CHAPTER 1

INTRODUCTION TO MEDICAL IMAGING
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Present day technological developments in imaging and vision have brought so many changes in the medical diagnosis, treatment planning and treatment verification procedures. The accurate precision, speed in diagnosis process and non-invasive clinical procedures are drastically improved.

These changes make the physician’s task easier in diagnosing the problem easier with less mental risk. The new evolutions in medical imaging are shown in Fig.1.1. The different diagnostic methods like Electro Encephalogram (EEG), Ultra-Sound, Magnetic Resonance Imaging (MRI), Digital X-Ray, Magneto Encephalogram, Positron Emission Tomography(PET), Vein Viewer and CT (left to right) are the some of the diagnosis techniques used for the better analysis of the problem. These are more useful than the conventional methods. For example, digital X-ray doesn’t require any film as in case of conventional X-ray. Ultra-sound clearly diagnoses the internal parts on computer screen through non-invasive methods. In this work, these advanced methods are used for the analysis of the brain disorders.
Fig. 1.1. Medical Imaging
One such method developed assists the Physician and Radiologist for the better diagnosis of the tumors. This thesis discusses about one of the most important brain disorders BrainTumor. Some of the brain tumors lead to brain cancer. According to the National Cancer Institute (NCI), primary brain tumors and other nervous system cancers are estimated to have been developed in about 22,000 people in 2010. In this thesis, brain tumors are segmented by using scan images and then they are registered for better recognition. This introductory chapter presents the basic knowledge of the anatomy of the brain, brain tumors, diagnosis methods and existing treatment methods.

1.1. BRAIN

The nervous system is the human body's decision and communication centre. The central nervous system (CNS) is made of the brain and the spinal cord and the Peripheral Nervous System (PNS) is made of nerves. The brain is a highly specialized organ. It serves as the control centre for functions of the body and allows us to cope with our environment. Words, actions, thoughts, and feelings are centered in the brain. The brain monitors and regulates the body's actions and reactions. It continuously receives sensory information, and rapidly analyzes this data and then responds accordingly by controlling bodily actions and functions. It is so complex that some theorists believe that people will never be able to fully understand it. It is to be known that
each part of the brain has a specific, important function and each part contributes to the healthy functioning of our body. The **brainstem** controls breathing, heart rate, and other **autonomic** processes that are independent of conscious brain functions. The **neocortex** is the centre of higher-order thinking, learning, and memory. The **cerebellum** is responsible for the body’s balance, posture, and the coordination of movement. The brain is very soft, having a consistency similar to soft **gelatin**.

The cerebral hemispheres form the largest part of the human brain and are situated above most other brain structures. They are covered with a **cortical layer** with a convoluted topography. Underneath the **cerebrum** lies the **brainstem**, resembling a stalk on which the cerebrum is attached. At the rear of the brain, beneath the cerebrum and behind the brainstem, is the **cerebellum**, a structure with a horizontally furrowed surface that makes it look different from any other brain area. The cerebral cortex is essentially a sheet of neural tissue, folded in a way that allows a large surface area to fit within the confines of the skull. Each cerebral hemisphere, in fact, has a total surface area of about 1.3 square feet. Anatomists call each cortical fold a **sulcus**, and the smooth area between folds a **gyrus**. The side view of brain is shown in Fig.1.2.
1.2. ANATOMY OF THE BRAIN

The brain is made of three main parts: the forebrain, midbrain, and hindbrain. The forebrain consists of the cerebrum, thalamus, and hypothalamus (part of the limbic system). The midbrain consists of the tectum and tegmentum. The hindbrain is made of the cerebellum, pons, and medulla. Often the midbrain, pons, and medulla are referred to together as the brainstem.

![Side-View of the Brain](image)

**Fig.1.2. Side-View of the Brain**

**Cerebrum** is the largest part of the brain and is associated with conscious thought, movement, and sensation. It consists of two halves, each controlling the opposite side of the body. The halves are connected by the corpus callosum, which delivers messages between them. Four
lobes make up the cerebrum: the frontal, temporal, parietal, and occipital lobes. The lobes of the is shown in Fig.1.3.

**Frontal Lobe** is one of the four lobes of the cerebral hemisphere. It controls attention, behavior, abstract thinking, problem solving, creative thought, emotion, intellect, initiative, judgement, coordinated movements, muscle movements, smell, physical reactions, and personality.

**Parietal Lobe** controls tactile sensation, response to internal stimuli, sensory comprehension, some language, reading, and some visual functions. The *sensory cortex* located in the front part of the *parietal lobe*, receives information from the spinal cord about the sense of touch, pressure, pain and the perception of the position of body parts and their movements. *Motor cortex* is an area located in the middle, top part of the brain that helps control movement in various parts of the body.

