BRAIN TUMOR DETECTION USING INTENSITY ADJUSTMENT BASED SEGMENTATION

A THESIS SUBMITTED TO THE GRADUTE
SCHOOL OF APPLIED SCIENCES
OF
NEAR EAST UNIVERSITY

by

AHMET İLHAN

In Partial Fulfillment of the Reguirements for

the Degree of Master of Science

in

Computer Engineering

NICOSIA, 2016

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ABSTRACT

Cancer in any form is the most deadly illness in the world. Scientists are investigating into this disease and developing methods and treatments to fight it. Brain cancer is an abnormal cell population in the brain tissue and may not always be visible in imaging techniques. In recent years magnetic resonance imaging (MRI) technique is being used to show the detailed image of the affected brain region. The image processing plays an important role in identification of the disease. In this thesis the brain MRI images are chosen to be investigated and a better method is targeted for more clear view of the region affected by cancer. The method used to obtain a segmented tumor region clear enough to be observed by the medical people and give them more detail about the tumor in their diagnoses. The method introduced is using morphological operations, pixel subtraction, noise removal, intensity adjustment based segmentation and pixel addition techniques. This method is based on obtaining clear images of the skull, brain and the tumor. Through several pixel subtraction operations on these images a clear background is constructed which made the tumor separation easy. The noise is removed from the image using mean filtering. Using the filtered image, the classification of the intensities of the pixels on the image identifies the tumor. Lastly, the segmented image of the tumor is added on the original image for a distinct identification.

Keywords: Brain cancer; Image processing; Intensity adjustment; MRI; Segmentation

ÖZET

Kanser, dünyadaki en ölümcül hastalıktır. Bilim insanları bu hastalıkla savaşmak için bir çok yeni metot ve tedevi yöntemleri üretmektedir. Beyin kanseri anormal hücrelerin beyin içerisinde üremesiyle oluşan bir türdür. Beyin tümörü, bazı görüntüleme yöntemleriyle belirgin olmayabilir. Son yıllarda, "Manyetik Rezonans Görüntüleme" (MRI) yöntemi ile beyin üzerinde yer alan tümörü en belirgin şekilde görüntüleyebilmektedir. Görüntü işleme yöntemleri, MRI görüntülerinin daha net ve detaylı bir şekilde görüntülenmesinde önemli bir rol oynamaktadır. Bu tezde, beyin görüntüleri kullanılarak daha iyi bir metot üretilmesi hedeflenmiştir. Böylece, elde edilecek temiz görüntü ile doktorlar tömürleri daha kolay bir şekilde tanımlayabileceklerdir. Bu metotta morfolojik işlemler, piksel çıkarma, gürültü temizleme, parlaklık ayarlama yöntemiyle bölümleme ve piksel ekleme teknikleri kullanıldı. Bu metot ile kafatası, beyin ve tümör görüntüleri temiz bir şekilde elde edildi. Piksel çıkarma işlemleri ile temiz bir geri plan görüntüsü elde edildi. Böylece tümör, daha kolay bir şekilde görüntüden ayrılmış oldu. Görüntü üzerindeki gürültü, averaj filter kullanılarak temizlendi. Temizlenmiş görüntüde, piksellerin parlaklık değerlerinin gruplandırılması ile tümör tanımlanmış oldu. Son olarak tümör, orjinal görüntü üzerine eklenerek daha temiz bir görüntü elde edildi.

Anahtar Kelimeler: Beyin kanseri; Bölümleme; Görüntü işleme; MRI; Parlaklık ayarlama

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LIST OF ABBREVIATIONS

CT	Computed tomography
PET	Positron emission tomography
MRI	Magnetic resonance imaging
CSF	Cerebrospinal fluid
CNS	Central nervous system
EDT	Eastern daylight time
CAT	Computerized axial tomography
ALU	Arithmetic logic unit
CCD	Charge coupled devices
CMOS	Complementary metal oxide semiconductor
CFA	Color filter array
LUTs	Lookup tables
DCT	Discrete cosine transform
JPEG	Joint photographic experts group
PNG	Portable network graphics
GIF	Graphics interchange format
TCIA	The cancer imaging archive
CDROM	Compact disc read-only memory
PC	Personal computer
TP	True positive
TN	True negative
FP	False positive
FN	False negative
GLCM	Gray level co-occurrence matrix
RBF	Radial basis function
PPN	Probabilistic neural network

CHAPTER 1

INTRODUCTION

In this chapter, numerical and medical information based on certain statistics about cancer in general is given. The importance of early diagnosis, treatment methods and medical imaging techniques are examined.

1.1 Background

Cancer, which is increasing in proportion to the aging population, has become a worldwide health problem. Based on the latest statistics of the World Cancer Research Fund, cancer is the deadliest disease in the world. Approximately 12.7 million people are diagnosed with cancer each year and 7.6 million people die from this disease (Gao et al., 2009). Every year the number of people who die from cancer is increasing. According to cancer research centers, the number of people diagnosed with cancer by 2030 will reach 26 million.

There are numerous kinds of cancer in the world. A few of these are breast cancer, brain cancer, lung cancer, liver cancer, prostate cancer and etc. The places where cancer cells are found, how they look with microscopes and how cancer cells develop is important for accurate diagnosis (Gao et al., 2009).

Each kind of cancer has many different types and it is difficult to provide detailed information about the types of cancer. Brain cancer is a very malignant and harmful disease. It is the fifth cancer type with the highest incidence and mortality, just behind stomach cancer, uterine cancer, breast cancer and esophageal cancer.

The brain tumor symptoms depend on tumor size and location. These symptoms are manifested by the tumor growing in a limited area, a pressure in the brain, and damage to vital tissues (Xuan, 2007). The tumor may cause hydrocephaly (water accumulation in the brain) as an obstacle to the formation and circulation of the cerebrospinal fluid. If the tumor grows slowly, it takes time for the symptoms to appear. The most common symptoms of the brain tumor include a headache, decreased hearing and sense of smell, swelling in the skull, fainting, nausea or vomiting, loss of sensation in the arms and legs, vision problems or various eye movements, insomnia, personality and memory changes and difficulty in speaking can be occur.

These symptoms in the brain tumors can also be seen in other diseases. Symptoms such as growth retardation, increased appetite, weakness and movement, mood changes can be seen in children with brain tumor symptoms. If one or more of these symptoms are present, a neurologist should be consulted as soon as possible. Performing the necessary examinations and early diagnosis is very important for the success of the treatment.

In order for the diagnosis of brain tumor to be established, the complaints of the patient are first questioned in detail by the neurology specialist. Family history and a complete physical examination are necessary (Fritz et al., 2013). After the general examination, a neurological examination is performed carefully. Muscle strength, muscle movements, reflexes and pain response are examined. Eye movements are also examined in detail. After the physical and neurological examinations, some radiological examinations are performed.

For these examinations, medical imaging techniques such as Computed Tomography (CT), Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) are used (Ozols et al., 2006).

Computed Tomography (CT) uses the radioactive rays to penetrate the human body, and the imaging is based on the different characteristics reflecting the rays of different tissues. PET needs to inject with radioactive drugs in the human body, and the drugs flow to all the cells, tissues and organs with the blood in the whole body (Prince & Links, 2006). The absorbed radiation will be metabolized and released by different tissues to form different rays which can be received for a specific imaging. CT/PET refers to the combination of CT and PET scans which are carried out on the same plane to form a fused image with the machine. Both CT and PET examination have radioactive hazards, and PET examinations are too expensive. Compared with all these imaging modalities above, MRI is the most cost-effective.

In the MRI imaging process, there is no instruments inserted nor any medication injected into the human body. There is no radiation damage to the human body, and the whole process is quite safe (Xuan, 2007). In addition, MRI imaging has high-resolution and accurate positioning of soft tissues and is sensitive to the characteristics of diseases, thus it is especially suitable for the diagnosis of brain diseases.

After these imaging procedures, it is necessary to examine the tissue from the brain in pathological methods. Pathological examination helps to know the presence of the disease and the presence or absence of cancer. If a brain tumor is diagnosed and the diagnosis of the secondary brain tumor becomes definite, other tests are performed to determine the source and extent of the disease (Prince & Links, 2006). This research is called staging. In tumor diagnosis, staging is done to find out if the cancer has spread or not, and if so, which parts of the body have the spread.

The treatment of brain tumor depends on several factors. The location of the brain tumor, the size of the tumor, the age of the patient, and general health status guide the choice of treatment. The method of treatment and the mode of administration are different in adults or children. In the treatment of brain tumors, surgical treatment, radiotherapy treatment and chemotherapy treatment are applied (Prince & Links, 2006).

The brain surgeon decides on the type of surgery, the size of the tumor, and the location of the locus (Doi, 2006). Radiotherapy kills cancer cells using high-energy rays. The use of anticancer drugs is called chemotherapy. These treatment methods are all applied on some of the patients one after another or only one of them is found to be satisfactory treatment.

Surgical treatment is the first method in the treatment of brain tumors. In surgical treatment, the procedure known as craniotomy is performed to open the skull and remove the tumor as much as possible. But if the removal of the tumor completely causes damage to the brain, some part of the tumor may be left (Webb, 2003). The remainder of the tumor can be treated with radiotherapy and chemotherapy. Some tumors are not removed and a biopsy is done. By taking a part of the tumor with biopsy, the tumor type is determined and the treatment method is selected.

In the side effects of brain tumor treatment, only the tumor cells are not damaged in the cancer treatment. In some cases, healthy cells can be destroyed. For this reason, patients sometimes face unwanted risks. The side effects may vary depending on the type of treatment, the region and the patient to be treated. The patient's doctor will try to treat as little as possible (Webb, 2003). These risks often end up when treatment is over. During the surgical treatment of the brain tumor, normal brain tissue may also be damaged, poor coordination, personality changes, speech, and thinking difficulties. After surgical treatment, the side effects become obvious, but over time the healing begins.

In surgical treatments, damage to healthy tissues other than harmful tissues is one of the most likely risks. In addition to medical imaging procedures, computer applications are also important tools for reducing these risks (Prince & Links, 2006). Image processing techniques are one of the most used and highly efficient applications. Images cleaned with image processing techniques, make it easy for doctors to distinguish unhealthy tissues. Thus, the risk of damage to healthy tissues is reduced during surgical treatment.

