CHAPTER 1
INTRODUCTION

Magnetic resonance imaging and computed tomography of the brain are powerful techniques for diagnosis, used by the clinician to detect structural abnormalities responsible of neurological disorder pathology. As recently as a few years ago, most neurologist only had available to them pictures of several cross sections of a brain on a light board, using their knowledge to make a diagnosis or determine the effect of a therapy only based on these images. With an increasing interest in the field of medical image processing, semi-automatic and automatic tools have appeared to assist medical diagnosis.

For instance, brain segmentation allows now, to not only visualize a volume of functional cortical structures but also to quantify it. It is not often possible to manually classify types of tumor, hematoma and hemorrhage brain Computed Tomography (CT) and Magnetic Resonance (MR) images, simply on the basis of visual inspection. Therefore, segmentation and classification of medical images are very important for clinical research, diagnosis and applications, leading to requirement of robust, reliable and adaptive segmentation techniques. In this chapter, different types of brain diseases considered for diagnosis are discussed and the problem is described along with the objectives and the proposed approach.
1.1 MEDICAL DIAGNOSIS

In the present thesis the purpose is to improve the level of accuracy of the diagnostic detection and classification of brain diseases. Clinical diagnosis of ischemic stroke, hematoma, hemorrhage and tumor is still challenging and its accuracy has been an issue of concern especially with lesions. Medical imaging plays an important role in the early detection and treatment of medical diagnosis. It provides physicians with information essential for efficient and effective diagnosis of various diseases. The objective of the research work included in this thesis is to provide a robust technique for automatic segmentation of ischemic stroke, hemorrhage, hematoma and tumor lesions from brain MR and CT images. It also focuses on using textural analysis in the classification process. With the aim of improving some of the existing methods and developing new techniques to facilitate accurate, fast and reliable computer based diagnosis of brain diseases.

1.2 ANATOMY OF THE HUMAN BRAIN

The brain has 10 billion of cells and 100 billion of neurons. The brain and the spinal cord are the masterpiece of the nervous system. The human brain coordinates the body’s functions such as vision, memory, learning and other activities. The brain is largely composed of only two main cell types, the neurons and the glia cells.
Structure of the brain

The brain is composed of three main parts. They are cerebrum, brain stem and cerebellum. The cerebrum is the largest portion of the brain. It is composed of two hemispheres and each hemisphere controls the opposite side of the body (right hemisphere controls the left side of the body and vice-versa). It is related to mental function like thinking, memory and speech. The cerebrum is divided into four lobes as shown in Figure 1.1.

- The frontal lobe is involved in organizing, problem solving, planning, selective attention and emotions.
- The parietal lobe is related with movement, orientation, recognition and perception of stimuli which control sensation.

![Figure 1.1: The four lobes of the brain](image)

- The occipital lobe involves processing of visual information.
- The temporal lobe is associated with perception and recognition of auditory stimuli, olfactory stimuli, visual and verbal memory.

The cerebellum concerns balance and coordination responsibilities for psychomotor function. The brain stem controls the essential living function such
as breathing, regulating the heart rate and the blood pressure. It is at the base of the brain and link the cerebral cortex, white matter and the spinal cord.

**Composition of the brain**

The neurons specialize in the transmission and processing of information. Their specialized structure consists of a cell (soma), an axon and dendrites. The soma is the central structure of the neuron, the information is processed in the nucleus within the soma and also the protein synthesis occurs in the soma. The dendrites are a treelike extension of the neurons and are specialized in receiving the majority of input information from the neuron. The axon carries nerve signals (of a form of an electric impulse) away from the neuron to other neurons or to muscles.

