

I. Introduction

Neurological diseases are disorders of the brain, spinal cord and nerves throughout our body, which arise due to structural, biochemical and electrical abnormalities. Many of the neurological disorders are relatively common, a few being exceptional. Assessing these disorders require a scrupulous neurological examination performed by dexterous neurologists and neuropsychologists. According to the Global Burden of Disease (GBD) study, a collaborative Endeavor of the World Health Organization (WHO), the World Bank and the Harvard School of Public Health, there are around 600 known types of neurological diseases ranging from migraines to epilepsy. It is estimated by the World Health Organization that these disorders and their scale have their effect on more than 1 billion people worldwide (World Health Organization, 2006). This number is expected to grow with the rise in population and these diseases are becoming a serious threat to public health. Intervention of these disorders includes preventative measures, lifestyle changes, physiotherapy or other therapy, neuro-rehabilitation, pain management, medication, or operations performed by neurosurgeons (www.renoveldiscoveries.com/diseases). Some of the symptoms contributing to these disorders are confusion, loss of sensation, muscle weakness, paralysis, poor coordination, seizures, pain and altered levels of consciousness (www.medicalmarijuanainc.com/index.php/neurological-disorder). Researchers and policy makers suggest that the principle measure of the seriousness of a disease is based on mortality statistics, based on which the countries and organizations have launched disease control programs. Such a statistic, however, underestimates the suffering caused by disease that may be non fatal but can cause substantial disability.

1.1. Types of Neurological Diseases

The statistics recorded by WHO suggests that neurological and psychiatric disorders are an important and growing cause of morbidity. The brutality of mental burden, neurological, and behavioral disorders is so enormous, that more

than around 450 million people have been afflicted worldwide. (<http://www.ncbi.nlm.nih.gov/books/NBK11793>). According to the Global Burden of Disease Report, 33 % of people live with disabilities and 13 % of the global population live a disability-adjusted life years (DALYs) which account for neurological and psychiatric disorders. The spectrum of neurological disorders varies considerably between countries and even in different regions of large countries depending on the environment, nutritional status, genetic profile and delivery of health care particularly with reference to preventive and primitive health care programs (Gourie Devi, 2005). A state of devastation is imposed by such chronic neurological conditions in counties which are underprivileged in the category. Dr Rajesh Kumar, consultant neurologist at Rockland Hospital, reiterates, “Neurological disorders are most often neglected due to the lack of awareness, which in turn acts as a hurdle in further treatment of the disorders. It is significant that people should be aware of the common neurological disorders, so that they are able to address the issue on time to prevent complications (<http://www.dnaindia.com/health/1755146/report-at-nerve-s-end-neurologists-in-short-supply-across-country>). It is also emphasized by senior neurosurgeons that awareness about detection and prevention of neurological diseases should be broadened. There is an urgent need to improve neurology care at all levels of the hierarchy of the health care pyramid. An enhancement in the budget meant for health sector should be emphasized by augmenting medical professionals along with the necessary armamentarium. There is also a need to increase the number of neurology training institutes without compromising on the standards of training.

Some of the prevalent neurological disorders in India are epilepsy, brain damage due to birth trauma, Parkinson’s disease, dementia, nerve weakness, and neurological disorders resulting due to nutritional deficiency and revelation due to neurotoxin chemicals (Sanders *et al.*, 2009).

The different types of neurological diseases are discussed below:

Dementia: This particular disorder is due to the deterioration of intellectual and other cognitive skills that have their own severity which act as a hindrance in their social or occupational participation. Alzheimer Disease is the most common subsect of Dementia prevalent among people of age group 65 and more (<http://health.usnews.com/health-conditions/brain-health/alzheimers-disease>).

Parkinson's disease: A neurologic syndrome usually resulting from deficiency of the neurotransmitter dopamine as the consequence of degenerative, vascular, or inflammatory changes, characterized by rhythmic muscular tremors, rigidity of movement, festinating, a droopy posture. Lower levels of dopamine, have a serious impact over the movement of muscles (parkinsons-tmj.com/the-shaking-palsy-a-review-on-parkinsons-disease).