1.2 Aim of Thesis

The aim of the thesis is to develop a system to better analyze and identify the brain tumors by using image processing techniques. The main goal of this system is to ensure that doctors can easily diagnose the illness and begin treatment as soon as possible.

1.3 Thesis Layout

In this thesis, chapter one includes the brief background, aim of thesis and thesis layout. Chapter two includes the anatomy of brain and brain tumor. Chapter three includes the fundamentals of the image processing and image processing techniques. Chapter four describes the proposed system that segments the region of the tumor from brain MRI images. Chapter five presents the obtained results from the proposed system designed and comparison of the analysis results. Chapter six includes the conclusion of the thesis.

CHAPTER 2
BRAIN ANATOMY AND BRAIN TUMOR

In this chapter, the structure and functions of the brain are examined in detail. In addition, types of the brain tumor and their structures analysis have also been examined. This information about brain tumors plays an important role in diagnosis and treatment.

2.1 Introduction to Brain Anatomy

The brain is an important structure that serves many important functions. This structure gives a meaning to the events of the world. The brain receives different messages from sensory organs at the same time.

The human brain manages memory, thought, speech, and the functioning of numerous organs. In addition the brain regulates heart and breath rates and determines how people will react in stressful situations (i.e. preparing an exam, loss of job, childbirth, disease, etc.). The brain is an organized structure that fulfills important functions and consists of many structures.

The weight of the human brain continues to change all through the life. After birth, the mean brain weight reaches about one pound. When childhood passes, the weight of the brain reaches two pounds. An adult woman's brain weight is about 2.6 pounds and an adult male's brain weight is about 2.9 pounds (American Association of Neurological Surgeons, 2016).

2.1.1   The cell structure of the brain

The brain consists of two cells. These cells are neurons and glial cells they are also referred to as neuroglia or glia (Nieuwennhuys et al., 2007). The task of neurons is to send and receive nerve urges or signals. Glial cells are unneuronal cells that supply nourishment and support, guard homeostasis, form myelin and simplify signal transduction in the nervous system.

In the brain, glial cells have more than 50 neurons. Glial cells are the most prevalent cells seen in primary brain tumors. When a brain tumor is diagnosed, a biopsy is performed to remove the tumor from the tissue so it can be determined by the pathologist. Pathologists

determine the kind of cells which are existing with the brain tissue and tumors are known as depending this relation. The kind of brain tumor and cells included effect individual diagnosis and treatment (Nieuwennhuys et al., 2007).

2.1.2 The nervous system

The nervous system is an important system that perceives internal and external events, obtains and processes information, transmits signals to different regions through the cell network located on the bed, and regulates the activities of organs and muscles. The body's nervous system consists of two parts (Michael-Titus et al., 2010). These are the central nervous system and the peripheral nervous system, comprising the brain and spinal cord.

The central nervous system is a complex biological system in humans. This complex structure serves as an interface to regulate people's behavior against events in the world. The peripheral nervous system allows the brain and spinal cord to connect to other organs in the body. It also controls the head muscles, nappies and sensory organs nervously.

2.1.3 The limbic system

The limbic system is found at the base of the cerebrum. This system is a complex structure that contains the inner parts of the temporal lobes, and the base of the frontal lobes. This structure collects mental functions and primitive senses in a single system known as the emotional nervous system. The limbic system is not only responsible for sensory functions, but it also has mental functions such as remembering and processing events in the past (Biaggoini, 2011). In addition, it has an important role in making some physical functions look pleasurable or in people's stress in medical matters.

2.1.4 The ventricular system

The ventricular system is partitioned into four holes. These holes are linked to a set of holes known as foramen and tubes. Two ventricles placed in the cerebral hemispheres are named lateral ventricles (Costa, 2008). The opening used to communicate with the third ventricle is named the Foramen of Munro. This ventricle is located in the center of the brain and their walls are composed of thalamus and hypothalamus. The tube that meets the third ventricle to the fourth ventricle is known as the aqueduct of sylvius (Borden, 2007). The cerebrospinal fluid that flows from the fourth ventricle passes through a different set of openings to gain access to the brain and spinal cord.

2.1.5 Cerebrospinal fluid

The cerebrospinal fluid (CSF) surrounds the brain and the spinal cord. It is a clear, watery substance that prevents the injury of the brain and spinal cord. The cerebrospinal fluid is continuously renewed using the spinal cord, and the channels around the brain. The ventricles are responsible for the production of the cerebrospinal fluid. The ventricles are found in the empty channels of the brain (Irani, 2008).

Each ventricle has a special structure called the choroid plexus. This structure produces the most part of the cerebrospinal fluid. The brain provides stability between the quantity of consumed fluid and the quantity produced (Borden, 2007). Sometimes it can cause the system to interruption while trying to maintain stability.

2.1.6 The meninges

The brain is found in a bone coating called a cranium. The cranium guards the brain from injuries. The cranium and bones come together to form the skull and guard the face area. Between the skull and the brain, there are three layers of meninges that guard the spinal cord. These layers are pia mater, dura mater and arachnoid (Rhoton, 2003).

The dura mater found in the brain comprises of whitish, inelastic film or brain membrane. The outer layer is named periosteum (Rhoton, 2003). The dura mater, an inner plate, draws the entire interior of the skull and forms small folds or chambers where the areas of the brain are covered and assured. There are two exclusive layers in the dura of the brain. These layers are known as falx and tentorium.

The falx divides the right and left half and tentorium divides the lower and upper parts of the brain. The second layer of the meninges is named arachnoid. This membrane is slim, sensitive and also wraps the whole brain. The gap between dura and arachnoid membranes is named subdural (Borden, 2007). Arachnoid is composed of elastic tissue and many different blood vessels.

The plate nearest to the brain surface is called pia mater. There are many blood vessels that descend to the depth of the brain. The pia mater covering the surface of the brain chases the other layers of the brain. The great arteries that supply the brain allow the pia mater to reach the blood vessels (Rhoton, 2003). The gap separating arachnoid and pia is called subarachnoid space. The fluid of the cerebrospinal fluid flows into this area.

2.2 Structure of the Brain

The brain structure is divided into five main parts. These are working in coordinated provide to a sense of reasoning, emotional life, and events that take place in the world. In addition, each one has its own specific functions (Apuzzo et al., 2009). The main parts of the brain are examined in detail below. Figure 2.1 shows the main parts of the brain and their locations.
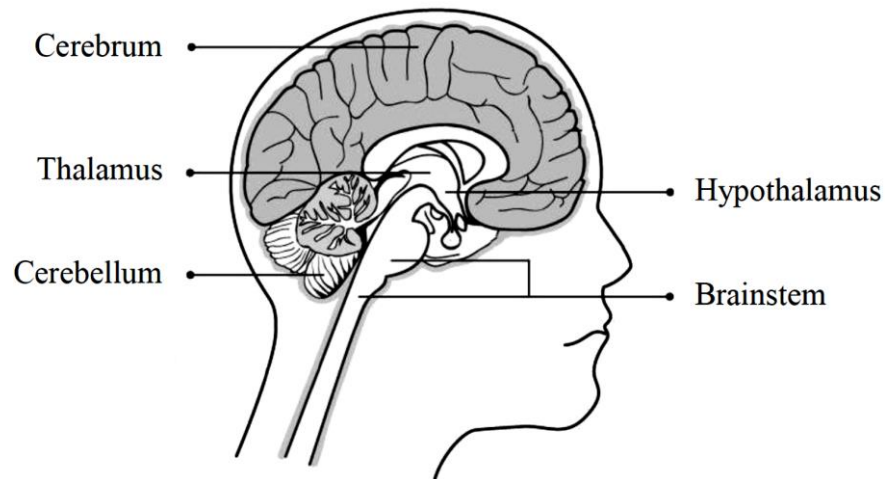
Figure 2.1: Main parts of the brain (Apuzzo et al., 2009)

2.2.1   Cerebrum

The Cerebrum forms the majority of the brain and is slipt up in two main compartments. These compartments are known as right and left cerebral. The Cerebrum is an expression to identifies the brain. The structure dividing the brain into two hemispheres is named great longitudinal fissure (Apuzzo et al., 2009). The two hemispheres of the brain are combined by the corpus callosum. The corpus connects the calyces of the calceum to provide communication between them. There are billions of neurons and glial cells on the surface of the cerebrum, and these cells form the cerebral cortex.

The cerebral cortex has a gray, brownish color and is known as the "gray matter". At this point, brain's face looks wrinkled. The cerebral cortex contains water (small grooves), cracks (large grooves) and grooves known as giyr. Scientists have special names for protrusions and grooves. Scientists have proven that the various parts of the brain have specific tasks as a result of years of experiments. Beneath the surface of the brain cortex and brain, fibers and neurons combine to form an area known as "white matter".

The brain recieves messages in many ways. Signals travel using tracts are called pathways. If the brain tissues are damaged by the tumor, the communication between the structures inside the brain may be impaired. Functions such as speaking, reading ability or the ability to follow simple commands may be delayed (Di salle et al., 2006).

The cerebral hemispheres have several different cracks. These cracks, which are located on the surface of the brain, are divided into pieces called "lobes" (Borden, 2007). Messages in the brain are conveyed from one protrusion to another, from a lobe to another, from one half of the brain to the other half, and from a lobe of the brain to a structure deep within the brain.

According to research done by scientists, it has been proven that when touching any side of the brain, it transmits signals to the other side of the body. When the primary motor on the right side of the brain is touched, the left side of the body moves. When the left primer is touched by the motor cortex, the right side of the body moves (Di salle et al., 2006). Movement messages cause the opposite arm to move or feel by moving to the other side of the brain. Accordingly, if a tumor develops in the region that controls arm movement on the right side of the brain, left weakness or paralysis occurs.

2.2.2   Brainstem

The brainstem is the inferior appendage of the brain. It situated ehead of the cerebellum and depends on the spinal cord. The brainstem includes three structures. These three structures are known as midbrain, pons and medulla oblongata.

