CHAPTER 1

INTRODUCTION

BRAIN ANATOMY

To understand a connection between brain and the MRI scans a brief introduction of human brain anatomy is described here[1]. The human brain is the centre of the human central nervous system (CNS) and is a highly complex organ in the body. This amazing organ is a control centre to receive, interpret, and direct sensory information throughout the body.

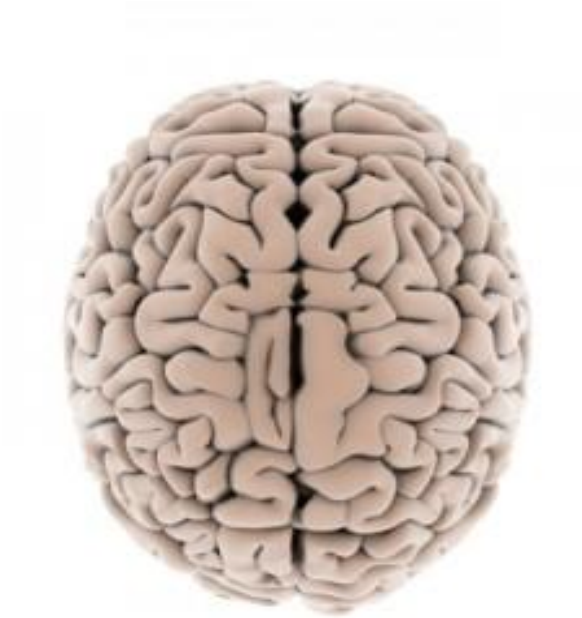


Figure 1.1: Human Brain

The brain can be divided into three major parts:

Forebrain

Midbrain

Hindbrain

The **forebrain** controls a variety of functions including thinking, perceiving, receiving and processing sensory information, understanding and producing language, and controlling motor function. There are two major parts of forebrain: the diencephalon and the telencephalon.

The diencephalon contains structures such as the thalamus and hypothalamus which are responsible for such functions as motor control, transmitting sensory information, and controlling autonomic functions. The telencephalon contains the biggest part of the brain i.e. cerebrum. Almost all of the actual information processing in the brain takes place in the cerebral cortex. It is approximately symmetrical with two hemispheres, right and left. Each of the two hemispheres has four lobes depending on which part of the scalp covers it, namely, the names are: frontal, occipital, parietal and temporal. It involves the cerebral cortex, basal ganglia and limbic system. The cortex is considered a cortical structure, and the basal ganglia and limbic system are subcortical structures place in the cerebral cortex. External layer of cerebral cortex is the neocortex, which is composed by Grey matter (GM) and contains most of the nerve cells. The surface is sulci and gyri that give its classical wrinkled appearance, and increases its outermost surface, called pial surface. The formed intra-cerebral ventricles are filled by

the Cerebrospinal Fluid (CSF), which is mainly water that protects the cortex. Under the neocortex but still inside of the cortex, it can be found the Water Matter (WM), which connects the nerve cells of the cortex to other parts of the CNS with nerve fibres. It allows the connection between both hemispheres through the corpus callosum.

The basal ganglia is a subcortical structure as shown in the Figure 1.2. It composd mainly the striatum.

The limbic system is another subcortical structure presented in the Figure 1.2.

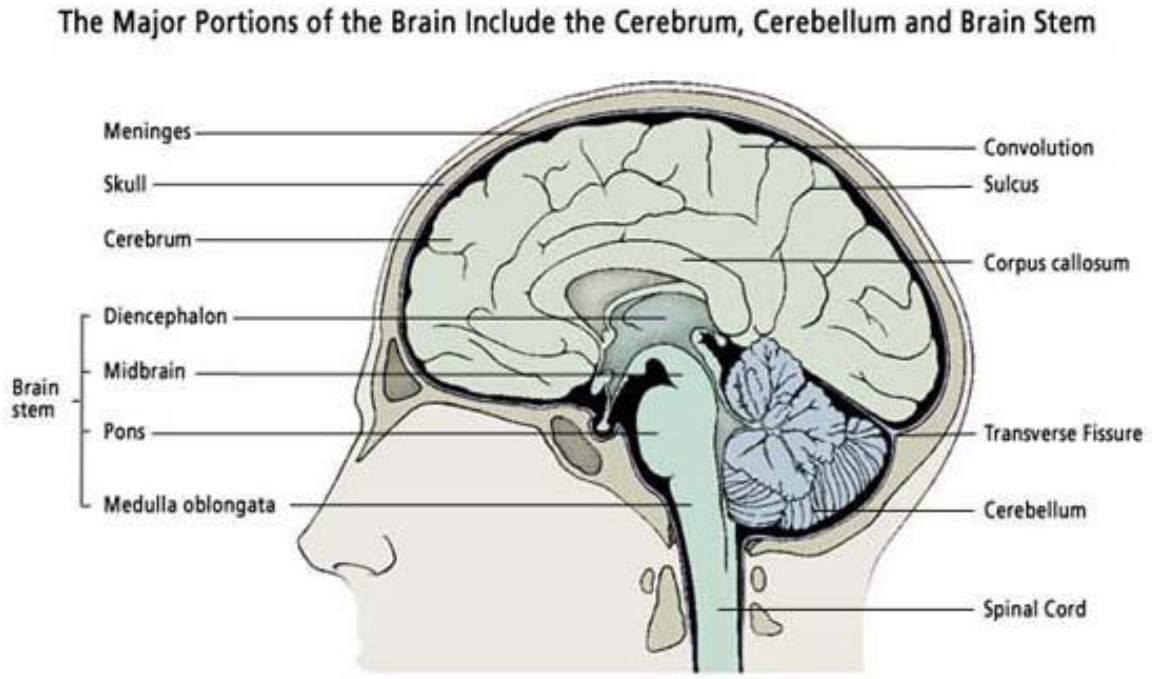


Figure 1.2: Human brain Structure

The **midbrain** and the hindbrain together make up the brainstem. The midbrain is the section of the brainstem that connects the hindbrain and the forebrain. This region of the brain is associated with auditory and visual responses as well as motor function. Its main tissue is white matter (WM).

The **hindbrain** extends from the spinal cord and is composed of the metencephalon and myelencephalon. The metencephalon imclude structures such as the pons and cerebellum. These regions supports in maintaining balance, movement co-ordination, and the transmission of sensory information. Its inner part contains WM and its thin cortex is composed by Grey Matter (GM).

The goal of this project is detect abnormalities in brain by the segmentation of White Matter (WM) and Grey Matter (GM) as described in [2,3]. The WM has a high content of fat, and the GM contains more water. In turn, the Cerebrospinal Fluid (CSF) is mostly composed by water. The different composition of these tissues gives a contrast in the MR scans that permits its differentiation. This is the basic of the segmentation process.

In these thesis brain abnormalities mainly tumour is studied.

TUMOUR

Tumour is an abnormal growth of tissue resulting from uncontrolled, progressive multiplication of cells. However tumour may not be cancerous. There are number of types of tumour that are detected and diagnosed. In our thesis we mainly emphasis on Brain Tumour.

BRAIN TUMOUR

A brain tumour is a growth of cells in the brain that multiply in an abnormal and uncontrolled way.

As a general rule, brain tumours increase in frequency with age, with individual exceptions (e.g pilocytic astrocytoma, the vast majority of which are found in young patients). There are few exceptions, gliomas are more frequent in men and meningiomas are more frequent in women.

TYPES OF TUMOUR

Brain tumours can be classified into two general groups: primary and secondary.

PRIMARY BRAIN TUMOURS

Tumours that originate within brain tissue are known as primary brain tumours. Primary brain tumours are categorized by the type of tissue in which they arise. The most common brain tumours are gliomas, which begin in the glial (supportive) tissue. There are many types of gliomas, some of them are:

- Astrocytomas grow from small and star shaped cells called astrocytes. They may grow in the brain or spinal cord anywhere. In adults, astrocytomas most often grow in the cerebrum. In children, they grow in the cerebrum, the brain stem, and the cerebellum.
- Oligodendrogliomas arise in the cells that produce myelin, the fat covering to protects nerves. These tumours usually arise in the cerebrum. They grow slowly and usually do not dispersed into surrounding tissue.

- Ependymomas usually develop in the lining of the ventricles. They may also occur in the spinal cord. Although these tumours can develop at any age, they are most common in childhood and adolescence.

There are other types of brain tumours that do not begin in glial tissue. Some of the most common are described below:

- Meningiomas arise from the meninges. Usually they are benign. Because these tumours grow very slowly, the brain may be able to adjust to their presence; meningiomas may grow quite large before they cause symptoms. They occur mostly in women between 30 and 50 years of age.
- Schwannomas are benign tumours that arise from Schwann cells, which produce the myelin that protects peripheral nerves. Acoustic neuromas are a type of schwannoma. They occur mainly in adults. These tumours affect women twice as often as men.
- Craniopharyngiomas develop in the region of the pituitary gland near the hypothalamus. They are usually benign; however, they are sometimes considered malignant because they can press on or damage the hypothalamus and affect vital functions. These tumours occur most often in children and adolescents.

- Germ cell tumours arise from primitive (developing) sex cells, or germ cells. The most frequent type of germ cell tumour in the brain is a germinoma.
- Pineal region tumours occur in or around the pineal gland, a tiny organ near the center of the brain. The tumour can be slow growing (pineocytoma) or fast growing (pineoblastoma). The pineal region is very difficult to reach, and these tumours often cannot be removed.

SECONDARY BRAIN TUMOURS

Secondary brain tumours are tumours caused from cancer that originates in another part of the body. These tumours are not the same as primary brain tumours.

The spread of cancer within the body is called metastasis. Cancer that spreads to the brain is the same disease and has the same name as the original (primary) cancer. For example, if lung cancer spreads to the brain, the disease is called metastatic lung cancer because the cells in the secondary tumour resemble abnormal lung cells, not abnormal brain cells.

Treatment for secondary brain tumours depends on where the cancer started and the extent of the spread as well as other factors, including the patient's age general health, and response to previous treatment.

There are more than 120 types of brain and central nervous system (CNS) tumours(). Today, most medical institutions use the World Health Organization (WHO) classification system to identify brain tumours. The WHO classifies brain tumours by cell origin and how the cells behave, from the least aggressive (benign) to the most aggressive (malignant). Some tumour types are assigned a grade, ranging from Grade I (least malignant) to Grade IV (most malignant), which signifies the rate of growth. There are variations in grading systems, depending on the tumour type.

There are numerous individual tumour entities which come under the umbrella term "brain tumour" (see WHO Classification of CNS tumours). They can broadly be divided into:

- neuroepithelial : 50% *
  - astrocytoma : 44%
  - ependymoma : 3%
  - medulloblastoma : 3%
  - oligodendroglioma : 2%
- meningioma : 15%
- metastases : 15%
- pituitary tumours: 8%

- acoustic schwannoma : 8%
- pineal tumours
- intracranial germ cell tumours 0.4% to 3.4% [4](around the pineal, third ventricle or suprasellar region)

*NB: figures vary widely depending on the study (figures quoted are from AH Kaye [3]).

Another set of figures to ponder [5]:

- overall incidence : 5 - 13 cases per 100,000
- incidence in children : 2 - 4 cases per 100,000
- 80% of all intracranial tumours are supratentorial
- 40% are metastases
- 70% of tumours in 1 year olds to adolescents are in the posterior fossa
- of supratentorial tumours
    - 50% are supratentorial
    - 30% are astrocytomas
    - 6% are gangliogliomas

(source: http://radiopaedia.org/)

Next section depicts the images of different types of tumour.