Stroke: A stroke otherwise called a cerebrovascular accident (CVA) is a critical condition which results in rapid loss of brain function due to disturbance in the blood supply to the brain. The most serious outcome is that brain cells begin to die (http://www.dartmouth.edu/~dons/part_3/chapter_27.html).

Brain Tumor: It is an abnormal growth of cells which are either malignant i.e. possessing cancer cells or benign which is non-cancerous in nature. Exposition of cancer could be due to tumor created by abnormal and uncontrolled cell division residing in the brain or in any one of the following locations cranial nerves, brain envelopes, skull, pituitary and pineal gland (<http://www.ncbi.nlm.nih.gov/books/NBK9553>).

Epilepsy: It is a chronic neurological disorder of the brain characterized by paroxysmal stereotyped alterations associated with excessive discharge in large aggregates of neurons. The pathogenesis of this disorder is not well understood. It is the second most common chronic non-degenerative neurological disease perceived by neurologists. It is estimated that there are around 5.5 million people with Epilepsy in India (Ray *et al.*, 2002). According to the epilepsy foundation, the

statistics of population with epilepsy in USA is more than 2 million and around 65 million people are afflicted worldwide (<http://www.epilepsyfoundation.org>).

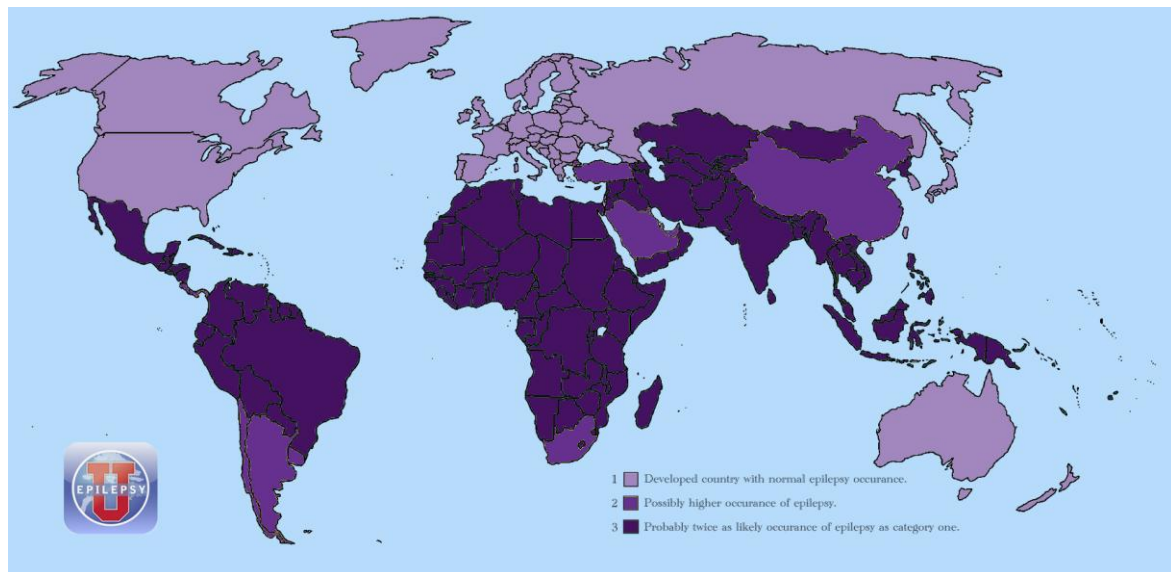


Figure. 1.1 Incidence of Epilepsy world wide

(Epilepsy.com/wp-content/uploads/2012/09/Global-epilepsy-rates.jpg)

The above map shows three categories of incidence of epilepsy world wide

- 1) The developed country has a normal occurrence of epilepsy.
- 2) The second category has a comparatively higher occurrence of epilepsy.
- 3) The developing and underdeveloped countries have the probability of epilepsy with twice the occurrence seen in that of developed countries.

1.2. Anatomy of Human Brain

The study of the structure of the nervous system is called neuroanatomy. The nervous system encompasses the Central Nervous System (CNS) and Peripheral Nervous System (PNS). Figure. 1.2 represents the cross sectional view of the brain. The CNS, which is the main concern of this study, comprises the brain and the nerves which are the control center of the body. It is divided into three main parts: The Cerebrum, Cerebellum and the Brain Stem. The PNS is the part of the nervous system, consisting of the nerves that connect the Central Nervous System (CNS) to the limbs and organs (<http://serendip.brynmawr.edu/bb/kinser/Structure1.html>).

