CHARACTERISING BRAIN STRUCTURES USING FRACTAL ANALYSIS FOR HUFFAZ GROUP

BY

IQBAL BIN JAMALUDIN

A thesis submitted in fulfilment of the requirement for the degree of Doctor of Philosophy in Health Sciences

Kulliyyah of Allied Health Sciences
International Islamic University Malaysia

JUNE 2020

ABSTRACT

Memorising the holy Quran has been the motivation for most Muslims due to the advantages that it offers, in this life and the hereafter. The robust process of memorising the holy Quran is expected to cause changes in the brain regions which is associated with the memory encoding, storage, and retrieval capacity. The main areas in the brain that are involved with memory encoding, storage, and retrieval capacity are the amygdala, hippocampus, cerebellum, and prefrontal cortex. At the moment, the analysis of neuroplasticity is limited to be analysed in binary image because gray-scale analysis requires the usage of more robust image processing techniques. Therefore, this study aims to investigate and characterise the complexity of textual memorisation brain structures using fractal analysis between huffaz and non-huffaz by means of global box-counting analysis, global FFD analysis, and VOI-based analysis. The study recruited 47 participants (mean±SD age, 22.55±1.472 years) from students of IIUM Kuantan Campus. Huffaz group had their 18 months of memorisation training at Darul Quran, Kuala Kubu Bharu, Selangor. The brain MRI images were acquired before being pre-processed using Voxel-Based Morphometry (VBM) toolboxes with MATLAB as platform. Processed images were then thresholded with three thresholding techniques to find the best thresholding method; Otsu, midpoint and hysteresis. Otsu method was proven to be the best thresholding technique (mean±SD, 2.3801±0.953) with a significant difference ($p<0.01$) tested with ANOVA. Global box-counting and FFD analysis were conducted on the brain MRI images concurrently with VBM to find out the possible brain regions with neuroplasticity. Both analyses found no significant statistical difference between brains of huffaz and non-huffaz ($p>0.05$), with VBM analysis also could not find any activated voxel brain regions. VOI-based analysis found nine significant areas ($p<0.05$); two for box-counting analysis (angular gyrus and medial temporal gyrus), six for FFD analysis (BA20, BA30, anterior cingulate, fusiform gyrus, inferior temporal gyrus and frontal lobe), and only a single area (BA33) have shown significant volume differences between huffaz and non-huffaz using VOI-based analysis. BA20 is part of the temporal cortex in the brain, BA30 is located at isthmus of the cingulate gyrus, while BA33 is located at the anterior cingulate gyrus of the brain cortex. All these Brodmann areas involve heavily in memory encoding, memory storage, and retrieval capacity of humans. The results have highlighted the sensitivity of VOI-based analysis because of its local analysis, as compared to the global analysis by box-counting and FFD. These findings have shown that brain neuroplasticity was managed to be detected using VOI-based analysis, and that neuroplasticity due to memorisation process occurred by involving multiple brain areas and regions, and not solely on a single area or a region. To conclude, the application of ability of fractal analysis has been proven to detect structural changes occurrence in brains of huffaz as compared to non-huffaz.

