CHAPTER 1

INTRODUCTION

1.1 Motivation

In the recent past, the brain tumor is the major source for the rise of fatality between children and adults. Most of the research work in developed countries has shown that the death rate of persons affected by brain cancer or tumor has grown up during the previous few years. The American Cancer Society’s estimates for the brain tumor in the United States is about 22,850 for the year 2015 and about 15,320 people will die from brain tumor [1]. In US, the brain tumor is the leading cause for cancer related deaths in patients.

Currently in healthcare, Magnetic Resonance Imaging (MRI) technique indicates a vital part during the whole medical procedure through diagnostics and treatment planning to surgical procedures and regular monitoring. The MRI of brain allows the clinical expert for the earliest detection of brain tumor which is the most treatable stage that gives patients the greatest chance of survival. The MRI offers far better contrast among different soft tissues of the brain than the Computed Tomography (CT) and hence it is more suitable particularly in diagnosing brain related problems such as lesion or tumor.

The MRI technique is more susceptible to artifacts during the process of image acquisition using MRI scanner. These artifacts can degrade the image quality and obscure important findings about the brain tumor. The radiologist must have the complete understanding of various types of artifacts, their cause and presence of probable external objects in order to eradicate the artifacts or to reduce their adverse influence on MRI images by adjusting the acquisition parameters of the scanner like FOV, sampling rate, receiver bandwidth, TE and TR times, type of sequence, RF pulse amplitude, slice thickness, number of slices, matrix size, magnetic field, receiver coils, flip angle, acceleration factor, etc. However some of the artifacts are beyond the radiologist’s immediate control. The evaluation of such artifacts and their removal during preprocessing is necessary for the efficient and accurate segmentation and detection of abnormalities in the brain. In the existing system the radiologists adjust the acquisition parameters to minimize or reduce the artifacts at the time of acquisition. However some
of the artifacts still present in the image leads to wrong pathology by the medical experts. The proposed research work is aimed at evaluating the acquired brain MRI images in respect of noise and artifacts, their elimination and developing methods and algorithms for detection and classification of abnormalities in the brain image.

1.2 Problem Statement

Magnetic Resonance Imaging (MRI) technique is sensitive to artifacts. There are various types of artifacts that appear during scanning which may be system hardware related or patient related. The presence of artifacts in MRI images of brain confuses and obscure or simulate the pathology. Hence the radiologists must have thorough knowledge of MRI physics as well as the scanner instrument itself to identify the artifacts and know, how to remove or minimize the artifacts by adjusting the scanning parameters of the MRI machine. The artifacts that are not under the immediate control of radiologists have to be removed by developing image processing techniques. It is desirable to preserve all the image details after removal of the artifact. The performance metrics like signal to noise ratio (SNR) and energy loss will be determined to technically evaluate the image quality after artifact removal. Accurate segmentation is required to know the exact location and extent of brain pathology to extract the abnormal region (tumor or lesion) of the brain image.

The segmentation of MRI images of brain is a difficult and challenging task since artifacts occur during image acquisition and also due to diverse kinds of tumors with different shapes, size, locations and intensity values. In this aspect, the proposed topic in the thesis will focus on formulating novel techniques for artifact removal and an efficient method to accurately segment the tumor part of the brain image. After segmentation, the features are extracted using Gray level co-occurrence matrix (GLCM) and an artificial neural network based algorithm such as the Support Vector Machine (SVM) is implemented to classify the brain MRI images as either normal (without tumor) or abnormal (with tumor). The algorithms will be implemented using MATLAB image processing toolbox.

1.3 Medical Imaging

The term “Medical imaging” refers to the methods and procedures for creating the images of internal human body organ(s) for clinical determinations and pathology. Various types of acquisition techniques and energy sources are applied to create different types of medical images known as the modalities in the field of medical imaging. The
modalities vary from X-ray, Ultrasound, CT, MRI, SPECT and PET. Each modality has its own applications in medicine. Due to the benefits of numerous advances in medical imaging technology and healthcare, the human life expectancy has clearly improved. Most imaging techniques provide static images of hard and soft tissues noninvasively. Now a day’s functional imaging is also available to clinicians for the rapid growth of imaging technology.

The medical images can be captured in the continuous domain on traditional X-ray film or in discrete space such as in MRI, CT and digital X-ray. Images in continuous domain are referred to as analog images and in discrete space are referred as digital images. In two-dimensional discrete space, the locations of every measured quantity or intensity is called a pixel and it is known as voxel in three-dimensional images.

1.4 Magnetic Resonance Imaging

The term “Magnetic resonance imaging” is the method which incorporates a strong and uniform magnetic field and radio frequency pulses to produce accurate images of the structures and tissue organs inside the body. In most of the cases, the MRI provides different and more useful statistical data or information of structures inside the body that cannot be seen in X-ray imaging, ultrasound imaging, or computed tomography (CT) scan.