Cerebrum: The human cerebral cortex is a thick layer of neural tissue that covers most of the brain . The cortex is divided into four "lobes", called the frontal lobe, parietal lobe, temporal lobe, and the occipital lobe. Each lobe contains numerous cortical areas; each associated with a particular functionality such as vision, motor control, language, etc. (http://psychology.about.com/od/biopsychology/ss/brainstructure_2.html).

Lobes of the Brain:

Frontal Lobe: It lies in the anterior part of the cerebral hemisphere and is the largest of all the lobes. It is considered to be the emotional control center and the abode of our personality. It is the most vulnerable part of the brain during any accident. Epilepsy that transpires in the frontal lobe is characterized by brief, recurring seizures and is referred to as Frontal Lobe Epilepsy (FLE). It is exemplified by the occurrence of Partial seizures. The manifestations which does not effect on the awareness or memory are called straightforward partial seizures and the ones which affect the memory are complicated partial seizures. The symptoms and clinical manifestations of FLE can also vary depending on the particular area of the lobe affected by epilepsy (<http://www.ncbi.nlm.nih.gov/books/NBK2609>).

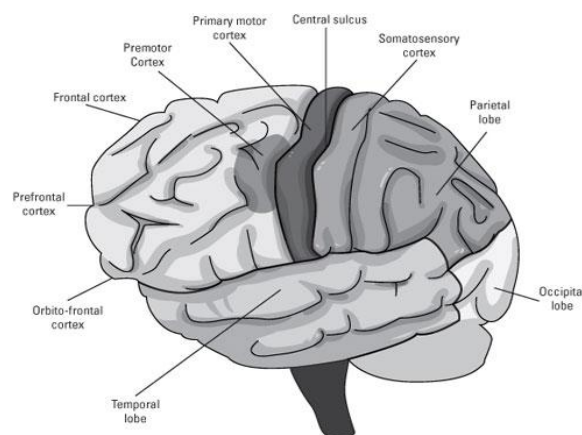


Figure. 1.2 Cross sectional view of brain

Parietal lobe: This part of the brain is positioned posterior to the frontal lobe and anterior to the occipital lobe. It plays an important role in integrating sensory input

from various parts of the body which involves sensation and perception primarily with the visual system. Damage to the parietal lobes shows deficits, such as abnormalities in body image and spatial relations (Kandel, Schwartz and Jessel, 1991). Parietal Lobe Epilepsy (PLE) is a relatively rare form of epilepsy, in which seizures arise from the parietal lobe of the brain. It may be a result of head trauma, birth difficulties, stroke, or tumor, though the cause is unknown in 20% of patients. Since the parietal lobe involves the processing and integration of sensory and visual perception, seizures originating from the parietal lobe can involve both sensory and visual sensations. Very common epilepsy arising due to damage in these lobes is Somatosensory Seizures. Patients with these types of seizures describe feeling physical sensations of numbness and tingling, heat, pressure, electricity and/or pain (epilepsy.med.nyu.edu/epilepsy/types-epilepsy/parietal-lobe-epilepsy).

Occipital lobe: This lobe is located in the rearmost part of the brain and is the smallest of all the lobes (<http://dailyhealthcenter.net/Lobes-Of-The-Brain.html>). It is the visual processing center predominant over the major portion of the anatomical visual cortex. The characteristic features of this lobe are visuospatial processing, discrimination of movement and color (Westmoreland *et al.*, 1994). Visual hallucinations and illusions are the major preponderance of the disorders of this lobe. Distorted perceptions are the consequences of visual illusions that manifest the objects appearing resized than they actually are, objects lacking color or objects having abnormal coloring. Occipital seizure is triggered mainly during the day, through television, video games or any flicker stimulation system (Destina *et al.*, 2000). Occipital seizures originate from an epileptic focus confined within the occipital lobes. They may be spontaneous or triggered by external visual stimuli.