خلاصة البحث

حفظ القرآن الكريم غاية معظم المسلمين لما له من منافع في هذه الدنيا والآخرة. تسبب العملية النشطة لحفظ القرآن الكريم، كما هو متوقع، في إحداث تغييرات في مناطق الدماغ المرتبطة بسعة ترميز وتخزين واسترجاع الذاكرة. مناطق الدماغ الرئيسية المسؤولة عن ترميز وتخزين واسترجاع الذاكرة هي: اللوزة، الحصين، المخيخ، والقشرة الجبهية الأمامية. يقتصر تحليل المرونة العصبية حاليا على تحليلها كصور ثنائية لأن التحليل على تدرج رمادي يتطلب استخدام تقنية معالجة صورية أكثر قوة. ولذلك هدفت هذه الدراسة إلى توصيف والتحقيق في مدى تعقيد الحفظ النصي لتراكيب الدماغ باستخدام التحليل الكسري بين المشاركين الحفاظ وغير الحفاظ بواسطة تحليل عد الصناديق العام، وتحليل FFD العام، والتحليل المبني على VOI. أشركت الدراسة 47 شخصا (المتوسط±الانحراف المعياري للعمر، 22.55±1.472 سنة) من طلاب الجامعة الإسلامية العالمية الماليزية بمدينة كوانتان. تلقت مجموعة الحفاظ تدريب الحفظ لمدة 18 شهرًا من في معهد دار القرآن في كوالا كوبو بارو بولاية سيلانجور. تم مسبقا الحصول على صور التصوير بالرنين المغناطيسي للدماغ قبل معالجتها باستخدام أدوات قياس الأشكال المعتمدة على فوكسل (VBM) وبواسطة MATLAB كمنصة. ثم تم تحديد عتبة الصور المعالَجة بثلاثة طرق للعثور على أفضل طريقة لتحديد العتبة وهي: أوتسو، ونقطة المنتصف، والتباطؤ. أثبتت طريقة أوتسو أنها أفضل تقنية لتحديد العتبة (2.3801±0.953) مع اختلاف ملحوظ ($p<0.01$) تم اختباره بواسطة ANOVA. تم إجراء عد الصناديق العام وتحليل FFD العام على صور الرنين المغناطيسي في الدماغ بالتزامن مع VBM للعثور على مناطق الدماغ المرنة عصبيا. لم يجد كلا التحليلين اختلافًا إحصائيًا كبيرًا بين أدمغة الحفاظ وأدمغة غير الحفاظ ($p>0.05$)، لم يعثر تحليل VBM أيضًا على أي منطقة دماغية فوكسلية نشطة. وجد التحليل المبني على VOI تسعة مناطق مهمة ($p<0.05$)؛ اثنان لتحليل عد الصناديق العام (التلفيف الزاوي والتلفيف الصدغي الإنسي)، وستة لتحليل FFD (BA20، و BA30، والحزامية الأمامية، والتلفيف المغزلي، والتلف الصدغي السفلي، والفص الجبهي)، وكان هناك منطقة واحدة فقط (BA33) ذات اختلاف كبير في الحجم بين الحفاظ وغير الحفاظ باستخدام التحليل المبني على VOI. BA20 هو جزء من القشرة الصدعية في الدماغ، أما BA30 فيقع في برزخ التلفيف الحزامي، ويقع BA33 في التلفيف الحزامي الأمامي لقشرة الدماغ. تشارك جميع مناطق برودمان هذه بشكل كبير في ترميز وتخزين واسترجاع الذاكرة في البشر. سلطت النتائج الضوء على حساسية التحليل المبني على VOI بسبب التحليل المحلي المستعمل وذلك مقارنة بالتحليل العام لعد الصناديق وFFD. أشارت هذه النتائج إلى إمكانية الكشف عن المرونة العصبية في الدماغ باستخدام التحليل المبني على VOI، وأن المرونة العصبية الناتجة عن عملية الحفظ تحدث في مناطق متعددة في الدماغ، وليس فقط في منطقة واحدة. في الختام تم إثبات قدرة تطبيق التحليل الكسري على الكشف عن حدوث التغيرات الهيكلية في أدمغة الحفاظ مقارنة بأدمغة غير الحفاظ.

APPROVAL PAGE

The thesis of Iqbal bin Jamaludin has been approved by the following:

_____
Assoc. Prof. Dr. Mohd. Zulfaezal Che Azemin
Supervisor

_____
Asst. Prof. Dr. Mohd Izzuddin Mohd Tamrin
Co-Supervisor

_____
Assoc. Prof. Dr. Akram Mohammed Zeki Khedher
Internal Examiner

_____
Prof. Dr. Md. Iqbal Saripan
External Examiner

_____
Assoc. Prof. Dr. Ahmad Nazlim Yusuf
External Examiner

_____
Assoc. Prof. Dr. Radhiana Hassan
Chairman

DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Iqbal bin Jamaludin

Signature ..... Date .....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

CHARACTERISING BRAIN STRUCTURES USING FRACTAL ANALYSIS FOR HUFFAZ GROUP

I declare that the copyright holders of this dissertation are jointly owned by the student and IIUM.

