Chapter 1
Introduction of Neurodegenerative Diseases (Dementia) and their diagnosis

1.1 Neurodegenerative Diseases (Dementia)

Neurodegenerative disorder is one of the most common causes of dementia in old people. The term ‘dementia’ is derived from the Latin word demens meaning ‘without mind’. Dementia refers to the loss of memory and other cognitive skills due to changes in the brain caused by disease or trauma. The changes can affect thinking, memory and reasoning, and may occur gradually or quickly. Memory loss alone is not always a sign of dementia, but memory loss along with other forms of cognitive impairment is an indicator that dementia may be occurring.

Cognitive functions that might be affected by dementia include:

- decision making/judgment
- memory
- spatial orientation
- thinking/reasoning
- verbal communication
- neglect of personal safety, hygiene, and nutrition
- coordination or balance

A person with dementia might...

- …repeatedly ask the same questions
- …become lost or disoriented in familiar places
- …be unable to follow directions
- …be disoriented as to the date or time of day
- …not recognize and be confused about familiar people
- …have difficulty with routine tasks such as paying the bills
- …neglect personal safety, hygiene, and nutrition

Dementia types

An estimate tells 24 million people worldwide suffer from dementia—and the numbers are growing. To make matters worse, many people don’t understand the
difference between Alzheimer’s and other forms of dementia, causing many cases to go undiagnosed and untreated.

AD - Alzheimer's disease

Alzheimer's disease is the most common cause of dementia. As the development of the aging process in the world, AD has become a common disease among the elderly in the aging society. Alzheimer’s is a brain disease characterized by lesions that gradually destroy cells in the brain. As nerve cells die, affected areas of the brain wither and become smaller as can be seen from fig.1.1.1. The areas of the brain that control memory, logical thinking, and personality are generally the most affected. As areas in the brain become smaller, cavities within the brain containing fluid become enlarged.

![Alzheimer's versus Normal brain](image)

Fig.1.1.1 Alzheimer’s versus Normal brain

Vascular dementia: (formerly known as arteriosclerotic or multi-infarct dementia), results from significant brain damage caused by cerebrovascular diseases. Onset of the disease may be sudden, following a stroke, or gradual, following a number of mini-strokes or because of small vessel disease. Dementia with Lewy bodies: Abnormal brain cells (Lewy bodies) form in all parts of the brain. Progress of the disease is more rapid than for dementia in Alzheimer’s disease.

Frontotemporal dementia: (e.g. Pick’s disease) Damage starts in the front part of the brain, with personality and behavioural symptoms commonly occur in the early stages.

Mixed dementia: Features of more than one type of dementia are present. For example, many people with dementia have features of both Alzheimer’s disease and vascular dementia.
There are also a number of less common types of dementia, including dementia in Parkinson’s disease, resulting from the loss of the neurotransmitter, dopamine, in the brain (dopamine is implicated in the control of voluntary movements)—dementia is common in people with Parkinson’s but not everyone with Parkinson’s develops dementia. In case of Alcohol-induced dementia (e.g. Wernicke/Korsakoff syndrome), brain function deterioration is associated with excess alcohol consumption, particularly in conjunction with a diet low in Vitamin B1 (thiamine). In Drug-related dementia patients, it is the side-effect of medications taken for other problems. Huntington’s disease is an inherited disorder of the central nervous system, which is characterised by jerking or twisting movements of the body and is usually eventually accompanied by dementia. Other forms of dementia are, such as that developing in the course of human immunodeficiency virus (HIV), or Creutzfeldt-Jakob disease. Reversible forms of dementia, such as dementia from B12 deficiency or hypothyroidism, which, are rare forms of Dementia. A definitive diagnosis of many of the diseases associated with the syndrome of dementia is often only possible after death, based on post-mortem examination of the brain, although serial magnetic resonance imaging (MRI) scans show potential in helping diagnose some types of dementia. [1]

MCI-Mild Cognitive Impairment:
The concept of mild cognitive impairment (MCI) has been introduced to describe older individuals who cognitively lie between normal ageing and dementia. Nowadays, there is a particular interest in MCI because this syndrome is thought to be a transitional stage to Alzheimer’s disease (AD) that may define a window for effective therapeutic interventions. However, not all patients with MCI will go on to develop AD [2].