Temporal lobe: It is the region of cerebral cortex which is located beneath the lateral fissure on both the cerebral hemisphere. It is concerned with retention of visual memories, comprehending languages, long term memory, storing new memory and emotions. The upper and the medial part of the lobe, receives auditory

input from the thalamus, which acts as a relay of information from the ears. The lower part of the lobe does the visual processing for recognition of objects and patterns. Temporal Lobe Epilepsy (TLE) is a form of focal epilepsy, a chronic neurological condition characterized by recurrent seizures. TLE is the most common form of refractory epilepsy with intractable complaints.

Cerebellum: The little brain positioned at rear end just above the brain stem and accounts for approximately 10% of the total volume of the brain. It contains a participation of around 50% of the brain's total neurons. It is relatively well protected from traumatic injuries when compared to the frontal, temporal lobes and brain stem. It plays a significant role in the coordination of voluntary motor movement, balance and equilibrium and muscle tone. The classic Jacksonian cerebellar seizures appear to encounter only a few cases in the contemporary population (http://www.neuro.iastate.edu/Uploads/seizures_jackson.pdf).

Brain Stem: This is the posterior part of the brain which adjoins the spinal cord. It plays a significant role in the regulation of cardiac and respiratory functions. It coordinates the Central Nervous System, which is pivotal in maintaining consciousness and regulating the sleep. Brainstem lesions may be responsible for the presence of seizures in patients with multiple sclerosis (Papathanasiou *et al.*, 2010).

1.3. Electroencephalogram

The discovery of electroencephalogram (EEG) in 1929 by the German psychiatrist Hans Berger was a historical breakthrough which provided a novel neurologic and psychiatric diagnostic tool at the time, without which the accomplishment of neurologic and psychiatric diagnosis and planning neurosurgical operative procedures would now be inconceivable. It was explicable that brain electrical stimulation produced the contra lateral motor response, but the idea that a spontaneous brain electrical current could be recorded was unknown. Canton was the first to discover the findings by recording electrical pulses from the

exposed brain of rabbits. Based upon this observation, Berger performed the first EEG electrocorticogram recording during a neurosurgical operation on a 17 year old boy. During this era diagnostic tool like lumbar puncture, pneumoencephalography and ventriculography were only present to detect and localize "sick sites" in the brain, the discovery of electroencephalography was a milestone in the advancement of neuroscience and of neurologic and neurosurgical practitioners (Tudor *et al.*, 2005). EEG revolutionized daily neurologic and neurosurgical procedures, and bridged a timeline of about 40 years (1930-1970) until the advent of computer tomography.

1.3.1. What is an Electroencephalogram?

The human brain contains about 10 billion nerve cells, or neurons. The brain's network of neurons forms a massively parallel information processing system. Neurons are responsive cells in the nervous system that process and transmit information by changing the flow of electrical currents across their membranes, which lead to the generation of electric and magnetic fields that can be recorded from the surface of the scalp (Brazier, 1949). The electric fields are measured by placing small electrodes on the scalp. The potentials between different electrodes are amplified and recorded using electroencephalogram (EEG). Electrical activity is recorded using EEG; tiny magnetic fields generated by the neurons of the brain are measured using Magnetoencephalogram (MEG), which came into subsistence in 1970.

1.3.2. Applications of EEG

Making the computer more empathetic to the user has encouraged in broadening all the functionalities of EEG. EEG is conventionally used to detect Seizures thereby identifying disorders like Epilepsy, Brain Tumor, Stroke, Dementia etc. It deals not only with the physiological level of the brain but also anatomy of the brain. Some of the applications, where EEG finds its prominence are Brain-Computer Interface (BCI), Brain Machine Interface (BMI), and Human-Computer Interaction (HCI).

A cerebral or Brain Computer Interface (BCI) allows people with communication problems to relate to their surroundings using a computer and electrophysiological signals from the brain. BMI offers a latest solution to a lack of control for paralyzed or prosthetic limbs. Development in the areas of Neuroprostheses and BMI has set a gateway for victims of trauma and stroke who are handicapped due to paralytic attack or amputations. The BMI makes use of neuroprosthetics implanted in the brain to extract spatial degrees of freedom (e.g. Up/down, left/right) from the number of neurons excited. BMI also allows patients to communicate with a computer through their thoughts. A thought controlled movement of wheel chair is made possible to facilitate people who are physically challenged.