The MRI is the diagnostic tool that helps the pathologist to understand the details of the soft tissues and its characteristics or body organs noninvasively which is frequently not found in traditional imaging modalities like X-rays and CT scans.

An imaging instrument known as MRI scanner which consists of hardware elements namely the main magnet, the magnetic field gradient coils, the radio-frequency transmitter, a receiver, a coil/probe and a computer that collects the data and coordinates the timing and usage of the entire system. The schematic block diagram showing the various components of the MR imaging arrangement is indicated in figure 1.1.

The main magnet in the system will be the permanent magnet that produces a strong and uniform static magnetic field denoted as $B_0$ field. This magnetic field is used for polarization of nuclear spins. Majority of the imaging systems today function at a fixed field strength in units of Tesla (1 Tesla = 10000 Gauss). The magnetic field gradient scheme generally consists of three orthogonal gradient coils, $G_x$ , $G_y$ and $G_z$ which are vital for signal localization. Radio frequency unit consists of a transmitter coil which is capable of generating a rotating magnetic field denoted as $B_1$ field which is used for
Figure 1.1 Schematic block diagram showing the components of MRI system exciting a nuclear spin system. The receiver coil electronics converts a precessing magnetization into an electrical signal. The signals picked up by the receiver are used to reconstruct the image of an object on the computer display. With the advancement in technology the MRI scanner machines are available with different magnetic field strength. The fig.1.2 shows the photographic appearance of a modern 1.5 Tesla scanner machine.

Figure 1.2 A photograph of modern MRI scanner machine
During MRI scanning, the patient is told to lie down on a table and then the table is moved inside the large circular magnet as shown in figure 1.3. This will take an image of the internal body tissue which has to be investigated. The MRI images are taken in thin slices from various directions in any of the three planes namely axial (neck to head), sagittal (ear to ear) or coronal (front to back). Three types of images based on longitudinal relaxation time (T1 weighted), transverse relaxation time (T2 weighted) and proton density (PD) are produced in MRI scan [2]. These three types of image samples which were taken along axial plane are shown in figure 1.4. The slice thickness varies from 3mm to 5mm and the number of slices in a single scan may vary from 20 to 25.
When the magnetic field is applied, the protons in the nuclei start to oscillate at a frequency which depends on the strength of magnetic field. The protons absorb energy from the applied electromagnetic field to oscillate. When the protons return to their initial state of equilibrium, they release energy. The energy released by the nuclei during their returning time to initial state is called an MRI signal. The protons in the nuclei takes some time to return to their initial state. The relaxation back to equilibrium of the nuclear magnetization which is parallel to the magnetic field is called $T_1$ time and the relaxation back to equilibrium of the nuclear magnetization which is perpendicular to the magnetic field is called $T_2$ time. The MRI image contrast depends on $T_1$, $T_2$ and proton density.

In $T_1$ weighted, the image contrast is predominantly due to the differences in $T_1$ recovery times of tissues. In $T_2$ weighted, the image contrast is predominantly due to the differences in $T_2$ decay time of tissues. The $T_2$ weighted scan uses a spin echo sequence with long echo time (TE) and short repetition time (TR). In proton density images, the effects of $T_1$ and $T_2$ contrast must be diminished so that the number of protons per unit volume decides the image contrast. The echo time is the time elapsed between the application of RF excitation pulse and the peak of the signal induced in the coil. The repetitive time is the time between the RF excitation pulses to the application of the next pulse. The spin echo and gradient echo are the two types of imaging sequences used which consists of a series of excitation pulses each separated by a TR.

Figure. 1.5 MRI imaging procedure regarded as forward and reverse Fourier Transforms
The entire process of acquiring the brain image of a patient can be regarded as an application of forward and reverse Fourier transforms as indicated by the schematic diagram shown in figure 1.5. The images that are created using MRI technique are digitized and stored on a digital computer which is usually located outside the scanning room. A radiologist observes the images and provides the complete description of the organ of interest. The advantage of MRI is that the image data can be transmitted electronically to the treating physician so that the diagnosis and treatment can be made faster and more accurate. The images created by the MRI scan can help the treating expert to show the differences between healthy and unhealthy tissue.

1.5 An outline of Brain Anatomy

Human brain is the biggest and more complex organ with a large processing capacity which is unmatched to any present computer system. It is made up of more than 100 billion nerves that communicate in trillions of connections called as synapses. The study of brain functions and information processing within is one of the greatest, interesting and challenging tasks in cognition.

The human brain performs controlling functions in our mind and body. The brain is made up of soft tissues and is protected by a very hard skull. The hard skull protects the brain from injuries. Along with hard skull, the brain is also surrounded by a layer of tissue called the meninges and cerebrospinal fluid (CSF) which fills the four ventricles in the brain and provides essential cushioning effect and also provides nutrients. Anatomically the brain is subdivided into three sections namely the forebrain, the midbrain and the hindbrain.