**The brain**

The connections between the extremity of axons and the dendrites or cell bodies of other neurons are called synapses. Their specialized structures allow the transition of chemical signal generated by the neurotransmitters, once triggers by the impulse received from the axon. Most neurons are unable to be repaired, so any loss of neuron leads to irreversible damage to the nervous system. The glia cells are the major constituent of the central nervous system. They are the major non-neuronal cell type present in the brain. Their function is to support the signal transmission abilities in the nervous system and to help defining synaptic contact even if they do not have a direct role in the neurotransmission.
In the human brain glia outnumber neurons by a ratio of 10:1. The white matter is the part of the brain containing myelinated nerve fibers that covers the axons. It connects various gray matter areas and enables the fast conduction of nerve impulses. The name comes from the color of the myelin which is white. The gray matter is composed of closely packed neuron cell bodies, their dendrites, axon terminals and glia cells. It is located in the cerebral cortex, the central portion of the spinal cortex, the cerebellar cortex and the hippocampal cortex. Cerebro-Spinal Fluid (CSF) immersed the central nervous system and the subarachnoid space of the spinal cord to cushion the brain inside the skull. This helps to protect the brain from shock. The CSF is secreted by the choroid plexus in the upper ventricles, it flows downward and it is absorbed by the venous system. As it flows down, it delivers hormones between regions of the brain and drain out the toxic wastes.

1.3 BRAIN TISSUES IN COMPUTED TOMOGRAPHY AND MAGNETIC RESONANCE IMAGING

Computed tomography (CT) and Magnetic Resonance Imaging (MRI) are the two modalities that are regularly used for brain imaging. Modern medical imaging technology such as MRI, X-ray, CT, Positron Emission Tomography (PET) and ultrasound has given physicians a non-invasive means to visualize internal anatomical structures and diagnose a wide variety of diseases. MRI is a powerful and versatile modality. Compared to other such techniques, MRI has superior soft tissue differentiation, high spatial resolution, contrast and does not
use ionizing radiation which may be harmful to patients. Such characteristics have shown MRI to be a valuable tool in the clinical and surgical environment.

With an MRI scan, it is possible to take images from different sections at most every angle, whereas a CT scan only shows cross sectional images. Therefore, it gives us more detailed information. The difference between normal and abnormal tissue is often clearer on the MRI scan than on the CT scan. CT images are widely used in the diagnosis of ischemic stroke, hemorrhage and hematoma because more accessible in clinical setting, less expensive to operate, quicker in scanning time and more reliable, its faster acquisition and compatibility with most life support devices.

Some patients cannot undergo MRI because of claustrophobia. MRI is also not feasible, if patients have a metallic implant, like metallic heart valves, aneurysm clips or other ferromagnetic material which will be affected by a strong magnetic field. Moreover, patients with severe bleeding are not suitable for MRI scanning, because the blood clots will become a tissue which is difficult to distinguish from the normal tissue. However, CT provides more excellent geometrical accuracy of the image. CT remains the method of choice for unconscious patients with suspected intracranial hemorrhage and hematoma in the emergency room [Atam1993].
With CT images, the most contrast occurs among bone, brain tissue and cerebro-spinal fluid. Bone appears bright, CSF appears dark and brain tissue appears somewhat in between. CT, sometimes called as CAT scan, uses special X-ray equipment to obtain image data from different angles around the body and then uses computer processing of the information to show a cross section of the body tissues and organs. Two safe and natural forces like magnetic field and radio waves are used to produce vivid images of internal body parts in MRI technique. These images commonly capture the fine details of the anatomical brain structures, such as three major brain tissue types: gray matter, white matter and cerebro-spinal fluid as shown in Figure 1.2. Gray Matter (GM) is one of the major components of the Central Nervous System (CNS) and is the region where the functional stimuli are processed. White Matter (WM) is another major component of the CNS and its connective fibers are responsible for passing messages between functional areas, while CSF, surrounding the surface of GM, protects the brain from mechanical pressure.

![Figure 1.2: Three major tissue classes of the brain [GM-Gray Matter; WM-White Matter; CSF-Cerebro-Spinal Fluid]](image-url)
The contrast presented in this image is mainly due to the different proton density between tissues. As shown in Figure 1.3, the T1-weighted image has very clear contrasts among all tissues (typically, CSF, GM and WM), however, the T2-weighted and Proton Density (PD) weighted image show less clear contrast between the tissues.