1.3.3. Devices on par with EEG

The second major category of diagnostic tests is imaging. Specialized imaging tests include Computer Tomography (CT) scans, Magnetic Resonance Imaging (MRI) scans, functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) scans. These scans allow medical practitioners to determine if there are any lesions or abnormalities in the patient's brain. Discussion of each of these devices is summarized below

X-ray Imaging: In 1970s, X-rays provided the first direct images of normal brain anatomy (http://faculty.vassar.edu/abbaird/resources/brain_science/imaging.php). X-rays are a type of ionizing radiations that are created as a result of interactions between electrons and atoms created to fire at the target object the brain.

Positron Emission Tomography (PET): It measures emissions from radioactively labeled chemicals called tracer that is injected into the bloodstream, which results in the distribution of chemicals. As soon as the tracer reaches the brain the PET picks up the signals. The Signals are converted into 2D or 3D images for further examination by the doctor (<http://www.nlm.nih.gov/medlineplus/ency/article/003827.htm>).

Single Photon Emission Computed Tomography (SPECT): SPECT is a tomographic modality that uses radioactive tracers similar to PET and the signals which are detected are fed into the computer to construct two or three-dimensional images of active brain regions.

Computed Tomography or CAT Scan (CT): It produces 3-D anatomic images of the X-ray density of the human body. Special X-ray equipment is used to obtain many images from different angles, and then joining them together to show a cross-section of body tissues and organs. CT of the brain is a patient-friendly examination which is subjected to radiation.

Magnetic Resonance Imaging (MRI): It allows visualizing the inside of the body by using a large magnetic radio waves, and powerful computers. The highly detailed images of an MRI can help us to visualize body tissues in a different way. It is something similar to taking virtual cuts or slices of the body. By using recent advances in Magnetic Resonance (MR) technology it is possible to perceive both structure and functionality of the brain. MRI does not use any radiation. MRI poses no risks unless participants have any metal objects implanted in their bodies.

Functional Magnetic Resonance Imaging(fMRI): It relies on the magnetic properties of blood to enable scientists to see images of blood flow in the brain. Thus researchers can make “movies” of changes in brain activity as patients perform various tasks or are exposed to various stimuli.

Near Infrared Spectroscopy (NIRS): It is a noninvasive technique that uses calibrated wavelengths of near infrared light to illuminate tissue and activity below the skin (i.e. inside the brain). These wavelengths of light scatter in the tissue and are absorbed differently dependent on the amount of oxygen attached to hemoglobin. Unabsorbed light returns as an optical signal and are analyzed to produce a ratio of oxygenated hemoglobin to total hemoglobin. In practice, near infrared light penetrates the tissues and is absorbed by chromophores (hemoglobin

and myoglobin) that have absorption wavelengths in the near infrared region (approximately 700-1000nm).

EEG being one of the ancient devices has not become extinct, and has ensured its position in the evolution of neuroimaging devices due to the following causes:

- Significantly lower hardware costs when compared to the other techniques.
- Due to the advent of wireless EEG sensors, it makes the possibility of mobility, whereas fMRI, SPECT, PET, NIRS, or MEG, are bulky and immobile equipments. For example, MEG requires equipment that can be used only in magnetically shielded rooms, and fMRI requires the use of a 1-ton magnet and again a shielded room.
- It has a very good temporal resolution in the order of milliseconds rather than seconds.
- It is quite tolerant to artifacts, unlike most other neuroimaging techniques.
- EEG is quiet unlike the other neuroimaging techniques and it allows for better study of the responses to auditory stimuli.
- It does not aggravate claustrophobia as opposed to MRI, fMRI, CT, PET.
- It is not exposed to radioactivity.
- It is very simple due to its non-invasive nature, unlike ECoG.
- It finds its significance in the field of neuroimaging as it can be integrated with an advanced technological device like MRI, fMRI.