Copyright © 2020 Iqbal bin Jamaludin and International Islamic University Malaysia. All rights reserved.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below

1. Any material contained in or derived from this unpublished research may be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make and transmit copies (print or electronic) for institutional and academic purposes.

3. The IIUM library will have the right to make, store in a retrieved system and supply copies of this unpublished research if requested by other universities and research libraries.

By signing this form, I acknowledged that I have read and understand the IIUM Intellectual Property Right and Commercialisation policy.

Affirmed by Iqbal bin Jamaludin

……..…….. ……..
Signature Date

ACKNOWLEDGEMENT

Bismillahirrahmannirrahim. Praise and thanks to The Almighty Allah S.W.T for blessing me with strength, grit and determination to finish the research for my PhD thesis. Undertaking this PhD has been a truly life-challenging experience for me, and it would not have been possible to complete without the support and guidance that I received from many people.

I would like to express my countless gratitude to my supervisor, Assoc. Prof. Dr. Mohd. Zulfaezal Che Azemin and co-supervisor, Asst. Prof. Dr. Mohd Izzuddin Mohd Tamrin for their advice, beneficial and constructive comments, patience, and kindness through this whole time guiding me without fail. Sincere thanks are also extended to Assoc. Prof. Dr. Radhiana Hassan for helping me with radiological procedures and allowing me an access to the MRI suite.

I shall thank all the lecturers and staffs from Diagnostic Imaging and Radiotherapy Department (DDIR), especially Br. Abdul Halim Sapuan for helping me with pre-processing procedures, Br. Mohd. Radzuan Md. Noor for image conversion assistance, Assoc. Prof. Dr. Sayed Inayatullah Shah as Head of Department for constantly checking up on me, as well as other lecturers and staffs from Kulliyyah of Allied Health Sciences (KAHS) IIUM, and Department of Radiology from IIUM Medical Centre for your time and kind assistance during data acquisition in your facility. Not to forget Azmir, Azri, Baddrul, Yusri, Hazman, Dr. Zafri, Fadzil, Zairul, Amin, Arshad, Azuwan, Dr. Lokman, Dr. Kamil and many whom I do not mention here, for your continuous support throughout this four year.

Also, sincere thanks to the Ministry of Education (MoE) Malaysia for their continuous financial support.

Lastly, my special appreciation would be to my both parents, my late father Jamaludin bin Dahalan and Hamidah binti Harun, my wife Faizah bin Sapian, Ihsan Faris, Irdina Faqihah, Irham Fariq, siblings, mother in-law and my family for always believe and being thoughtful for every single thing I have done to complete this journey. Millions of thanks for their untold commitment, continuous support and understanding throughout my PhD journey. May each and every single person who involves in this journey, directly or indirectly, is granted with His blessings for this life and hereafter.

Thank you.

TABLE OF CONTENTS

Abstract ii
Abstract in Arabic iii
Approval page iv
Declaration v
Copyright Page vi
Acknowledgement vii
Table of Contents viii
List of Tables xi
List of Figures xii
List of Equations xiv
List of Symbols / SI Units xv
List of Abbreviations xvi

CHAPTER ONE: INTRODUCTION 1
1.1 Background Of The Study 1
1.2 Statement Of The Problem 2
1.3 Motivation Of The Study 3
1.4 Research Questions 4
1.5 Research Objectives 4
1.5.1 General Objective 4
1.5.2 Specific Objectives 4
1.6 Significance Of The Study 5
1.7 Scope Of The Research 6
1.8 Summary Of Methodology 7
1.9 Outline Of The Thesis 7
1.10 Chapter Summary 9

CHAPTER TWO: LITERATURE REVIEW 10
2.1 Introduction 10
2.2 Brain Imaging 11
2.3 Magnetic Resonance Imaging (Mri) 13
2.4 Human Memory 15
2.4.1 Types Of Memory 15
2.4.2 Memorisation Process 17
2.5 Brodmann Area And Its Functions 20
2.6 Huffaz And Memorisation 24
2.7 Brain And Neuroplasticity 26
2.8 Fractal Analysis 30
2.8.1 Application Of Fractal Analysis In Neuroscience 32
2.8.2 Box-Counting (Bc) Fractal Dimension 33
2.8.3 Fourier Fractal Dimension (Ffd) 36
2.9 Chapter Summary And Research Gaps 38