The forebrain (or prosencephalon) is made up of incredible cerebrum, thalamus, hypothalamus and pineal gland. The midbrain (or mesencephalon), located near the center of the brain between the interbrain and the hindbrain, is composed of a portion of the brainstem. The anatomy of human brain is as shown in figure 1.6. The cortex is the outermost layer of brain cells. The voluntary movements and thinking begin from the cortex. The brain stem is in between the spinal cord and the rest of the brain. The basic functions such as breathing and sleep are controlled from here.
• The cerebellum is at the base and the back of the brain and it is responsible for coordination and balance.
• The frontal lobes which are responsible for problem solving, judgment and motor function.
• The parietal lobes which manage body position, handwriting and sensation.
• The temporal lobes that are involved with hearing and memory.
• The occipital lobes that contain the visual processing system of brain

1.6 Brain Tumors

The brain is made up of numerous different varieties of cells. The abnormal, uncontrolled growth of brain cells develop brain tumor. The nature of brain tumor, its position, dimension and state of development are the factors which decide the threat level to the patient. Brain tumors can be categorized as benign or malignant. The malignant tumors invade the brain tissues, grow and spread aggressively and are cancerous. The
benign tumors are slow growing, less serious and are noncancerous but still can cause many serious problems in the brain. The brain tumors that result from uncontrolled and abnormal growth of cells in the brain are called primary brain tumors. The most commonly found primary brain tumors are gliomas, pituitary adenomas, meningiomas, medulloblastomas and glioblastoma. Gliomas originate from nerve cells called glial cells. The secondary or metastatic brain tumors are caused by the spread of cancerous cells from another part of the body through the blood stream. The cancerous or tumor cells spread to the brain from another part of a body tumor in a process called metastasis. The symptoms of brain tumors are many and not specific to the brain tumors. The only way to find the tumor is to undergo medical diagnostic test using MRI scan.

The most frequently used treatments for tumor are surgery, radiation therapy and chemotherapy. The MRI scan technique is used to detect the precise location and dimension of the tumor in the brain so that surgery can be done. In radiation therapy, high energy radiation beams are applied from different angles which destroy the tumor cells and further stop them from growing and multiplying. In Chemotherapy, more powerful drugs are used to kill the cancerous cells. Based on the tumor characteristics the pathologists can determine the dangerous level of a tumor for the patient.

1.7 Medical Image Processing

The term “Medical image processing” (MIP) is the technique of developing algorithms for processing of medical images on a digital computer. It involves the development and implementation of problem-specific methods to enhance the quality of raw medical data (obtained from different modalities) for the determinations of specific visualization, further analysis and treatment planning. The MIP has undergone a dramatic growth and became an interdisciplinary research field by attracting expertise from computer science, engineering, mathematics, physics, biology, statistics and medical science. Now a days the computer-aided diagnostic and treatment planning has already become an important part of clinical procedure. The fastest growth, development and availability of high speed technological advancement and various modern imaging modalities has enabled to perform processing and analysis of a substantial volume of image data so that a quality image can be formed for diagnosis of disease as well as further treatment planning by medical expert.
1.8 Organization of Thesis

The research work entitled “Development of techniques to remove herringbone artifact in brain MRI images and analysis for detection and classification of abnormalities” comprises seven chapters. The chapter 1 highlights the problem definition, motivation towards selection of this topic for research, a brief overview of magnetic resonance imaging, medical image processing, anatomy of brain and brain tumors. The chapter 2 depicts the broad literature survey of the research work that has been carried out by researchers in the relevant topic of the thesis. It gives the complete outline of review of MRI artifacts, review of medical image segmentation techniques, application of neural networks for feature extraction and classification for detection of abnormalities in brain MRI images. The important and relevant research papers are discussed and summarized. The objectives of this research work are stated. The methodology to implement the stated objectives is given in steps and finally the MRI image data collection and database creation is discussed.

In chapter 3, various types of MRI artifacts that arise at the time of image acquisition using MRI scanner, their origin, cause and possible remedies taken by the radiologist are discussed in detail. The chapter 4 presents the implementation of two novel techniques to process and remove herringbone artifact from MRI images of brain. It also explains how the image quality is assessed before and after artifact removal by finding the signal-to-noise ratio (SNR) and energy loss metrics.

The chapter 5 highlights the segmentation techniques for brain MRI image segmentation. The EM, FCM and Morphological segmentation methods are implemented and compared their performance and finally morphological segmentation is applied in this thesis work. The chapter 6 discusses basics of artificial neural networks, GLCM for feature extraction and implementation of SVM classifier for detection and classification of brain abnormalities. The chapter 7 concludes with the summary of findings and scope for future work.