1.3.4. Working of EEG

Electroencephalography is the science of recording and analyzing the electrical activity of the brain. Electrodes are special sensors, placed on or just under the scalp and, are linked to an electroencephalograph, which converts electrical impulses into the vertical movement of a pen over a sheet of paper. The electrodes

detect the brain waves and the EEG machine amplifies the signals and records them in a wave pattern on graph paper or a computer screen. These recordings show the overall activity of millions of neurons in the brain and the pattern of electrical activity produced on an EEG can diagnose a number of conditions that affect the brain.

1.3.5. Electrode Placement

Electrodes are small metal discs usually made of stainless steel, tin, gold or silver covered with a silver chloride (AgCl) coating. The input signals to the differential amplifiers are provided from the electrodes which are placed on the scalp after applying a conductive gel. The 10-20 System is an International placement guide for positioning electrodes on the scalp and provides relationship between the location of an electrode and the underlying area of cerebral cortex covering a distance from nasion (dip between nose and forehead) and inion (the bump at the back of the head above the neck). The EEG is a record of brain activity which is a consequence of the activity of thousands of neurons in the brain. The pattern of brain activity depends on the level of a person's arousal i.e. Fast wave patterns are observed using EEG if a person is excited otherwise slow waves are recorded. The EEG is used to record brain activities for varied purposes such as sleep research and also in diagnosing disorders such as dementia, epilepsy, tumors, schizophrenia etc. Figure. 1.4 and 1.5 represents 10-20 placements of electrodes in side view and overhead view. Each site has a letter (to identify the lobe) and a number or another letter to identify the hemisphere location. The letters F, T, C, P, and O represent Frontal, Temporal, Central, Parietal and Occipital respectively.

For the purpose of simplified identification an imaginary lobe called central lobe is used by the Electroencephalographers. Even numbers (2, 4, 6, and 8) refer to the right hemisphere and odd numbers (1, 3, 5, and 7) refer to the left hemisphere. The z refers to an electrode placed on the midline. Electrodes with small numbers are closer to the midline than electrodes with larger numbers. The "10" and "20" refers to the 10% or 20% inter electrode distance. Another important factor that is to be

noted is that the number of electrode usage can also vary. For example, in case of neonates the size of the head being small; the electrode usage is considerably reduced.