The task of the brainstem is to communicate between the various areas from the body and the cerebral cortex (Costa, 2008). All the basic functions necessary to survive are found here. Pons provides coordination between eye and face actions, face senses, ability to hear and balance. In addition, the brainstem is an important center for ocular motion.

The task of Medulla oblongata is to monitor the functions of respiration, blood pressure, heart rhythm and swallowing. Messages from the spinal cord and spinal nerves are sent through pons and brainstem. Damage to these areas causes brain death. The reticular activating system serves four different structures (Costa, 2008). People cannot survive when these structures do not work. These structures are the midbrain, pons, medulla and thalamus.

The brainstem is also controls sleep patterns and allows people to pay attention to events. It uses 10 flour of 12 cranial nerves to control ability to hear, eye actions, face senses, taste, swallowing, neck and shoulder actions and tongue muscles, which are functions of the brainstem (Borden, 2007).

2.2.3 Cerebellum

The cerebellum is found under the occipital lobes and behind the brain. It leaves the brain through the tentorium (fold of dura). The cerebellum precisely adjusts motor activity and action (Apuzzo et al., 2009). An example of this is the movement of fingers and drawing pictures when performing surgery. In addition, it controls muscle tone, helping to maintain posture and balance. Cerebellum is a structure that has the capability to perform repetitive actions as fast as playing games. Abnormalities on the right side of the cerebellum also form symptoms within the same region of the body.

2.2.4 Thalamus

The thalamus is a structure that acts as a transition tunnel for all messages that are transmitted to the cortex. The thalamus plays an essential role in ache sense, notice and vigilance. This structure is partitioned into four compartments hypothalamus, epythalamus, ventral thalamus and dorsal thalamus (Rhoton, 2003). The thalamus is surrounded by nerve cells called basal ganglia.

2.2.5 Hypothalamus

The hypothalamus is an essential construction that sends messages to the pituitary gland via nerve ligaments. The hypothalamus manages messages from the autonomic nervous system (Costa, 2008). The hypothalamus controls all functions like eating, sexual attitude and sleep. It also regulates body heat, feelings, hormone secretions and actions. The hypothalamus develops pituitary gland from a component that extends downward from its extension and upward from the roof of the mouth.

2.3 Brain Lobes

The brain lobes are forms most of the brain. There are four lobes in the brain. All lobes are presents in both hemispheres of the brain. These lobes are controls the reaction of the human body to events and each one has different functions (Apuzzo et al., 2009). The brain

lobes and their functions are examined in detail below. Figure 2.2 shows the brain lobes and their locations.
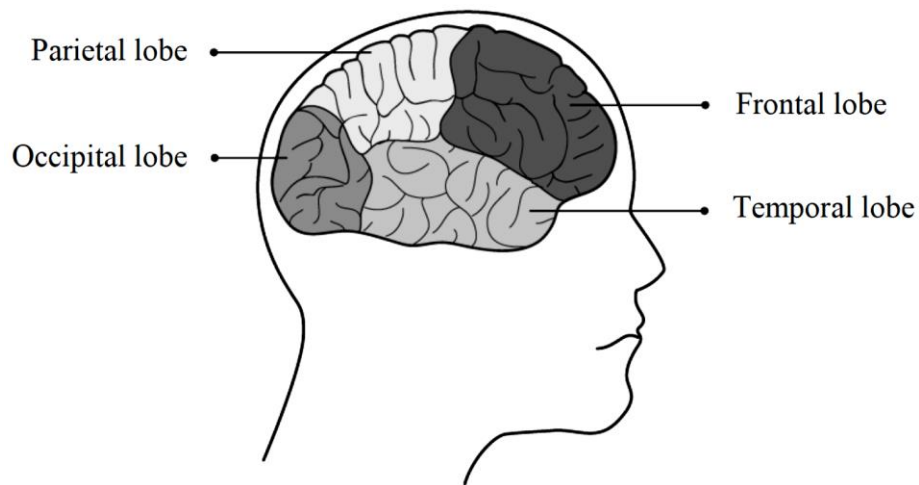
Figure 2.2: The brain lobes and their locations (Apuzzo et al., 2009)

2.3.1 Frontal lobe

The frontal lobe is found in front of the brain. This lobe consists of two parts are known as left and right frontal lobe. The frontal lobe is an essential structure that serves more than one function. Besides, frontal lobe is bigger than the other lobes (Aghababian et al., 2010). The frontal lobe is responsible from motor abilities. The most essential of these abilities are voluntary motion, speech and intellectual behavior. Motion-producing areas of the body are located in the motor cortex or precentral gyrus. The prefrontal cortex has an essential functions such as memory, intelligence, focus, fury and personality.

The premotor cortex, is located the side of the primary motor cortex. This structure is responsible for directing eye and head actions as well as the personal sense of tendency. Broca's area, which plays an essential role in language manufacturing, is located on the left part of the frontal lobe (Aghababian et al., 2010).

2.3.2 Occipital lobe

The occipital lobe is found in the backside of the brain. The occipital lobe consists of two parts are known as left and right occipital lobe. This lobe affects people's perception of colors and shapes (Di salle et al., 2006). The occipital lobe allows people to get visual information and gives meaning to this information. The left occipital lobe sees the right visual area while the right occipital lobe sees the left visual area.

2.3.3 Parietal lobe

The parietal lobe is found in the center of the brain. This lobe plays an essential role in the processing of sensory information such as temperature, touch, and ache. The region known as the somatosensory cortex, is found in this lobe and is necessary for the processing of sensory information (Di salle et al., 2006).

2.3.4 Temporal lobe

The temporal lobe on each edges of the brain is found at the ear degree. The temporal lobe is partitioned into two parts (Apuzzo et al., 2009). The first part is at the base of every hemisphere and the second part is at the side of every hemisphere. This lobe, contributes significantly to sensory analysis, auditory perception, language and memory.

2.4 Language and Speech Functions

The left hemisphere of the brain is responsible for the ability to speak. Thus, the left hemisphere is called the "dominant" hemisphere. The right hemisphere plays a major role in processing and interpreting visual information (Aghababian et al., 2010). Nearly one-third of the left-handed people have speech function on the right side of the brain. It is necessary to determine whether people who mainly use the left hand are on the left or right side of the damaged area before any surgical operation in that area. Doctors may need some testing for this operation.

Neuroscientists think that the left hemisphere is very important for language. Aphasia is a language disease. Some structures of the brain also plays an important role in language production (Apuzzo et al., 2009). These brain structures have many different aphasia types depending on their role in language production according to the regions they are in. In the left hemisphere of the brain, there is an area called the Broca's area in the frontal lobe.

This area is located next to the area that controls facial muscles, tongue, jaw and throat movements. If this area is damaged, people may have difficulty producing words and controlling facial actions (Aghababian et al., 2010). Someone with Broca's aphasia can read and understand something but can have difficulty speaking and writing. In the left temporal lobe of the brain, there is an area called Wernicke. When this area is damaged, Wernicke's aphasia occurs. When this aphasia occurs, people can hear their voices, but these voices do not make sense to people.

2.5 Endocrine Glands

The diapers that release the secreted substances directly into the blood are called endocrine glands. Endocrine glands create new substances from the bloodstream. These substances are distributed to the organs through the blood and provide the organs to work in harmony with each other. It also ensures that the body develops, nourishes, grows, and regulates the spiritual life (Neal et al., 2002). These substances which are composed of endocrine glands are called hormones. There are two types of endocrine glands in the brain. These are named as pituitary and pineal gland.

The pituitary gland is found at the base of the brain. Besides, the pituitary gland is a small region that is known as fossa or sella turcica (Greenstein & Wood, 2011). It controls all hormonal secretions in the body. Therefore, it is known as the "main gland". The tasks for which the pituitary gland is responsible for controlling and coordinating are given below.

- Controls the improvement of the body.
- Controls the function of the organs of the body.
- Coordinates and controls all other glands in the body.

The pineal gland is a structure that occurs after the third verticle or at one of the posterior parts. It controls the reaction of the mammals to the darkness and light. The pineal gland is known to have a sexual enhancement contribution, even if the effect on people is not fully known (Greenstein & Wood, 2011).

2.6 Brain Tumors

The brain tumor is a tissue mass in which some cells grow uncontrollably with the mechanism that manages healthy cells (Lois et al., 2007). When the tumor begins to grow, it takes up space in the skull and negatively affects the brain's functioning. Brain tumors can cause damages on brain tissues and the nerves by making pressure which pushes parts of the brain toward the skull. Brain tumors can build pressure on the nerves which cause disabilities for the humans.

Based on the statistics of the World Health Organization, brain tumors have more than 120 varieties. Brain tumors are categorized according to the region, tissue type, non-cancerous or cancerous (benign or malignant) cells, site of originate (primary or secondary) and other

important factors (Lois et al., 2007). The World Health Organization categorizes tumors of the brain as cell progenitors and cells as least aggressive to the most aggressive.

2.6.1 Primary brain tumors

Primary brain tumors are the tumors that originated in the brain and are named for the cell types from which they originated (Buckner et al., 2007). Such tumors can start in the brain tissue, the brain lining (meninges), the skull, the nerves, or the pituitary gland. Primary brain tumors can be benign or malignant.

Benign brain tumors

Benign brain tumors are consists of innocuous cells, grow slowly and do not cause symptoms for a long time. These tumors are very unlikely to spread to other parts of the brain but can cause problems as they grow which pressure on surrounding tissue. Some may not come back after treatment but others may need further treatment. Benign tumors may sometimes transform to malignant (Buckner et al., 2007). The most common types of benign brain tumors are given below.

- Meningiomas
- Acoustic Neuroma
- Chondroma
- Craniopharyngioma
- Cysticastrocytomas

Malignant brain tumors

Malignant brain tumors grow faster than benign tumors. They cause problems by spreading into and damaging surrounding brain tissue. These tumors may spread to other parts of the brain or the spinal cord. Malignant brain tumors are more likely to repeat after treatment (Lois et al., 2007). The most common types of malignant brain tumors are given below.

- High-grade astrocytomas
- Oligodendrogliomas
- Ependymomas
- Glioblastoma
- Mixed gliomas

2.6.2 Grades of the primary brain tumors

The tumor grade is determined by examining the cells through the microscope. Primary brain tumors are divided into four grades and the details of these grades are given below (National Cancer Institute, 2016).