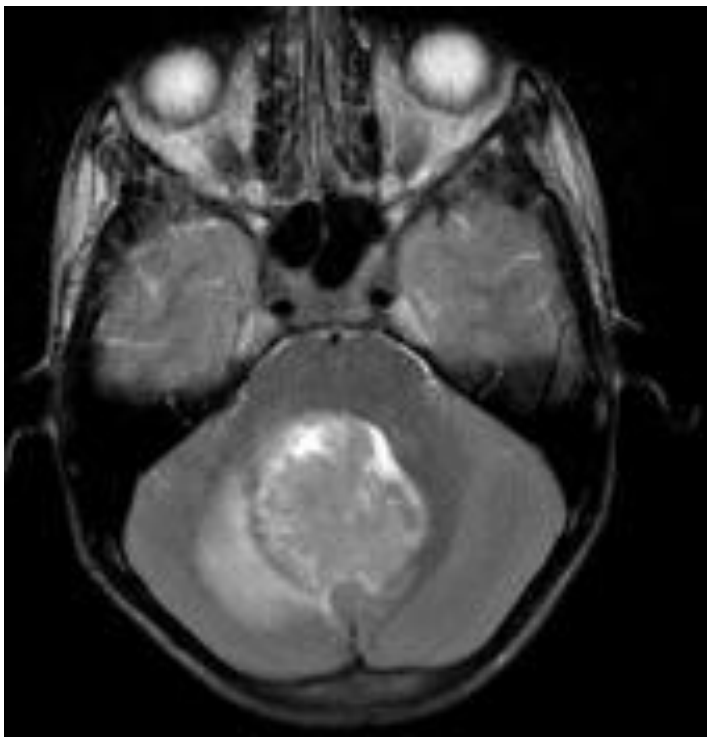


Figure 1.3- Medulloblastoma

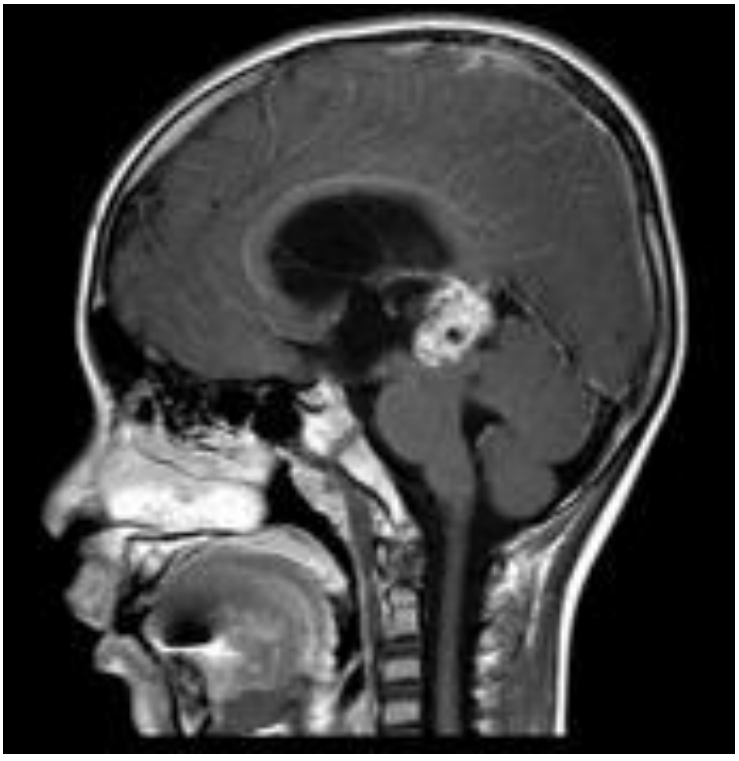


Figure 1.4- Pineal tumour

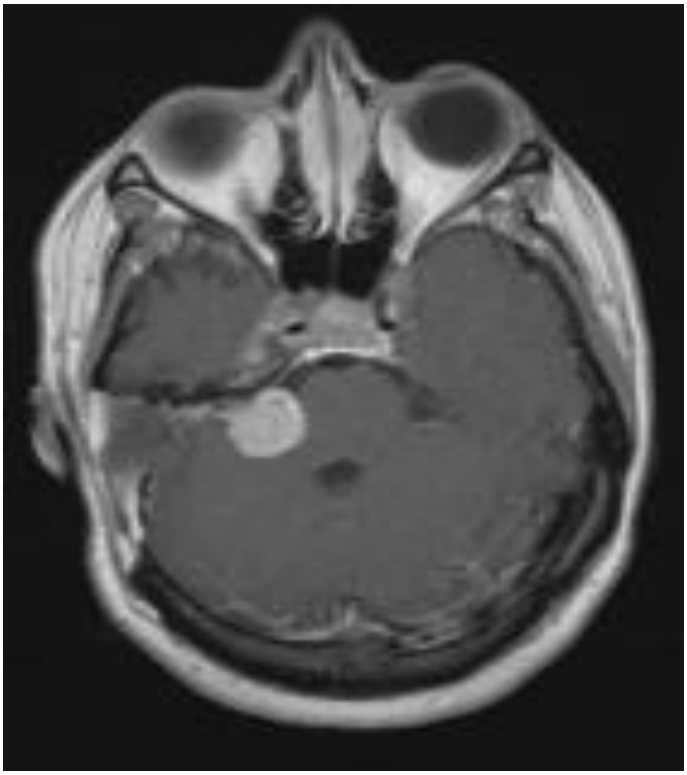


Figure 1.5 Acoustic schwannoma

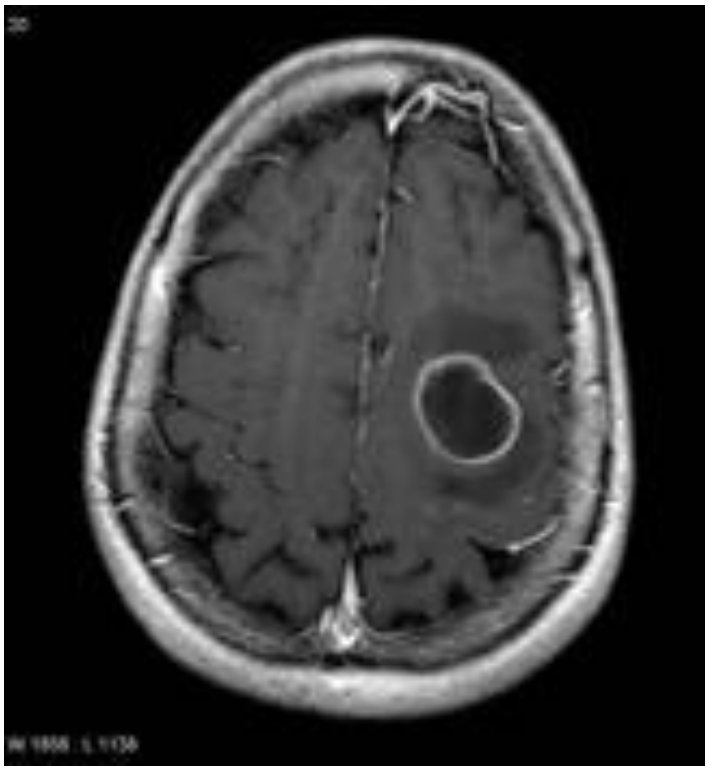


Figure 1.6 Cerebral Metastasis

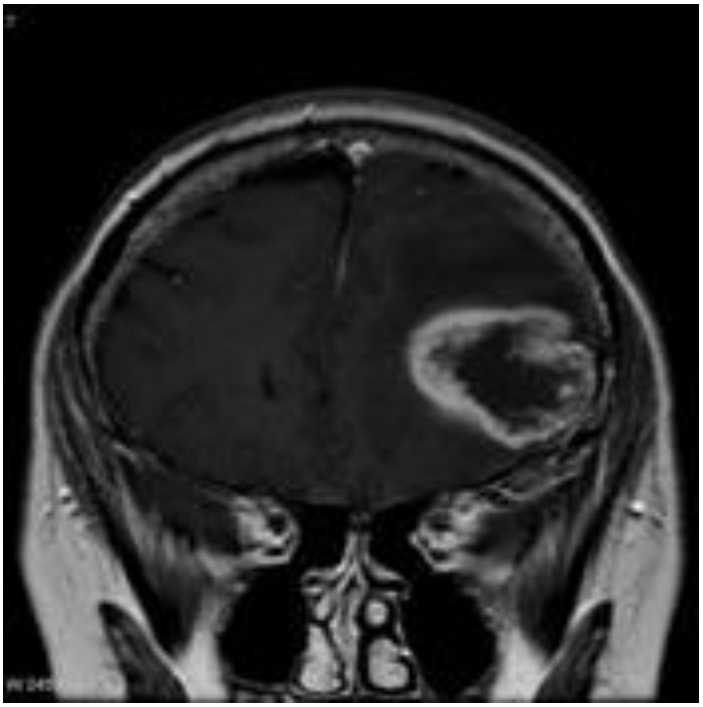


Figure 1.7 Glioblastoma multiforme

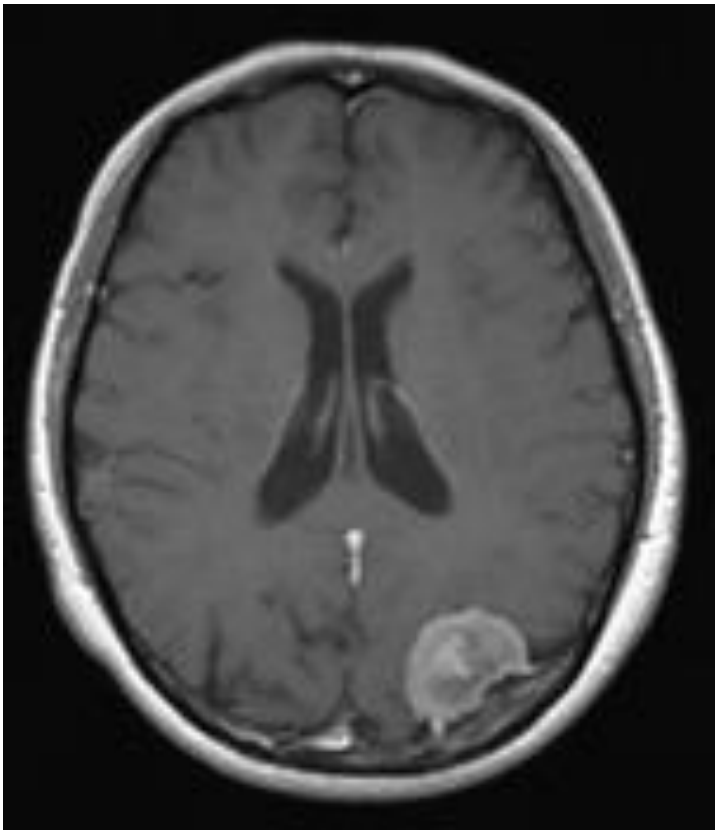


Figure 1.8 Meningioma

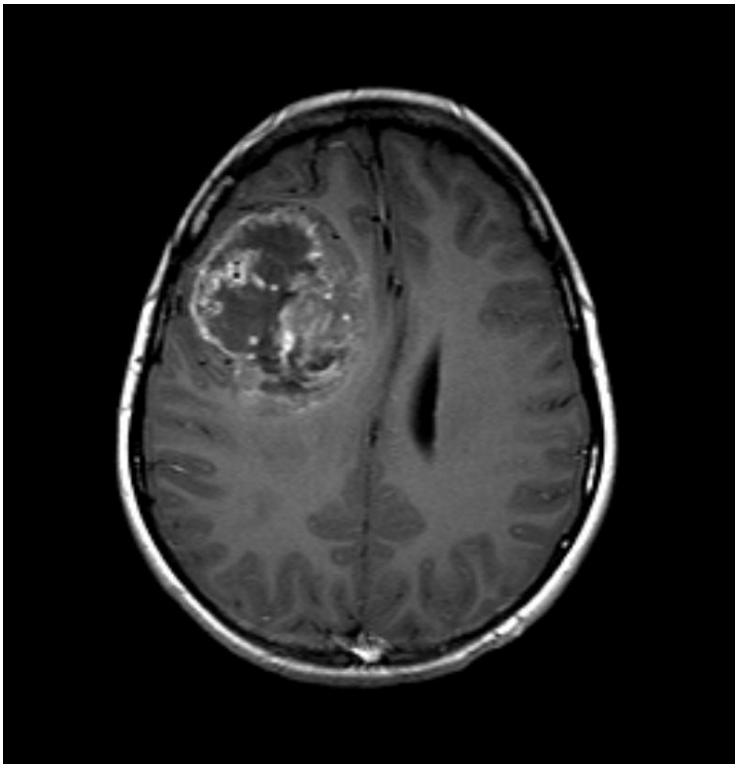


Figure 1.9 Supratentorial

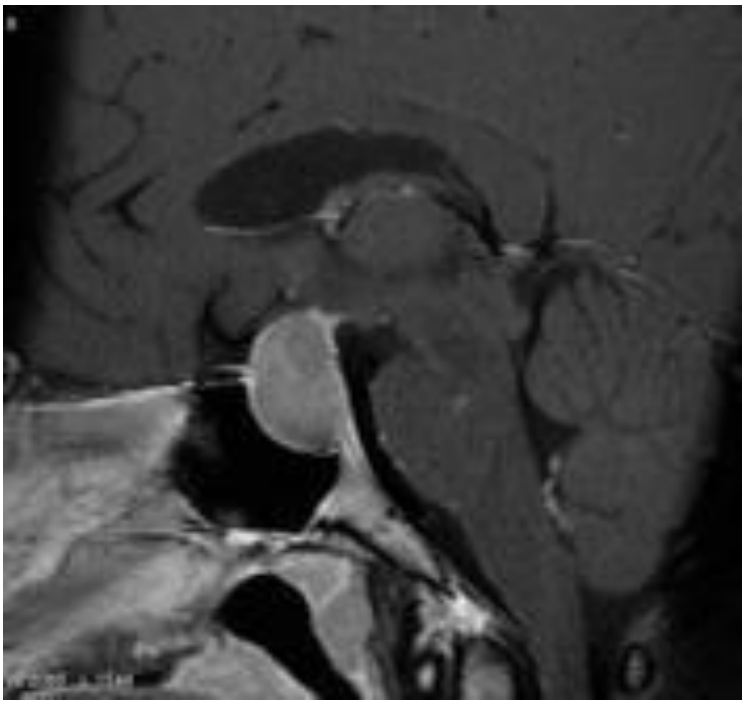


Figure 1.10 Pituitary macroadenoma

TECHNIQUES EXISTING TO DIAGNOSE TO BRAIN TUMOUR

IMAGING TECHNIQUES

Many imaging techniques are used to diagnosis of brain tumour. Some of them are:

MAGNETIC RESONANCE IMAGING

An MRI (magnetic resonance imaging) scan is a radiology technique that uses magnetism, radio waves, and a computer to produce images of body. Magnetic resonance imaging is the standard step for diagnosing a brain tumour. Pictures from various angles are taken that are used to construct a three-dimensional image of the tumour. It clearly gives a picture of tumours near bones, brain stem tumours, smaller tumours, and low-grade tumours. MRI is also useful during surgery to show tumour bulk, for accurately mapping the brain, and for detecting response to therapy.