Dementia status in India:
In India, 4% of population is aged above 65 years. Life expectancy at birth is 61 years. India is a country with huge diversity and 1,652 dialects. The Hindu culture prepares for old age with the disengagement theory. At old age, people give up their authority over family and property, and devote to self-realization. According to Indian social norms, care of elderly people is taken by family. Hence Dementia is regarded as normal part of ageing and not requiring any kind of medical care [3].

According to the world Alzheimer’s report, released by - The Alzheimer’s and Related Disorders Society of India (ARDSI),
• About 3.7 million elderly people in India have Dementia
• Estimated figure is 7.2 million in 2030, and 14.4 million in 2050
• By 2025, developing countries will have 75% of the world Dementia population
• A new case of dementia is generated, every 7 seconds worldwide

1.2 Conventional Methods of Dementia Diagnosis

Diagnosis of the common dementias of old age is principally operationally defined on the basis of their differing constellations of symptoms and neuropsychological profiles. In doing so, clinicians use a variety of sources of evidence in the reasoning process, which include evidence-based clinical guidelines, often supplemented by individual consultations. Clinical guidelines, developed by domain-specific experts, identify, summarize and evaluate the state of the art in medical evidence and current data about prevention, diagnosis, prognosis, therapy, management, risk, benefit and cost-effectiveness, and, in addition, address practical issues. Furthermore, clinical guidelines define important questions related to clinical practice, and identify possible decision options and their outcomes, thus guiding the clinician's decisions. The overriding objective of clinical guidelines is to standardise medical care, raise quality of care, reduce risk and achieve a balance between cost and medical parameters [4]. Clinical guidelines alone do not replace the knowledge and skills of the clinician ultimately responsible for patients; it is the responsibility of the clinician to make judgements and decisions in consultation with the patient, or where appropriate, close relatives or carers.

The Diagnostic and Statistical Manual (DSM), currently in its 4th edition [5], lists different categories of mental disorder and the criteria for diagnosing them. The mental disorders Section of the International Classification of Diseases, version 10 (ICD-10), is another commonly-used guide which provides codes to classify diseases and a wide variety of signs, symptoms and abnormal findings. Furthermore, a careful, methodical and detailed history is an important part of the clinical assessment of someone with suspected dementia. In progressive degenerative dementias, during the very early stages cognitive deficits are usually subtle and their manifestations, though representing change from premorbid function in an individual, may remain within the normal range for the general
population. This presents considerable challenges to early diagnosis. Cognitive screening and regular monitoring may be of assistance in tracking deterioration in cognitive and functioning abilities. Nevertheless, early diagnosis and categorisation of dementia-causing pathology is of value in planning treatment and, in some cases, initiating specific drug intervention. Accordingly, a diagnosis of dementia can be formed by evaluation of the clinical syndrome based on diagnostic criteria, history and examination, paying particular attention to mode of onset, course of progression, pattern of cognitive impairment and presence of non-cognitive symptoms. Additionally, screening investigations, and, where appropriate, additional more specialised investigations, such as neuropsychological testing, imaging, blood tests and systemic investigations may be required [6]. There are several other tools used to support in the diagnostic procedure, such as the mini mental state examination (MMSE) [7], the clinical dementia rating scale (CDR) [8].

The MMSE test is a 30-point questionnaire used for measuring severity and decline in cognition. It deals with function, such as memory function, calculation, language abilities and attention. Gaining a score of 24-30 is considered as no dementia, 19-23 as mild dementia and 13-18 indicates moderate dementia. The CDR scale is also used for the evaluation of staging severity of dementia. This is a five point scale, rating six functional domains. These are memory, orientation, judgment and problem solving, community affairs, home and hobbies and finally personal care. The five point scale is as follows:

CDR=0: no dementia
CDR=0.5: very mild dementia
CDR=1: mild dementia
CDR=2: moderate dementia
CDR=3: severe dementia

Until recently, the most significant issue a family physician is facing is the diagnosis and treatment of AD. However, as more treatment options become available, it will become increasingly important to diagnose AD early. Dementia of AD type may be suspected if memory deficits are exhibited during the medical history and physical examination. Information from the patient’s family members, friends and caregivers may also point to signs of AD. Distinguishing age-related cognitive decline, mild cognitive impairment and Alzheimer’s disease may be difficult and requires evaluation of cognitive and functional status. The prevalence
of AD is expected to increase dramatically in future years as life expectancy continues to increase. The cumulative incidence of Alzheimer’s disease has been estimated to be as high as 4.7 percent by age 70, 18.2 percent by age 80 and 49.6 percent by age 90. Proposed risk factors for AD include a family history of dementia, previous head injury, and lower educational level. Alzheimer’s disease is the most common cause of dementia; many of the remaining cases of dementia are caused by vascular disease and Lewy body disease. Vascular disease and Lewy body disease often occur in combination with Alzheimer’s disease. Hence there is an urgent need to understand the disease, to develop prophylactic strategies which can distinguish the different states of AD, so that the proper step can be taken to manage the disease. [9]