**Temporal lobe** controls auditory and visual memories, language, some hearing and speech, language, plus some behaviour. *Wernicke's Area* is part of the temporal lobe that surrounds the auditory cortex and is thought to be essential for understanding and formulating speech. Damage in Wernicke's area causes deficits in understanding spoken language.
Fig. 1.3. (a) Lobes of the Brain

Fig. 1.3. (b) Cerebrum of the Brain
**Occipital Lobe** is located in the back of the head and controls vision. **Broca's Area** is located in the opercular and triangular sections of the inferior frontal gyrus. The function of this area is the understanding of language, speech, and the control of facial neurons.

![Ventral View of the Brain](image)

**Fig.1.4.Ventral View of the Brain**

**Brain Stem** is located at the bottom of the brain and connects the cerebrum to the spinal cord. The brain stem controls many vitally important functions including motor and sensory pathways, cardiac and respiratory functions, and reflexes. The Vertical cross-section of the brain showing stem and lobes shown in Fig.1.4.Brain and Spinal cord connection is shown in Fig.1.5.
**Cerebellum** is located at the lower back of the head and is connected to the brain stem. It is the second largest structure of the brain and is made up of two hemispheres. The cerebellum controls complex motor functions such as walking, balance, posture, and general motor coordination.

**Cerebrospinal Fluid**, also called **CSF**, is a clear substance that circulates through the brain and spinal cord. It provides nutrients and serves to cushion the brain and therefore protect it from injury. As this fluid gets absorbed, more is produced from the choroid plexus, a structure located in the ventricles. A brain tumor can cause a build-up or blockage of CSF.

**Four Ventricles** of the brain are connected through cavities within the brain, where cerebrospinal fluid is produced.

**Hypothalamus** is a region of the brain in partnership with the pituitary gland that controls the hormonal processes of the body as well as temperature, mood, hunger and thirst.

**Pineal Gland** controls the response to light and dark. The exact role of the pineal gland is not certain.

**Pituitary Gland** is a small, bean-sized organ that is located at the base of the brain and is connected to the hypothalamus by a stalk. The
pituitary gland secretes many essential hormones for growth and sexual maturation.

**Meninges** are the membrane covering the brain and spinal cord. A tumor arising from this tissue is called a meningioma.

![Fig.1.5. Brain and Cervical Spinal Cord (CNS)](image)

**Thalamus** is located near the center of the brain and controls input and output to and from the brain, as well as the sensation of pain and attention.

### 1.3. DISEASES OF THE BRAIN

Despite being protected by the thick bones of the skull, suspended in *cerebrospinal fluid*, and isolated from the bloodstream by the *blood-brain barrier*, the human brain is susceptible to many types of damage and disease. The most common forms of physical damage are *closed head injuries* such as a blow to the *head*, a *stroke*, or poisoning by a wide variety of chemicals that can act as *neurotoxins*. 
1.3.1. Degenerative Disorders of the Brain

Infection of the brain, though serious, is rare due to the biological barriers which protect it. The human brain is also susceptible to degenerative disorders, such as *Parkinson's disease*, *Alzheimer's disease* and *multiple sclerosis*. A number of psychiatric conditions, such as *schizophrenia* and *depression*, are thought to be associated with brain dysfunctions, although the nature of such brain anomalies is not well understood. All three, however, as well as other serious neurological conditions, may have similar root causes related to design changes in the skull, spine and circulatory system of the brain due to upright posture.

In addition to Alzheimer's disease, Parkinson's disease and multiple sclerosis other neurological conditions that share suspiciously similar roots include: *migraine headaches*, *seizure disorders*, *transient ischemic attacks* (mini strokes), *normal pressure hydrocephalus* (NPH) *Chiari malformations*, *tethered cord syndromes*, *amyotrophic lateral sclerosis* (ALS), and *primary lateral sclerosis* (PLS) to name a few.

1.3.2. Brain Tumor

One of the dreadful diseases which make the people afraid is Cancer. It may affect the any part of the human body. In this work
concentration is paid on the brain tumors. A brain tumor takes up space within the skull and can interfere with normal brain activity. It can increase pressure in the brain, shift the brain or push it against the skull, and/or invade and damage nerves and healthy brain tissue. The location of a brain tumor influences the type of symptoms that occur. Identifying the presence of a brain tumor is the first step in determining a course of treatment. In this work identification of tumors is performed by segmenting them from tomographs. They are also registered for better identification and analysis.