An MRI of the brain creates a detailed image of the complex structures in the brain.

COMPUTED TOMOGRAPHY

Computed tomography (CT) scan uses a sophisticated x-ray machine and a computer to create a detailed picture of the body's tissues and structures. It is less sensitive as an MRI in detecting small tumours, brain stem tumours, and low-grade tumours. It is useful in certain situations, however. Often, doctors will inject the patient with a contrast material to make it easier to see abnormal tissues. A CT scan helps locate the tumour and can sometimes help determine its type. It can also help detect swelling, bleeding, and associated conditions. In addition, computed tomography is used to evaluate the effectiveness of treatments and watch for tumour recurrence.

POSITRON EMISSION TOMOGRAPHY

Positron emission tomography (PET) provides a picture of the brain's activity rather than its structure by tracking a sugar that has been

labelled with a radioactive tracer. It is sometimes able to distinguish between recurrent tumour cells and dead cells or scar tissue caused by radiation therapy PET is not routinely used for diagnosis, but it may supplement MRIs to help determine tumour grade after a diagnosis. Data from PET may also help improve the accuracy of newer radio surgery techniques. PET scans are often done along with a CT scan.

OTHER IMAGING TECHNIQUES.

Numerous other advanced or investigational imaging techniques include:

SINGLE PHOTON EMISSION TOMOGRAPHY (SPECT)

Single photon emission tomography (SPECT) is similar to PET but is not as effective in distinguishing tumour cells from destroyed tissue after treatments. It may be used after CT or MRI to help distinguish between low-grade and high-grade tumours.

MAGNETOENCEPHALOGRAPHY (MEG)

Magnetoencephalography (MEG) scans measures magnetic fields created by nerve cells. Nerve cells produces electrical currents and this create magnetic field. It is used to check functioning in various parts of the brain. However, this procedure is not widely available.

MRI ANGIOGRAPHY

MRI angiography estimate blood flow. MRI angiography is usually limited to planning surgical removal of a tumour suspected of having a large blood supply.

LUMBAR PUNCTURE (SPINAL TAP)

A lumbar puncture is used to obtain a sample of cerebrospinal fluid, which is examined for the presence of tumour cells. Spinal fluid may also be examined for the presence of certain tumour markers (substances that indicate the presence of a tumour). However, most

primary brain tumours do not currently have identified tumour markers.

A computed tomography (CT) scan or magnetic resonance imaging (MRI) should generally be performed before a lumbar procedure to make sure that the procedure can be performed safely.

BIOPSY

A biopsy is a surgical procedure. In biopsy, a small sample of tissue is taken from the suspected tumour and examined under a microscope for malignancy. The results of the biopsy also provide information on the cancer cell type. Biopsies may be performed as part of surgery to remove a tumour, or as a separate diagnostic procedure.

In some cases, such as with brain stem gliomas, a standard biopsy might be too hazardous because removing any healthy tissue from this area can affect vital functions. In these cases, surgeons can use alternative techniques such as needle biopsy and stereotaxic biopsy. Stereotaxic biopsy is computer-directed type of needle biopsy that uses images provided from MRI or CT scans to provide precise information on the tumours location.

DATASET

The MRI dataset includes approximately 400 T_1 and T_2 weighted volumes from a 3T scanner. The original resolution for T_1 and T_2 modalities is 1mm and 1.1mm, respectively. Although, they are re-sliced to have a final resolution of 1mm isotropic voxels. The age span of the volunteers goes from few months to 61 years. The whole data set have been recorded with the same scanner and acquisition protocol, which did not suffer any update or modification. The images have been co-registered in order that T_1 and T_2 scans are in the same spatial coordinate system and with the same resolution. However, the number of scans that have been re-sliced after the normalization is much smaller. None of the image volumes have been segmented manually, as it is a hard and time consuming process with high risk of error and high variability.

Image source: http://radiopaedia.org/

https://public.cancerimagingarchive.net

https://public.cancerimagingarchive.net/ncia/legalRules.jsf

CHAPTER 2

MAGNETIC RESONANCE IMAGING

MAGNETIC RESONANCE IMAGING

BASICS

Magnetic resonance imaging (MRI), nuclear magnetic resonance imaging (NMRI), or magnetic resonance tomography (MRT) is a radiology technique that uses magnetic field, radio waves, and a computer to produce images of body structure. It visualizes internal structures of the body in detail. MRI principle is based on property of nuclear magnetic resonance (NMR) .MRI used to create more detailed images of the human body structure.

The MRI scanner is a tube surrounded by giant circular magnets. The patient is supposed to lie on a moveable bed that is inserted into the magnet. The magnets produce a strong magnetic field that aligns the magnetization of some atomic nuclei in the body, which are then exposed to a beam of radio waves. This causes spin in the various protons of the body, and they generate a signal that is detected by the receiver portion of the MRI scanner. This information is recorded and a computer processes the receiver information and an image is produced of the scanned area of the body. 2D images or 3D volumes

can be obtained in any arbitrary orientation by using magnetic field gradients in different directions.

MRI yields good contrast between the different soft tissues of the body, which makes it especially useful in imaging the brain, the heart, muscles and cancers when compared to other medical imaging techniques such as computed tomography (CT) or X-rays. MRI does not use ionizing radiation, unlike traditional X-rays.

HOW MRI WORKS

MRI machines make use of the fact that body tissue contains lots of water, and hence protons (^{1}H nuclei), which will be aligned in a large magnetic field. Each water molecule contains two hydrogen nuclei or protons. When a person lies inside the powerful magnetic field of the scanner, the strong magnetic field aligns the magnetic moment of many protons with the direction of the field. A radio frequency current is briefly switched on, that produces a varying electromagnetic field. This electromagnetic field has the right frequency, known as the resonance frequency, that is to be absorbed and flip the spin of the protons in the magnetic field. After the electromagnetic field is switched off, the spins of the protons acquire thermodynamic equilibrium and the bulk magnetization created

becomes realigned with the static magnetic field. During the relaxation process, a radio frequency signal (electromagnetic radiation in the RF range) is originated, which is measured by receiver coils.

Information about the origin of the signal in 3D space can be learned by applying additional magnetic fields during the scan. These additional magnetic fields can be used to generate detectable signals only from specific locations in the body (spatial excitation) and/or to make magnetization at different spatial locations process at different frequencies, which enables k-space encoding of spatial information. The 3D images obtained in MRI can be rotated along arbitrary orientations and manipulated by the doctor to be better able to detect tiny changes of structures within the body. These fields, generated by passing electric currents through gradient coils, make the magnetic field strength vary depending on the position within the magnet. Because this makes the frequency of the released radio signal also dependent on its origin in a predictable manner, the distribution of protons in the body can be mathematically recovered from the signal, typically by the use of inverse Fourier transform.

Protons in different tissues return to their equilibrium state at different relaxation rates. Different tissue variables, including spin density, T_1 and T_2 relaxation times, and flow and spectral shifts, can be used to construct images. By changing the settings 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.

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 tumours.

MEDICAL MRI SCANNER

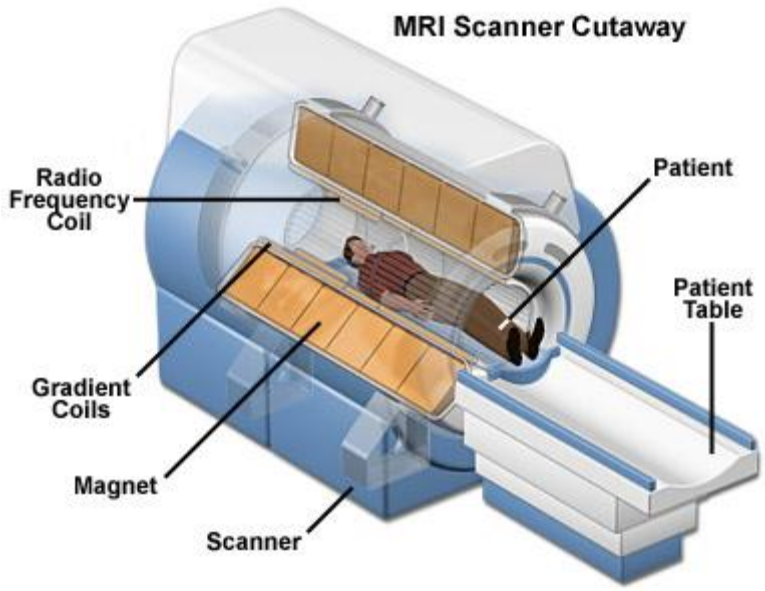


Figure 2.1 MRI Scanner

MAGNETIC FIELD

MRI scans require a magnetic field with two properties, uniform field density and strength. The magnetic field cannot vary more than 1/10,000 of 1% and field strength ranges (depending on the scanner) from 0.2 to 3 teslas in strength in scanners currently used clinically, with research scanners investigating higher field strengths such as 7 teslas. The lower field strengths can be achieved with permanent magnets, which are often used in "open" MRI scanners for claustrophobic patients. Higher field strengths can be achieved only with superconducting magnets. An MRI with a 3.0 tesla strength magnet may be referred to as a "3-T MRI" or "3-tesla MRI"

Since the gradient coils are within the bore of the scanner, there are large forces between them and the main field coils, producing most of the hammering noise that is heard during operation. Without efforts to damp this noise, it can approach 130 decibels (dB) with strong fields

CONTRAST AGENTS AND IMPLANTS

MRI contrast agents may be injected intravenously to enhance the appearance of blood vessels, tumours 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. There are many electronically activated devices that have approval from the US FDA to permit MRI procedures in patients under highly specific MRI conditions. 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, so patients with such implants are generally not eligible for MRI.

HISTORY

Before beginning a thesis consider the brief history of MRI. The idea of MRI starts around 1946 when Felix Bloch proposed some new properties for the atomic nucleus in a Nobel Prize winning paper. He stated that the nucleus behaves like a magnet. He discover that when a charged particle, such as a proton etc spinning around its own axis creates a magnetic field which is known as a magnetic momentum. In 1960 Nuclear Magnetic Resonance spectrometers were introduced for analytical purposes. During the 1960s and 1970s NMR spectrometers were widely used in academic and industrial research. Spectrometry is used to analyze the molecular configuration of material based on its NMR spectrum.

In the late 1960s Raymond Damadian discovered that malignant tissue had different NMR parameters than normal tissue. Based on these differences, it should be possible to characterize tissues. Based on this discovery he produced the first ever NMR image of a rat tumour in 1974. In 1977 Damadian and his team constructed the first super conducting NMR scanner (known as The Indomitable) and produced the first image of the human body, which took almost 5 hours to scan.

At the same time Paul Lauterbur was pioneering in the same field. One could discuss who was responsible for bringing MRI to us, although, in all fairness, one could accept that both gentlemen had their contribution.

The name Nuclear Magnetic Resonance (NMR) was changed into Magnetic Resonance Imaging (MRI) because it was believed that the word nuclear would not find wide acceptance amongst the public.

The rest is, as they say, history. In the early 1980s just about every major medical imaging equipment manufacturer researched and produced MRI scanners. Since then a lot has happened in terms of development. The hardware and software became faster, more intelligent and easier to use. Because of the development of advanced MRI pulse sequences more applications for MRI opened up, such as MR Angiography, Functional Imaging and Perfusion / Diffusion scanning.

APPLICATIONS

In clinical practice, MRI is used to distinguish pathologic tissue (such as a brain tumour) from normal tissue. One advantage of an MRI scan is that it is harmless to the patient. It uses strong magnetic fields and non-ionizing electromagnetic fields in the radio frequency range,

unlike CT scans and traditional X-rays, which both use ionizing radiation.

While CT provides good spatial resolution (the ability to distinguish two separate structures at a small distance from each other), MRI provides comparable resolution with far better contrast resolution (the ability to distinguish the differences between two similar but not identical tissues). The basis of this ability is the complex library of pulse sequences that the modern medical MRI scanner includes, each of which is optimized to provide image contrast based on the chemical sensitivity of MRI.

MRI : TYPES

T_1-WEIGHTED MRI

T_1-weighted scans refer to a set of standard scans that depict differences in the spin-lattice (or T_1) relaxation time of various tissues within the body. T_1 weighted images can be acquired using either spin echo or gradient-echo sequences. T_1-weighted contrast can be increased with the application of an inversion recovery RF pulse. Gradient-echo based T_1-weighted sequences can be acquired very

rapidly because of their ability to use short inter-pulse repetition times (T_R). T_1-weighted sequences are often collected before and after infusion of T_1-shortening MRI contrast agents. In the brain T_1-weighted scans provide appreciable contrast between gray and white matter. In the body, T_1 weighted scans work well for differentiating fat from water—with water appearing darker and fat brighter.

T_2-WEIGHTED MRI

T_2-weighted scans refer to a set of standard scans that depict differences in the spin-spin (or T_2) relaxation time of various tissues within the body. Like the T_1-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 T_2-weighted images. These scans are therefore particularly well suited to imaging edema, with long T_E and long T_R. Because the spin echo sequence is less susceptible to inhomogeneities in the magnetic field, these images have long been a clinical workhorse.