1.4 ISCHEMIC STROKE

Stroke or cerebrovascular accident is a disease, which affects the vessels that supply blood to the brain. The stroke occurs when a blood vessel either bursts or there is a blockage of the blood vessel. Due to loss of oxygen, nerve cells in the affected brain area are not able to perform basic functions which lead to death of the brain tissue. Stroke leads to serious long term disability or death. This can be due to ischemia (lack of blood flow) caused by blockage (thrombosis, arterial embolism), or a hemorrhage (leakage of blood). In an ischemic stroke, blood supply to part of the brain is decreased leading to death of the brain tissue in that region [Adam2005].
According to the World Health Organization (WHO), 15 million people are affected by stroke; of these 5 million die and another 5 million (2002 estimates) are permanently disabled. As the average human life span has increased, stroke has become the third leading cause of death worldwide after heart disease and cancer. Between these, ischemic stroke accounts for about 80 percent of all strokes [Thom2006]. A lacunar stroke, a subtype of ischemic stroke, is relatively difficult to identify, as it manifests as a small hypodense area of less than 15 mm in diameter on CT [Toni2000]. There are various classification systems for acute ischemic stroke. The Oxford Community Stroke Project (OCSP) classification relies primarily on the initial symptoms; the stroke episode is classified as Total Anterior Circulation Infarct (TACI), Partial Anterior Circulation Infarct (PACI), Lacunar Infarct (LACI) or Posterior Circulation Infarct (POCI).

Clinical diagnosis of ischemic stroke is difficult within the first few hours after the onset of stroke. Therefore, early detection of ischemic stroke is crucial. Early detection solely relies on some important early abnormal signs, including Loss of Insular Ribbon (LIR), loss of gray-white matter Attenuation of the Lentiform Nucleus (ALN), Hemispherical Sulcus Effacement (HSE) and the Hyperdense Middle Cerebral Artery Sign (HMCAS) [Tomu1988]. Hypodense changes are found to be the most frequent sign of early ischemia. However, its detection is difficult, since the early infarct sign is subtle hypo attenuation. An early and rapid diagnosis of stroke is critical for proper treatment of the patients.
Definitive therapy is aimed to remove the blockage by breaking the clot (thrombolysis) or by removing it mechanically (thrombectomy), where immediately the blood flow is restored to the affected tissue.

MRI is the most sensitive diagnostic method in detecting ischemic stroke, especially in very early stages and to determine whether thrombolysis is needed or not. In most instances, CT provides information required to make decisions during emergency. Compared to MRI, brain imaging with CT is more accessible, less expensive and quicker especially in severely ill patients. Non-enhanced CT is often the first radiologic examination performed in case of suspicion of stroke [Von2005].

In CT images, an ischemic stroke appears as a dark region (hypo dense) well contrasted against its surrounds. Accordingly, stroke is characterized as a distortion between the two halves of the brain in terms of tissue density and texture distribution. The human head is roughly bilaterally symmetric. For many focal brain diseases manifested as intracranial mass (e.g. Hematoma, tumor, abscess, etc.) clinicians rely on a Midline Shift (MLS) to quantify the change of symmetry for diagnosis and outcome prediction. The amount of midline shift can be used to measure the “mass effect” of the brain lesion and has been shown to correlate well with the outcome of the patients. Therefore, MLS is considered as the ‘gold standard’ by neurologists, neurosurgeons and neuro radiologists.
1.4.1 Classification

Strokes are mainly classified into two categories: ischemic stroke or infarct (due to blood clotting) and hemorrhagic stroke (due to bleeding inside the brain) and they require opposite treatments. A lacunar stroke is a subtype of ischemic stroke. Figure 1.4 shows the normal CT brain image and ischemic stroke image.

![Figure 1.4: Original CT brain images: (a) Normal brain image and (b) Abnormal brain image (Ischemic stroke region marked in green color)](image)

1.4.2 Causes

Lacunar infarcts are caused by small vessel disease, which is a term used to describe a vascular lesion seen in cases of hypertension, diabetes and old age.