1.3 Automated Methods of Dementia Diagnosis

EEG (Electroencephalography) seems an attractive brain imaging modality for diagnosing AD, since EEG recording systems are relatively inexpensive and mobile. Moreover, in contrast to most other non-invasive brain imaging methods, EEG has high temporal resolution, and may as a consequence contain crucial information about abnormal brain dynamics in AD patients. In particular, three major effects of AD on EEG have been observed: slowing of the EEG, reduced complexity of EEG signals, and perturbations in EEG synchrony. Numerous studies have investigated potential of EEG to diagnose AD still it is hard to assess whether EEG can be used as tool to diagnose Dementia. Because in these studies, a single measure is applied to single EEG data set. Almost every study considers different measure and different dataset. Hence it is hard to compare existing studies for consistent results [10]. Also at present it is fairly difficult to gain access to EEG data of MCI or AD patients, such databases are not publically available in contrast with other imaging databases, described in chapter 3.

Amongst various neuroimaging methods used for Dementia diagnosis most popularly used methods are MRI and CT.

A computed tomography (CT) scanner uses X-rays, a type of ionizing radiation, to acquire images, making it a good tool for examining tissue composed of elements of a higher atomic number than the tissue surrounding them, such as bone and calcifications (calcium based) within the body (carbon based flesh), or of
structures (vessels, bowel). MRI, on the other hand, uses non-ionizing radio frequency (RF) signals to acquire its images and is best suited for soft tissue.

MRI is also best suited for cases when a patient is to undergo the exam several times successively in the short term, because, unlike CT, it does not expose the patient to the hazards of ionizing radiation.

Currently, due to the socioeconomic importance of the disease Dementia, in occidental countries it is one of the most studied. The diagnosis of AD can be done after the exclusion of other forms of dementia but a definitive diagnosis can only be made after a post-mortem study of the brain tissue. This is one of the reasons why early diagnosis based on Magnetic Resonance Imaging (MRI) is a current research hot topic in the neurosciences.

Magnetic resonance imaging (MRI) also referred to as nuclear magnetic resonance (NMR), is a powerful and flexible medical imaging modality. Among many other capabilities, it can produce high-resolution images with good contrast of the different biological soft tissue types. As a non-invasive technique, it is widely used in the clinical and research environments for imaging both anatomy and function. Hence it was planned to use MR images for classification task in hand. An accurate and robust tissue classification is the basic aim which is achieved employing various techniques such as: quantitative measurements of tissue volume in normal and diseased populations, VOI analysis, texture features, and wavelet transform.

1.4 MRI Technology

Magnetic Resonance imaging (MRI) is a medical imaging technique that permits the detailed visualization of internal anatomical structures in living human subjects. In today's clinical settings, MR has become a standard diagnostic tool, and the increased availability of imaging techniques permit the routine scanning of patients to detect a variety of tumor, lesions and abnormalities in a non-invasive way as reported by Ozkan et al. [11]. MRI has proved to have sensitivity perhaps 10 times greater than that of Computerized Tomography (CT) in detecting MS lesions. The most common MR technique used for diagnostic studies is based on the magnetic resonance of hydrogen nuclei. Since water is by far the most common source of hydrogen nuclei in living tissue, it is likely that the water content of tissue produces most of the signal seen on the scans as reported by Paty et al [12]. The
body is largely composed of water molecules. Each water molecule has two hydrogen nuclei or protons. When a person is inside the powerful magnetic field of the scanner, the magnetic moments of some of these protons become aligned with the direction of the field. A radio frequency transmitter is briefly turned on, producing a further varying electromagnetic field. The photons of this field have just the right energy, known as the resonance frequency, to be absorbed and flip the spin of the aligned protons in the body. The frequency at which the protons resonate depends on the strength of the applied magnetic field. After the field is turned off, those protons which absorbed energy revert back to the original lower-energy spin-down state. Now a hydrogen dipole has two spins, 1 high spin and 1 low. In low spin both dipole and field are in parallel direction and in high spin case it is antiparallel. They release the difference in energy as a photon, and the released photons are detected by the scanner as an electromagnetic signal, similar to radio waves. As a result of conservation of energy, the resonant frequency also dictates the frequency of the released photons. The photons released when the field is removed have energy — and therefore a frequency — which depends on the energy absorbed while the field was active. It is this relationship between field-strength and frequency that allows the use of nuclear magnetic resonance for imaging. An image can be constructed because the protons in different tissues return to their equilibrium state at different rates, which is a difference that can be detected. Five different tissue variables — spin density, T1 and T2 relaxation times and flow and spectral shifts can be used to construct images.[13] By changing the parameters on the scanner, this effect is used to create contrast between different types of body tissue or between other properties, as in fMRI and diffusion MRI.