T*2-WEIGHTED MRI

T*2 (pronounced "T 2 star") weighted scans use a gradient echo (GRE) sequence, with long T_E and long T_R. The gradient echo sequence used does not have the extra refocusing pulse used in spin echo so it is subject to additional losses above the normal T_2 decay (referred to as T_2'), these taken together are called T* 2. This also makes it more prone to susceptibility losses at air/tissue boundaries, but can increase contrast for certain types of tissue, such as venous blood.

SPIN DENSITY WEIGHTED MRI

Spin density, also called proton density, weighted scans try to have no contrast from either T_2 or T_1 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 T_E and long T_R.

DIFFUSION MRI

Diffusion MRI measures the diffusion of water molecules in biological tissues. Clinically, diffusion MRI is useful for the diagnoses of conditions (e.g., stroke) or neurological disorders (e.g., multiple sclerosis), and helps better understand the connectivity of white matter axons in the central nervous system. In an isotropic medium (inside a glass of water for example), water molecules naturally move randomly according to turbulence and Brownian motion. In biological tissues however, where the Reynolds number is low enough for flows to be laminar, the diffusion may be anisotropic. For example, a molecule inside the axon of a neuron has a low probability of crossing the myelin membrane. Therefore the molecule moves principally along the axis of the neural fibre. If it is known that molecules in a particular voxel diffuse principally in one direction, the assumption can be made that the majority of the fibres in this area are parallel to that direction.

The recent development of diffusion tensor imaging (DTI) enables diffusion to be measured in multiple directions and the fractional anisotropy in each direction to be calculated for each voxel. This enables researchers to make brain maps of fibre directions to examine the connectivity of different regions in the brain (using tractography)

or to examine areas of neural degeneration and demyelination in diseases like multiple sclerosis.

Another application of diffusion MRI is diffusion-weighted imaging (DWI). Following an ischemic stroke, DWI is highly sensitive to the changes occurring in the lesion. It is speculated that increases in restriction (barriers) to water diffusion, as a result of cytotoxic edema (cellular swelling), is responsible for the increase in signal on a DWI scan. The DWI enhancement appears within 5–10 minutes of the onset of stroke symptoms (as compared with computed tomography, which often does not detect changes of acute infarct for up to 4–6 hours) and remains for up to two weeks. Coupled with imaging of cerebral perfusion, researchers can highlight regions of "perfusion/diffusion mismatch" that may indicate regions capable of salvage by reperfusion therapy.

Like many other specialized applications, this technique is usually coupled with a fast image acquisition sequence, such as echo planar imaging sequence.

FLUID ATTENUATED INVERSION RECOVERY (FLAIR)

Fluid Attenuated Inversion Recovery (FLAIR) is an inversion recovery pulse sequence used to nullify the signal from fluids.

For example, it can be used in brain imaging to suppress cerebrospinal fluid (CSF) so as to bring out periventricular hyperintense lesions, such as multiple sclerosis (MS) plaques. By carefully choosing the inversion time TI (the time between the inversion and excitation pulses), the signal from any particular tissue can be suppressed.

MAGNETIC RESONANCE ANGIOGRAPHY

Magnetic resonance angiography (MRA) generates pictures of the arteries to evaluate them for stenosis (abnormal narrowing) or aneurysms (vessel wall dilatations, at risk of rupture). MRA is often used to evaluate the arteries of the neck and brain, the thoracic and abdominal aorta, the renal arteries, and the legs (called a "run-off"). A variety of techniques can be used to generate the pictures, such as administration of a paramagnetic contrast agent (gadolinium) or using a technique known as "flow-related enhancement" (e.g., 2D and 3D time-of-flight sequences), where most of the signal on an image is due to blood that recently moved into that plane, see also FLASH MRI. Techniques involving phase accumulation (known as phase contrast angiography) can also be used to generate flow velocity maps easily and accurately. Magnetic resonance venography (MRV) is a similar

procedure that is used to image veins. In this method, the tissue is now excited inferiorly, while the signal is gathered in the plane immediately superior to the excitation plane—thus imaging the venous blood that recently moved from the excited plane.

MAGNETIC RESONANCE SPECTROSCOPY

Magnetic resonance spectroscopy (MRS) is used to measure the levels of different metabolites in body tissues. The MR signal produces a spectrum of resonances that corresponds to different molecular arrangements of the isotope being "excited". This signature is used to diagnose certain metabolic disorders, especially those affecting the brain,[49] and to provide information on tumour metabolism.[50]

Magnetic resonance spectroscopic imaging (MRSI) combines both spectroscopic and imaging methods to produce spatially localized spectra from within the sample or patient. The spatial resolution is much lower (limited by the available SNR), but the spectra in each voxel contains information about many metabolites. Because the available signal is used to encode spatial and spectral information, MRSI requires high SNR achievable only at higher field strengths (3 T and above).

FUNCTIONAL MRI

Functional MRI (fMRI) measures signal changes in the brain that are due to changing neural activity. The brain is scanned at low resolution but at a rapid rate (typically once every 2–3 seconds). Increases in neural activity cause changes in the MR signal via T* 2 changes; this mechanism is referred to as the BOLD (blood-oxygen-level dependent) effect. Increased neural activity causes an increased demand for oxygen, and the vascular system actually overcompensates for this, increasing the amount of oxygenated hemoglobin relative to deoxygenated hemoglobin. Because deoxygenated hemoglobin attenuates the MR signal, the vascular response leads to a signal increase that is related to the neural activity. The precise nature of the relationship between neural activity and the BOLD signal is a subject of current research. The BOLD effect also allows for the generation of high resolution 3D maps of the venous vasculature within neural tissue.

While BOLD signal analysis is the most common method employed for neuroscience studies in human subjects, the flexible nature of MR imaging provides means to sensitize the signal to other aspects of the blood supply. Alternative techniques employ arterial spin labeling (ASL) or weighting the MRI signal by cerebral blood flow (CBF) and cerebral blood volume (CBV). The CBV method requires injection of

a class of MRI contrast agents that are now in human clinical trials. Because this method has been shown to be far more sensitive than the BOLD technique in preclinical studies, it may potentially expand the role of fMRI in clinical applications. The CBF method provides more quantitative information than the BOLD signal, albeit at a significant loss of detection sensitivity.

OTHER SPECIALIZED MRI TECHNIQUES

New methods and variants of existing methods are often published when they are able to produce better results in specific fields. Examples of these recent improvements are T* 2-weighted turbo spin-echo (T_2 TSE MRI), double inversion recovery MRI (DIR-MRI) or phase-sensitive inversion recovery MRI (PSIR-MRI), all of them able to improve imaging of brain lesions.

MRI has the advantages of having very high spatial resolution and is very adept at morphological imaging and functional imaging. MRI does have several disadvantages though. First, MRI has a sensitivity of around 10^{-3} mol/L to 10^{-5} mol/L which, compared to other types of imaging, can be very limiting. This problem stems from the fact that the difference between atoms in the high energy state and the low energy state is very small. For example, at 1.5 teslas, a typical field

strength for clinical MRI, the difference between high and low energy states is approximately 9 molecules per 2 million. Improvements to increase MR sensitivity include increasing magnetic field strength, and hyperpolarization via optical pumping or dynamic nuclear polarization. There are also a variety of signal amplification schemes based on chemical exchange that increase sensitivity.

To achieve molecular imaging of disease biomarkers using MRI, targeted MRI contrast agents with high specificity and high relaxivity (sensitivity) are required. To date, many studies have been devoted to developing targeted-MRI contrast agents to achieve molecular imaging by MRI. Commonly, peptides, antibodies, or small ligands, and small protein domains, such as HER-2 affibodies, have been applied to achieve targeting. To enhance the sensitivity of the contrast agents, these targeting moieties are usually linked to high payload MRI contrast agents or MRI contrast agents with high relaxivities.

CONTRAST AGENTS

The most commonly used intravenous contrast agents are based on chelates of gadolinium. In general, these agents have proved safer than the iodinated contrast agents used in X-ray radiography or CT. Anaphylactoid reactions are rare, occurring in approx. 0.03–0.1%.[95]

Of particular interest is the lower incidence of nephrotoxicity, compared with iodinated agents, when given at usual doses—this has made contrast-enhanced MRI scanning an option for patients with renal impairment, who would otherwise not be able to undergo contrast-enhanced CT.

Although gadolinium agents have proved useful for patients with renal impairment, in patients with severe renal failure requiring dialysis there is a risk of a rare but serious illness, nephrogenic systemic fibrosis, which may be linked to the use of certain gadolinium-containing agents. The most frequently linked is gadodiamide, but other agents have been linked too.[97] Although a causal link has not been definitively established, current guidelines in the United States are that dialysis patients should only receive gadolinium agents where essential, and that dialysis should be performed as soon as possible after the scan to remove the agent from the body promptly. In Europe, where more gadolinium-containing agents are available, a classification of agents according to potential risks has been released. Recently, a new contrast agent named gadoxetate, brand name Eovist (US) or Primovist (EU), was approved for diagnostic use: this has the theoretical benefit of a dual excretion path.

ADVANTAGES

The MRI technique has several advantages compared to other neuroimaging techniques. For example, it is fast and it does not use ionizing radiation; therefore, it can be used several times on the patients because the absorbed radiation is minimal. Its isotropic resolution is around 1 mm^3 with 3T MRI scanners, which outperforms the 8 mm^3 of PET. It has a high versatility, because it can be used to study structural and functional brain features with different configurations. Besides, it is not affected by the hardening beam effect of CT because the range of frequencies is small, and the attenuation coefficient of the tissues is almost homogeneous.

DISADVANTAGES

It is an expensive and complex technique. There are many parameters that must be tuned up correctly in order to optimize the image acquisition. In addition, all the metal objects of the patients should be removed before the scanning starts, which is impossible for some kind of surgical implants. Besides, this technique is only suited to analyse soft tissues because the bones have not a significant contrast in the images.

CHAPTER 3

PREPROCESSING AND SEGMENTATION

A. ENHANCEMENT

Image processing and enhancement stage is the simplest categories of medical image processing. Image enhancement techniques are the algorithms which improve the quality of images by removing blurring and noise, increasing contrast and sharpness of digital medical images. This stage highlights edges or displaying digital images. Some more techniques can employ medical image processing of coherent echo signals prior to image generation. The enhancement stage includes resolution enhancement and contrast enhancement. These are used for suppressing noise and imaging of spectral parameters. The medical image is converted into standard image without noise, film artifacts and labels after this stage.

Image enhancement methods improves the visual appearance of images from Magnetic Resonance Image (MRI), Computer Tomography (CT) scan; Positron Emission Tomography (PET) and the contrast enhancing brain volumes are linearly aligned. The enhancement activities are removal of film artifacts and labels, filtering the images. This part is use to enhances the smoothness towards piecewise homogeneous region and reduces the edge-blurring effect. Conventional Enhancement techniques such as Low pass filter, Median filter, Gabor Filter, Gaussian Filter and Prewitt edge-finding filter. The

Pre-processing aspects are surveyed and analyzed in this section.

There are many image enhancement approaches [4] (theories) like Contrast stretching, Range compression, Histogram equalization and noise smoothing. A certain amount of trial and error usually is required before a particular image enhancement approach is selected.

The enhancement methods can broadly classified as:

1. Spatial Domain Methods
2. Frequency Domain Methods

In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values.

Image enhancement is applied in every field where images are ought to be understood and analyzed. For example, medical image analysis,

analysis of images from satellites etc.

Image enhancement simply means, transforming an image f into image g using T. (Where T is the transformation. The values of pixels in images f and g are denoted by r and s, respectively. As said, the pixel values r and s are related by the expression,

$$s = T(r)$$

Eq(3.1)

Where T is a transformation that maps a pixel value r into a pixel value s. The results of this transformation are mapped into the grey scale range as we are dealing here only with grey scale digital images. So, the results are mapped back into the range [0, L-1], where $L=2^k$, k being the number of bits in the image being considered. So, for instance, for an 8-bit image the range of pixel values will be [0, 255].

I will consider only gray level images. The same theory can be extended for the color images too. A digital gray image can have pixel values in the range of 0 to 255.

SPATIAL DOMAIN METHODS

Spatial domain methods for image enhancement, that operate

directly on the aggregate of pixels composing an image. Some of them are point processing methods, histogram processing etc.