Grade I tumors

The tissue is composed of benign cells. Cells are very similar to normal brain cells and grow slowly. Surgical operations alone are an effective treatment method for such tumors.

Grade II tumors

The tissue is composed of malignant cells. Cells resemble more abnormal cells than cells in Grade I tumors. Such tumors may sometimes be reproduced as a higher grade tumor.

Grade III tumors

The tissue is composed of malignant cells and grows quickly. Grade III tumors are not very different in appearance from Grade II tumors. Such tumors can sometimes be repeated as Grade IV tumors.

Grade IV tumors

The tissue is composed of malignant cells. It grows more rapidly than other tumor grades and can be easily distinguished from normal cells when examined with a microscope.

2.6.3 Secondary brain tumors

Secondary brain tumors (metastasis) are growing within the brain that has arisen from the spread of a malignant tumor (cancer) elsewhere in the body (Buckner et al., 2007). These tumors have formed from cells that have broken away from the primary brain tumor and have spread through the bloodstream to the brain. The most common source is a lung or breast cancer but they can arise from bowel, kidney, skin and other cancers. Secondary brain tumors are by definition, can truly be called "brain cancer".

CHAPTER 3
IMAGE PROCESSING

Image processing is an important field that enables human interpretation, processing, data storage and transmission of refined pictorial view of images. It also makes the row images machine readable. In recent years image processing is improved great deal which covers many fields of science and technology. In this chapter the basic image processing methodology is covered giving details in image acquisition, image compression, image enhancement and image segmentation.

3.1 History of Image Processing

In the early 1960s first powerful computers suitable for image processing came into use. Digital image processing was born on those days in parallel with the development of these machines. Engineers in Jet Propulsion Laboratory (Pasadena, California) in 1964 were working on improving the pictures of the moon transmitted from the spacecraft called Ranger 7 onboard television camera taken on July 31, 1964 at 9:09 A.M. Eastern Daylight Time (EDT) for the first time by a U.S.A spacecraft as shown in Figure 3.1. 17 minutes before hitting the moon's surface (Gonzalez & Woods, 2008). Image distortions were processed and corrected by computers for the first time which is the start of the digital image processing we use today.
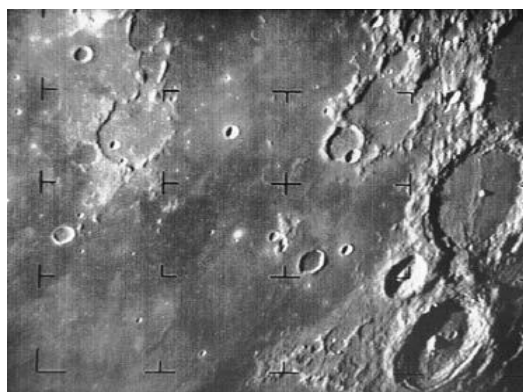
Figure 3.1: The first picture of the moon (Gonzalez & Woods, 2008)

In the late 1960s and early 1970s the digital image processing began to be used in medical imaging in parallel with the space imaging such as astronomy and remote earth resources

observation. One of the most important inventions in early 1970s was the computerized axial tomography (CAT), which was also known as computerized tomography (CT). This was the most important event in the history of applications of image processing in medical field leading to better diagnosis of diseases.

Computerized axial tomography uses multiple detectors placed around the patient and an X-ray source, this ring of detectors are moved around the patient and the X-ray source take a continuous picture of the area under observation. Tomography was introduced by Sir Godfrey N. Hounsfield and Professor Allan M. Cormack. They won 1979 Nobel Prize jointly in Medicine for their invention (Gonzalez & Woods 2008). X-rays were invented in 1895 by Wilhelm Conrad Roentgen. He received the 1901 Nobel Prize in Physics. Two inventions, led to one of the most important area of application of image processing today.

3.2 Fundamentals of Image Processing

Today image processing is a very important technology used in many fields. Branches like computer science, electrical and electronic engineering, robotics, biomedical engineering and even sciences involving environment physics and biology. Because of this importance the scientists continuously increase their knowledge in image processing in order to develop new ideas in their field or introduce new applications for computer aided work and research (Gonzalez & Woods, 2008).

Image processing is a method to perform the necessary operations on images mostly captured by cameras, for the purpose of getting better quality images or to extract certain attribute information from them. The process carried out is a kind of signal processing which takes an image as an input and outputs a more detailed image or characteristics of the image that reveals important information about it.

Today, image processing is one of the fast growing technologies that interest many scientists and researchers (Nagabhushana, 2009). It is very popular in engineering and computer science disciplines. Image processing is conducted using three steps as shown below.

- Importing the image using image acquisition tools.
- Analysis and manipulation of the image.
- Output which is a better image or a report that reflects the image analysis results.

There are two methods used in image processing. One is the analogue and the other is the digital image processing. In the analogue image processing, the hard copies of the images are refined by the specialists using editing tools to make them more presentable. They basically use visual techniques (Nagabhushana, 2009). In the digital image processing techniques suitable software are used to manipulate the digital images using high performance computers. There are three basic phases that the image data have to pass when digital techniques are used. These are Image compression, image enhancement and image segmentation.

3.3 Components of Image Processing System

Image processing systems are sophisticated bundle of large and expensive imaging applications, processing of satellite images is a good example, the trend moves toward embedding of special image processing hardware in general-purpose computers. There are 8 main components in image processing system (Gonzalez & Woods, 2008).

- Image sensors
- Special image processing hardware
- Computer
- Software
- Mass storage
- Image display
- Hard copy
- Network

3.3.1   Image sensors

The image sensors have two parts to acquire digital images. The first one is the hardware which is sensitive to light reflected from the object of interest and the second one is the digitizer which converts the object's reflection into digital form to be processed.

3.3.2   Specialized image processing hardware

The disadvantage of standard personal computers is the slow speed that processes the image data using its CPU (Radhika & Vishalini, 2016). To overcome this disadvantage specialized computers with high speed CPUs are used. The fast arithmetic and logic unit

(ALU) is employed for averaging and digitizing the images in very high speeds which reduces the noise at the same time. The hardware suitable for this purpose is sometimes called a front-end subsystem whose characteristics include the fast speed leading to fast data throughput that ordinary computers cannot handle.

3.3.3 Computer

Basically the computers used in image processing work are mostly general-purpose machines that range from a personal computer to supercomputers. In some special cases where high performance is required custom-built computers can be used to achieve the required level of standard. But in this case a general purpose personal computer with a high performance central processing unit (CPU) and large enough memory (RAM) is suitable for off line image processing work (Burger & Burge, 2009).

3.3.4 Software

Image processing software can be a specialized collection of modules built for specific jobs or mixture of these modules with user code that gives the software flexibility and advantages in performance. Some software packages are open source allowing the user to add code of their own to them which integrates the functions to act together. This is of course possible when the computer language used is common (Nagabhushana, 2009).

3.3.5 Mass storage

One of the essential parts of the image processing tasks is the mass storage. If the image is not compressed where its size is expressed in pixels, to represent the intensity for each, an 8-bit quantity should be used. This can take megabytes of storage space (Radhika & Vishalini, 2016). When there are thousands or millions of images to be processed, vast amounts of random access memory is needed. The storage of digital image processing applications can be divided into three parts:

- Short term storage to be used during processing.
- On line storage for faster input.
- Storage, aimed for rare access.

Storage capacities involving digital image processing today are expressed in Giga Bytes, and Tera Bytes.

3.3.6 Image display

Today's image displays are mostly flat color screens similar to TV monitors. They are driven by output data that are processed by the graphic display cards used in computer systems (Burger & Burge, 2009). Very rarely, digital image processing applications require more sophisticated display unites which are not included in the standard hardware of commercial computer configurations. In such cases stereo display units come into play which are embedded in the glasses of the users that work with remote computer systems transmitting image data.

3.3.7 Hardcopy

Laser printers, thermal printers, inkjet printers, digital cameras and other optical devices are commonly used devices that images are recorded as hard copies. Mainly the paper is the first printed material that comes to mind but for high resolution images can be observed using films especially when presentation of images needed for transparencies. Projection devices are also very common today which convey the computer output to the white screen for the purpose of presentation (Radhika & Vishalini, 2016).

3.3.8 Network

In recent years the networking is one of the basic functions of the computer systems. The image processing applications produces large amounts of data which needs to be transmitted via networks. The dedicated transmission lines will have no problems in sending image data but communications using public networks such as internet can cause bandwidth problems in transmission (Gonzalez & Woods, 2008). Transmission lines using fiber optic cables and broadband technologies are the improvements on the speed of transmission.

3.4 Image Processing Applications

Image Processing is an application to enhance raw images coming from sources like cameras, medical equipment, sensors mounted on satellites, aircrafts, surveillance equipment and every day personal devices (Sarala & Jacob, 2014). In the last four or five decades many techniques are developed for military purposes. Some of these techniques are used for enhancing images that comes from unmanned aircrafts, spacecrafts or military reconnaissance flights. Image processing techniques are becoming very popular due to the

advances in technologies leading to the powerful personal computers with high speed processors, large random access memories and graphics hardware/software etc. Image processing is used in various applications such as:

- Distance Sensing
- Medical Imaging
- Material Science
- Military imaging
- Film technology
- Document manipulation
- Graphics
- Printing technology

3.5 Medical Image Processing

Medical image processing requires an interdisciplinary field that includes medicine, computer science, electrical engineering, physics and mathematics. Medical Image processing is aimed at developing systems to solve the medical diagnosis problems using computerized systems that make use of above mentioned fields of sciences. The computer application programs used in image processing is to extract clinically useful data from medical images. Medical image processing focuses on the computational analysis of the images (Mishra et al., 2014).

Medical image processing can be carried out in four stages. The first stage is to use a set of images collected from the patients to be investigated. The second stage is to apply image enhancement techniques to obtained better quality images (Mishra et al., 2014). The third stage to apply image segmentation methods which is the most important part of image processing procedures, and lastly the fourth stage is to extract the necessary features from enhanced and segmented images which give important information of normality or abnormality of images.