The 3D position from which photons were released is learned by applying additional fields during the scan. This is done by passing electric currents through specially-wound solenoids, known as gradient coils. These fields make the magnetic field strength vary depending on the position within the patient, which in turn makes the frequency of released photons dependent on their original position in a predictable manner, and the original locations can be mathematically recovered from the resulting signal by the use of inverse Fourier transform. Contrast agents may be injected intravenously to enhance the appearance of blood vessels, tumors or inflammation. Contrast agents may also be directly injected into a joint in the
case of arthrograms, MRI images of joints. Unlike CT, MRI uses no ionizing radiation and is generally a very safe procedure. Nonetheless the strong magnetic fields and radio pulses can affect metal implants, including cochlear implants and cardiac pacemakers. In the case of cochlear implants, the US FDA has approved some implants for MRI compatibility. In the case of cardiac pacemakers, the results can sometimes be lethal, [14] so patients with such implants are generally not eligible for MRI. MRI is used to image every part of the body, and is particularly useful for tissues with many hydrogen nuclei and little density contrast, such as the brain, muscle, connective tissue and most tumors.

An advantage of MRI is its ability to produce images in axial, coronal, sagittal and multiple oblique planes with equal ease. MRI scans give the best soft tissue contrast of all the imaging modalities. With advances in scanning speed and spatial resolution, and improvements in computer 3D algorithms and hardware, MRI has become an important tool in neuroradiology.

Basic MRI scans:

T1-weighted MRI - T1-weighted scans are a standard basic scan, in particular differentiating fat from water - with water darker and fat brighter use a gradient echo (GRE) sequence, with short TE and short TR. This is one of the basic types of MR contrast and is a commonly run clinical scan. The T1 weighting can be increased (improving contrast) with the use of an inversion pulse as in an MP-RAGE sequence. Due to the short repetition time (TR) this scan can be run very fast allowing the collection of high resolution 3D datasets. A T1 reducing gadolinium contrast agent is also commonly used, with a T1 scan being collected before and after administration of contrast agent to compare the difference. In the brain T1-weighted scans provide good gray matter/white matter contrast; in other words, T1-weighted images highlight fat deposition.

T2-weighted MRI - T2-weighted scans are another basic type. Like the T1-weighted scan, fat is differentiated from water - but in this case fat shows darker, and water lighter. For example, in the case of cerebral and spinal study, the CSF (cerebrospinal fluid) will be lighter in T2-weighted images. These scans are therefore particularly well suited to imaging edema, with long TE and long TR.
Because the spin echo sequence is less susceptible to inhomogeneities in the magnetic field, these images have long been a clinical workhorse.

Proton Density weighted MRI- Spin density, also called proton density, weighted scans try to have no contrast from either T2 or T1 decay, the only signal change coming from differences in the amount of available spins (hydrogen nuclei in water). It uses a spin echo or sometimes a gradient echo sequence, with short TE and long TR.