POINT PROCESSING OPERATION

The simplest spatial domain operations occur when the neighbourhood is simply the pixel itself. In this case T is referred to as a grey level transformation function or a point processing operation. Point processing operations take the form shown

$$g(x, y) = T[f(x, y)]$$

Eq(3.2)

CONTRAST STRETCHING

The difference between the intensity of two adjacent pixels is termed as "Contrast". In high contrast images this difference will be more and in low contrast images this difference will be less. Low-contrast images occur often due to poor or non uniform lighting conditions or due to non linearity or small dynamic range

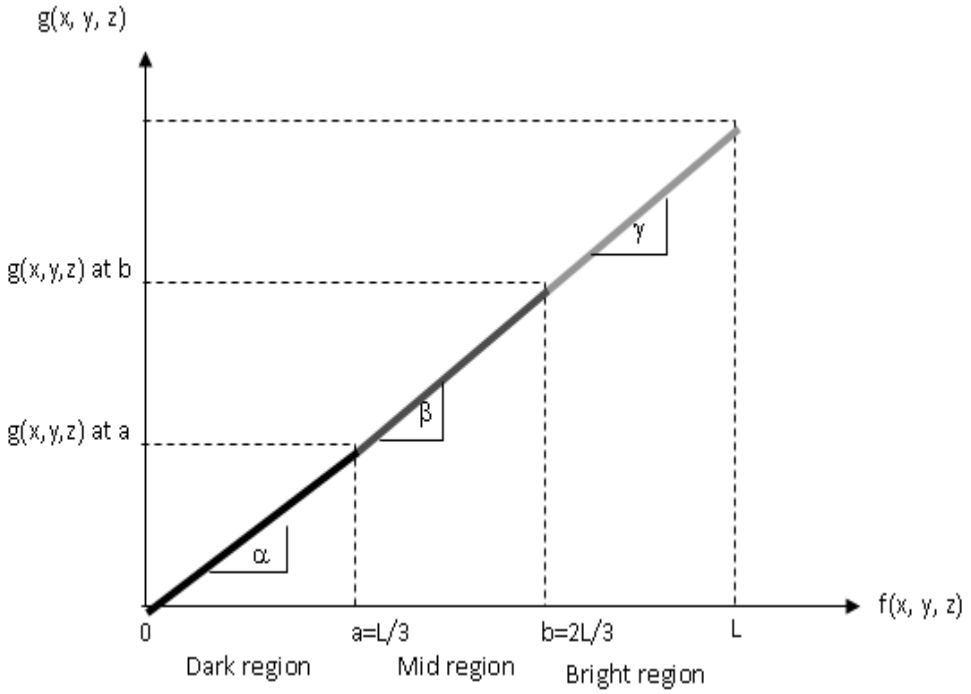
of the imaging sensor. The Contrast stretching transformation is given by

$$g(x, y) = \begin{cases} \alpha * f(x, y) & 0 <= f(x, y) <= a \\ \beta * (f(x, y) - a) + g(x, y) \text{ at } a & a < f(x, y) <= b \\ \gamma * (f(x, y) - b) + g(x, y) \text{ at } b & b < f(x, y) <= L \end{cases}$$

Eq(3.3)

The slope of the transformation is chosen greater than unity where there is need of contrast stretch.

- For dark region stretch $\alpha > 1$
- For mid region stretch $\beta > 1$
- For bright region stretch $\gamma > 1$
- a = L/3
- b = 2L/3
- g(x, y) at a = a * a;
- g(x, y) at b = b * (b –a) + g(x, y) at a



- If 'f' represents an image, 'x' represents number of rows, 'y' represents number of columns then f(x, y) is used to represent intensity at position (x, y).
- If we use 8 bits to represent intensity, then we can represent 2^8 intensities (levels), i.e. from 0 to 255 levels.
- Therefore the value of f(x, y, z) lies in between 0 to 255 (0 to L-1), where L represents number of levels.

Thus by contrast stretching the details in very dark or bright areas become clearly visible.

HISTOGRAM PROCESSING

The histogram of a digital image with intensity levels in the range [0, L-1] is a discrete function.

Histograms are frequently normalized by the total number of pixels in the image. Histogram equalization is a common technique for enhancing the appearance of images. Suppose we have an image which is predominantly dark. Then its histogram would be skewed towards the lower end of the grey scale and all the image detail is compressed into the dark end of the histogram. Histogram equalization is used for enhancing the contrasts in an intensity image. This works for images where almost all of the different intensity levels are represented.

GAMMA CORRECTIONS:

If an image is low contrast and dark image, we try to improve its contrast and brightness. The widespread histogram equalization method cannot correctly improve all parts of the image. When the original image is irregularly illuminated, some details on resulting image will remain too bright or too dark. So we go for gamma correction which performs nonlinear brightness adjustment. For darker pixels brightness is increased and bright pixels remain bright almost same as before. Thus more details are clearly visible. If

gamma=1 the mapping is linear. When gamma = 0.5, number of pixels having high/brighter intensity level are more. So the image will be brighter having high contrast. When gamma = 1.5, number of pixels having low/dark intensity level are more. So the image will be dark having low contrast. Thus by varying the gamma value the contrast of image is varied.

$$J(x,y)=c*(I(x,y))^{gamma};$$

Where, I=original image

J= gamma corrected image

c= constant

The following plots show the resulting image and its histogram after three different gamma correction settings with c=1.

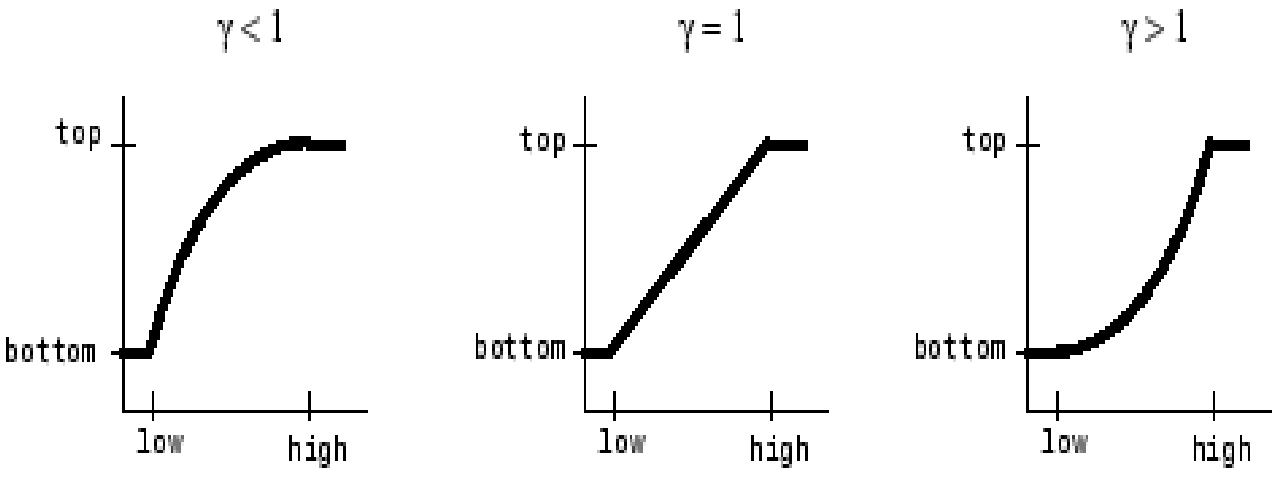


IMAGE ENHANCEMENT USING NOISE SMOOTHING

Noise artifacts are a part of every medical image obtained with any technology which can significantly hinder the diagnostic quality. Noise can be removed using median filter. The main idea of the median filter is to run through the image pixel intensity values, replacing each pixel value with the median of neighbouring pixel values. The pattern of neighbours is called the "window", which slides, over the entire image signal. For 2D image this window is of a box pattern.

The median filters smooth the transient changes in signal intensity (noise). They are very effective in removing impulsive noises from the image by preserving the edge information.

B. SEGMENTATION

INTRODUCTION

Image segmentation is the division of scenes into its component regions, a prerequisite for labelling of organs, organelles, and anatomic substructures found in images. Segmentation is the signal and image processing equivalent of anatomic or surgical dissection that results in separate components, typically much fewer in number

than the individual image elements (pixels or voxels). Segmentation is achieved by subjective or objective methods that associate and aggregate locally homogeneous image elements based on some measurable feature (or features) such as intensity, texture, gradient or many others. Segmentation is an important aspect of computer vision and statistical pattern recognition, based upon feature extraction and classification. Segmentation is an essential first step in many applications that require image modelling, visualization, and /or registration. There are many published segmentation algorithms over the years. The segmentation can be undertaken by several ways. Based on approach, we can divide the segmentation algorithms to:

1) Methods based on edge detection (edge-based) such as active contours [5], or level-sets – These methods are oriented to detect significant edges in an image. Local edges are detected by using edge detectors based, which takes an advantage of different values of neighbouring pixels. There are a number of edge detection algorithms that produce a set of edges (points, pixels, or fragments) in the image.

2) Methods oriented regions in the image (region-based) such as Region growing, or Split and merge – They are using similar principles as edge-based methods as described here [6]. If you can identify the edges, should in theory delimiting the regions found by

region-based segmentation. Contours of regions may be broken, not delimiting the region. Otherwise there is no guarantee that the boundaries of regions found by edge-based method will be the same as found by region-based method.

3) Statistical methods – Segmentation is based on statistical analysis of image data, and pixel values. Structural information is usually neglected. The most known methods are thresholds, clustering and Fuzzy Connectedness [7].

4) Hybrid methods such as Watershed Transform – These segmentation techniques contain elements of the previous three categories – they are taking advantages from each of them. Mathematical morphology-based methods are also included among the hybrid methods. It is a group of methods for segmentation, which uses mathematical characteristics of the image, for example -gradient progress.

5) Knowledge (knowledge-based) methods such as Active Appearance Model (AAM) – Method known the properties of segmented objects (shape, colour, texture, etc.) The AAM can facilitate segmentation greatly. Methods, which belongs to this

category, uses atlas originals or models of segmented objects (in the case of medical data e.g. atlas of human tissues). Atlas is generated automatically or manually from the set of training data, or information entered manually, based on human experience. Algorithm seeks the transformation of familiar objects, templates in the Atlas, the objects found in the image during the segmentation. This process is usually called the atlas-warping and it often uses a linear transformation.

There is a possibility for introducing some auxiliary criteria for classification of segmentation techniques. The first one is the type of the processed image data.

1) 2D image algorithms – two dimensional image processing algorithms, e.g. image raster data.

2) 3D volumetric algorithms – work with 3D raster data. Most of data are a medical CT or MRI

3) Data type independent algorithms are often a statistical method.

SEGMENTATION MEDICAL IMAGE DATA

The Segmentation is the process of extraction of the White matter (WM), Gray matter (GM) and Cerebrospinal Fluid (CSF) from the MRI pictures. Volumetric calculations are carried out on the segmented cortical tissues. The accuracy in determining the volume depends on the correctness of the segmentation algorithm. The selection of imaging methods matches the type of examination, e.g. CT, MRI, and ultrasound. There is not guaranteed, that the complex anatomical structure of tissues will be well separable. Boundaries of tissues may not be obvious due to noise and in homogeneity artifacts, which are resulting from the acquisition of data. Objects can be very complex and/other boundaries may overlap. In this case, the distinguishing of individual objects is difficult even for trained human eye, much less for a computer algorithm. The medical image data, e.g. CT, MRI, could be viewed through the traditional image processing. Computed tomography could provide to us good information about the anatomical structure of organs and soft tissues, but it is very sensitive to tissue density differences. Magnetic resonance imaging produces information about the chemical composition of the tissues. The major advantages of MRI are providing a good resolution of soft tissues and no affecting the measured signal by the bones. For these reasons, MRI is used mainly for soft tissue examination to detect

pathological changes, such as malignant tumours. Generally medical data are produced as a series of planar slices, from which you can build 3D data image. We can use a specialised 3D segmentation algorithm after that. While the 2D models have been commonly used since 1990, widespread use of 3D models emerged in recent years. It is due to breakthroughs in the automatic detection of shape correspondence. Due to the wide range of shape correspondence methods, a comparison between them should be able to distinguish between suitable and unsuitable approaches. Unfortunately, this comparison is simply not practicable because of various reasons. Davies therefore introduced three measures to evaluate the general quality of the approaches: generalisation ability, specificity and compactness. Generalisation ability of the model quantifies the ability to introduce new shapes. All measures are generally defined as a function of the number of modes and parameters which are used in the model and displayed as piecewise linear graphs. Lower values indicate better models. There are other evaluations e.g. Styner. In addition to these three theoretical measures, it is possible to evaluate the segmentation accuracy of the model on test data. The first evaluations of various methods of correspondence analysis of the shape are shown in the publication Styner. Due to the very difficult evaluation of selected algorithms and the quality of the achieved results, we propose a new segmentation procedure possible, which should provide very reliable results. Our algorithm combines several

methods to use their advantages and provide better and faster results. Among the most promising techniques for extraction of complex objects from digital images are active contours or snakes, originally introduced by Kassetal. Since the seminal work of Kassetal and colleagues, Active contours technique have been applied to many object extraction tasks with a gives different degree of success. Particularly, snakes are used to locate the objects in various applications of medical image processing such as segmentation of abnormalities in the images of the human heart, liver, brain, breast, etc.

The analysis on execution time of traditional serial segmentation algorithm for multiple slices shows that the time taken for execution is directly proportional to the number of slices and increases exponentially as the number of slices increases.