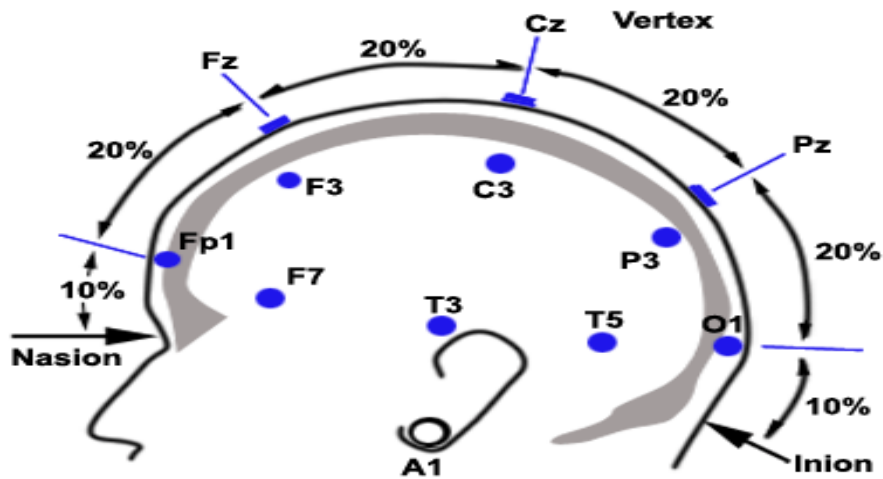


Figure. 1.3. 10-20 system of electrode placement in a side view

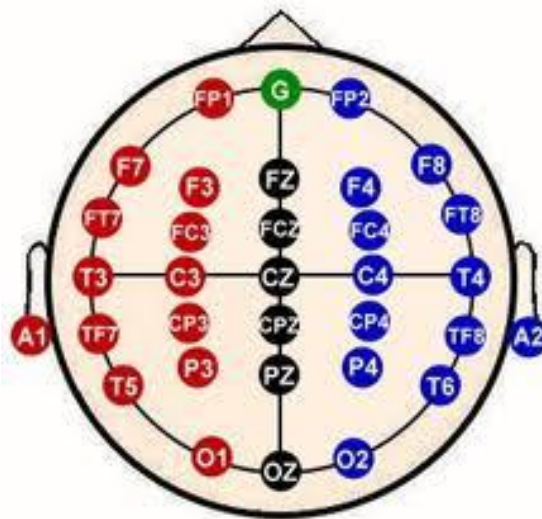


Figure. 1.4. 10-20 system of electrode placement in overhead view

1.3.6. Montages

Each EEG channel is made from two inputs; one is the input from electrode at one of the locations where it is meant to be and the other input is reference voltage that is the voltage which is used for comparison. There are different approaches to

generate the reference voltage and this type of configuration is referred to as montages. Different configurations are outlined below:

Common Reference: In this configuration, a common reference point is given as one of the inputs to the differential amplifier. Each channel of EEG is created by the potential difference between one scalp electrode and the reference channel. The choice of the reference electrode is very critical and depends upon locating the electrode which is electrically silent. C_z is often used as a reference voltage.

Average Reference: This pattern is similar to the common reference montage with an exception that instead of using the same electrode as a reference point, here the most common reference is formed by summing all the activity from the electrode, averaging it and passing through a high value resistor thereby eliminating the problem of locating a quiet electrode.

Bipolar: This configuration connects all the scalp electrodes in a chain form. An electrode which serves as an input for one differential amplifier serves as a reference for the next.

1.3.7. Recording EEG using diverse equipments

EEG recording equipment generally is classified of 3 types and is discussed in the following section.

Conventional Scalp EEG: It is a non-invasive type of recording obtained by placing electrodes on the scalp with a conductive gel or paste usually by light abrasion in order to reduce impedance. The brain activities are monitored without giving any physical encumbrance to the patient. Figure 1.5 shows the disc electrodes attached to individual wire which are placed on the scalp. The data collected for this study, was acquired from this type of conventional scalp EEG.



Figure. 1.5. EEG cables

Electrocorticogram ECoG or intracranial EEG (iEEG): It is invasive in nature and the recording of the electrical activity of the brain is performed by surgical incision to implant the electrodes. Here the electrodes are in direct contact with the cerebral cortex. ECoG is considered a gold standard for assessing neuronal activities in patients with Epilepsy. Neurosurgery techniques have been prevalent for many decades, but the risk involved in exposing the brain to infection is always present.

EEG caps: These caps are soft caps and can be used for ambulatory EEG studies and tests on young children who need not strictly adhere to one place. They fit snugly over the head to hold the electrodes in fixed positions, even when the patient nods his head or engages himself in any physical activity. The EEG caps are designed to be supple so that they could be covered with a hat or scarf for various discreet reasons as desired by the patients. EEG cap designs can also vary for different applications. Some caps are designed to suit for activities like biofeedback studies, where a limited number of electrodes may be adequate and under a different circumstance it could be desirable that more number of electrodes are required to observe patients with epilepsy, where an examination of isolated activity of a specific region of the brain is required. Figure. 1.6. represents electrode caps.



Figure. 1.6. Electrode caps

There are a varied number of electrodes in these caps and the figures being 16, 32, 64, 128, 160 and 256. A larger number of electrodes track a larger area thus providing a better spatial resolution for signal propagation. The EEG used for recording this research work was done by using a Conventional Scalp EEG using 10-20 electrode placement using bipolar montages.

1.3.8. Signal Frequencies

The recorded waveforms of EEG replicate the cortical electrical activity. The signal intensity of EEG is quite small, measured in microvolts (μV). Each stimulus or mental activity causes activation of a certain group of neurons that are specialized for processing a received stimulus type. For a person with a brain disorder, different group of neurons will be activated for similar activity performed on a person without any disorder. The brain potentials are classified broadly into Spontaneous brain potentials and Event potentials.