CHAPTER THREE: GENERAL METHODOLOGY 41
3.1 Introduction 41

3.2 Demographic Data And Subjects Characteristics 42
3.3 Ethical Approval 44
3.4 Iq Test 44
3.5 Equipments And Materials 46
3.6 Mri Imaging Protocols 47
3.7 Image Format Conversion 51
3.8 Pre-Processing Steps 52
3.8.1 Realignment Process 52
3.8.2 Segmentation Process 54
3.8.3 Spatial Normalisation Process 55
3.8.4 Smoothing Process 56
3.9 Total Gray Matter (Tgm) Volume Calculation 59
3.10 General Linear Model (Glm) Analyisis 59
3.11 Chapter Summary 60

CHAPTER FOUR: EXPERIMENTS AND RESULTS 62
4.1 Introduction 62
4.2 Evaluation Of Thresholding Techniques 63
4.2.1 Otsu Method 65
4.2.2 Midpoint Method 66
4.2.3 Hysteresis Method 66
4.2.4 Fractal Dimension (Fd) Measurement 67
4.2.5 Statistical Analysis 68
4.2.6 Results 68
4.3 Global Binary Analysis On Brain Structures 74
4.3.1 Structural Brain Images Realignment, Segmentation And Normalisation. 76
4.3.2 Thresholding Technique 77
4.3.3 Fractal Dimension (Fd) Measurement 77
4.3.4 2d Fractal Dimension 78
4.3.5 3d Fractal Dimension 78
4.3.6 Voxel-Based Morphometry Analysis By Statistical Parametric Mapping 12 80
4.3.7 Statistical Analysis 80
4.3.8 Results From Global 2d Fd And 3d Fd 80
4.3.9 Results From Vbm Analysis 81
4.4 Global Grayscale Analysis On Brain Structures 81
4.4.1 Global Ffd Analysis 82
4.4.2 Result From Vbm Analysis 83
4.4.3 Results From Global Ffd Analysis 83
4.5 Volume Of Interest (Voi)-Based Analysis On Brain Structures 83
4.5.1 Results For Voi-Based Analysis 88
4.6 Chapter Summary 89

CHAPTER FIVE:DISCUSSION 90
5.1 Introduction 90
5.2 Discussion On Thresholding Techniques 90
5.3 Discussion On Global Binary Analysis 92
5.4 Discussion On Global Gray Scale Analysis 94

5.5 Discussion On Voi-Based Analysis 97

CHAPTER SIX:CONCLUSION 104
6.1 Conclusion And Implications Of The Study 104
6.2 Recommendation For Future Study 106

REFERENCES 108

APPENDIX A: LIST OF PUBLICATIONS AND PRESENTATIONS 127
APPENDIX B: CONSENT FORM 128
APPENDIX C: INFORMATION SHEET 129
APPENDIX D: DEMOGRAPHIC DATA 131
APPENDIX E: MRI PATIENT SAFETY SCREENING FORM 133
APPENDIX F: KPGRC APPROVAL LETTER 135
APPENDIX G: IREC APPROVAL LETTER 136
APPENDIX H: SPSS RESULTS 138

LIST OF TABLES

Table No.		Page No
2.1	Memory functions and their Brodmann areas	24
2.2	Summary of findings from previous literature	39
3.1	Demographic data between huffaz and non-huffaz group	42
4.1	Mean score for IQ test	62
4.2	Summary of FD Values based on Thresholding Techniques	68
4.3	Post-hoc Pair-wise Comparison Test for Different Thresholding Techniques	69
4.4	Two-sample t-test between global 2D FD and 3D FD Box-counting technique	80
4.5	Two-sample t-test of global FFD technique between huffaz and non-huffaz	83
4.6	Classes of VOI masking by TD and their respective anatomical structures	85
4.7	Two-sample t-test of VOI-based analysis between huffaz and non-huffaz	88