3.6 Image Acquisition

Image capturing devices vary depending on their quality as well as their specifications and purpose of use. Nowadays mobile phones are fitted with high quality and high pixel cameras that can take good quality pictures (Wu & Liu, 2007). Mobile phones generally

fitted with complementary metal oxide semiconductor (CMOS) image sensors which are cheaper than the ones used on professional digital cameras. Professional cameras are also improved using charge coupled devices (CCD) which make use of the voltages sensed from each color when they are exposed to light. Compared with CMOS devices CCDs have less noise. Scanners are another way to capture images. These are basically second choice method in the absence of the camera systems as their quality is not very good.

Scanners use a trilinear color filter array (CFA) to capture red, green and blue colors at the same time of each raster line (Wu & Liu, 2007). Professional cameras and mobile phone cameras make use of square CFA shown as the Bayer pattern. This enables such camera systems to capture the whole area of the two dimensional scene with one shot. Here only one color per pixel can be registered. The other two colors can be estimated using interpolation process. This process varies from one camera to another.

3.7 Image Compression

One of the major problems in image processing is the lengthy times that consumed by the software and the bulky size of the images in process. There is not much that can be done with the image processing software in terms of its size but images can be resized to a smaller file which can contribute to the speed of processing. The size of the images can be reduced using image compression techniques. These techniques are intended to make the digital images more compact which will take less storage area and be handled much quicker by the application software (Vijayvargiya et al., 2013).

Basically all data files have redundant data; that is data that are duplicated many times. These can be repeating pixels or patterns in the image file. A simple explanation of data compression is that it involves transforming a piece of data string into a new string that totally has the same characteristics as the original one and hence no loss of information (Vijayvargiya et al., 2013). Compression is the operation of removing the unnecessary data redundancies from the image file. There are 3 techniques to remove data redundancies.

3.7.1   Inter pixel redundancy

In images pixels have neighbors arround them. Each pixel has certain correlation with its neighbors. Therefore it is highly likely that some of the neighboring pixels will have the same value making them redundant (Khashman & Dimililer, 2008). Redundancy of this

type is called Inter-pixel redundancy. It is also known as spatial redundancy. There are several ways to detect redundant pixels. One method is to predict the value of a pixel by evaluating the neighboring pixels.

3.7.2 Coding redundancy

Some variable length code made of pixel values is formed and look for its match in the original image data. The process uses lookup table tables (LUTs) in removing the redundant data but there is always a chance to reverse this process which provide security against data losses. The Huffman codes and the arithmetic coding technique are examples of detecting redundant data (Khashman & Dimililer, 2008).

3.7.3 Psycho visual redundancy

Experiment conducted on psycho physical characteristics of human vision showed that the human eye cannot sense equally every visual signal that comes along. Some of the signals are regarded as more important than the others. Information not so important is regarded as redundant and therefore removed from the image (Vijayvargiya et al., 2013). This type of redundancy is very commonly used in todays algorithms. Discrete Cosine Transform (DCT) based algorithm is very popular and is the JPEG encoding standard.

3.8 Compression Methods

In accordance with the requirements, the image compression methods can be categorised as the following:

- Lossy compression
- Lossless compression

3.8.1 Lossy compression technique

This technique causes some of the data to be lost during the compression. Here the compressed image file is not exactly same as the original when decompressed but it looks very similar (Padjama & Chandrasekhar, 2012). JPEG images are the type of image file that this technique is commonly used. The algorithm used to restore or resemble the presentation of the original image is called lossy technique. Lossy image compression is not very suited for images to be processed for medical purpose.

3.8.2 Lossless compression technique

In the lossless compression of the image the compression work is carried out by encoding the data read from the original image file. The result of decompression reconstructs the exact copy of the original image file (Yang & Bourbakis, 2005). PNG and GIF images are examples of lossless compression method.

3.9 Image Enhancement

The image enhancement is a technique that identifies the characteristics in the image which are not so visible because of the blurred parts. The technique improves the image contrast allowing the best possible view of the object of interest for a good medical diagnosis. Two kinds of domains can be used in this process.

- Spatial domain methods.
- Frequency domain methods.

This procedure is not a very objective because it aims for the visual interpretation of the images. The procedure varies from one operator to another so is the concept of image quality (Gonzalez & Woods, 2002).

3.9.1 Spatial domain

This approach involves the direct transformation of the image plane which is the manipulation of the pixels on and around the object (Gonzalez & Woods, 2002). The following mathematical expression shows the method:

$$g\,(x, y)\ =\ T\,[f\,(x, y)] \tag{3.1}$$

In this case, f(x,y) represents the initial image, g(x,y) is the resultant image and T is the transformation operator that operates on the (x,y) neighborhood. This technique is the most commonly used one on this type of domain. The most common spatial domain based transformation methods are given below.

Negative transformation

In this operation, the pixel values are basically read and registered as de image negative values after they are inverted. This type of processing is useful for enhancing white or gray

detail embedded in dark regions of an image, especially when the black areas are dominant in size (Gonzalez & Woods, 2004).

Thresholding transformation

To identify the object clearly it has to be separated from the background. The image is first converted to binary format and then a certain threshold is determined. Each pixel has a value of 0 or 1. By comparison the pixels are divided into two groups. Pixels below the threshold form the background and above it construct the object.

Histogram-based transformation

Histograms which are representation of tone values of the pixels can be used for equalization, histogram matching or definition of a threshold (Maini & Aggarwal, 2010). This method is used to improve the image.

3.9.2   Frequency domain

The frequency domain is a strait forward method used in reducing the noise. It is a simple and easy way of identifying the domain. In this method first step is to compute the Fourier transform of the domain, in this case the image so that work in a frequency domain can be carried out. The enhancement operation is performed for improving on brightness and contrast on the image as well as distribution of the grey levels (Gonzalez & Woods, 2002). Hence it can be established that:

$$G\,(u,v)\ =\ H\,(u,v)\,F(u,v) \tag{3.2}$$

Where G is the resultant image, H is the transformation function and F is the initial image. Considering that F(u,v) is the Fourier transformed image of F(x,y), it means that we have a set of different frequency values. The low frequencies generally correspond to smooth regions or blurred structures, and high frequencies correspond to image details, edge or noise (Gonzalez & Woods, 2008).

3.10   Image Segmentation

Segmentation is the separation of the part of the image from the rest for the purpose of analysis. The aim of image segmentation is to cluster the pixels into different regions to make them more visible. The areas of interest can be better analyzed when they become

more meaningful when segmented. The image segmentation is very successful process in locating the objects and detecting their boundaries (curves and lines) in images (Gonzalez & Woods, 2008). When the natural parts of the areas of interest have been detected the process of segmentation should stop.

Discontinuity and similarity are the basic properties of intensity that most segmentation algorithms are based upon. There are two different methods in segmentation. The first method is to use the sharp changes in intensity of pixels on the image. The second method is a partitioning of the image into different areas that look similar using a predefined set of criteria called thresholding, region growing and merging techniques (Gonzalez & Woods, 2008).

One of the most important techniques in brain tumor detection is the segmentation technique. It is very effective in detection and extraction of the tumor region in the image. It plays a very important role in image processing of MRI images (Gajanayake et al., 2009). Due to the advances in these techniques, vast amount of information are collected that helped building of the patient database regarding the characteristics of the brain tumor such as size and location of the brain tumors detected on MRI images (Rana et al., 2013). The brain tumor segmentation of MRI images requires an intensive work and equally challenging as they contain anatomical structures which are too complicated and it makes the segmentation a difficult task. The segmentation has to be accurate and very precise for the medical people to use in diagnosis (Sharma, 2014). Due to the inaccurate detection and extraction causing wrong diagnosis of the brain tumor, many patients died.

There is different segmentation algorithms used for the purpose of diagnosing the brain tumors. Many automatic image segmentation applications developed to identify and extract the brain tumors can fail in some cases. The failures generally occur due to the unidentified and irregular noise. In homogenity, low contrast and fade boundaries also contributing elements in the medical images (Balaji & Gumaste, 2015). The following are the basic areas that segmentation algorithms have to challenge.

- Noise
- The bias field (the presence of smoothly varying intensities inside tissues)
- The partial-volume effect (a voxel contributes in multiple tissue types)

3.10.1 Fundamentals of the segmentation technique

Let us suppose R represents the entire spatial region occupied by an image. Therefore, image segmentation can be viewed as a process that partition R into n sub regions such as R1, R2, R3 as shown in figure 3.2.

a. $\bigcup_{i=1}^{n} R_i = R$

b. R_i is a connected set, i=1,2,....,n.

c. $R_i \cup R_j = \emptyset$ for all i and j, i ≠ j.

d. $Q(R_i) = $ TRUE for i= 1,2,.....n.

e. $Q(R_i \cup R_j) = $ FALSE for any adjacent regions Ri and Rj.

Figure 3.2: The process for how a segmentation technique works (Sharma, 2014).

From steps above, Q(Rk) is a logical predicate defined over points in set Rk, and the null set is Ø. On the other hand, the symbol ∪ and ∩ represent sets union and intersection respectively (Gajanayake et al., 2009). As a result the two regions Ri and Rj are said to be adjacent if their union forms a connected set. However, condition (a) shows that the segmentation must be complete because every pixel must be in a region, while condition (b) indicates that the points in a region be connected in some predefined sense.

For example, the points must be 4- or -8 connected. On the other hand, condition (c) shows that the regions must be disjointed, while the condition (d) indicates the properties that must be satisfied by the pixels in a segmentation region. Therefore, Q(Ri) = TRUE if all pixels in Ri have the same intensity level. Eventually, the condition (e) shows how the two adjacent regions Ri and Rj must be different in the sense of predicate Q. Against this background, there is a fundamental problem in segmentation which is to partition an image into regions that satisfy the preceding conditions (Gonzalez & Woods, 2008).