![Sagittal View](image1) ![Axial View](image2) ![Coronal View](image3)

Fig.1.4.1 Three dimensions in brain MRI

1.5 Artificial Neural Networks in Medical Diagnosis

The physician’s prognosis and predicted trajectory of cognitive decline often form the basis of treatment and health care decisions taken by patients and their families. These predictions are difficult to make because of the high variability and non-linearity exhibited by individual patterns of cognitive decline. Artificial neural networks (ANNs) are, computer paradigms that can learn, excel in pattern recognition tasks such as disease diagnosis. A supervised learning ANN can emulate human expert diagnostic performance and identify relevant predictive markers in the diagnostic task, while an unsupervised learning ANN can suggest reasonable alternative diagnostic classification criteria [15]. From medical diagnosis point of view, an artificial neural network (ANN) is an information processing system that is inspired by the way biological nervous systems store and process information like human brains. It contains a large number of highly interconnected processing neurons working together in a distributed manner to learn from the input information, to coordinate internal processing, and to optimize its final output. In the past decades, neural networks have been successfully applied to
a wide range of areas, including computer science, engineering, theoretical modelling, and information systems. Medical imaging is another fruitful area for neural networks to play crucial roles in resolving problems and providing solutions. Numerous algorithms have been reported in the literature applying neural networks to medical image analysis. Neural network applications in CAD represent the mainstream of computational intelligence in medical imaging. Their penetration and involvement are comprehensive for almost all medical problems because (a) neural networks can adaptively learn from input information and upgrade themselves in accordance with the variety and change of input content; (b) neural networks can optimize the relationship between the inputs and outputs via distributed computing, training, and processing, leading to reliable solutions desired by specifications; (c) medical diagnosis relies on visual inspection, and medical imaging provides the most important tool for facilitating such inspection and visualization. Medical image segmentation and edge detection remains a common problem fundamental to all medical imaging applications. Any content analysis and regional inspection requires segmentation of featured areas, which can be implemented via edge detection and other techniques. Conventional approaches are typified by a range of well-researched algorithms, including watershed, region-growing, snake modelling, and contour detection. In comparison, neural network approaches exploit the learning capability and training mechanism to classify medical images into content-consistent regions to complete segmentations as well as edge detections. Another fundamental technique for medical imaging is registration, which plays important roles in many areas of medical applications. Typical examples include wound care, disease prediction, and health care surveillance and monitoring. Neural networks can be designed to provide alternative solutions via competitive learning, self-organizing, and clustering to process input features and find the best possible alignment between different images or data sets. [16]

**ANN basics**

In the field of neural networks, we study the properties of networks of idealized ‘neurons’. Three motivations underlie work in this broad and interdisciplinary field.

i. **Biology:** The task of understanding how the brain works is one of the outstanding unsolved problems in science. Some neural network models are intended to shed light on the way in which computation and memory are performed by brains.
ii. Engineering: Many researchers would like to create machines that can 'learn', perform 'pattern recognition' or 'discover patterns in data'.

iii. Complex systems: A third motivation for being interested in neural networks is that they are complex adaptive systems whose properties are interesting in their own right.

ANN Terminology - Every time in this thesis a neural network algorithm is described typically with three things.

i. Architecture: The architecture specifies what variables are involved in the network and their topological relationships - for example, the variables involved in a neural net might be the weights of the connections between the neurons, along with the activities of the neurons.

ii. Activity rule: Most neural network models have short time-scale dynamics: local rules define how the activities of the neurons change in response to each other. Typically the activity rule depends on the weights (the parameters) in the network.

iii. Learning rule: The learning rule specifies the way in which the neural network's weights change with time. This learning is usually viewed as taking place on a longer time scale than the time scale of the dynamics under the activity rule. Usually the learning rule will depend on the activities of the neurons. It may also depend on the values of target values supplied by a teacher and on the current value of the weights.

Where do these rules come from? Often, activity rules and learning rules are invented by imaginative researchers. Alternatively, activity rules and learning rules may be derived from carefully chosen objective functions. Neural network algorithms can be roughly divided into two classes.

i. Supervised neural networks are given data in the form of inputs and targets, the targets being a teacher's specification of what the neural network's response to the input should be.

ii. Unsupervised neural networks are given data in an undivided form - simply a set of examples \{x\}. Some learning algorithms are intended simply to memorize these data in such a way that the examples can be recalled in the future. Other algorithms are intended to 'generalize', to discover 'patterns' in the data, or extract the underlying 'features' from them.
Some unsupervised algorithms are able to make predictions - for example, some algorithms can `fill in' missing variables in an example \{x\} and so can also be viewed as supervised networks. [17]

Artificial neural network’s structure: The basic stand cell of the artificial neural network is the computation cell called neuron, which has multiple inputs and one output, as shown in fig. 1.5.1.

