THE COMPARISON OF IMAGE MANIFOLD METHOD AND VOLUME ESTIMATION METHOD IN CONSTRUCTING 3D BRAIN TUMOR IMAGE

SHAMSHIYATULBAQIYAH BINTI ABDUL WAHAB

UNIVERSITI TEKNOLOGI MALAYSIA

THE COMPARISON OF IMAGE MANIFOLD METHOD AND VOLUME ESTIMATION METHOD IN CONSTRUCTING 3D BRAIN TUMOR IMAGE

SHAMSHIYATULBAQIYAH BINTI ABDUL WAHAB

A thesis submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Science (Mathematics)

Faculty of Science
Universiti Teknologi Malaysia

OCTOBER 2014

To my beloved family and the person who loves me,

Thanks for your love and support…

ACKNOWLEDGEMENTS

Bismillahirrahmanirrahim. In the name of Allah, The Most Greatest and Most Merciful. Praise Upon the Beloved Prophet, His Family and Companion. There is no power except by the power of Allah and I humbly return my acknowledgement that all knowledge belong to Allah. Alhamdulillah, I thank Allah for granting me this opportunity to broaden my knowledge in this field. Nothing is possible unless He made it possible.

First and foremost I would like to express my deepest appreciation to my supervisor, Associate Professor Dr. Norma bt Alias for her enthusiastic guidance, invaluable help, encouragement and patient for all aspect during this dissertation progress. Her numerous comments, criticism and suggestion during the preparation of this dissertation are gratefully praised.

I wish to express my thanks to Cik Maizatul Nadirah bt Mustaffa and Encik Mahardhika Candra Prasetyahadi who actually work tirelessly and patiently to guide me the most how to work with *MATLAB* software and 3D Image Slicer software until the completion of this thesis.

I acknowledge, appreciate, and return the love and support of my family, without whom I would be lost. To my father, Hj. Abdul Wahab bin Ibrahim and my mother, Hjh. Pauziah bt Natak, thank you very much for your continuous support. I also would like to express my thanks to my beloved siblings which gives me moral support through-out this dissertation.

Last but not least, thanks a lot to all my beloved friends. Your kindness and helps will be a great memory for me.

ABSTRACT

Three dimensional (3D) image visualization is one of the important processes that extract information from the given two dimensional (2D) images. This study deals with the 3D object visualization via 2D images that included difference surfaces. The main objective of this work is to combine the contour of the brain tumor in 2D Magnetic Resonance Imaging (MRI) slices and reconstruct the 3D object. The fundamental research is based on the Alternating Operating Splitting and Geodesic Active Contour methods where these methods are used to detect the contour on a brain tumor MRI image. To combine these contours, we will apply Image Manifold method by using 3D Slicer Software and to calculate the volume of the 3D image, we will apply Volume Estimation method by using MATLAB. The objective of this study is to investigate the performance evaluation of some numerical methods for constructing 3D image and estimating the volume of the image. The obtained results indicate a good resolution of the reconstruction 3D image visualization process.

ABSTRAK

Visualisasi tiga dimensi (3D) imej adalah salah satu proses penting bagi mendapatkan maklumat daripada dua dimensi (2D) imej. Tujuan penyelidikan ini adalah untuk menghasilkan objek 3D melalui imej 2D yang terdiri daripada pelbagai permukaan yang berbeza. Objektif utama kajian ini adalah untuk menggabungkan kontur tumor otak dalam bentuk 2D Pengimejan Resonans Magnet (MRI) dan membina objek 3D. Penyelidikan asas adalah berdasarkan kaedah Pemisahan Pembekal Semi-implisit dan Kontur Aktif Geodesic di mana kaedah ini digunakan untuk mengesan kontur pada imej MRI tumor otak. Untuk menggabungkan kontur ini, kami akan mengaplikasi gabungan imej dengan menggunakan Perisian 3D Slicer dan untuk mengira jumlah isipadu imej 3D, kami akan mangaplikasi kaedah penganggaran isipadu dengan menggunakan MATLAB. Objektif projek ini adalah untuk membandingkan prestasi beberapa kaedah berangka bagi membina imej 3D dan menganggarkan jumlah isipadu imej. Keputusan yang diperolehi dapat menunjukkan resolusi yang baik dalam proses pembinaan imej 3D.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