CHAPTER 4
BRAIN TUMOR DETECTION SYSTEM

In this chapter, the proposed system is described. This system can be summarised in three stages. First stage is the pre-processing which enhances the brain MRI image and make it more suitable to analyze. Enhenced images are obtained using morphological operations, pixel subtraction and image filtering. Second stage is the intensity adjustment based segmentation which segments the region of the tumor from the enhanced image. Third stage is pixel addition which shows the location of the tumor on the original image. Figure 4.1 shows the proposed system's flowchart.

```
┌─────────────────────────────────┐
│      Input brain MRI image       │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│      Pre-processing Stage        │
│  ┌───────────────────────────┐  │
│  │    Background extraction   │  │
│  │ using morphological operations │
│  └───────────────────────────┘  │
│  ┌───────────────────────────┐  │
│  │  Skull extraction using pixel │
│  │        subtraction         │  │
│  └───────────────────────────┘  │
│  ┌───────────────────────────┐  │
│  │  Image filtering using mean │ │
│  │          filter            │  │
│  └───────────────────────────┘  │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│   Segment region of tumor using  │
│        intensity adjustment      │
└─────────────────────────────────┘
                 │
                 ▼
┌─────────────────────────────────┐
│   Add segmented image to original │
│              image               │
└─────────────────────────────────┘
```
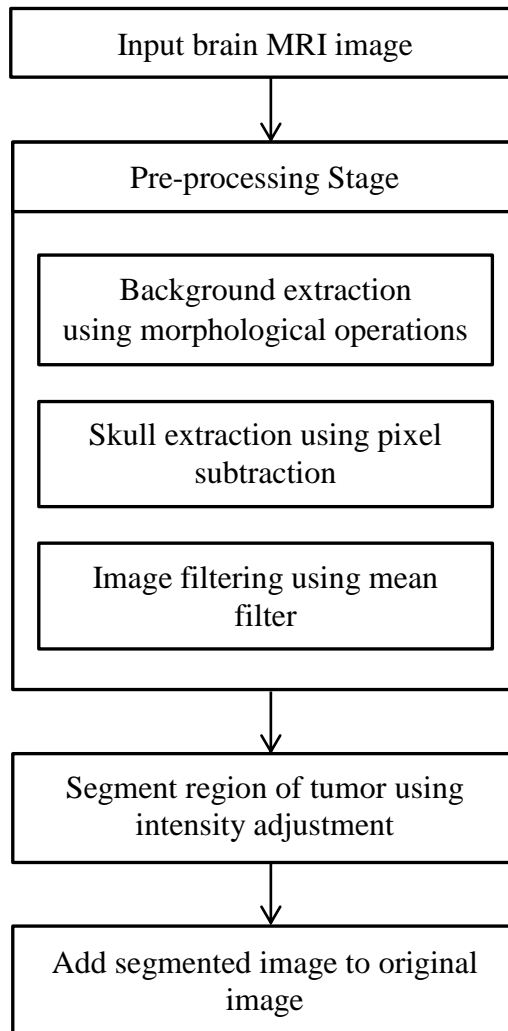
Figure 4.1: Flowchart of the proposed system

4.1 Database

In this thesis, the digital magnetic resonance images (MRI) are used. The database is obtained from The Cancer Imaging Archive website (The Cancer Imaging Archive, 2016). All images are 256 x 256 pixels and 8 – bit grayscale. There are 100 images in the database which contain 70 abnormal and 30 normal (with and without tumor) brain MRI images. The original data is in dicom format. The images are converted to raw format in order to be used in MATLAB environment. Figure 4.2 shows the samples of the brain MRI image.
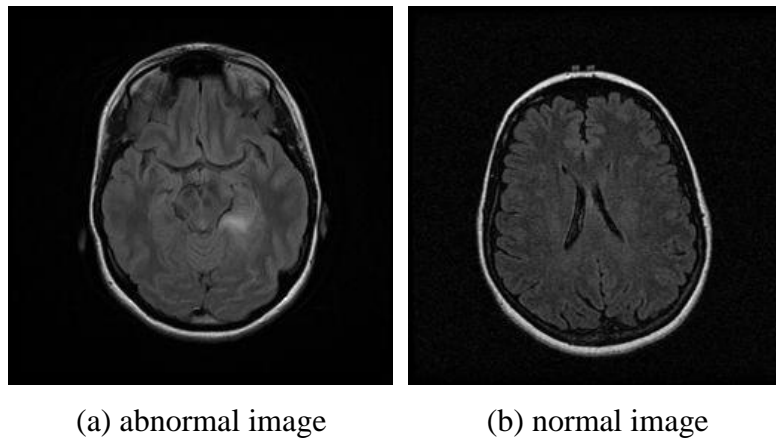

(a) abnormal image   (b) normal image

Figure 4.2: Brain MRI images

4.2 Morphological Operations

Mathematical morphology is known as a non-linear effective technique used to identify the boundaries and skeleton of objects in an image. Besides, this technique is used to extract components of objects. Morphological operations create a small shape or template called a structural element on an image (Gonzalez & Woods, 2008). This template is placed in all possible locations on the image and the corresponding pixel is compared with the neighborhood by querying. By selecting the size and shape of the neighborhood, builds a morphological operation which is sensitive to particular shapes within the input image. In this thesis, the background of the image is extracted using a morphological operation with the structure element "disk" and radius "7". The most commonly morphological operations are dilation and erosion.

Dilation is a morphological operation that can be applied to both binary and grayscale images. Dilation causes objects to grow by expanding the boundaries. With the effect of this operation, the small holes in the regions that begin to expand become even smaller.

Erosion is a morphological operation that can be applied to both binary and grayscale images like dilation. Erosion causes object dimensions to be examined. Erosion basically erodes the boundaries of objects in the image (Radha & Lakshman, 2013). In the region where erosion is applied, the size of the pixels shrinks and the size of the holes starts to grow.

4.2.1 Background extraction

The background extraction occurs with the morphological operation named image opening (Chugh et al., 2015). The image opening is a morphological operation that occurs from erosion and then dilation using the same structure element. Figure 4.3 shows the implementation of the background extraction technique.
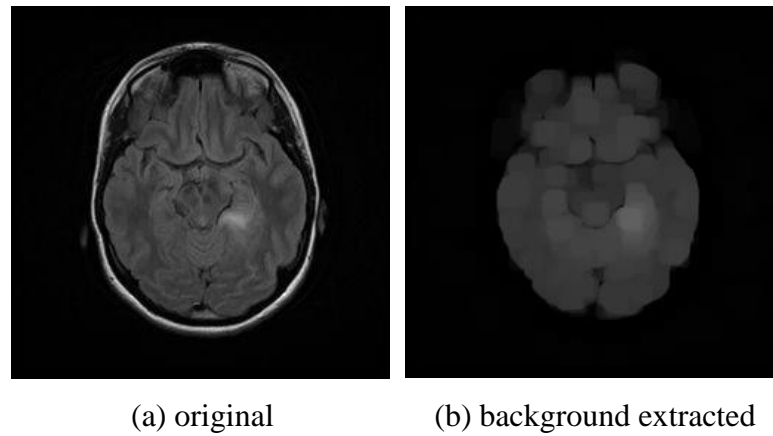

(a) original   (b) background extracted

Figure 4.3: Images before and after background extraction

In this thesis, background extraction is used to remove skull on the image. When the skull is removed, some of the pixels are also removed from the tumor region unintentionall. Therefore, background extracted image cannot be used directly for segmentation of the tumor. The background extraction on its own is not enough to remove the skull properly. Pixel subtraction is used to extract the skull from the brain image in a more efficient manner.

4.3 Pixel Subtraction

The pixel subtraction operator takes as input two images of the same size. The pixel values of the second image are subtracted from the respective pixel values in the first image and a third image is obtained at the end of this process. Taking an image as input and subtracting a fixed value from all the pixels is also a common process (Qidwai & Chen, 2009).

Some of the subtraction operators are output the absolute difference of two pixels, instead of the signed output. Using a single pass two images are subtracted giving a signed output. The pixel values of the output image are given as follows.

$$R(m, n) = P(m, n) - Q(m, n) \qquad (4.1)$$

In this thesis, the following pixel subtraction operations are conducted. First, the image obtained from background extraction is subtracted from the original image which seperates the skull from the original image. Figure 4.4 shows the result of the skull extraction process.

(a) original   (b) background extracted   (c) skull
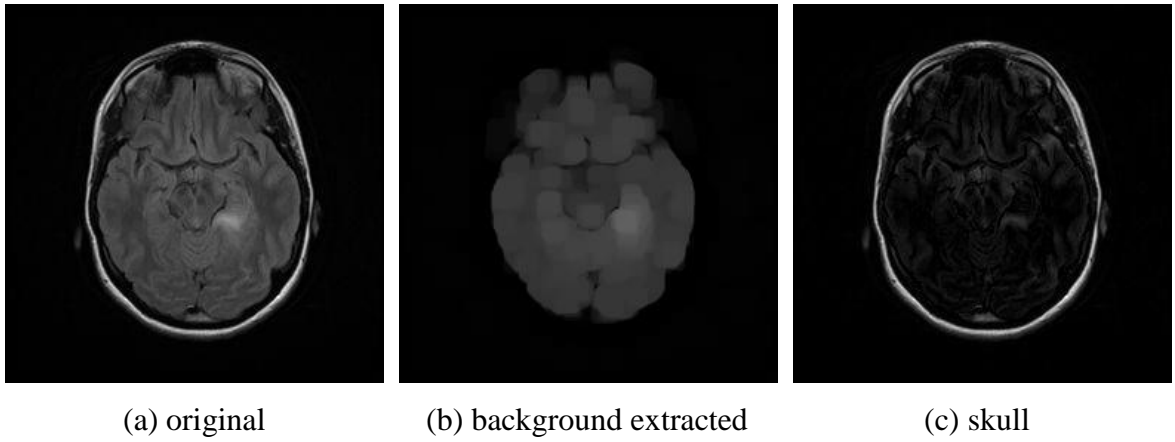
Figure 4.4: Images of skull extraction process