1.4.3 Risk Factors

Risk factors for stroke include old age, high cholesterol, hypertension, previous stroke or Transient Ischemic Attack (TIA), diabetes, cigarette smoking and atrial fibrillation. High blood pressure (hyper tension) is a major contributor to lacuna strokes because of the pounding pulse causes.
1.4.4 Signs and Symptoms

The symptoms of stroke include acute hemi-paresis, aphasia, non-focal neurological defect, etc.

1.4.5 Treatment

The treatment protocols for ischemic stroke and hemorrhagic stroke are quite different. The treatment for ischemic stroke is mainly to dissolve the blood clot while the treatment for hemorrhage is to stop bleeding. The treatment for ischemic stroke, tissue Plasminogen Activator (tPA) is the best to be given within 3 hours so as to dissolve the clot and restore blood flow.

1.5 BRAIN HEMORRHAGE AND HEMATOMA

Traumatic Brain Injury (TBI) occurs when an external force traumatically injures the brain [Bull2006]. It is also known as intracranial injury. Based on severity, mechanism, or other features (e.g. Occurring in a specific location or over a widespread area) TBI is classified. TBI usually refers to head injury, but it is a broader category because it can involve damage to structures other than the brain, such as the scalp and skull. An intracranial hemorrhage is a bleeding process, within the skull. Intracranial bleeding occurs if a blood vessel within the skull bursts or leaks. It can result from nontraumatic causes (as occurs in hemorrhagic stroke) such as a ruptured aneurysm etc. An intracranial hematoma occurs when a blood vessel ruptures between skull and brain. Intracerebral hemorrhage, with bleeding into the brain tissue itself, is an intra-axial lesion.
Extra-axial lesions include epidural hematoma, subdural hematoma and subarachnoid hemorrhage. Hematomas or focal lesions are collections of blood in or around the brain that can result from hemorrhage.

Epidural hemorrhage (extradural hemorrhage) occurs between the dura mater and the skull [Smit2010]. It may result from a laceration of an artery and most commonly the middle meningeal artery. Patients have a loss of consciousness, lucid interval and sudden deterioration. Larger hematomas cause more damage. Epidural bleeds expand quickly and compress the brain stem. On images produced by CT scans epidural hematomas appear convex in shape because their expansion stops at the skull sutures, where the dura mater is closely attached to the skull. It expands inward toward the brain rather than along the inside of the skull, as in a subdural hematoma. The lens like shape of the hematoma causes the appearance of these bleeds to be "lentiform". Epidural hematomas may occur in combination with subdural hematomas, or either may occur alone. The 10% of epidural bleeds may be venous, due to shearing injuries from rotational forces. Thus only 20 to 30% of epidural hematomas occur outside the region of the temporal bone. The brain may be injured by prominences on the inside of the skull as it scrapes past them.

Subdural hemorrhage results from tearing of the bridging veins in the subdural space between the dura and arachnoid mater [Koiv2009]. In CT scanning subdural hematomas appear crescent in shape and the brain that does
Cross suture lines will be noted on CT scan. At times, they may be caused by arterial lacerations on the brain surface. Acute subdural hematomas are associated with cerebral cortex injury. Patients have loss of consciousness, but they recover and do not relapse.

A cerebral hemorrhage or Intra Cerebral Hemorrhage (ICH) is a subtype of an intracranial hemorrhage that occurs within the brain tissue itself [Brod2007]. Intracerebral hemorrhage is caused by brain trauma, or it occurs spontaneously in hemorrhagic stroke [Yuh2008]. Nontraumatic intracerebral hemorrhage is a spontaneous bleeding into the brain tissue. The second most common cause of stroke is intracerebral bleeds. Traumatic intracerebral hematomas are divided into acute and delayed. Acute intracerebral hematomas occurred at the time of the injury while delaying intracerebral hematomas have been reported from as early as 6 hours post injury to as long as several weeks. It is important to keep in mind that intracerebral hematomas can be delayed because if symptoms begin to appear several weeks after the injury.