2D	-	Two dimensional
3D	-	Three dimensional
ACM	-	Active Contour Method
AOS	-	Additive Operator Splitting
IBVP	-	Initial Boundary Value Problem
IM	-	Image Manifold
GAC	-	Geodesic Active Contour
LSE	-	Linear System of Equation
VE	-	Volume Estimation

LIST OF SYMBOLS

β	Weighted of energy
∇	Gradient operator
Ω	Image domain
ρ	Acceleration parameter
g	Stopping function
v	Positive constant
τ	Time
k	Number of iterations
D	The distance function
α	The initial scaling factor
Δs	The smoothing parameter
ϕ (x, y, z)	Distance function
V_g	Volume of manifold
I_σ	Initial image
g (x, y, z)	Edge indicator
K_ϕ	Curvature operator

LIST OF APPENDIXES

CHAPTER 1

INTRODUCTION

1.1 Introduction

A brain tumor is a growth of abnormal cells and normal cells in an inappropriate place in the brain. Clinically, magnetic resonance imaging (MRI) is widely used for brain tumor detection. MRI is a medical imaging technique and used in radiology to investigate the anatomy and function of the body in both health and disease. MRI scanners use a strong magnetic fields and radio waves to form images of the body in two dimensional images (2D).

Based on the segmentation of 2D brain tumor images, early *diagnosis* and *treatment* of *brain tumor become inaccurate prediction. It is because 2D images do not present the overall natural tumor images in 3D visualization. In this project, we will prove that the* 2D MRI images can be used to construct 3D image by using two different methods. Visualisation of 3D image will gives significant information of the tumour growth, feature and property. The function of image visualization is very important for diagnosis and treatments process. The significant potential of 3D visualization remains undiscovered and undeveloped completely. Thus, 3D

visualisation becomes an important area of researcher to provide a new tool, devices, procedures, propose an accurate diagnosis and recommends a treatments strategy.

This project will propose two different numerical methods of 3D image construction. The methods are Image Manifold (IM) and Volume Estimation (VE). IM method describes an approach of 3D model reconstruction from 2D MRI image. The construction will be from three points of view; front view, side view and top view of 2D MRI images. All of these can be done using 3D Slicer software. VE method is an automatic procedure of calculation region of brain tumor in 2D MRI images and this method was proposed by K. Krechetova *et al*, 2008. In this project, we will use the VE method to construct 3D images by using a few 2D MRI images which is from the various size of brain tumor images visualization. IM and VE methods will provide the practical improvements to the reliability of medical diagnosis process by constructing the 3D visualization of brain tumor.

1.2 Background of the Problem

One of the problems in constructing 3D image is we need to join the contour of 2D MRI images. In order to get the contour of 2D images, we need to apply the result from previous study in Active Contour Model.

From the previous study, Rosdiana Shahril, 2010, has introduced GAC model based on Additive Operator Splitting (AOS). AOS scheme is used to detect the edges of brain tumor on 2D MRI images. Gauss Seidel method is used as a numerical solution of the matrix system and the numerical result obtained were in terms of time execution, number of iterations, root mean square error, accuracy, rate of convergence, and computational cost.

The result obtained was the edge detection on brain tumor 2D MRI images. The figures below show the result of edge detection from the previous study.

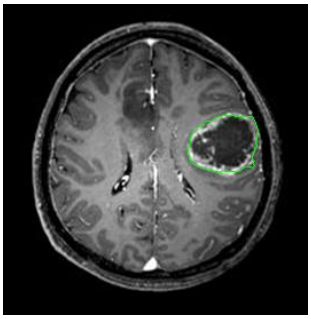

Figure 1.1 : 2D MRI brain image with edge detection

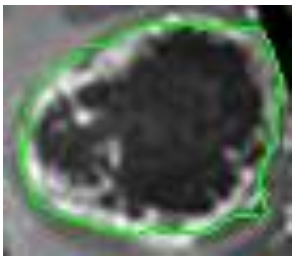

Figure 1.2 : Enlargement of the edge detection from Figure 1.1

Figure 1.1 shows 2D MRI brain image with edge detection and Figure 1.2 shows the selected area of brain tumor image obtained by the previous study. In this work, we will extend this result from 2D MRI brain tumor images to 3D visualization by implementing IM and VE methods.