LIST OF FIGURES

Figure No.		Page No.
1.1	Scope of the research activities using Fractal Dimension	6
2.1	MRI system schematic diagram	14
2.2	Brodmann area	20
2.3	Earlier application of fractal analysis on the coast of Britain	31
2.4	Measurement of coast of Britain using Fractal Analysis	31
2.5	Calculation of box-counting fractal dimension from the regressed slope	34
2.6	Box-counting fractal dimension	35
2.7	Fourier Fractal Dimension application	37
3.1	Head coil used for imaging of the brain	47
3.2	MRI console system	49
3.3	Realignment of the images to centre at the anterior commissure	53
3.4	Segmentation of brain MRI images into gray matter (GM), white matter (WM) and cerebrospinal fluid (CSF)	54
3.5	Flowchart of pre-processing steps for brain MRI images	58
3.6	Flowchart of methodology used in this study	61
4.1	The thresholding used to convert a) gray scale image b) into binary image, improving the details of the text on the image	64
4.2	Bland-Altman plot for Otsu vs Midpoint	70
4.3	Bland-Altman plot for Hysteresis vs Midpoint	71
4.4	Bland-Altman plot for Otsu vs Hysteresis	72
4.5 A	Normal brain MRI image without any thresholding technique applied	73
4.5 B	Otsu’s method	73
4.5 C	Midpoint method	73

4.5 D	Hysteresis method	73
4.6	Slices of brain images by SPM12	77
4.7	Box-Counting Method for 2D FD	78
4.8	The steps for global 3D box-counting FD quantification	79
4.9	The flowchart of VOI-based analysis with masking	87

LIST OF EQUATIONS

Equation		Page No.
2.1	Box-counting FD equation	34
2.2	Fourier Fractal Dimension equation	36
3.1	Sample size equation	42
3.2	Full-Width Half-Maximum equation	56
3.3	Total Gray Matter Volume equation	59
4.1	Thresholding equation	63
4.2	Global Fourier Fractal Dimension equation	82

LIST OF SYMBOLS / SI UNITS

cm	Centimetre
mm	Millimetre
µm	Micrometre
ms	Milliseconds
mT/m	Millitesla per Metre
T/m/s	Tesla per Metre per Second

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
4G	4th Generation
ALS	Amyotrophic Lateral Sclerosis
ANOVA	Analysis of Variance
ATI	Array Technology Inc
BA	Brodmann Area
BA20	Brodmann Area 20
BA30	Brodmann Area 30
BA33	Brodmann Area 33
BC	Box-Counting
CAD	Computer Aided Design
CSF	CerebroSpinal Fluid
CT	Computed Tomography
DARTEL	Diffeomorphic Anatomical Registration Through Exponentiated Lie
DICOM	Digital Imaging and Communications in Medicine
DTI	Diffusion Tensor Imaging
FA	Fractal Analysis
FD	Fractal Dimension
FFD	Fourier Fractal Dimension
FWE	Family Wise Error
FWHM	Full Width-Half Maximum
FOV	Field-of-View
GHz	GigaHertz
GLM	General Linear Model
GM	Gray Matter
HD	Hard Disk
i.e.	id est
IIUM	International Islamic University Malaysia
IREC	IIUM Research Ethical Committee
IQ	Intelligent Quotient
KAHS	Kulliyyah of Allied Health Sciences
KPGRC	Kulliyyah PostGraduate and Research Committee
LTM	Long-Term Memory
MATLAB	Matrix Laboratory
MB	Megabytes

MNI	Montreal Neurological Institute
MPRAGE	Magnetisation-Prepared Rapid Gradient Echo
MRI	Magnetic Resonance Imaging
MTL	Medial Temporal Lobe
NEMA	The National Electrical Manufacturers Association
NIfTI	Neuroimaging Informatics Technology Initiative
PET/CT	Positron Emission Tomography/Computerised Tomography
RF	Radio-Frequency
SAR	Specific Absorbtion Rate
SD	Standard Deviation
SNR	Signal-to-Noise Ratio
SPM	Statistical Parametric Mapping
STM	Short-Term Memory
TD	Talairach Daemon
TIM	Total Imaging Matrix
UIAM	Universiti Islam Antarabangsa Malaysia
VBM	Voxel-Based Morphometry
VOI	Volume-of-Interest
WAIS	Weschler Adult Intelligent Scale
WFU	Wake Forest University
WM	White Matter