CHAPTER 4

PROPOSED METHODOLGY

The proposed methodology consists of the following stages, viz. MR image database, feature extraction and segmentation method uses mathematical morphology based operation called erosion for skull stripping and Fuzzy C-means clustering for tumour extraction. The proposed technique for MR brain tumour image is shown in fig 4.1

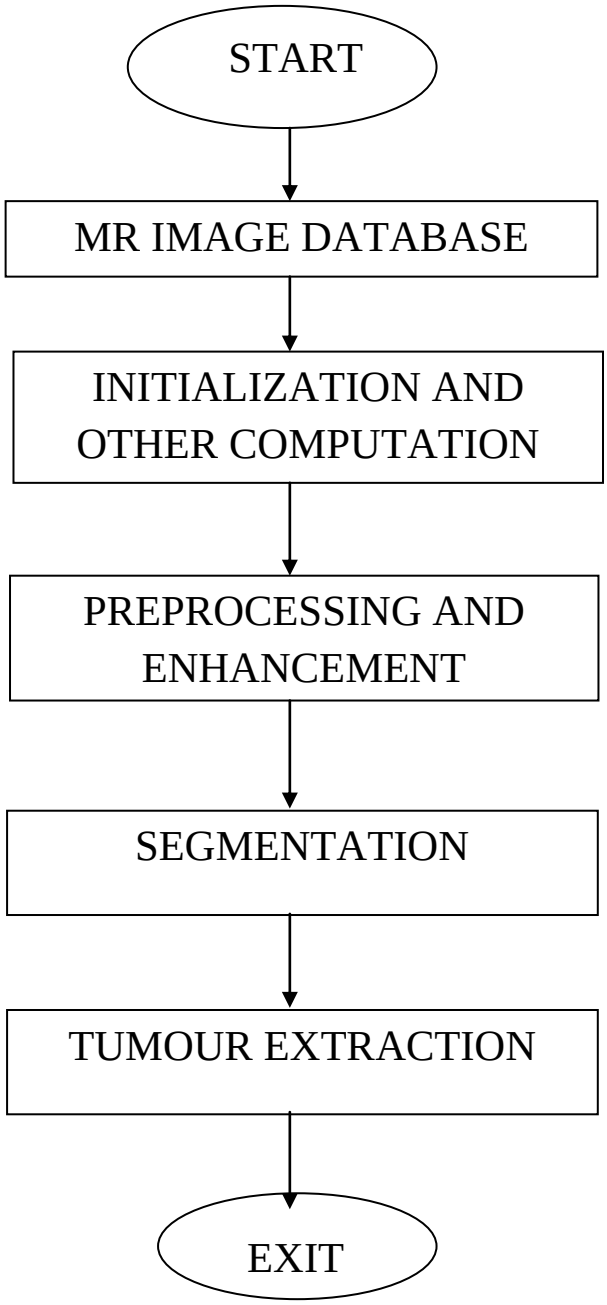


Fig 4.1 PROPOSED FRAMEWORK

MR IMAGE DATABASE

MR brain tumour image database comprising of approximately 400 256*256 gray level images with intensity value ranges from (0 to 255).

The images used are collected from radiologists and renowned database sites. Initially, these MRI images are normalized to gray level values from (0 to 1) and the features are extracted from the normalized images. As normalization reduces the dynamic range of the intensity values, feature extraction is much simpler than before. Some of the samples of the MRI database have been displayed in following Figures of different patient cases.

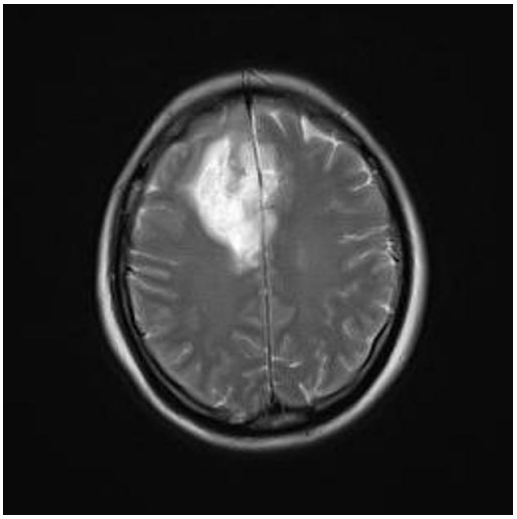


Figure 4.2

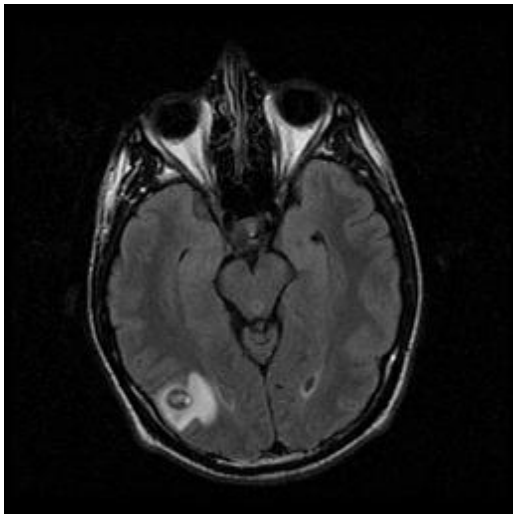


Figure 4.3

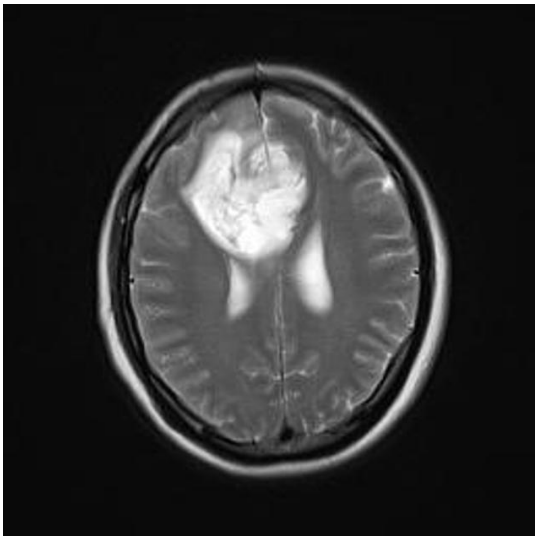


Figure 4.4

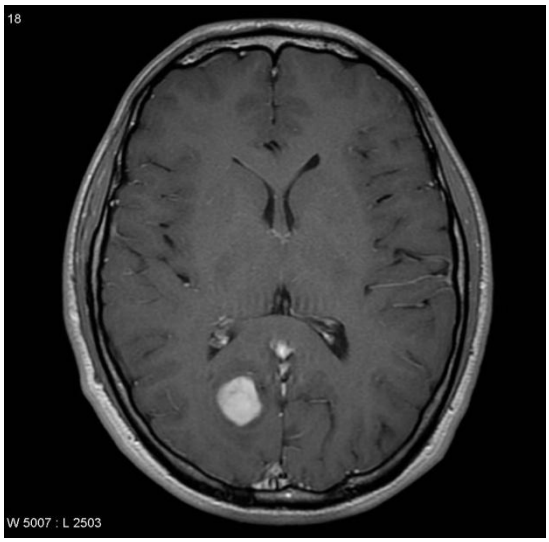


Figure 4.5

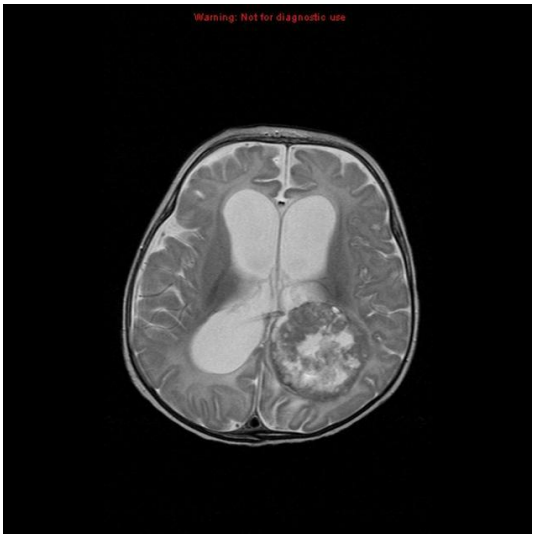


Figure 4.6

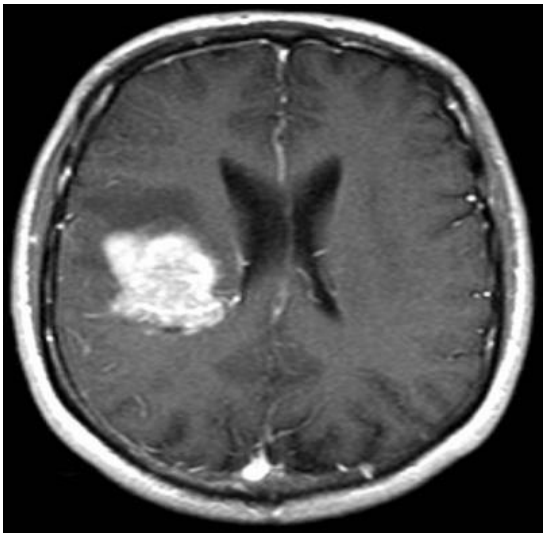


Figure 4.7

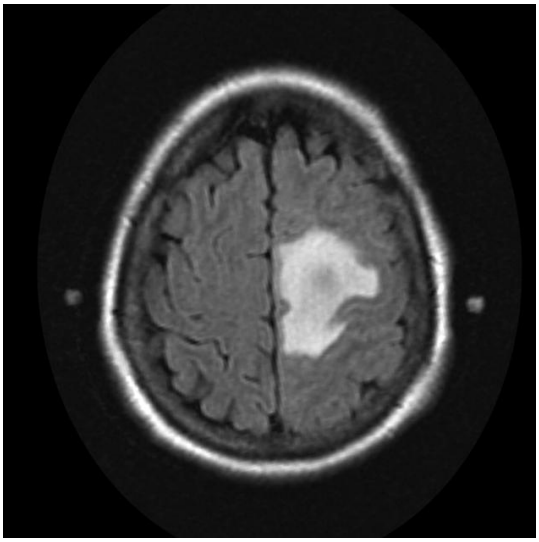


Figure 4.8

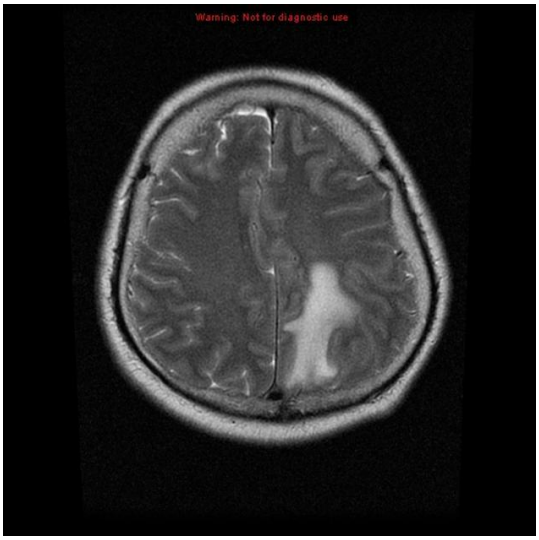


Figure 4.9

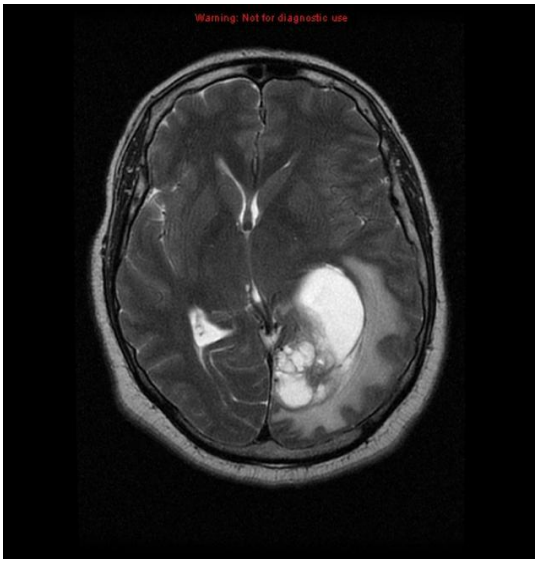


Figure 4.10

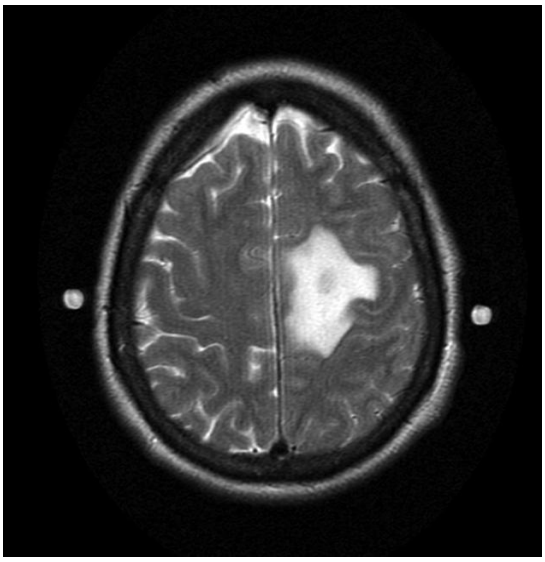


Figure 4.11

The enhancement and segmentation procedures proposed in thesis are described in detail in the following sections:

ENHANCEMENT

The main objective of enhancement is to improve the overall perceptual quality of image using algorithms or to provide better input for other automated image processing techniques so that accurate results can be obtained.

Following enhancement techniques are proposed in this thesis to attain better results:

Contrast Enhancement

Mid-range Stretch

CONTRAST ENHANCEMENT

Contrast is the difference between the intensity of two adjacent pixels. In high contrast images this difference will be more and in low contrast images this difference will be less. A contrast stretch technique improves the brightness differences uniformly across the dynamic range of the image, whereas tonal enhancements enhance the brightness differences in the shadow (dark), midtone (greys), or highlight (bright) regions at the expense of the brightness differences in the other regions. When the original image is irregularly illuminated, some details on resulting image will remain too bright or too dark. So we go for gamma correction which performs nonlinear

brightness adjustment. For darker pixels brightness is increased and bright pixels remain bright almost same as before. Thus more details are clearly visible.