Brain cancers can arise from primary brain cells. Although many growths in the brain are popularly called brain tumors, not all brain tumors are cancerous. Cancer is a term reserved for malignant tumors. Malignant tumors grow and spread aggressively, overpowering healthy cells by taking their space, blood, and nutrients. Like all cells of the body, tumor cells need blood and nutrients to survive. This is especially a problem in the brain, as the added growth within the closed confines of the skull can lead to an increase in intracranial pressure or the distortion of surrounding vital structures, causing their malfunction. Tumors that do not grow aggressively are called benign. Almost all tumors that begin in the brain do not spread to other parts of the body. The major difference between benign and malignant tumors is that malignant tumors can invade the brain tissues and grow rapidly. This rapid growth in the confines of the skull can
quickly cause damage to nearby brain tissue. In general, a benign tumor is less serious than a malignant tumor. However, a benign tumor can still cause many problems in the brain, but usually the problems progress at a slower rate than malignant tumors.

The most common primary brain tumors are gliomas, meningiomas, pituitary adenomas, vestibular schwannomas, primary CNS lymphomas, and primitive neuroectodermal tumors (medulloblastomas). The term glioma is an expansive one since it includes numerous subtypes, including astrocytomas, oligodendrogliomas, ependymomas, and choroid plexus papillomas. These primary tumors are named after the part of the brain or the type of brain cell from which they arise.

Brain tumors vary in their growth rate and ability to cause symptoms. Some of brain tumors are shown in Fig. 1.6 and Fig. 1.7. These are obtained with CT and MRI scan machines. The National Cancer Institute (NCI) uses a grading system to classify tumors. The NCI lists the following grades:

**Grade I**: The tissue is benign. The cells look nearly like normal brain cells, and cell growth is slow.

**Grade II**: The tissue is malignant. The cells look less like normal cells than do the cells in a grade I tumor.
**Grade III:** The malignant tissue has cells that look very different from normal cells. The abnormal cells are actively growing. These abnormal appearing cells are termed anaplastic.

**Grade IV:** The malignant tissue has cells that look most abnormal and tend to grow very fast.

**Symptoms of a Brain Tumor**

Brain tumors may have a variety of symptoms ranging from headache to stroke. Different parts of the brain control different functions, so symptoms will vary depending on the tumor’s location. Brain tumors are great mimics of other neurological disorders, and many of the common symptoms could indicate other medical conditions. Fig.1.5. indicates MRI scan of brain cancer.

Possible symptoms of a brain tumor include:

- A new seizure in an adult
- Gradual loss of movement or sensation in an arm or leg
- Unsteadiness or imbalance, especially if it is associated with headache
- Loss of vision in one or both eyes, especially if the vision loss is more peripheral
- Double vision, especially if it is associated with headache
- Hearing loss with or without dizziness
o Speech difficulty of gradual onset

Other symptoms may also include nausea or vomiting that is most severe in the morning, confusion and disorientation, and memory loss.

1.3.3. Brain Tumor Diagnosis

Identifying a brain tumor usually involves a neurological examination, brain scans, and/or an analysis of the brain tissue. Doctors use the diagnostic information to classify the tumor from the least aggressive (benign) to the most aggressive (malignant). In most cases, a brain tumor is named for the cell type of origin or its location in the brain. Identifying the type of tumor helps doctors determine the most appropriate course of treatment.

A **neurological examination** is a series of tests to measure the function of the patient’s nervous system and physical and mental alertness. If responses to the exam are not normal, the doctor may order a brain scan or refer the patient to a neurologist or neurosurgeon, who will then order a brain scan.

A **brain scan** is a picture of the internal structures in the brain. A specialized machine takes a scan in much the same way a digital camera takes a photograph. Using computer technology, a scan compiles an image of the brain by photographing it from various angles. Ex: - CT, MRI
Some types of scans use a contrast agent (or contrast dye), which helps the doctor see the difference between normal and abnormal brain tissue. The contrast agent is injected into a vein and flows into brain tissue. Abnormal or diseased brain tissue absorbs more dye than normal healthy tissue. EX: - PET, SPECT.

A biopsy is a surgical procedure in which a sample of tissue is taken from the tumor site and examined under a microscope. The biopsy will provide information on types of abnormal cells present in the tumor. The purpose of a biopsy is to discover the type and grade of a tumor.
Fig. 1.7. Brain Tumors
A biopsy is the most accurate method of obtaining a diagnosis. An open biopsy is done during a craniotomy. A craniotomy involves removing a piece of the skull in order to get access to the brain. After the tumor is resected (completely removed) or debulked (partially removed), the bone is usually put back into place. A closed biopsy (also called a stereotactic or needle biopsy) may be performed when the tumor is in an area of the brain that is difficult to reach. In a closed biopsy, the neurosurgeon drills a small hole into the skull and passes a narrow hollow needle into the tumor to remove a sample of tissue.