Subarachnoid hemorrhage involves bleeding into the subarachnoid space between the arachnoid membrane and the pia mater. Intraventricular hemorrhage occurs when there is bleeding into the ventricles. Subarachnoid hemorrhage, can result either from trauma or from ruptures of aneurysms or arteriovenous malformations. Blood is found to be layered into the brain along sulci and fissures. Several Clinical Practice Guidelines (CPG) have been proposed for
physicians to determine whether to surgically remove the intracranial hematoma or not, based on the type, volume, thickness of the hematoma and degree of brain compression. In the intracranial hematomas, the blood may be removed surgically to remove the mass and reduce the pressure it puts on the brain. Surgery is required if the hematoma is greater than 3 cm, if there is a structural vascular lesion or lobar hemorrhage in a young patient. However, a smaller intracranial hematoma may not require surgery. In other words, once the qualitative diagnosis (type) and the quantitative diagnosis (volume) of the intracranial hematoma have been determined, physicians can plan the treatment strategy. Intracranial hematomas are readily diagnosed on CT images, as they appear as hyper dense regions, or regions with gray levels higher than the brain. The accuracy of the diagnosis depends both on the quality of image acquisition and interpretation.

1.5.1 Classification

Types of intracranial hemorrhage are classified as intra-axial and extra-axial. Intra-axial hemorrhage or intra-parenchymal hemorrhage is bleeding within the brain. This category includes intracerebral hemorrhage, or bleeding within the brain tissue and intraventricular hemorrhage, bleeding within the brain's ventricles. Intra-axial hemorrhages are more dangerous and harder to treat than extra-axial bleeds. In extra-axial hemorrhage, bleeding occurs within the skull but outside of the brain tissue. Its three subtypes are epidural hemorrhage, subdural hemorrhage and subarachnoid hemorrhage. The types of intracranial
hematomas are Epidural Hematoma (EDH), Subdural Hematoma (SDH), Intra Cerebral Hematoma (ICH) and Subarachnoid Hemorrhage (SAH). Figure 1.5 shows the types of hemorrhage and hematoma.

**Figure 1.5:** Original CT brain images: (a) Subarachnoid hemorrhage; (b) Subdural hematoma; (c) Epidural hematoma and (d) Intra cerebral hematoma

**1.5.2 Causes**

The most common cause of hemorrhage and hematoma is trauma. Both blunt and penetrating head injury can cause all kinds of hemorrhage, depending on the mechanism and extent of injury. EDH occurs when an artery supplying the dura is torn and is frequently associated with skull fracture. SDH is usually resulting of torn veins that bridge the brain and venous sinuses. SAH can result from trauma to vessels in the leptomeninges or surface vessels or the brain surface itself. Intracerebral hematoma may occur in shear injury in both the acute
and delayed stages. In addition, major causes of hemorrhage include hemorrhagic infarction, hypertensive hemorrhage, aneurysms, vascular malformations, intratumoral hemorrhage, vasculitis, dural sinus thrombosis, mycotic aneurysm, amyloid angiopathy, bleeding dyscrasias or anticoagulation therapy.

1.5.3 Risk Factors

High blood pressure increases the risk of spontaneous intracerebral hemorrhage by two to six times. It is more common in adults than in children, risk factors for ICH include hypertension, diabetes, menopause, current cigarette smoking and alcoholic drinks (≥2/day).

1.5.4 Signs and Symptoms

Hemorrhage and hematoma can produce variable neurological symptoms, depending on the different functions served by the affected regions. In general, it is not possible to differentiate between hemorrhage from other causes of neurological disturbances, e.g. ischemia central nervous system infection, or neoplasm, based on clinical findings. Symptoms for subarachnoid hemorrhage may include headache, decreased level of consciousness and hemiparesis (weakness of one side of the body).

1.5.5 Treatment

Patients with bleeding inside of the brain must be monitored very closely. Early treatment includes stabilizing blood pressure and breathing. A breathing
assists machine (ventilator) can be required to ensure that enough oxygen is supplied to the brain and other organs. Intravenous access is needed so that fluids and medications can be given to the patient, especially if the person is unconscious. Sometimes specialized monitoring of heart rhythms, blood oxygen levels, or pressure inside of the skull is needed.