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The advancement of technology in medical imaging grows rapidly nowadays. Current medical imaging modalities which was scarce 30 years ago such as Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), are almost easily accessible nowadays. With the availability of modern medical imaging modalities, quality of services provided to the patients in term of radiological services and procedures have increased, leading to the inclining quality of life for human. Advanced medical imaging modalities such as CT and MRI have proven to be the heart of radiological services, providing better radiological images which not only help radiologists to diagnose the disease better, but also predicting the manifestation of the pathology in earlier stage. However, due to the total reliance for visual diagnosis of the radiological images by the radiologists, the time taken for the diagnosis to be made may be compromised, leading to longer decision management for the patient. The timing for diagnosis can be further cut down with the usage of Computer Aided Design (CAD) software such as Voxel-Based Morphometry (VBM) and Fractal Analysis (FA) (Farahibozorg et al., 2015). This software will help the radiologists to make a diagnosis decision based on the algorithm setting depending on the pixels and voxels appearance on the radiological images, reducing their time for visual and manual diagnosis of the radiological images.

FA has been extensively used in clinical and medical fields (Di Ieva et al., 2015). Since its development by Mandelbrot, (1983), FA is capable of representing an estimation of morphological complexity including the brain structure (Liu et al., 2003;

Squarcina et al., 2015; & Zhang et al., 2006). However, the lack of application of FA in characterizing brain structure as compared to its application in detecting pathologies in the brain as well as measuring the impact of aging to the brain. This study intends to evaluate the effectiveness of FA application in measuring the possible increase of plasticity within the brain cortex for huffaz (people who memorise the holy Quran). The study hypothesized that the brain of huffaz is expected to establish increase in plasticity and gray matter volume due to robust process of memorizing the Quran.

Previous study conducted to study the neuroplasticity caused by working memory mostly on ball jugglers (Draganski et al., 2004), medical students (Draganski et al., 2006), professional athletes (Macnamara et al., 2014), musicians (Suárez, Elangovan, & Au, 2016), taxi driver (Maguire et al., 2000) and Vedic scriptures memoriser (Hartzell et al., 2016; Kalamangalam & Ellmore, 2014). Most of these previous studies were conducted using VBM method to analyse the possible plasticity occurrence in the brain cortex. Recent finding by Hartzell et al., (2016) found a notable increase in gray matter and cortical thickness in visual, memory and language region on the Pandit (people who memorise the Vedic Sanskrit Books) brains. They measured and calculated the gray matter and cortical thickness using a well-established VBM method. From this basis, the study of the textual memorization brain structure for huffaz was conducted, with analysis and measurement done using FA application.

1.2 STATEMENT OF THE PROBLEM

Currently, there are few textural measures being used to characterize the textual memorization brain structures especially the gray matter. The well-established existing technique to assess the gray matter is VBM (Ashburner & Friston, 2001; Ashburner & Friston, 2000a; Whitwell, 2009). VBM has been vastly used not only for detecting the

pathological appearance (Good et al., 2001) but also for studying the neuroplasticity and brain changes related to working memory as discussed earlier. The aforementioned research works mostly analysed the brain structure using VBM technique (Jednoróg et al., 2015). VBM is an objective and well-established neuroimaging analysis tool for identifying brain morphological alteration in normal and diseased people. As the term implies, it examines the local composition for different brain tissue types on a voxel-by-voxel basis analysis. Another more recent technique is based on complexity measure using fractal analysis technique (Hashemi-Golpayegani et al., 2013; Squarcina et al., 2015). Among applications of FA are on both macroscopic (i.e. anatomic) and microscopic (i.e. histological) images as well as high-resolution radiological imaging (i.e. MRI) (Esteban et al., 2007). Apart from disease detection and measuring the aging effect, FA is also capable of estimating the topological complexity of an object (Di Ieva et al., 2013).

On the other hand, Koch et al., (2016) stated that VBM managed to measure the increased plasticity of the brain structures due to extensive learning. In their study, they detected neuroplasticity changes for the brain that undergoes continuous activity dependent. Hence, since the application of FA especially in studying the textual memorisation and possible increased of brain structure plasticity due to memorisation process is still lacking (Hartzell et al., 2016), this study is conducted in intention to fill such gap.