1.3 Statement of the Problem

This study is to investigate the enhancement of 2D brain tumor image (MRI) based on GAC and AOS methodology. The enhancement process from 2D to 3D image visualization will be obtained by implementing IM and VE methods. The study will focus on the performance comparison between IM and VE methods to visual 3D brain tumor images in terms of volume calculation and the quality of 3D visualization quality.

1.4 Objective of the Research

The objectives of this study are:

i. To apply the edge detection method of 2D MRI brain tumor image based on AOS technique in constructing 3D image.

ii. To construct high resolution of the 3D images using IM and VE methods based on (i).

iii. To implement (ii) using 3D Slicer Software and MATLAB version R2011.

iv. To analyse the numerical performance in (iii) using the comparison of volume calculation between IM and VE methods.

1.5 Scope of the Research

The scope of research will focus on constructing 3D brain tumor image and calculating the volume of the brain tumor by using IM and VE methods. The solution for IM method can be done by using 3D Slicer software while VE method can be done in MATLAB version R2011a. The application of AOS modelling in detecting the contour of 2D MRI image for both IM and VE methods will be considered. This experiment will be applied to real MRI brain tumor images of a patient from Hospital Kubang Kerian, Kelantan.

1.5.1 The Chart of the Research Scope

The Figure 1.3 shows the flow chart of research scope. The research scope is based on the rounded rectangles with the yellow colour. This project will be started on detecting the edges of brain tumor by integrating GAC model and AOS scheme. This experiment will be applied to brain tumor on the real 2D MRI images of a patient from Hospital Kubang Kerian, Kelantan. The digital results of edge detection in 2D images will be used to construct the 3D brain tumor images by using IM and VE methods. The algorithm will be run on MatlabR2011a and 3D Slicer software. Finally, the performance comparison between IM and VE methods will provide the alternative method to visualize high resolution of 3D brain tumor images. The performance evaluation will be focused on the expected volume size and visualization quality.

1.6 Significance of Study

This project expecting a successful application of GAC and AOS strategies to obtain the edge detection of 2D images. The selected contour line of 2D MRI brain tumor images will be used to construct the 3D image by applying the IM and VE methods. Based on the comparison of numerical performance of IM and VE methods, the significance of the project will assume that IM is better than VE in terms of visualization. Finally, the result of this project is significance to enhance the medical images to *3D visualization* of *medical imaging* since the methods have an interesting application in reconstructing a high resolution of 3D medical images.

1.7 Thesis Organization

This thesis consists of six chapters. Chapter 1 describes the introduction of AOS model. In this chapter, we presented the result from previous study, introducing IM and VE methods under consideration, objectives, scope, and significance of the research.

Chapter 2 focuses on the literature review of previous studies related to constructing 3D images and also IM and VE methods. We also describe the use and application of GAC method and AOS scheme in constructing 3D image.

In Chapter 3, we will discuss the methodology for GAC-AOS scheme and also IM and VE method.

In Chapter 4, we will describe the implementation of IM method in constructing 3D image based on the edge detection of 2D brain tumor MRI images. We will perform this method by using 3D Slicer software.

In Chapter 5, we will describe the implementation of VE method to join the 2D images and calculate the volume of the 3D image. We will perform this method in Matlab programming.

In Chapter 6, we will analyse the results based on the expected volume calculation obtained by both methods. We will also make a comparison of the performance between the two methods. In this chapter, we also state the conclusions of this research based on the results that are shown in Chapter 4 and Chapter 5 and relate them with our objectives in Chapter 1.

In Chapter 7, we summarize the whole work and provide some suggestions and recommendations for the future researchers.

