

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(قَالُوا سِيِّدُنَا وَرَبُّنَا لَمْ يَعْلَمْ لَنَا إِلَّا مَا حَلَّمْنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْمَكِيمُ)

سُبْحَانَ اللَّهِ الْعَظِيمِ

DEDICATION

To the sole of my father

To my mother

For her endless love, support and prayers.

To my beloved fiancé

To my sisters and brothers

To my university

To my teachers and all who taught me a letter

To my best friends and Colleagues.

To all those whom I love

*I dedicate this work hoping that it will be of some
benefit.....*

ACKNOWLEDGEMENT

This thesis would not have been possible without the contribution of many people. I regret it is not possible to name them all.

Particularly, I am extremely indebted to Dr. Zeinab Adam Mustafa for her continuous help and fruitful supervision, and I cannot find words to express to Dr. Zeinab for her unlimited support, suggestions, motivation and encouragement.

Sincere thanks must also go to the staff of my Colleagues in Sudan University of Science and Technology.

I would like to thank all those who participated in taking this research out to light by data entry and printing. I am greatly thankful to my nice brother Anas Mohamed Hassan.

Above and before all, thanks to Allah who has me the will and ability to fulfil this work.

ABSTRACT

In this thesis, we propose a new technique for noise filtering in (MRI) Magnetic Resonance Imaging. In medical image processing, medical image are corrupted by different type of noises. It is very important to obtain precise images to facilitate accurate observations for the given application. Magnetic Resonance Imaging scans are the diagnostic tool of choice in medical field. De-noising is always a challenging problem in magnetic resonance imaging and important for clinical diagnosis and computerized analysis, such as tissue classification and segmentation. It is well known that the noise in magnetic resonance imaging has a rician distribution. Unlike additive Gaussian noise, rician noise is signal dependent, and separating signal from noise is a difficult task. Because of this reason noise removal techniques have been customarily applied to improve MR image quality.

In this thesis firstly, a study of MR image denoising filters was made, these filters have been implemented using MATLAB for reduction rician noise. The quality of the output images is measured by the statistical quantity measures: mean square error (MES), signal to noise ratio (SNR), image quality measure (UQI) and method noise. Secondly, technique was introduced to reduce rician noise in magnetic resonance images (MRI) this done by wavelet transform decomposition and sub-bands mixing (inverse wavelet transform) to obtained the proposed technique image. The proposed technique has been implemented using MATLAB program, applied to synthetics and real MR images, the MSE, SNR, UQI and method noise are taken as performance measures. Experimental results are compared with the results of denoising filters that explain firstly at different noise levels and the proposed technique showing superior performance in most causes was analyzed.

CONTENTS

DEDICATION	II
ACKNOWLEDGEMENT	III
ABSTRACT	IV
CONTENTS	V
LIST OF TABLES	VIII
LIST OF FIGURES	IX
LIST OF NOMENCLATURE	XI
LIST OF SYMBOLS	XII
CHAPTER ONE: INTRODUCTION	1
1.1 Introduction	2
1.2 Problem Statement	3
1.3 Objectives	3
1.4 Research Plan	4
CHAPTER TWO: LITERATURE REVIEW	5
2.1 Introduction	6
2.2 Noise	8
2.3 Image Enhancement	10
2.4 Noise Properties of MR Data	12
2.5 Gaussian noise	13
2.6 Image Quality Evaluation Metrics	14
2.7 Method Noise	16
2.8 The Image Denoising	16

CHAPTER THREE: LITERATURE REVIEW	23
3.1 "Denoising MRI Images Using A Non-Linear Digital Filter"	24
3.2 "Imaged denoisig techniques"	24
3.3 "Using Extended Threevalued Increment Sign for a denoising model of high-frequency artifacts in JPEG images by estimation of specific frequency"	25
3.4 "Monochromatic Noise Removal via Sparsity-Enabled Signal Decomposition Method"	25
2.5 "Performance Analysis of Magnetic Resonance Image Denoising Using Contourlet Transform"	26
3.6 "Image de-noising based on optimized NLM algorithm"	27
3.7 "A New Method to Remove Noise in Magnetic Resonance and Ultrasound Images".	27
3.8 "Contourlet-based image denoising algorithm using adaptive windows"	28
3.9 "Regression Models for Identifying Noise Sources in Magnetic Resonance Images".	28
3.10 "MRI Brain Image Enhancement Using Filtering Techniques"	29
CHAPTER FOUR: STUDY OF MR IMAGE DENOISING FILTERS	30
4.1 Introduction	31
4.1.1 Spatial filtering	32
4.1.2 Transform Domain filtering	39
4.2 The Filters Method	41
4.2.1 The Filters Algorithm	41
4.3 Experimental Results	42

4.4 Discussion	52
4.4.1 Method noise comparison	52
4.4.2 Image metrics comparison	52
CHAPTER FIVE: PROPOSED TECHNIQUE	54
5.1 Introduction	55
5.2 The Proposed Technique Algorithm	57
5.3 Wavelet sub-bands	57
5.4 Experimental Results	60
5.5 Discussion	71
CHAPTER SEX: CONCLUSION AND FUTURE WORK	72
6.1 Conclusion	73
6.2 Future work	74
REFERENCES	75