Then image obtained from background extraction is subtracted from the skull image which removes the undesierd gray pixels from the skull image. Figure 4.5 shows the result of the skull cleaning process.
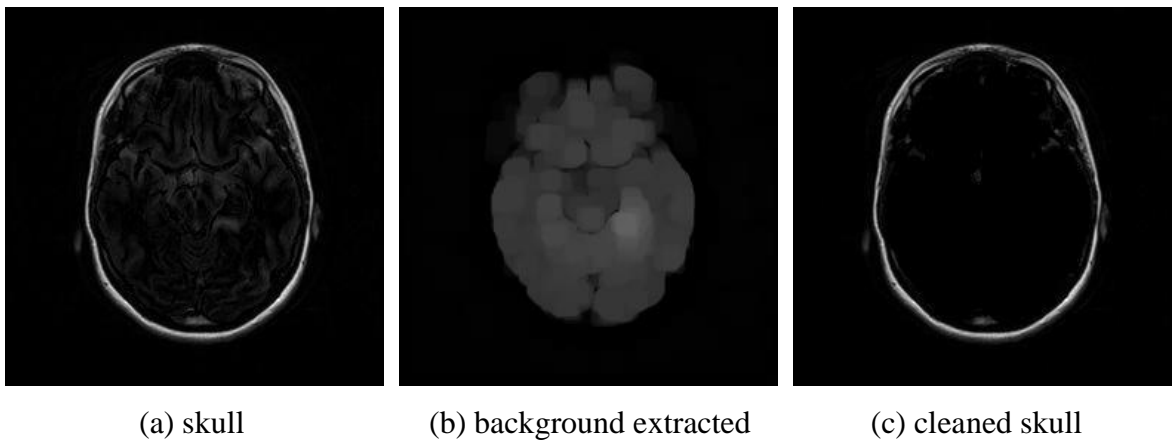

(a) skull   (b) background extracted   (c) cleaned skull

Figure 4.5: Images of skull cleaning process

Lastly, the cleaned skull image is subtracted from the original image. This gives us an image of the brain without the skull. Figure 4.6 shows the result of the skull removal process.
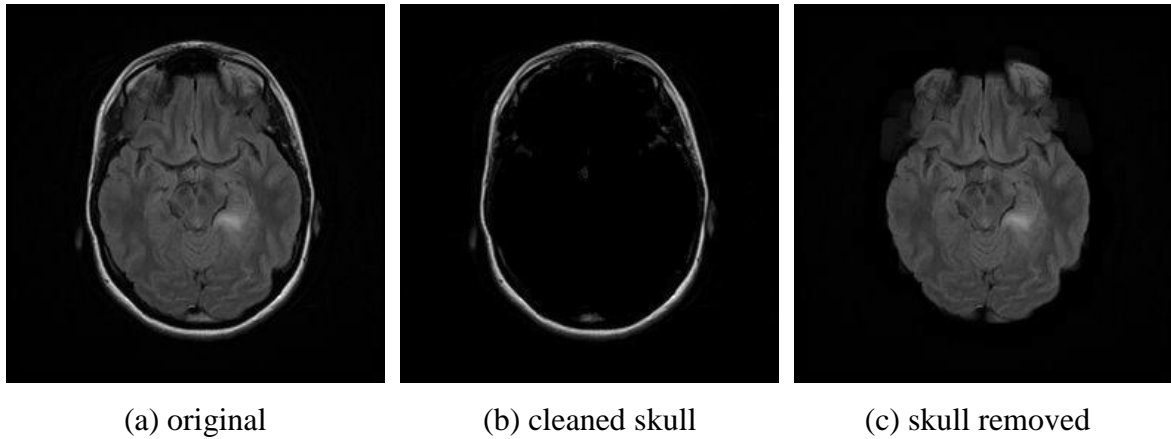

| (a) original | (b) cleaned skull | (c) skull removed |

Figure 4.6: Images of skull removal process

4.4 Image Filtering

The purpose of image filtering is to remove the noises on the digital images. Image filtering is one of the most common issues in digital image processing. Image filtering is the main tool in the majority of image processing software (Gonzalez & Woods, 2008). Image filtering is one of the most common methods used to improve image quality. Image quality is important for human vision. In image processing, the image often has noise that cannot easily be removed.

The noise affects the quality of the image badly. There are many ways to get rid of the noise in the image. In the noisy environment, many image processing algorithms do not work well (Tania & Rowaida, 2016). This is why the image filter is used as a pre-processing tool. However, conventional filtration based on numerical computation is quickly disintegrated in noisy environments. One of the most commonly used methods for image filtering is the mean (average) filter.

The mean filter is a linear filter and is an intuitive and easy to apply filtering method for filtering images. Reducing the density variation between the pixels is an example of this definition. The mean filter is usually used to remove noises from the image. The working principle of the mean filter is to change each pixel value on the image with an average value that includes its neighbors as well as itself (Tania & Rowaida, 2016). As a result of

this process, pixel values that do not represent the surroundings are removed from the image. The average filter is generally regarded as the convolution filter. Like other convolution filters, it is based on a kernel that represents the neighborhood shape and size to be determined when computing the mean. Figure 4.7 shows a description of the mean filter operator.

Unfiltered		
5	3	6
2	1	9
8	4	7

$$5 + 3 + 6 + 2 + 1 + 9 + 8 + 4 + 7 = 45$$

$$45 / 9 = 5$$

Mean filtered		
*	*	*
*	5	*
*	*	*

Figure 4.7: Graphical description of the mean filter operation (Tania & Rowaida, 2016)

In this thesis, 5x5 square neighborhood (kernel) pixels around the evaluated pixel are used. Figure 4.8 shows the result of the noise removal process.
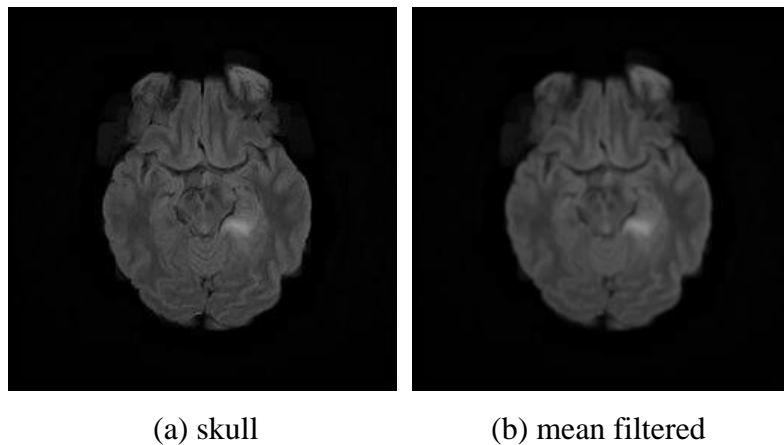

(a) skull   (b) mean filtered

Figure 4.8: Images before and after noise removal

4.5 Intensity Adjustment

The intensity is a concept that interests the entire image. The intensity value should be at an appropriate level so that the image can be seen clearly. If the intensity of the image is not at the proper level, it needs to be adjusted. The method called intensity adjustment is used to find the appropriate intensity value of the image (Gonzalez et al., 2004). In addition, this technique expands the pixel intensity to improve the quality of the image.

The intensity adjustment technique is applied to grayscale images. In this technique, the pixel values below a certain value appear in black, whereas the pixel values above a certain value appear in white. Pixels between these two values appear in gray tones (Gonzalez et al., 2004). In short, this technique is to improve the image by changing the low and high intensity values.

In this thesis, the intensity adjustment is used on the mean filtered image. After skull removal, the highest intensity pixel takes place on the tumor region. To be able to segment the tumor, some adjustments had to be made on the image. The low and high intensity values are set to 0.41 and 0.42 respectively.

The pixel values below low intensity are set to 0 and the pixel values above high intensity are set to 1. By this operation, gray pixels are removed and the tumor is segmented from the image. High intensity value is determined by sampling the database. This value is calculated as the overall average of the mean value of the column containing the highest intensity pixel on the tumor of the sample images. Determination of the high intensity value is given in appendix b. Figure 4.9 shows the result of the tumor segmentation.
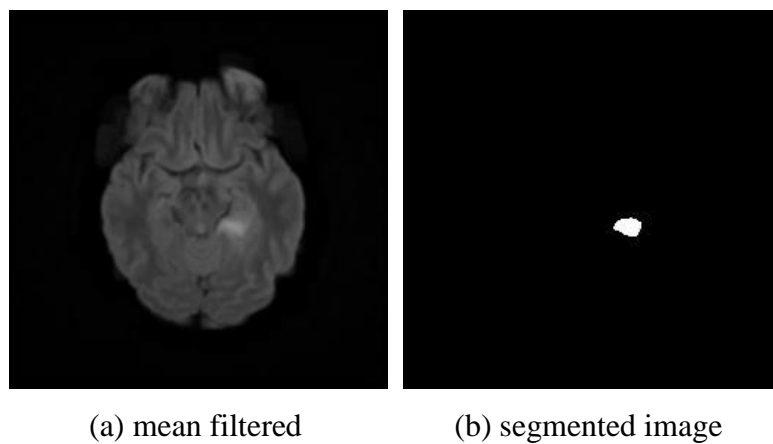

(a) mean filtered   (b) segmented image

Figure 4.9: Images before and after tumor segmentation

4.6 Pixel Addition

The pixel addition operator takes as input two images of the same size. This operator obtains a third image by adding the pixel values of the first image to the respective pixels of the second image. Using the same procedure, it can be applied to more than one image in the continuation of the previous process. Taking an image as input and adding a fixed value to all the pixels is also a common process (Qidwai & Chen, 2009). The pixel values of the output image are given as follows.

$$R(m, n) = P(m, n) + Q(m, n) \qquad (4.3)$$

In this thesis, the segmented image is added to the original image anabling the medical people to analyze the image and make their decision. Figure 4.10 shows the clarification of the tumor.
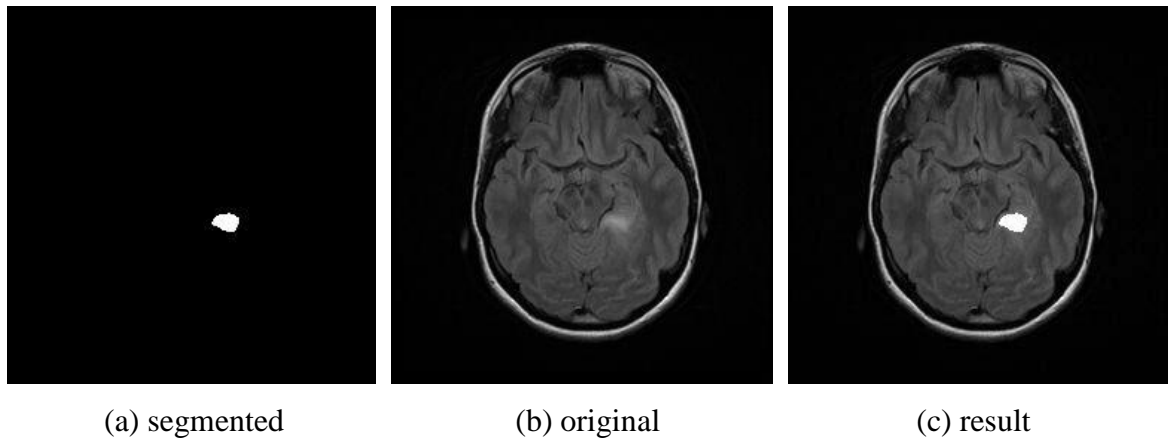

(a) segmented   (b) original   (c) result

Figure 4.10: Images of clarification of the tumor

CHAPTER 5
RESULTS AND DISCUSSION

In this chapter, the system performance is tested. The brain MRI images stored in database are subjected to the proposed system and discussion. The accuracy is compared with other researches conducted on the similar subject.