MID-RANGE STRETCH

The mid range Stretch is a powerful tool for enhancing images and generally complements other manipulations within the image and thus highlights or improves the quality of brain tissues and lightens the non-brain tissues present in the MRI image. Since here there is need to segment out the brain tissues, the mid-range stretch techniques yields good results. It takes into consideration the intensity values of brain and non-brain tissues. The intensity values of brain tissues lies in the range of 0.2 -0.7 as per literature survey. In order to apply mid-range stretch to an image we need to map each and every pixel of the grayscale image to a value between 0 to 1 just by dividing the intensity value by 255 as shown below:

$$X_{ij} = Image_{ij}/255 \quad \text{(Eq 4..1)}$$

Where

X is the image matrix.

i refers to rows of image matrix.

j refers to columns of image matrix

then we compute the stretching transformation which is given by,

$$g(x, y) = \begin{cases} \alpha * f(x, y) & 0 <= f(x, y) <= a \\ \beta* (f(x, y) – a) + g(x, y) \text{at } a & a < f(x, y) < = b \\ \gamma* (f(x, y) – b) + g(x, y) \text{ at } b & b < f(x, y) <= L \end{cases}$$

(Eq 4..2)

The slope of the transformation is chosen greater than unity where there is need of contrast stretch.

- For dark region stretch α >1
- For mid region stretch β>1
- For bright region stretch γ >1
- a = L/3
- b = 2L/3
- g(x, y) at a = a * a;

  g(x, y) at b = b * (b –a) + g(x, y) at a

Here we are applying this transformation for mid range, so we choose the value for β greater than one and less than one for α and γ.

SEGMENTATION

Segmentation for brain infected areas from MR images is important tasks on understanding tissue construction, computing and extracting abnormal areas in the brain.

In proposed methodology, morphological function used for skull stripping is erosion and Fuzzy C-means clustering technique for segmentation. Using these techniques together gives good results for detecting brain abnormalities.

SKULL STRIPPING:

Skull stripping is a crucial pre-processing step in neuroimaging analysis. Skull stripped as described here [8] should be done before other processing algorithms from the MR images. Following steps are involved in the process of skull stripping:

DOUBLE THRESHOLDING:

Double thresholding creates the mask. Here the grayscale image is converted to binary image by setting all the pixels in the range 0.2*255-0.7*255 to white and the remaining pixels to black. Thus most of the pixels are discarded that corresponds to non-brain

tissue. The technique is known as double thresholding because it uses two thresholds viz upper and lower threshold.

$$g(x,y) = 1 \quad , \quad 0.2*255 >= f(x,y) <= 0.7*255$$
$$0 \quad , \quad \text{otherwise}$$

(Eq 4..3)

EROSION:

Erosion is applied on the image after thresholding. The basic idea of morphology is to erode an image with a simple, pre-defined shape known as structuring element. Here we use disk as structuring element. This structuring element removes all the unwanted pixels contributing to the skull portion of the image. Let E be a Euclidean space or an integer grid, and A a binary image in E. The erosion of the binary image A by the structuring element B is defined by:

$$A \ominus B = \{z \in E \mid B_z \subseteq A\}$$

(Eq 4..4)

Where B_z is the translation of B by the vector z, i.e.,

$$B_z = \{ b + z \mid b \in B \}, \quad \forall z \in E.$$

(Eq 4..5)

REGION FILLING:

The morphological filtering is used to fill holes in images. The eroded image obtained contains holes in the brain MR image in case if tumour is present. So in order to get the complete skull strip image including the tumour portion we apply the region filling algorithm to the generated mask. The conventional imfill algorithm is used for this purpose to fills holes present in the eroded image.

FUZZY C-MEANS CLUSTERING

FCM (fuzzy C-means) is an iterative algorithm that based on the principle of fuzzy clustering; it allows one pixel to belong to two or more clusters in a degree of membership.

In fuzzy clustering, a value between zero and one is assigned to each pattern by a membership function [9]. The FCM algorithm [10] partition a finite collection of pixels into a collection of "c" fuzzy clusters with respect to some given criterion. Depending on

the data and the application, different types of similarity measures may be used to identify classes. Some examples of values that can be used as similarity measures include distance, connectivity, and intensity. In the proposed work, the images are segmented into four clusters namely white matter, grey matter, CSF and the abnormal tumour region based on the feature values. Fuzzy clustering algorithm is based on optimization of the basic c-means objective function, or some modification of it. The objective function J for FCM is given by:

$$\boldsymbol{J(X,Y,U)} = \sum_{\mathbf{j=1}}^{\mathbf{K}} \sum_{\mathbf{i=1}}^{\mathbf{N}} \mathbf{U_{ij}^{m}\, d^{2}(X_i Y_j)}$$

(Eq 4.6)

Where

$X = (X_i,\ i = 1 \ldots N)$

K: Number of cluster

N: Total number of pixels

Y_j: Centre of cluster i

$d^2(X_i Y_j)$: Distance between Y_j and the pixel X_i

U_{ij}^{m} : Degree of membership

m : the fuzzy degree

The objective function J is minimized under the following constraints:

$$\mathbf{0} \leq \mathbf{U_{ij}} \leq \mathbf{1} \ ,\forall \boldsymbol{i} \in \{\mathbf{1}, \ldots \ldots, \boldsymbol{N}\} \text{ and } \forall \boldsymbol{j} \in \{\mathbf{1}, \ldots \ldots, \boldsymbol{K}\}$$

(Eq 4.7)

, and

$$\sum_{\mathbf{j=1}}^{\mathbf{K}} U_{\mathbf{ij}} = 1 \quad \forall \boldsymbol{i} \in \{\mathbf{1}, \ldots \ldots, \boldsymbol{N}\}$$

(Eq 4.8)

Considering these constraints and calculating the first derivatives of J. The matrix U satisfies the conditions stated above.

$$\mathbf{U_{ij}} = \left(\sum_{\mathbf{i=1}}^{\mathbf{k}} \left(\frac{\boldsymbol{d^2(X_i Y_j)}}{\boldsymbol{d^2(X_i Y_j)}} \right)^{\frac{\mathbf{1}}{\boldsymbol{m-1}}} \right)^{\mathbf{-1}} \quad \forall \boldsymbol{i} \in \{\mathbf{1}, \ldots \ldots, \boldsymbol{N}\}$$

(Eq 4.9)

$$\mathbf{Y_j} = \frac{\sum_{i=1}^{K} \mathbf{U_{ij}^m X_i}}{\sum_{i=1}^{K} \mathbf{U_{ij}^m}} \qquad \forall \, \boldsymbol{i} \in \{\mathbf{1}, \ldots \ldots, \boldsymbol{N}\}$$

(Eq 4.10)

The FCM algorithm iteratively optimizes J , by evaluating Eq 4.9 and Eq 4.10, until the following stop criterion is satisfied

$$\left\| \mathbf{Y^{new}} - \mathbf{Y^{old}} \right\| < \boldsymbol{\varepsilon}$$

(Eq 4.11)

Parameter m represents degree of fuzziness of the partition introduced by [10] .The choice of this parameter influences the process of FCM algorithm according to Besdek [11] the parameter m must be strictly greater than 1.

FCM ALGORITHM

- Step 1: Initialize the parameters:

  $X = (X_i, \ i = 1 \ldots N)$

  K: Number of cluster

  m : the fuzzy degree

  ε : threshold representing the convergence error

- Step 2:

  Initialize the matrix U by membership degree random values in the interval [0,1] and it also satisfies the condition in equation 4.8.

- Step 3:

  Repeat the following steps:

  Update the matrix Y cluster centres in (4.10).

  Update the matrix U degree of membership in (4.9).

  To obtain the stability of the matrix Y:

$$\left\| \mathbf{Y}^{\mathbf{new}} - \mathbf{Y}^{\mathbf{old}} \right\| < \boldsymbol{\varepsilon}$$

CHAPTER 5

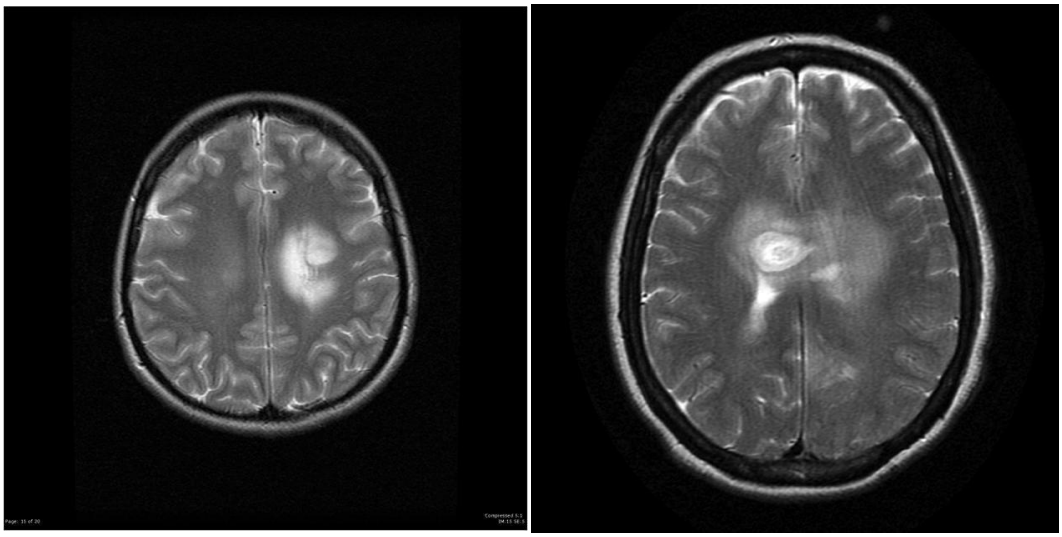
RESULTS

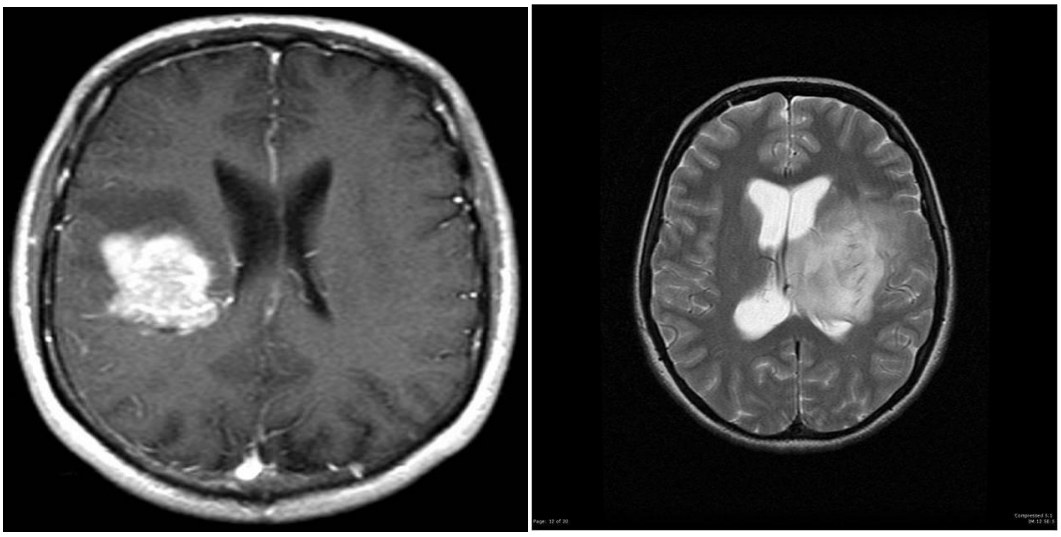
The proposed methodology is tested on approximately 400 MR brain images which were collected from the different database management website and cancer society. The datasets include MRI images of several tumour patients of different age groups. The method was able to successfully identify the tumourous images and extract the tumour. The proposed work is implemented in MATLAB.

The approach which uses combination of morphological operation and Fuzzy C-Means clustering gives faithful results for given set of input MRI datasets. Some of the sample input containing set of MRI images corresponding to different patients is shown in the Fig.5.1.

The algorithm works for all the sizes of input MRI images since it suitably extracts the area under consideration. Some of the sample input containing set of MRI images corresponding to different patients is shown in the Fig.5.1.