Once a sample is obtained, a pathologist examines the tissue under a microscope and writes a pathology report containing an analysis of the brain tissue. Sometimes the pathologist may not be able to make an exact diagnosis. This may be because more than one grade of tumor cells exists within the same tumor. In some cases, the tissue may be sent to another institution for additional analysis.

1.4. AVAILABLE CANCER TREATMENTS

The treatment given for cancer is variable and dependent on a number of factors including the type, location and amount of disease and the health status of the patient. Most treatments are designed to either directly kill/remove the cancer cells or to lead to their eventual death by
Fig. 1.8. Scanning Machines

(a) CT SCANNER

(b) MRI SCANNER
depriving them of signals needed for cell division. Other treatments work by stimulating the body's own defences against the cancer cells.

The treatments may be divided into different categories based on their goal and mode of action. Often the different types of treatment are used in combination, either simultaneously or sequentially. The following sections describe some of the most common forms of cancer treatment. The actual types of treatment and the order in which they are used are decisions made by the physician and patient. The major types of treatment and their objective are briefly described below:

- **Surgery:** This is often the first line of treatment for many solid tumors. In cases in which the cancer is detected at an early stage, surgery may be sufficient to cure the patient by removing all cancerous cells. Benign growths may also be removed by surgery.

- **Radiation:** This may be used in conjunction with surgery and/or drug treatments. The goal of radiation is to kill the cancer cells directly by damaging them with high energy beams.

- **Chemotherapy:** A term used for a wide array of drugs used to kill cancer cells. Chemotherapy drugs work by damaging the dividing cancer cells and preventing further reproduction.

- **Hormonal Treatments:** These drugs are designed to prevent cancer cell growth by preventing the cells from receiving signals necessary for their continued growth and division.
• **Targeted Therapy:** This class of drugs is relatively new in the treatment of cancer. They work by targeting specific proteins and processes that are limited primarily to cancer cells or that are much more prevalent in cancer cells. Inhibition of these processes prevents cancer cell growth and division.

• **Antibodies:** This treatment involves the use of antibodies to target cancer cells. While antibodies are naturally occurring proteins in our bodies, the antibodies used in the treatment of cancer have been manufactured for use as drugs. The antibodies may work by several different mechanisms, either depriving the cancer cells of necessary signals or causing the direct death of the cells. Because of their specificity, antibodies may be thought of as a type of specific inhibitor.

• **Biological Response Modifiers:** These treatments involve the use of naturally occurring, normal proteins that stimulate the body's own defenses against cancer.

• **Vaccines:** The purpose of cancer vaccines is to stimulate the body's defenses against cancer. Vaccines usually contain proteins found on or produced by cancer cells. By administering these proteins, the treatment aims to increase the response of the body against the cancer cells.

• **Complementary and Alternative Medicines:** These treatment methods are not practiced by conventional western medicine. They
can include herbal, animal derived and mind-body approaches to treating cancer. The scientific evidence about the efficacy of these treatments either refutes cancer fighting claims or is inconclusive at the present time.

1.5. BRAIN CANCER PREVENTION

In general, there is no known way to prevent brain cancers. However, early diagnosis and treatment of tumors that tend to metastasize to the brain may reduce the risk of metastatic brain tumors. Avoiding or reducing contact with radiation (especially to the head) and avoiding toxic chemicals associated with the oil and rubber industry, embalming chemicals, and other environmental toxins may help prevent brain cancers. Avoiding HIV infection is also suggested. The popular press and some web sites suggest that avoiding cell phone use and using a macrobiotic diet will help avoid brain cancer.

1.6. GOAL OF THE DISSERTATION WORK

The main objective of this work is to develop an algorithm which will accurately detect the tumors for the analysis. In this, tomographs will be used for the diagnosis purpose. Tomographs of CT or MRI consist of many slices. For accurate boundary detection more number of slices is to be aligned. In this thesis joint registration and segmentation are performed so that more information is fused.
1.7. ORGANIZATION OF THE THESIS

This dissertation is organized in seven chapters including introduction, diseases, and treatment methods of brain in chapter 1. In chapter 2, the literature review corresponding to joint registration and segmentation.

Chapter 3: Describes the automatic rigid registration process using MI. It includes four basic steps of registration and their performance metrics.

Chapter 4: Background, includes a full review of the available deformable models and their efficient discretization techniques. It also includes initial and boundary value formulation and the force functions used for the evolution of levelsets.

Chapter 5: Illustrates a deformable model based segmentation using Variational and DRLSE methods.

Chapter 6: Joint Registration and segmentation describe a non-rigid registration and contour-based segmentation using DRLSE.

Chapter 7: Concludes the dissertation by summarizing the work and suggests future work in relation to observed results.