1.3 MOTIVATION OF THE STUDY

The role of FA in clinical application has caught an attention across a number of researchers in recent years. Albeit with the presence of quite a number of researches on its application in clinical and medical fields, there is still lack of discussion and new

information regarding the effectiveness of FA in analyzing textual memorisation brain structures of huffaz.

To date, the application of FA in textual memorisation has still not been extensively investigated yet. Therefore, this research sought to identify and locate the possible brain areas that underwent neuroplasticity changes due to memorisation process, by using the FA.

1.4 RESEARCH QUESTIONS

1. Which is the best thresholding techniques for binary conversion of gray scale MRI images between Otsu, midpoint and hysteresis techniques?
2. What are the Brodmann areas detected to be significant between huffaz and non-huffaz by using binary analysis?
3. How many Brodmann areas that differ between huffaz and non-huffaz can be detected when analysis using gray scale being conducted?
4. Which Brodmann areas that differ in volume between huffaz and non-huffaz when analysis using VOI-based being performed?

1.5 RESEARCH OBJECTIVES

1.5.1 General Objective

To study the textual memorization brain structure using fractal analysis between huffaz and non-huffaz groups.

1.5.2 Specific Objectives

1. To explore the effects of three different thresholding techniques (Otsu, midpoint and hysteresis) used on MRI images.

2. To identify specific brain areas that have significant changes due to memorization process according to Brodmann Area by using global binary complexity analysis.

3. To determine Brodmann areas affected by memorization process using global gray-scale complexity analysis.

4. To quantify the volume on brain structures between huffaz and non-huffaz in relation to neuroplasticity changes due to memorisation.

1.6 SIGNIFICANCE OF THE STUDY

The importance and originality of this study are that it explores the usage of regional fractal analysis in binary and gray-scale images. By providing the findings from this study, it makes important contribution to the society and medical imaging field by promoting the availability and efficacy of using fractal analysis in helping the radiologist making decision, apart from the current visual diagnosis practice by them.

In general, this study contributes to the recent continuous researches of fractal analysis in mapping and locating the abnormalities in the MRI brain images. Apart from that, this study shows not only fractal analysis is sensitive to detect abnormalities, but it also capable of finding the neuroplasticity dynamics due to memorisation process. This finding is believed to be able to fill the gap in both previous and future literature, as well as providing an exciting opportunity to increase the understanding of fractal analysis methodology and effects.

On the other hand, the subjects used for this study were match with age, gender, IQ level and academic background. The method used in this study can serve as initiation factor for future interest in examining the consequences of memorisation process on the brain.

1.7 SCOPE OF THE RESEARCH

Prior commencement of the main study, the brain images were acquired using MRI, and pre-processed using Statistical Parametric Mapping (SPM) under MATLAB platform. The images were then being analysed using General Linear Model by VBM, 2D and 3D Box-Counting Fractal Dimension, 3D Fourier Fractal Dimension and VOI-based analysis. Figure 1.1 summarises the overall experimental research scope and activities.