LIST OF TABLES

Table No.	Name of Table	Page No.
4.1	The mean square error (MSE), the signal to noise ratio (SNR) and image university quality index (UQI) for Brain MR image (5% & 12% Rician noise) denoised by filters.	50
4.2	The mean square error (MSE), the signal to noise ratio (SNR) and university quality index (UQI) for Ankle MR image (5% & 12% Rician noise) denoised by filters.	51
5.1	The mean square error (MSE), signal to noise ratio (SNR) and university quality index (UQI) of Brain MR Image, at different noise levels, denoised by different techniques.	66
5.2	The mean square error (MSE), signal to noise ratio (SNR) and university quality index (UQI) of Ankle MR Image, at different noise levels, denoised by different techniques.	67

LIST OF FIGURES

Figure No.	Name of Figure	Page No.
2.1	Gaussian distribution.	13
4.1	Work flow. The input image was noise free image the rician noise added to it then denoised by different types of filters.	42
4.2	Images filtering methods for Brain MR Image 5%.	44
4.3	Images filtering methods for Brain MR Image 12%.	45
4.4	Images filtering methods for Ankle MR Image 5%.	46
4.5	Images filtering methods for Ankle MR Image 12%.	47
4.6	Images method noise for Brain MR Image 5%.	48
4.7	Images method noise for Ankle MR Image 5%.	49
5.1	Workflow. First, the input image was noise free image the rician noise added to it, then denoised by Bilateral filter and Lee filter result tow images $[I_a \text{ and } I_b]$ then each image decomposed into low-and high-frequency sub-bands by dwt2, the high frequency sub-bands of image I_b and the low frequency sub-bands of image I_a are mixed (reconstruction) the image by idwt2, to get output image.	59
5.2	Images filtering methods for Brain MR Image 5%.	61
5.3	Images filtering methods for Ankle MR Image 5%.	62
5.4	Images method noise for Brain MR Image 5%.	63
5.5	Images method noise for Ankle MR Image 5%.	64
5.6	Real images experience. Two types of real MR Images (Brain and Ankle) denoised by proposed technique.	65
5.7	The MSE of Brain MR image at noise level 5%, denoised by different techniques.	68
5.8	The SNR of Brain MR image at noise level 5%, denoised by different techniques.	68

Figure No.	Name of Figure	Page No.
5.9	Figure4.10: The university quality index (UQI) of Brain MR Image at noise level 5%, denoised by different techniques.	69
5.10	The MSE of Ankle MR Image at noise level 5%, denoised by different techniques.	69
5.11	The SNR image of Ankle MR Image at noise level 5%, denoised by different techniques.	70
5.12	The university quality index (UQI) of Ankle MR Image at noise level 5%, denoised by different techniques.	70

LIST OF NOMENCLATURE

MR	Magnetic Resonance
MRI	Magnetic Resonance Imaging
NMRI	Nuclear Magnetic Resonance Imaging
FMRI	Functional Magnetic Resonance Imaging
MSE	Mean Square Error
SNR	Signal to Noise Ratio
Q	Image quality measure.
CT	Computed Tomography
RF	Radio Frequency
HVS	Human Visual System
OS	Order Statistic (filter)
PDE	Partial Differential Equation
LMS	Least Mean Square
NLM	Non Local Mean
TV	Total Variation
PPMRI	Partially Parallel Magnetic Resonance Imaging
GRAPPA	Generalized Approach to Parallel Magnetic Resonance Imaging
SENSE	Sensitivity Encoding Magnetic Resonance Imaging
TF	Trilateral Filter
ML	Maximum Likelihood
DUDE	Discrete Universal Denoiser
UINTA	Unsupervised Information Theoretic Adaptive filter
1D	One Dimensional
2D	Two Dimensional
ETIS	Three-valued Increment Sign
MMSE	Minimum Mean Square Error
CWT	Continuous Wavelet Transform
DWT	Discrete Wavelet Transform

LIST OF SYMBOLS

$F(g)$	Gaussian distribution
G	Gray level
Σ	Standard deviation
M	Mean
M	Magnitude image
U	Original image in gray scale
D_h	Denoised operator depending on h
$w(x)$	Input signal to filtering
$z(x)$	Output signal filtered
$h(t)$	Impulse response
$F(x,y)$	Filterd image at point (x,y)
$S_{x,y}$	Set of coordinates in rectangular sub image
$NL[v]$	Estimated value
N_k	Square neighborhood of fixed size and centered of pixel k
$z(i)$	Normalizing constant
H	Parameter acts as a degree of filtering
σ_d	Spatial distance
σ_r	Intensity distance
C	Normalization constant
$N(x)$	Spatial neighborhood of pixel (x)
$X(t)$	Original signal
$\Psi_{m,k}(t)$	Discrete analysis wavelet
$\phi_{1,k}(t)$	Discrete scaling
$D_m(k)$	Detailed signal at scale 2^m
$A_1(k)$	Approximated signal at scale 2^m
H	Low pass filter
G	High pass filter