![Neuron Model](image)

Fig. 1.5.1 Neuron Model

Fig. 1.5.1 shows the model of a single neuron, where \( X\{x_i, i = 1, 2, \ldots, n\} \) represents the inputs to the neuron and \( Y \) represents the output. Each input is multiplied by its weight \( w_i \), a bias \( b \) is associated with each neuron, and their sum goes through a transfer function \( f \). As a result, the relationship between input and output can be described as follows.

\[
Y = f\left( \sum_{i=1}^{n} w_i x_i + b \right)
\]

A range of transfer functions have been developed to process the weighted and biased inputs. Four of the basic transfer functions widely adopted for medical image processing are illustrated in Fig. 1.5.2.

![Transfer Functions](image)

Fig. 1.5.2: Four widely adopted transfer functions: (a) hard limit, (b) linear, (c) RBF, and (d) sigmoid
Via selection of transfer function and connection of neurons, various neural networks can be constructed to be trained for producing the specified outputs. Major neural networks commonly used for medical image processing are classified as feedforward neural network, feedback network, and self-organizing map.

The artificial neural network is constructed by many basic stand cells, from decades of neurons to even thousands of neurons. These neurons are divided by layers, and usually three kinds of the layers together form a completed artificial neural network, which are input-layer, hidden-layer and output-layer, as shown in fig.1.5.3.

Feed-forward algorithm

The feed-forward classification is the algorithm used for calculating the output of the artificial neural network. Once the training process has finished, the feed-

![Artificial neural network with 3 layers](image)

Fig. 1.5.3 Artificial neural network with 3 layers

Forward process can be performed, which is executed by feeding in the inputs from outside to the input-layer of the network. Each neuron performs the summary among the production of input and according weight, and then performs activation function. The final outputs of the neurons in this layer, become the inputs to the neurons of next layer. The process repeats layer by layer among the hidden-layers, and the final outputs of the last hidden-layer feed into output-layer as the inputs. At last, the outputs of the output-layer become the final outputs of the whole artificial neural network, as the final outputs of feed-forward classification [16], [17], [18].
1.6 Chapters Summary

The rest of the thesis is organised as follow.

Chapter 2 Literature Review, takes review of research in the same area, ANN for medical diagnosis, ANN for MRI based dementia diagnosis and specially MRI feature extraction.

Chapter 3 Neurodegeneration Database, briefs about database survey for problem in hand and details about three major databases used, OASIS, ADNI and Whole brain atlas.

Chapter 4 Problem Statement Formulation, describes the complications in Dementia Diagnosis, then discusses computational representation of brain (MRI) and concludes with aims, objectives and work plan.

Chapter 5 Experimentation, details one by one all the experiments carried out, starting with Exp.1 MLP classifier for Dementia Levels which is implemented in C language uses OASIS database and successfully classifies levels in Dementia. Then Exp.2 VBM based MR Imaging Volumetric Analysis of AD and MCI, uses voxel based morphometry for dual purposes MRI normalization and finding tissue volumes. Exp.3 ANN based diagnosis of neurodegenerative diseases from 3D MR Images with voxel based morphometry as feature extraction tool, introduces ANN classifier using tissue volumes as inputs for categorizing Dementia. Exp.4: Diagnosis of Alzheimer’s disease from 3D MR Images with statistical features of Hippocampus, the most important part of brain affected in Dementia is focussed for feature extraction. Exp. 5: ANN based voxel wise texture classification of 3D MR images of Neurodegenerated brains, introduces calculation of Haralick Texture features and ANN classifier design. Exp.6: Spatial features based ANN classification of frequency filtered 3D MR images of Neurodegenerated brains, describe frequency filtering for 3D MR images of brain and subsequent ANN classification. Exp. 7 DWT based ANN classification of 3D MR images of Neurodegenerated brains; describe calculation of DWT coefficients for 3D MR images of brain and subsequent ANN classification. Exp. 8: Classification of 2D Magnetic Resonance Images of Brain using Slantlet Transform, describe calculation of Slantlet coefficients on 2D MRI. Exp. 9: Classification of 2D Magnetic Resonance Images of Brain using Spatial features of Frequency filtered image,
describe frequency filtering for 2D MR images of brain and subsequent ANN classification.

Chapter 6 Outcome of Research describes the outcomes of the research and contribution to research community. Chapter 7 Limitations, Future Directions and Conclusion, summarises the work in this thesis and outlines possible future research directions. Some of the limitations of the approach presented in this thesis are also discussed.