian ketumpatan digunakan untuk mengelompok bahan-bahan putih dan kelabu, cecair *cerebrospinal* dan *meninges*. Keputusan segmentasi disahkan oleh ahli neuro-radiologi.

Visualisasi 3D dilaksanakan untuk segmentasi bahagian dan *lesion* otak. visualisasi struktur segmen tersebut menggunakan kombinasi terjemahan jumlah dan terjemahan permukaan.

Algoritma informasi bersama yang digunakan dalam kerja ini telah dibangunkan dan dieksperimen di dalam sistem ini dan terbukti kesahihan dan ketepatannya berbanding dengan algoritma yang lain.

Kesahihan ketepatan segmentasi yang dicadangkan dalam perbandingan *MS lesion* terutamanya dalam tahap kelabu dan putih tisu struktur menggunakan rangkaian neural sistem segmentasi. Kaedah yang dicadangkan dibandingkan antara rangkaian neural menunjukkan purata kebolehpercayaan dalam nisbah > 85% untuk tahap kelabu dan putih tisu struktur serta *MS lesion* menunjukkan purata nisbah > 87%.

ACKNOWLEDGEMENTS

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.

The author gratefully wish to express his profound appreciation and gratitude to his supervisor, Associate Professor Dr. Abdul Rahman Ramli, for his supervision, guidance, supporting, and constructive suggestion and comments throughout the duration of the project until it turns to real success.

The author also indebted to the members of his supervisory committee, Associate Professor Dr. Rozi Mahmud and Dr. Rahmita Wirza, for their affectionate guidance, prompt decision and valuable assistance during this period.

Appreciation also to the assistance rendered by the respective lecturers, staffs, technicians of the faculty of engineering for providing the facilities required for undertaking this project.

The author would like to thank his family for the encouragement and support without which is impossible for the success of this project, specially my lovely wife Suzan A. Tahir which she stand supporting me all the way until the end of my study and my friends, for offering helps and supports all the time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MRI	Magnetic Resonance Imaging
NMR	Nuclear Magnetic Resonance
CT	Computerized Tomography
PET	Positron Emission Tomography
FMRI	functional Magnetic Resonance Imaging
SPECT	Single Photon Emission Computed Tomography
RF	Radio Frequency
CSF	Cerebrospinal Fluid
MPT	Moment Preserving Thresholding
ML	Maximum Likelihood
KNN	Nearest Neighborhood (*kNN*)
EM	Expectation Maximization
MAP	Maximum-A-Posterior
SE	Spin Echo
TSE	Turbo Spin Echo)
FOV	Field of View
PDF	Probability Density Function
PCMR	Phase Contrast MR
PV	Partial Volume
MLE	Maximum Likelihood Estimation
ROI	Regions-of-Interests

UPMMC	University Putra Malaysia Medical Center
MOS	Mean Opinion Score

CHAPTER I

INTRODUCTION

Recently radiologists can review images of several cross sections of a brain and abdomen. Some times, they required to make 3D reconstruction in order to make a clinical diagnosis or to evaluate the results of a therapy on a patient. In recent years, the interdisciplinary field of medical image processing has produced several automatic and semi-automatic tools to assist medical practitioners and researchers. For instance, tools for 3D visualization of anatomy (i.e. reconstruction and rendering) used in surgical planning as well as educational purposes, are available in several hospitals and research laboratories.

The validations of automatically anatomical structures models are frequently non-rigid and exhibit substantial morphological variation from subject to subject. Hence the task of segmenting these structures from medical images is one of the difficulties to identify a region in an image with only approximate knowledge of its shape, size, gray level appearance, and spatial location. Different segmentation applications are available to add some knowledge in each of these categories, and the challenge is to combine them to overcome lack of information in one category is offset by the information in the others. In this thesis, methodology for segmentation of brain tissue of MRI and MS lesion will be studied. By applying a series of combined techniques that exploit gray level, topological and spatial information in the brain images will be discussed.

The specific techniques used are probability of density function segmentation for an intensity based correction and classification of the data. Where it combined with a binary and grayscale morphology and connectivity for incorporation of relative topological information. Four steps have been implemented where the segmentation of the brain divided base on the brain structure intensity and statistical distribution of the tissues.

The goals of medical image processing include increased automation of the existing tools that have proven useful to the medical community yet still require assistance from experts.

1.1 The Brain Segmentation Problem

Segmentation is an important step in most medical image analysis. In many classification processes, segmentation forms the first step. The applications of segmentation include diagnosis, evaluation and treatment of the disease. Since manual segmentation is tedious, time consuming and subjective, attempts have been made to automatically classify and quantify tissues, organs, and disease states from images obtained by various medical imaging modalities.

Segmentation of medical images is a challenging task due to the complexity of the images and the absence of models of anatomy that fully capture the possible deformities in each structure. Due to the relative low signal to noise ratios and inherent artifacts generally present in medical images, their segmentation is particularly difficult. Because of these problems, even though many algorithms have been reported, most of them have inconsistent results and limited applications. Thus, only a few algorithms are being used in practice.

No other imaging modality has witnessed the explosive growth and development that Magnetic Resonance Imaging (MRI) has over the past 10 years. Once labeled NMR, for Nuclear Magnetic Resonance imaging, the nuclear term has been removed due to its negative connotations among the general public. Using a combination of the inherent magnetic resonance properties of tissue and application of radio frequency pulses, MRI obtains images by measuring various tissue characteristics. The result of frequency information is converted, using Fourier Transform techniques, to spatial intensity information of slices through the body. These slices can be integrated using advanced computer graphics techniques to produce 3D views of the imaged tissues.

MRI is extensively used in brain studies, that it is an advanced medical imaging technique providing rich information about the anatomy of human soft tissue.

Brain tissue is a particularly complex structure, and its segmentation is an important step for derivation of computerized anatomical atlases, as well as pre-and intra-operative guidance for therapeutic intervention.

MRI segmentation has been proposed for a number of clinical investigations of varying complexity. Measurements of tumor volume and its response to therapy have used image grayscale methods as applied to X-Ray Computerized Tomography (CT) or simple MRI datasets (Cline et al, 1987). However, the differentiation of tissues within tumors that have similar MRI characteristics such as edema, necrotic or scar tissue have proven to be important in the evaluation of response to therapy. Hence, multi-spectral methods have been proposed (Vannier el at, 1991; Clarke, et al, 1993). Recently, multi-modality approaches, such as Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) studies using radiotracers (Tjuvajev et al, 1994), or contrast materials (Tjuvajev et al, 1994; Buchbinder et al, 1991) have been suggested to provide superior tumor tissue specification and to identify active tumor tissue. Hence, segmentation methods need to include these additional image data sets. In the same context, a similar progression of segmentation methods is evolving for the planning of surgical procedures primarily in neurological investigations (Hill et al, 1993; Zhang, 1990; Cline et al, 1987), surgery simulations (Hu et al, 1990; Kamada et al, 1993) or the actual implementation of surgery in the operating suite where both normal tissues and the localization of the lesion or mass needs to be accurately identified.

The methods proposed include grayscale image segmentation and multi-spectral segmentation for anatomical images with additional recent efforts directed toward the mapping of functional metrics fMRI to provide locations of important functional regions of the brain as required for optimal surgical planning.