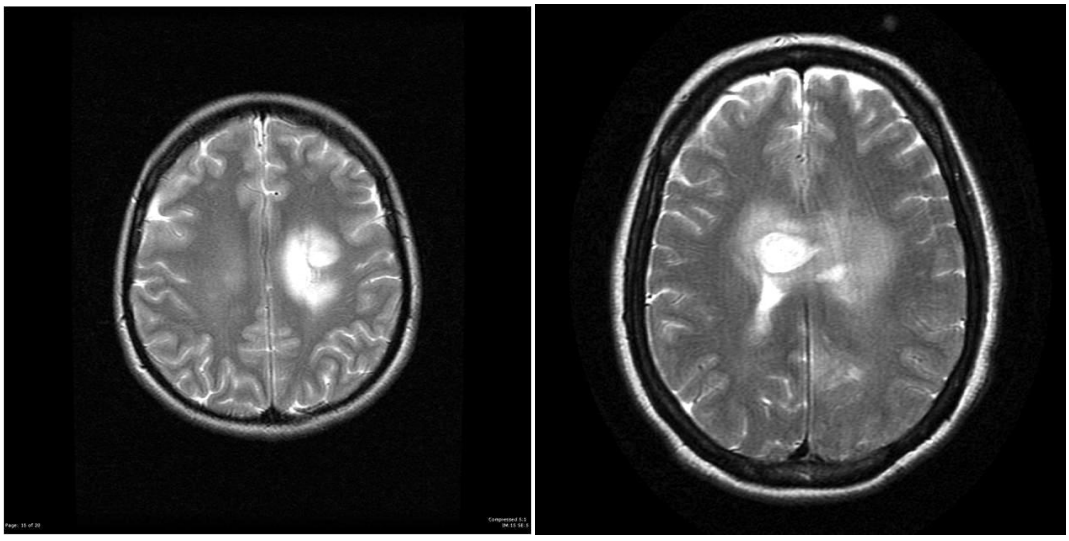
ORIGINAL IMAGES

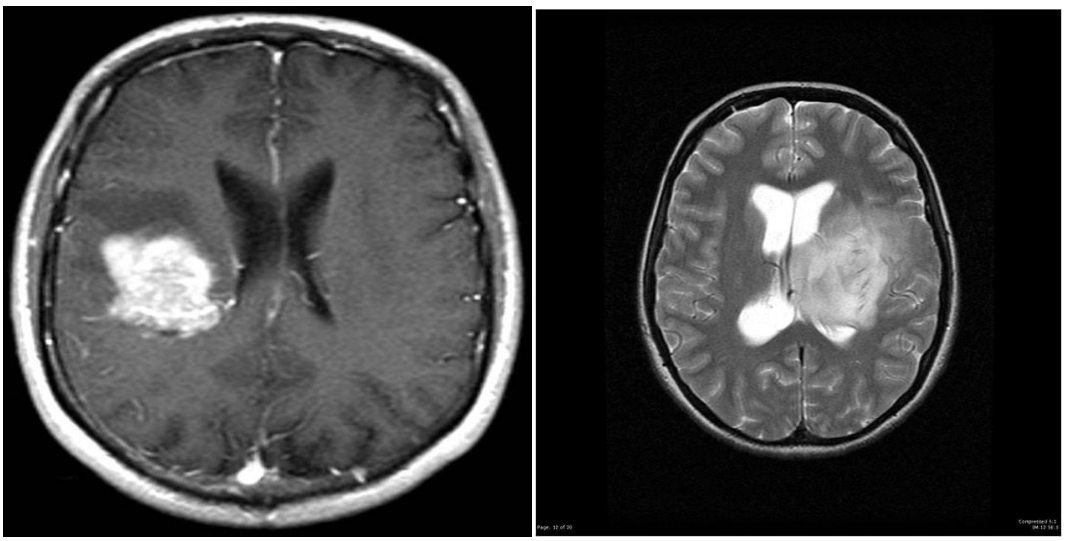




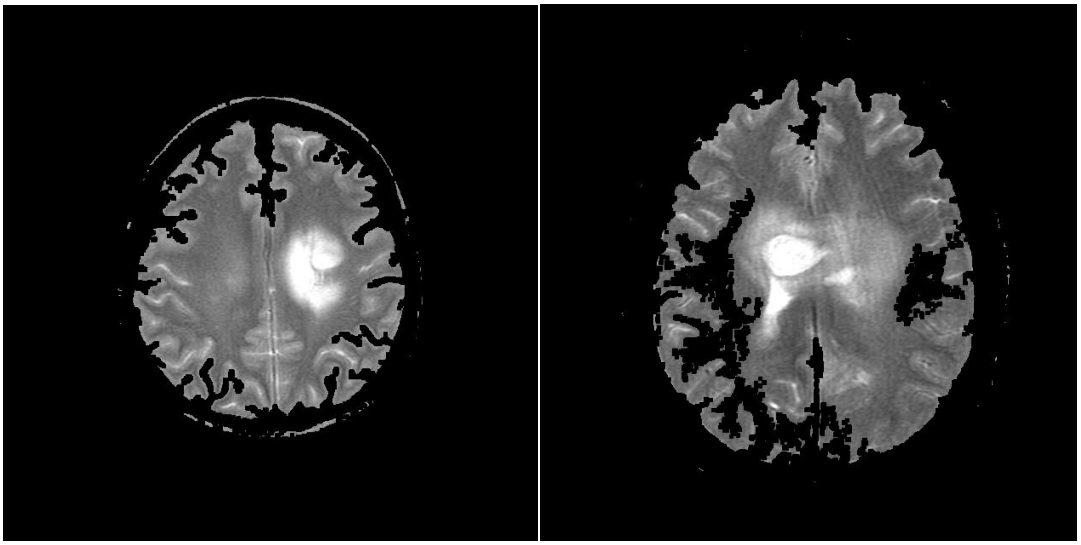
The step by step detailed output for MRI images is shown here.

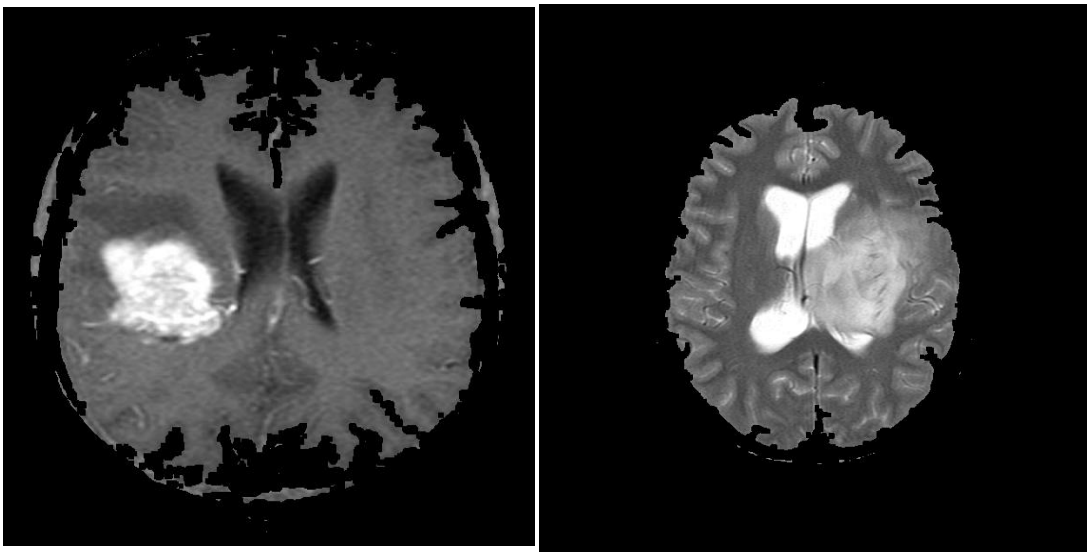
ENHANCED IMAGES



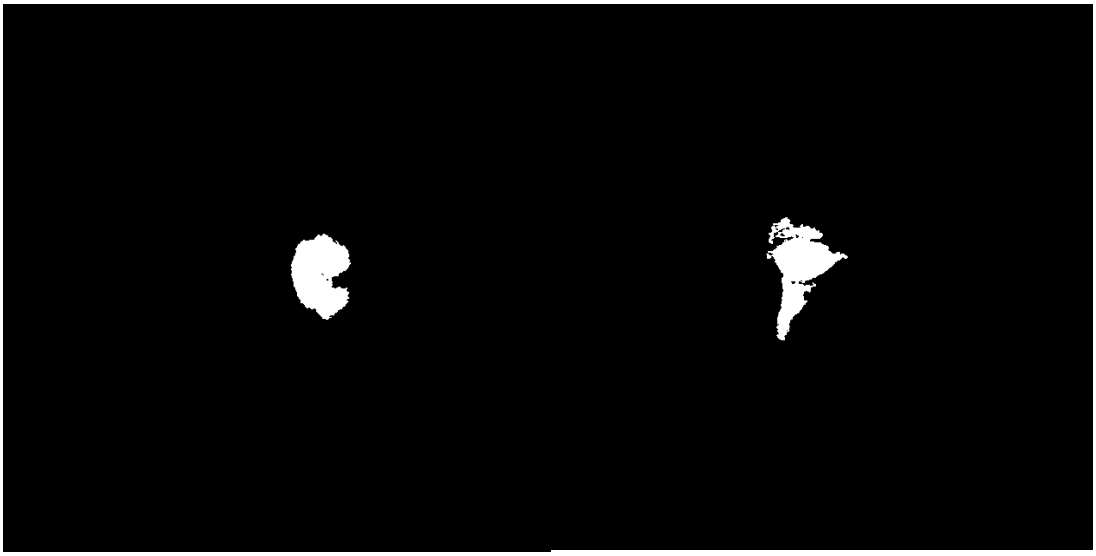


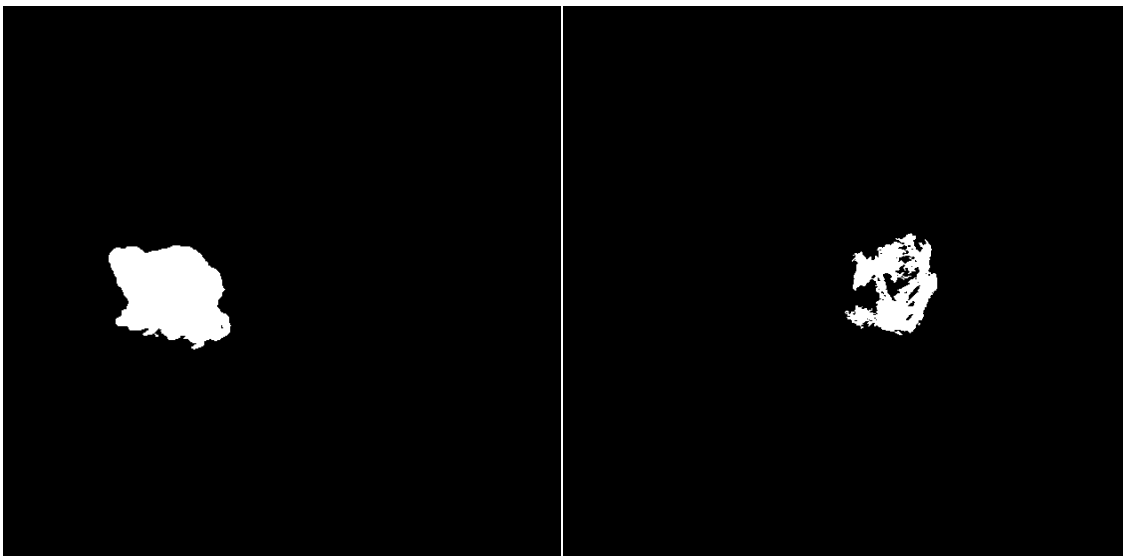
SKULL STRIPPING





CLUSTERED IMAGES





From the above images it is clear that the hybrid approach of using morphological operation and Fuzzy C-means clustering for segmentation efficiently identified the tumour from the datasets images. Also the proposed tumour extraction technique is automatic and carried out without any user intervention and without use of any training data.

CHAPTER 6

CONCLUSION AND FUTURE WORK

In the proposed methodology, a new approach to segmentation based fuzzy clustering approach is presented. Our approach combines and cooperates morphological functions and FCM to overcome the limitations encountered in the clustering process. The enhancement methods proposed here improved the contrast of the input images drastically and also midrange stretch enhancement has proved to be beneficial in obtaining desired quality image which serves as an input for segmentation. The enhanced image was successfully segmented and the tumour was extracted from images. Also automatic segmentation was performed on the MRI slices without any user intervention and without use of any training data. The performance evaluation of our method has been validated successfully.

This work can be extended to build 3D model using multithreading of the segmented tumour thus incorporating parallelism thereby improving the speed of the time consuming graphical procedures.

REFERENCES

[1] Christensen, G.E., Joshi, S., Miller, M.I., Volumetric Transformation of Brain Anatomy, IEEE Trans Med Image (16) 1997.

[2] H.E.Cline, W.E.Lorensen, R. Kikinis, and F.Jolesz, "Three-Dimensional Segmentation of MR Images of the Head Using Probability and Connectivity," Journal of Computer Assisted Tomography, vol. 14, pp. 1037-1045, November/ December 1990.

[3] M. J. Berg, E. A. Ashton, L. Ketonen, E(. J. Parker, C. W. Chen, and J. Weisberg, "Novel method for automatically determining volumes of hippocampus and other anatomic structure on MRI.

[4] Raman Maini and Himanshu Aggarwal., 'A Comprehensive Review of Image Enhancement Techniques', Journal of computing, Volume 2, Issue 3, March 2010, ISSN 2151-9617.

[5] T.F. Chan and L.A. Vese, "Active Contours Without Edges," IEEE Transaction on Image Processing, vol.lO, n07, pp.266-277, 2001.

[6] S. Wan and W. Higgins, "Symmetric region growing," IEEE Trans. Image Process., vol. 12, no. 9, pp. 1007-1015, Sep. 2003.

[7] R Xu, D Wunsch, "Survey of Clustering Algorithms," IEEE Transactions on Neural Networks. 2005,16(3): 645-67S

[8] Vidhya s. Dessa, Megha P. Araker, Ram Mohana Reddy Guddeti, "A Parallel Segme1ntation of Brain Tumour from Magnetic Resonance Images" ICCCNT' 12, 26th_28th July 2012.

[9] Bezdek, Pattern Recognition with Fuzzy Objective Function Algorithms. New York:Plenum,1 98

[10] B S R Kannan, "Segmentation of MRI using new unsupervised fuzzy C-means algorithm", ICGST-GVIP journal, vo1.5, no.2, 2005.

[11] Bezdek, J.C., 1974, Cluster validity with fuzzy sets J. Cybernit.3,

[12] Image (source: http://radiopaedia.org/)