5.1 System Performance

This system is designed to extract the tumor from brain MRI image for better analysis. Prior tumor segmentation contain pre-processing techniques are used. To be able to segment the tumor from the brain image, intenstiy adjustment technique is used. In this system, 70 images with and 30 images without a tumor have been tested. To evaulate the system accuracy, sensitivity and specificity the following attributes are used in the calculations.

- TP (True positive): Existing tumor and detected correctly.
- TN (True negative): Non-existing tumor and not detected.
- FP (False positive): Existing tumor and not detected.
- FN (False negative): Non-existing tumor and detected.

Accuracy is the measure of successful classification. The accuracy is given by:

$$\text{Accuracy} = \frac{\text{TN} + \text{TP}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} * 100 \qquad (5.1)$$

Sensitivity is the measure of successful determination of the person having a tumor. The sensitivity is given by:

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} * 100 \qquad (5.2)$$

Specificity is the measure of successful determination of the person not having a tumor. The specificity is given by:

$$\text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} * 100 \qquad (5.3)$$

Tables below shows the detection rate and the performance of the proposed system.

Table 5.1: The detection ratio of the proposed system

	Number of images	Correct detected images	Detection ratio
Abnormal	70	66/70	94.29%
Normal	30	30/30	100%
Total	100	96	96%

Table 5.2: The performance of the proposed system

	Number of images	Accuracy	Sensitivity	Specificity
Total	100	96%	94.29%	100%

5.2 Result Discussion

In this thesis, the proposed system is tested on 100 brain MRI images. There are 70 images with and 30 images without a tumor. Out of 70 images with the tumor 66 images evaulated correctly by the system. Other 4 images are identified as without a tumor incorrectly. The reason of this mulfunctioning was due to the fact that there is no clear distinction between the tumor area and the rest of the brain in terms of intensity of the pixels. 30 images without a tumor was correctly identified by the system as images without a tumor with a 100% success.

5.3 Result Comparison

The system used in this thesis is compared with two different methods accepted by "International Journal of Advanced Research in Computer Engineering and Technology" and "International Journal of Computer Science and Information Technologies".

The method used in "Brain MRI Image Classification Using Probabilistic Neural Network and Tumor Detection Using Image Segmentation" begins with the pre-processing stage. Using the Gray level co-occurrence matrix (GLCM), texture features are extracted from the image (Pergad & Shingare, 2015). Then using the Probable Neural Network (PPN), the images are classified as normal and abnormal according to the features obtained from the

images. Lastly, tumors are extracted from the image by using threshold segmentation and morphological operations. The accuracy of this system is 88.2%.

The method used in "Detection of Brain Tumors using Learning Machine Approach and Spatial Fuzzy Segmentation" includes MRI brain image classification and segmentation approach (Lavanya & Suganthini, 2015). It is a learning machine approach where the network is trained with Probabilistic Neural Network and Radial Basis Function (PNN-RBF). The neural network is trained with images in each benign, malignant and normal stage. The proposed segmentation process includes Spatial fuzzy clustering where the process is carried out by calculating centroid, distance, and membership. The system also uses to segment the tumor cells along with this morphological filtering which is used to remove background noises for smoothening up of the region. The accuracy of this system is 90.9%.

The method used in proposed system consists three stages as pre-processing, intensity adjustment based segmentation and pixel addition. The pre-processing stage is removed the skull from the brain MRI image by using morphological opearations and pixel subtraction. The noise is removed from image using mean filter. In the second stage intensity adjustment based segmentation is used to seperate the tumor from the rest of the image. In the last stage the segmented image is added to the original image to make it more suitable to help medical people to make their decision. The accuracy of the proposed system is 96%.

Table 5.3: The comparison of the proposed system

Paper Title	Authors	Detection Ratio
Brain MRI Image Classification Using Probabilistic Neural Network and Tumor Detection Using Image Segmentation	Pergad & Shingare	88.2%
Detection of Brain Tumors using Learning Machine Approach and Spatial Fuzzy Segmentation	Lavanya & Suganthini	90.9%
Proposed system	Ahmet İlhan	96%

CHAPTER 6
CONCLUSION

The system developed in this thesis is an aid to the medical people to diagnose the brain cancer using MRI images. The system uses morphological operations, pixel subtraction, mean filtering, intensity adjustment based segmentation and pixel addition to identify the images with and without tumor. The images obtained from The Cancer Imaging archive (TCIA) are used in this thesis. 70 images with tumor and 30 images without tumor are tested. The method is introduced has 100% recognition rate on the images without a tumor and 94.29% recognition rate on ones with the tumor. The overall success rate is 96% which is better a performance our the methods compared with. There are two issues that are to be improved in my system. One is the inaccurately classified images that have tumor. Here perhaps different methods of classification like Neuro Fuzzy or Support Vector Machine should be tried. Second is that the proposed method is not an automatic procedure. The technologies used may be brought together for a single processing environment.

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APPENDICES

APPENDIX A
SOURCE CODE

% Clear worksheet.

clear;
clear all
clc;

% Read raw images.

img = fopen ('image(1)_256_T.raw' , 'r+');
a = fread (img , [256,256] , 'uint8=>uint8');
a = a';

figure
imshow (a)
colormap (gray);
title('Original Image')

% Save the image in jpeg format.

imwrite (a, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step1)original.jpg')

% Background extraction using image opening.

se = strel('disk',7);
b = imopen(a,se);

figure
imshow(b);
colormap(gray);
title ('Image Opening')

imwrite (b, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step2)opening.jpg')

% (Original image) - (Background extracted image) = Skull image obtained.

c = a - b ;

```matlab
figure
imshow(c)
colormap(gray)
title('Subtraction 1')

imwrite (c, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step3)subtract1.jpg')

% ( Skull image ) - ( Background extracted image ) = Cleaned skull image obtained.

d = c - b ;

figure
imshow(d)
colormap(gray)
title('subtraction 2')

imwrite (d, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step4)subtract2.jpg')

% ( Original image ) - ( cleaned skull image ) = Skull extracted image obtained.

e = a - d ;

figure
imshow(e)
colormap(gray)
title('subtraction 3')

imwrite (e, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step5)subtract3.jpg')

% Remove noises from the skull extracted image using mean filter.

f = fspecial ('average', [5 5]);
f1 = imfilter (e,f);

figure
imshow(f1)
colormap(gray)
title('Noise Remove')

imwrite (f1, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step6)meanfilt.jpg')
```

% Segment the tumor from the mean filtered image using intensity adjustment.

g = imadjust(f1,[0.41;0.42],[0;1],0.1);

figure
imshow(g)
title('Segmented image')

imwrite (g, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step7)tumor.jpg')

% Add segmented image to original image using pixel addition.

h = g + a;

figure
imshow(h)
colormap(gray)
title('Area of Tumor')

imwrite (h, 'C:\Users\Ahmet\Desktop\program\brain-program\saved
images\human(1)\(step8)Area-of-Tumor.jpg')

% CALCULATION PART

% TP: True Positive: Tumour Present and true detected.
% TN: True Negative: Tumour not present and not detected.
% FP: False Positive: Tumour not present and detected.
% FN: False Negative: Tumour present and false detected.

TP = 66 ;
TN = 30 ;
FP = 0 ;
FN = 4 ;

Sensitivity = TP / (TP+FN) * 100
Specificity = TN / (FP+TN) * 100
Accuracy = ((TN+TP) / (TP+TN+FP+FN)) * 100

% Find the highest intensity pixel.

maxValue = max(f1(:))

```matlab
% Find the location of the highest intensity pixel.

[rowsOfMaxes colsOfMaxes] = find(f1 == maxValue)

% Finding highest intensity pixel on the image and mark it.

figure
[x_p,y_p] = find(f1 == maxValue);
imshow(f1);
hold on;
plot(y_p,x_p,'o');
hold off;

% Calculate the column average containing the highest intensity pixel.

Colmn_Avg = mean(f1(:,colsOfMaxes))

% Save the column averages to text file.

fid = fopen('Overall Average.txt', 'wt');
  fprintf(fid, '%f ', Colmn_Avg);
  fclose(fid);
```

APPENDIX B

DETERMINATION OF HIGH INTENSITY VALUE

Step 1. Input variables

     Sample_size = 15

     Column_avg = 0

     Icount = 1

Step 2. Input image (Icount)

Step 3. Find high intensity pixel

     For I = 1 to 256

         For J = 1 to 256

     Mat (k) $\longleftarrow$ pix (I , J)

       End.

     End.

     Sort – Decs (Mat (k))

     Bright $\longleftarrow$ Mat (1)

Step 4. Calculate mean value of the column containing the highest intensity pixel

     Column_avg $\longleftarrow$ Column_avg + Avg (Column_Bright)

Step 5. Calculate overall average

     If Icount $\leq$ Sample_size then

     Icount = Icount + 1

     Goto Step 2

     Else

     Overall_avg $\longleftarrow$ Column_avg / Sample_size

     End if

     Output Overall_avg