After a person has been stabilized, then a determination of how to address the bleeding is made. This stabilization and decision-making process takes place very rapidly. The decision to perform surgery is based on the size and location of the hemorrhage. Not everyone with an intracranial hemorrhage needs to have surgery. Various medications may be used to help decrease swelling around the area of the hemorrhage, to keep blood pressure at an optimal level and to prevent seizure. If a patient is awake, pain medication may be needed.

1.6 BRAIN TUMOR

Brain tumor is a cluster of abnormal cells due to loss of normal aging and cell death. It may occur in any person at almost any age. It may even change from one treatment session to the next, but its effects may not be the same for each person. Brain tumors appear at any location, in different image intensities, can have a variety of shapes and sizes. Brain tumors can be malignant or benign. In this research work astrocytoma, medulloblastoma, glioma, glioblastoma multiforme and craniopharyngioma type of brain tumors are used. Gliomas are a group of tumors that arise in the central nervous system.
Benign brain tumors have a homogeneous structure and do not contain cancer cells. They may be either monitored radiologically or surgically destroyed completely and they seldom grow back. Malignant brain tumors have a heterogeneous structure and contain cancer cells. Therefore, diagnosing the brain tumors in an appropriate time is very essential for further treatments. Neurology and basic neuroscience are the imaging tools in recent years that enable in vivo monitoring of the brain. MRI has proven to be a powerful and versatile brain imaging modality that allows non-invasive longitudinal and 3D assessment of tissue morphology, metabolism, physiology and function [Barj2006, Arms2004]. The information which MRI provides greatly increased the knowledge of normal and diseased anatomy for medical research and it is an important component in diagnosis and treatment planning [Hane2001].

MR imaging is currently the method of choice for early detection of brain tumor in human brain. However, the interpretation of MRI is largely based on radiologist’s opinion. In India, totally 80,271 people are affected by various types of tumor (2007 estimates). The National Brain Tumor Foundation reported the highest rate of primary malignant brain tumor occurred in Northern Europe, the United States and Israel. The lowest rate is found in India and in Philippines.

1.6.1 Classification

Brain tumors can be malignant or benign. It is classified according to WHO as neuroepithelial tumors, non-neuroepithelial tumors, astrocytic lineage
tumor grading systems and mutations leading to astrocytic tumors. Low grade gliomas and meningiomas are benign tumors [Ricc2001]. Glioblastoma multiforme is a malignant tumor and may arise anywhere in the brain. A Craniopharyngioma is a benign tumor that develops near the pituitary gland that occurs most commonly in children but also in men and women in their 50s and 60s. Figure 1.6 shows the types of tumor images.

Figure 1.6: Original MR brain images: (a) Normal MR brain image; (b) Astrocytoma tumor; (c) Craniopharyngioma tumor; (d) Glioblastoma multiforme tumor; (e) Glioma tumor and (f) Medulloblastoma tumor

Medulloblastoma is a highly malignant primary brain tumor that originates in the cerebellum or posterior fossa. Astrocytoma tumors are the most
common type of brain tumors (30% of all) and are usually malignant one. The glioma family of tumors comprises 44.4% of all brain tumors. According to WHO, there are 126 types of different brain tumors of which many of them arise from structures intimately associated with the brain such as tumors of the covering membranes (meningiomas) to the posterior fossa.

1.6.2 Causes

Besides an identified association with exposure to vinyl chloride, there are no known chemical or environmental agents that lead to the development of brain tumors. Although there has been some concern that electromagnetic fields might provoke some glial tumors, there is no evidence to support this notion. A predisposition to developing a brain tumor could be induced by a number of inherited, genetic syndromes including von hippel-lindau syndrome, neurofibromatosis and tuberous sclerosis.