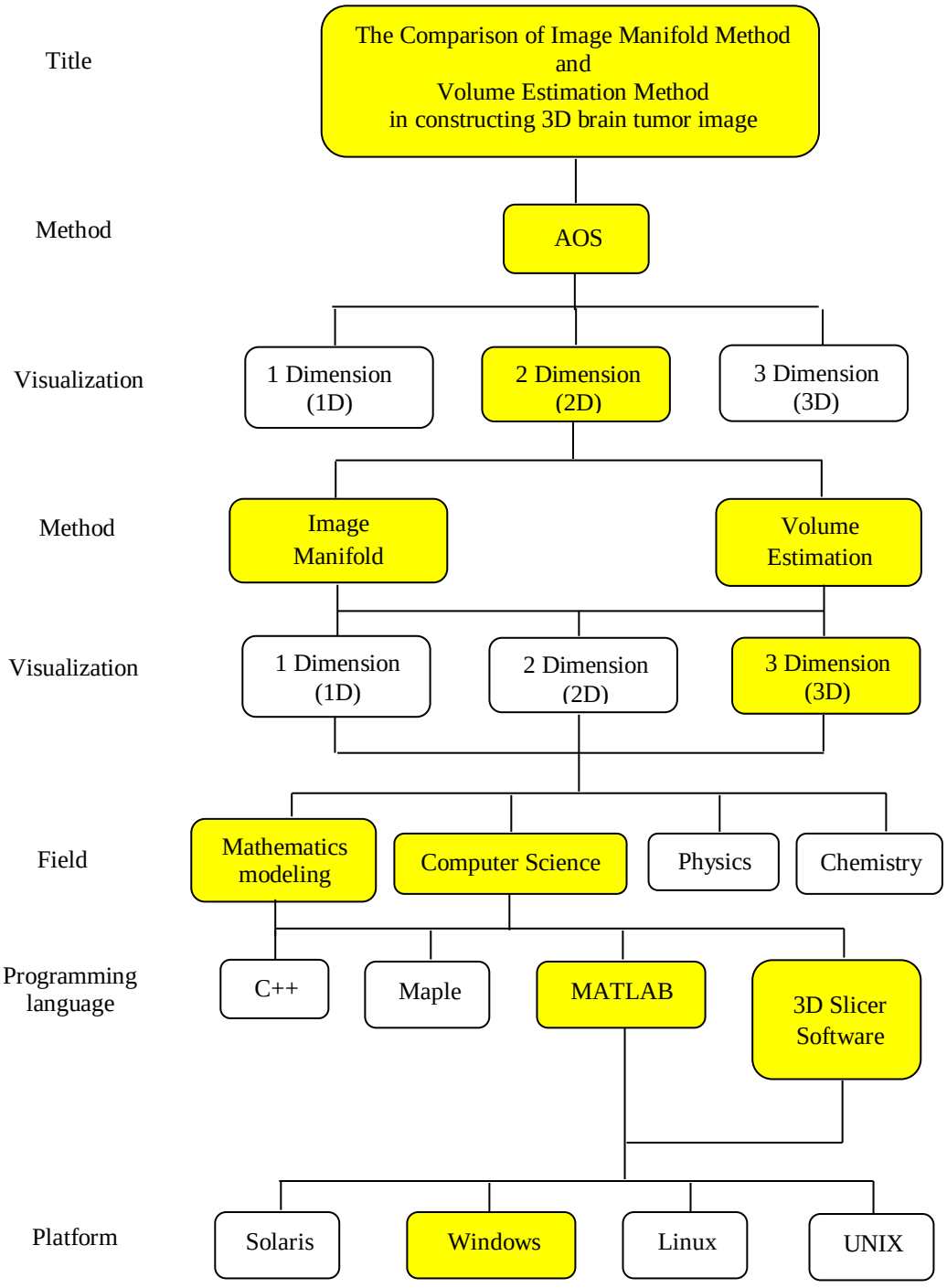

Figure 1.3: The chart of research scope in constructing 3D brain tumor image.