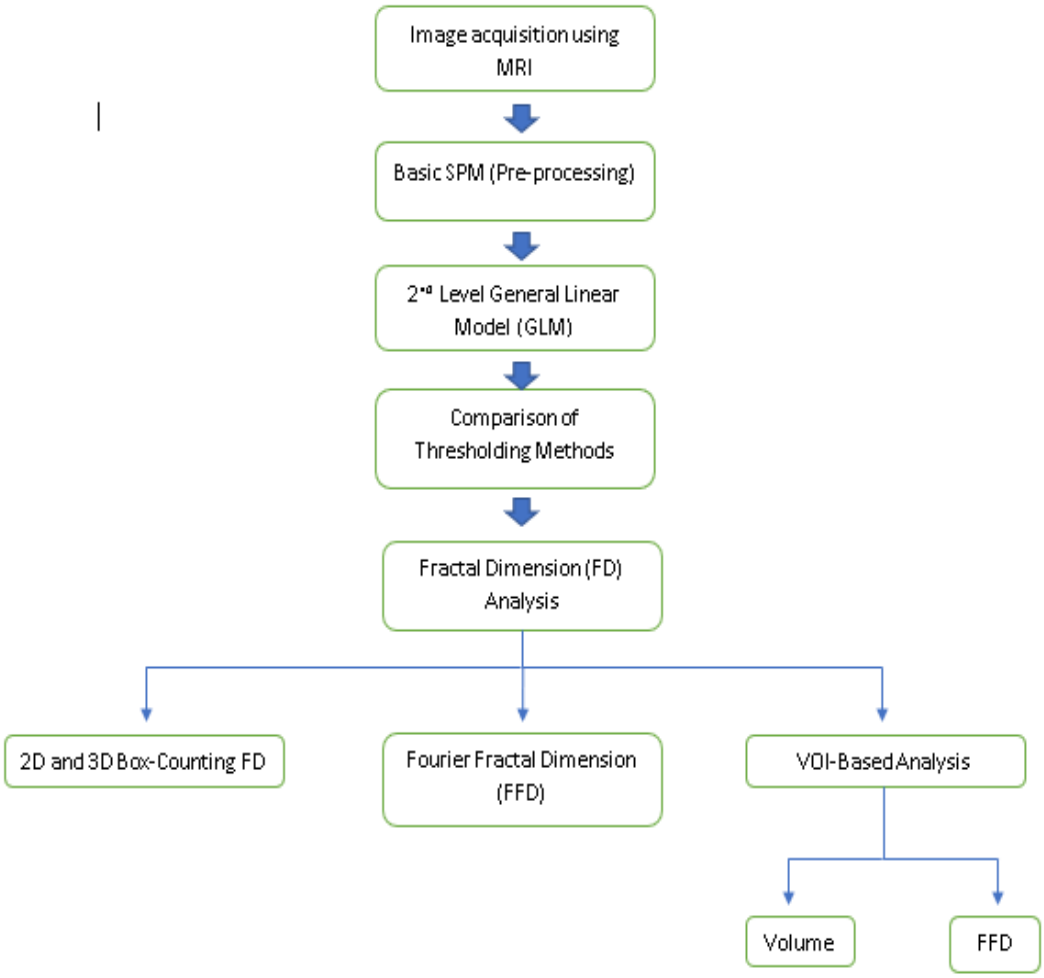

Figure 1.1 Scope of the research activities using Fractal Dimension.

1.8 SUMMARY OF METHODOLOGY

Recruitment of 47 volunteers aged between 20 to 25 years for huffaz and non-huffaz group were conducted and divided into two groups, 23 volunteers for huffaz group and 24 volunteers for non-huffaz group. The image acquisition of brain images was scanned using 3 Tesla MRI at Department of Radiology, IIUM Medical Centre for twelve weeks. The brain MRI images were then converted from Digital Imaging and Communications in Medicine (DICOM) into NeuroImaging Informatics Technology Initiative (NIfTI) format at the Radiography Lab, Kulliyyah of Allied Health Sciences IIUM Kuantan Campus before being pre-processed using Statistical Parametric Mapping (SPM). Analysis of the images was conducted using VBM, box-counting fractal analysis (2D and 3D), Fourier Fractal Dimension (FFD) analysis and Volume-of-Interest (VOI)-based analysis under MATLAB platform. The values of fractal dimension obtained were then be tested statistically using two-sample t-test by Statistical Package for Social Sciences (SPSS, version 24.0; IBM-SPSS, Chicago, IL). The details of research methodology will be discussed thoroughly in Chapter Three in this thesis later.

1.9 OUTLINE OF THE THESIS

The thesis consists of six chapters. Chapter One opens with introductory content for this study. A brief overview of huffaz, memorisation process, textual brain memorization and fractal analysis will be introduced here. The problem statement, research scope, research questions and research objectives of the study will also be presented in Chapter One. Chapter Two will be the part for literature review of the relevant component with regards to this study. An in-depth analysis of literature especially the fractal analysis contribution in this field will be discussed here. Previous studies that provide the sturdy basis for this study will also be presented, discussed, criticised and analysed. This will