1.6.3 Risk Factors

In general, brain tumor occurs more frequently in whites than they do with people of other races. The risk of a brain tumor increases as the age increases. Brain tumors are most common in older adults. However, a brain tumor can occur at any age. Certain types of brain tumors, such as medulloblastomas, occur almost exclusively in children. People who have been exposed to a type of radiation called ionizing radiation have an increased risk of brain tumor. People working in certain industries may have an increased risk of brain tumors,
possibly because of the chemicals they are exposed to on the job. A small portion of brain tumors occurs in people with a family history of brain tumors or a family history of genetic syndromes that increase the risk of brain tumors.

1.6.4 Signs and Symptoms

Symptoms of brain tumors, ranging from headache to stroke, may differ among people since they depend on the size and position of the tumor in the brain and the functions that are controlled by that part of the brain. The national brain tumor society lists the following symptoms: a new seizure in an adult, gradual loss of movement or sensation in arms or legs, 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 and speech difficulty of gradual onset. In addition, nausea or vomiting, confusion and disorientation and memory loss may be observed.

1.6.5 Treatment

Treatment of brain tumors depends on a number of factors such as the type, location and size of the tumor. Other factors that are taken into account are the age and general health of the patient. Several types of treatment may be used for CNS tumors, including surgery, radiotherapy, chemotherapy and currently developed innovative targeted therapies. In many cases a combination therapy is used. If the location of a brain tumor is accessible for surgery, the neurosurgeon
may remove as much as possible of the tumor. Craniotomy is the main type of operation for brain tumor treatment. It involves making an incision in the scalp, folding back the skin and removing the piece of bone over the tumor. The risks of surgery might be too high for certain tumors when they are located near vital areas in the brain and some tumors that tend to spread diffusely are also not cured by surgery.

1.7 MOTIVATION

Automatic segmentation of medical images can facilitate an imaging based diagnosis, providing an aid to surgery and treatment planning. Despite a variety of techniques proposed in the past decades, fully automatic segmentation of MR image is still at the stage of laboratory research. In the literature, there are many computer-aided detection systems for MR and CT brain images most of them are used to detect and classify abnormalities. In the existing systems, importance is not given to select optimal set of features in tumor classification.

Less attention is paid towards detection of ischemic stroke with small lesions (lacunar stroke) due to its challenging nature. It is relatively difficult to identify, as it manifests as a small hypodense area of less than 15mm in diameter on CT. Therefore, early detection of ischemic stroke with small lesions is important and this necessitates a more efficient method to improve the detection rate. In modern medicine, detection of hemorrhage and hematoma relies on the use of brain CT. Automatic detection of cranial lesions in CT images is
complicated and challenging task for computer vision researchers. This is because the presence of noise, artifacts and other human head anatomy together with the brain in the CT image increases the level of complexities involved during the lesion detection and segmentation. In the existing method SDH, ICH and EDH are classified and hematoma region is identified. In the proposed method in addition to that SAH is detected and classified.

Radiologists may miss the abnormal lesions (ischemic stroke, hematoma, hemorrhage and Tumor) on brain images. There are several problems with human based diagnosis; they include perception, experience, fatigue, bias and noise. To cope with them, the automated system has been introduced. It is not often possible to manually classify the types of brain CT and MR images, simply on the basis of visual inspection. Therefore, there is a need for automatic segmentation and classification.

1.8 PROBLEM DESCRIPTION

1.8.1 Objectives and Scope

The research reported in this thesis is an attempt to improve some of the existing algorithms and develop new techniques to facilitate accurate, fast and reliable computer-based diagnosis of brain diseases. The main objectives of this research work are:

1. To develop Computer-Aided Detection (CAD) system for the early detection of ischemic stroke, hematoma, hemorrhage and tumor using k-
means clustering in CT and MR images to increase the detectability. The brain region related to a lesion is exactly separated from the brain image using segmentation.

2. To develop an automated method for classification of ischemic stroke in CT, four different types of hemorrhage and hematoma in brain CT, five different types of tumors in brain MR images using Support Vector Machine (SVM), Artificial Neural Network (ANN) and decision tree classifiers.

3. Quantitative analysis is performed for ischemic stroke, hemorrhage and hematoma and tumor.

4. To determine the optimal subset of texture features to improve the classification accuracy.

5. To establish the texture features based classification system incorporating pattern recognition methods using SVM, ANN and decision tree.