REFERENCES

A. Bardera et al. (2009). *Image Segmentation Using Access Entropy*. Journal Signal Processing Systems, vol.54, no.1-3, pp 205-214.

A. Sisojevs and A. *Glazs.Volume Estimation of 3D Object Modelled By Parametrical Iso-Surfaces*. Conference "Biomedical Engineering"

Antoine Rosset et al. (2004). *OsiriX: An Open Source Software for Navigating in Multidimensional DICOM Images*. Journal of Digital Imaging, vol.17, no.3, pp 205-216.

Bjourn Hamre (1998). *Three-dimensional Image Registration of Magnetic Resonance (MRI) Head Volumes*. Thesis.

C. Liu, J. Ma, and G. Ye (2007). *Medical Image Segmentation by Geodesic Active Contour Incorporating Region Statistical Information*. Fourth International Conference on Fuzzy System and Knowledge Discovery FKSD, vol. 3, pp. 63-67.

Carlos Albarola et al. (2000). *A Collaborative Environment for Medical Images Analysis and Visualization*. Medical Image Computing and Computer-Assisted Intervention (MICCAI 2000), Third International Conference, Pittsburgh, Pennsylvania, USA, pp 814-823, 2000.

Che Rahim, C. T. (2009). *Numerical Method: Algorithm and Matlab Programming*. Third Edition. Johor: Universiti Teknologi Malaysia.

Christian Wachinger, Mehmet Yigitsoy, Erik-Jan Rijkhorst and Nassir Navab. *Manifold Learning for Image-Based Breathing Gating in Ultrasound and MRI*. Medical Image Analysis 16 (2012) 806–818.

D. Krishnan, P. Lin and X.-C. Tai. *An Efficient Operator-Splitting Method for Noise Removal in Images*. Communications In Computational Physics. Vol. 1, No. 5, Pp. 847-858.

G. M. Clarke et al. (2012). *3D Pathology Volumetric Technique: A Method for Calculating Breast Tumour Volume from Whole-Mount Serial Section Images*. International Journal of Breast Cancer Volume 2012, Article ID 691205, 9 pages.

Goldenberg, R., Kimmel, R., Rivlin, E., and Rudzsky, M. (2001). *Fast Geodesic Active Contours*. IEEE Transaction on Image Processing. 10 (10), 1467-1475.

Guy Rosman, Lorina Dascal, Xue-Cheng Tai and Ron Kimmel. *On Semi-implicit Splitting Schemes for the Beltrami Color Image Filtering*. J. Math Imaging Visual (2011) 40: 199–213.

Han, Z., and Liu, X. (2010). *An Additive Operator Splitting Method for Microscopic Image Segmentation*. IEEE Transaction on Image Processing.

Hunt., Lipsman, R. L., and Rosenberg, J. M. (2001). *A Guide To MATLAB for Beginners and Experienced Users*. First Edition. United States of America. Cambridge University Press.

J.A. Sethian (1999). *Level Set Methods: Evolving Interfaces in Geometry, Fluid Mechanics, Computer Vision and Materials Sciences*. Second Ed. Cambridge Univ. Press, Univ. of California, Berkeley.

Joachim Weickert (2000). *Efficient Image Segmentation Using Partial Differential Equations And Morphology*. Journal of Pattern Recognition.

J.West, J.B.M. Warntjes and P.Lundberg (2011). *Novel Whole Brain Segmentation and Volume Estimation Using Quantitative MRI*. Journal European Society of Radiology 2011.

K. Krechetova, A. Glaz and A. Platkajis (2008). *3D Medical Image Visualization and Volume Estimation of Pathology Zones*. (Eds.): NBC 2008, Proceedings 20, pp. 532–535

Kitara Kadhim Al-Shayeh and Muzhir Shaban Al-Ani (2009). *Efficient 3D Object Visualization via 2D Images*. Journal of Computer Science and Network Security, vol.9 no.11

Kuhne, G., Weickert, J., Beir, M., and Effelsberg, W. (2002). Fast Implicit Active Contour Models. In Proceedings of the 24th DAGM Symposium on Pattern Recognition. Springer-Verlag, 133-140.

Kuleshov A.P. and Bernstein A.V. *Tangent Bundle Manifold Learning for Image Analysis*. Sixth International Conference on Machine Vision (ICMV 2013), Proc. of SPIE Vol. 9067, 906720.

Manuel Ferre et al. (2007). *3D Image Visualization and Its Performance in Teleoperation*. HCI International Conference (HCII 2007), Peking, China.

Martin Grochulla (2007). *Additive Operator Splitting*. Seminar Numerical Algorithms for Image Analysis.

R. Kimmel (2002). *3D Shape Reconstruction from Autostereograms and Stereo*. J. Visual Comm. and Image Representation, vol. 13, pp. 324-333.

R. Malladi and J.A. Sethian (1995). *Image Processing via Level Set Curvature Flow*. Proc. Nat'l Academy of Sciences of the USA, vol. 92, pp. 7046-7050.

R. Malladi and J.A. Sethian (1996). *Image Processing: Flows under Min/Max Curvature and Mean Curvature*. Graphical Models and Image Processing, vol. 58, no. 2, pp. 127-141.

R. Malladi and J.A. Sethian (1998). *A Real-Time Algorithm for Medical Shape Recovery*. Proc. IEEE Int'l Conf. Computer Vision, pp. 304-310.

R. Malladi and J.A. Sethian (2000). *Subjective Surfaces: A Geometric Model for Boundary Completion*. International Journal of Computer Vision 46(3), 201–22.

Rosdiana, S. (2010). *Two Dimensional Active Contour Model on Multigrids For Edge Detection of Images.* Master of Science, Universiti Teknologi Malaysia, Skudai.

Stephen M. Pizer, et al.(2003). *Deformable M-Reps for 3D Medical Image Segmentation*. International Journal of Computer Vision 55(2/3), pp58-106, Kluwer Academic Publishers, Netherland.

Sun K. Yoo et al. (2006). *3D Visualization for Tele-medicine Visualization*. The International Conference on Computational Science and Applications (ICCSA 2006**)**, LNCS 3980, Glasgow, UK, pp 335-345.

T. Deschamps (2001). *Curve and Shape Extraction with Minimal Path and Level - Sets Technique - Applications to 3D Medical Imaging*. PhD thesis, Universite´ Paris-IX Dauphine.

T. Deschamps (2004). *Fast Evolution of Image Manifolds and Application to Filtering and Segmentation in 3D Medical Images*. IEEE Transactions on Visualization and Computer Graphics, Vol.10, No.5.

T. Lu, P. Neittaanm ki, and X. C. Tai (1991). *A parallel Splitting Up Method and its Application to Navier Stokes Equation*. Applied Mathematics Letters., vol. 4, no. 2, pp. 25-29.

Q. Zhang et al.(2007). *Rapid Voxel Classification Methodology for Interactive 3D Medical Images Visualization*. The 10th International Conference on Medical Image Computing and Computer Assisted Intervention, in Brisbane, Australia, pp 86-93, 2007.

V. Caselles, R. Kimmel, and G. Sapiro (1997). *Geodesic Active Contour*. International Journal of Computer Vision., vol. 22, no. 1, pp. 61-79..

Weickert, J., Ter Haar Romeny, B. M., and Viergever, M. A. (1998). *Efficient and Reliable Schemes for Nonlinear Diffusion Filtering*. IEEE Transactions on Image Processing.7 (3), 398-410.

Xin Shu, Xiao-Jun Wu. *A Novel Contour Descriptor For 2D Shape Matching and Its Application to Image Retrieval*. Image and Vision Computing 29 (2011) 286–294.

Yongjie Zhang, Thomas J.R. Hughes and Chandrajit L. Bajaj. *An Automatic 3D Mesh Generation Method for Domains with Multiple Materials*. Computer Methods Application Mechanical Engineering. 199 (2010) 405–415.

Zawanah, M.Z. (2013). *Alternating Group Explicit Method For Edge Detection On Brain And Breast Tumour Images*. Master of Science, Universiti Teknologi Malaysia, Skudai.