The application of the proposed method for early detection of ischemic stroke, hemorrhage, hematoma and the tumor is demonstrated to improve efficiency and accuracy of clinical practice hence it decreases the risk of misdiagnosis and mismanagement. It helps the physicians to better diagnose human brain stroke, hemorrhage and hematoma and tumor for further treatment. The proposed system can help the physicians to know about the type of brain tumor, type of hemorrhage and hematoma for further treatment. There is no human intervention.
1.8.2 Proposed Approach

The proposed approach makes contributions in various stages of development of a computer-aided detection system of brain diseases; namely, image segmentation, feature extraction, feature selection and classification. K-means clustering technique is used for segmentation. It is often suitable for biomedical image segmentation as the number of clusters is usually known for images of particular regions of the human anatomy. So it is an effective tool in segmenting the medical images for further treatment plan.

Medical images are often highly textured so texture analysis becomes well suited for classification of images because they provide unique information on the texture of the region or image where they are applied. In this thesis, three advanced classification techniques are used namely, SVM, ANN and decision tree. A genetic algorithm is used to search among the candidate features to find an optimal subset which results in the higher classification accuracy. Automated systems are highly preferred for lesion detection and image classification because of its high accuracy. Accurate identification of the type of the brain abnormality is highly essential for the treatment planning, which is different for all the brain abnormalities.

The computer aided detection and classification system for ischemic stroke, hemorrhage, hematoma and tumor is given in Figure 1.4. In the ischemic stroke classification midline of the brain is traced and then fourteen texture
features are extracted using gray level co-occurrence matrix for the left and right side of the brain. Optimal features are selected using genetic algorithm. The optimal features are used to train the binary classifier, which can automatically infer whether the image is that of a normal brain or an ischemic brain, suffering from a brain lesion. For ischemic brain image the stroke region is extracted by using k-means clustering technique.

Figure 1.7: The proposed computer aided detection system

In tumor detection, the lesion region is extracted by using k-means clustering technique. Then fourteen texture features are extracted using gray level co-occurrence matrix of the brain. The optimal features are used to train the classifier, which can automatically classify the types of brain tumor image, suffering from a brain lesion. In hemorrhage and hematoma detection and classification to locate the lesion region k-means clustering is used and texture
features are used to classify the type of hemorrhage and hematoma. A quantitative analysis is performed for all brain diseases.

1.9 ORGANIZATION OF THE THESIS

This thesis is organized as the following nine chapters: In the first Chapter, anatomy of the human brain, brain tissues in MR and CT images, background information of ischemic stroke, hemorrhage, hematoma and tumor diseases, motivation, objective, advantages of the proposed method and outline of this thesis are stated. Chapter 2 presents a comprehensive literature survey. The survey covers the existing CAD system for automatic ischemic stroke, hemorrhage, hematoma and tumor detection and classification in CT and MR images. Different techniques for image pre-processing, segmentation, feature extraction, feature selection and classification are reviewed and discussed. In Chapter 3, the proposed approach is developed to detect and classify ischemic stroke that uses the textural features with a robust segmentation technique to locate lesion in the brain CT images are explained. Chapter 4 presents the proposed technique, utilized in this work for four types of intracranial hemorrhage and hematoma detection and classification. In Chapter 5 the materials and the proposed technique, utilized in this work for brain tumor detection and classification are explained. Chapter 6 presents the experimental results of SVM classification model for diagnosing ischemic stroke, hemorrhage, hematoma and tumor. Chapter 7 presents the experimental results of ANN classification model for diagnosing ischemic stroke, hemorrhage, hematoma and
tumor. In Chapter 8 the experimental results of decision tree classification model for diagnosing ischemic stroke, hemorrhage, hematoma and tumor are discussed. This is followed by Chapter 9 which concludes this thesis. Chapter 9 concludes the works that have been done and some recommendations are proposed for future development. In Appendix-I the screenshots of brain diseases detection and classification are given.