Spontaneous brain potentials: These potentials are the signal frequencies which represent electrical activity emanating from human brain. The brain frequencies are classified as follows

Delta: It has a frequency range of up to 4 Hz or below. It is likely to have higher amplitude but slow frequency. It is normal as the dominant rhythm in infants of up to one year and in stages 3 and 4 of sleep. It may occur focally with sub cortical

lesions and in general distribution with diffuse lesions, or deep midline lesions. It is usually more prominent in the frontal part in adults (e.g. FIRDA - Frontal Intermittent Rhythmic Delta) and posterior part in children e.g. OIRDA - Occipital Intermittent Rhythmic Delta) (Manouchehr Javidan, 2012).

Theta: It has a frequency range from 4 to 7 Hz and is classified as "slow" activity. It is found to be normal for children up to 13 years of age and for every person during sleep and in meditation. It can be seen in the state of arousal for adults. Excess theta in adults represents abnormal activity.

Alpha: Its frequency ranges between 8 to 13 Hz and is usually seen in the posterior regions of the head on each side of an adult, when the patient is relaxing. It appears when closing the eyes and relaxing, and tends to attenuate with open eyes or alerting by any mental exertion.

Beta: Its frequency ranges from 14 Hz to about 30 Hz. Beta activity is "fast" activity and also called normal rhythm activity. It is usually seen on both sides of the hemisphere in symmetrical distribution and is most evident in the frontal areas. Sedative-hypnotic drugs have an effect on this activity. It may be missing or reduced in regions of cortical damage. It is accentuated in patients who are very anxious or have their eyes open.

Gamma: Its frequency ranges from 30 Hz-100 Hz. Gamma rhythms represent binding of an enormous collection of neurons assimilated for carrying out a certain cognitive or motor function (http://www.biomedresearches.com/root/pages/researches/epilepsy/electrical_activity.html).

Evoked Potentials: These potentials occur with a brain reaction by stimulating the amplitude up to few hundred times lower than the background EEG.

Morphology of brain waves:

Morphology refers to the shape of brain waveform. Spike and Sharp wave are the two important morphologies considered in this study and are described as follows:

Spike: a transient waveform with a pointed peak of duration between 20-70msec.

Sharp wave: a transient waveform with a pointed peak of duration between 20-70msec.

A transient waveform is an isolated wave or pattern that is distinct from the background activity.

1.4. Epilepsy

Epilepsy is the most common non-infectious neurological disease especially in developing countries, that have significant psychological, social as well as medical consequences and may be life threatening (WHO, 2006). It is important to gain a contextual overview of epilepsy and hence this section intends to endow with an overview by describing certain issues in Epilepsy. This dreaded disease has prejudiced Patients With Epilepsy (PWE) being ostracized, stigmatized and misunderstood as it is an amalgamation of indigenous beliefs to be incursion of evil spirits, effects of witchcraft, the revenge of an aggrieved ancestral spirit. The social implications are very serious in major parts of India.

1.4.1. Etiology of Epilepsy

The word 'epilepsy' comes from the Greek word *epilambanein*, which means to seize or attack (World Health Organization, 2001). Etiology is a term used inside and outside medical parlance and expounds on the determinants i.e. Origin of the disease or phenomenon, historical and scientific background. The earliest medical texts on epilepsy were produced by the Babylonians around 1050BC and indicate that they believed epilepsy was caused by demons and ghosts (Wilson and Reynolds, 1990). The Greek physician Hippocrates has been attributed with writing the first book about epilepsy, where he described it as a brain dysfunction and argued against the idea that seizures were supernatural (Bladin, 2001). However, during the middle Ages (5th -15th century), possession, magic and witchcraft again became the dominant explanations for the illness (Masia and

Devinsky, 2000). These mythical beliefs continue in some cultures even today (Awaritefe, Longe, and Awaritefe, 1985; Baskind and Birbeck, 2005) and almost certainly contribute to the stigma sometimes attached to the condition.

1.4.2. Classification of Epilepsy

Epilepsy is a chronic disorder and has the propensity of two or more unprovoked seizures (World Health Organization, 2001). A seizure is a “clinical manifestation presumed to result from an abnormal and excessive discharge of a set of neurons in the brain” (Hopkins and Shorvon, 1987). Seizures are finite events that have a distinct beginning and ending and may result in unusual sensations, emotions or behaviour, muscle spasms, loss of consciousness or convulsions (Victor and Ropper, 2001). The term ‘unprovoked seizure’ refers to the seizure not been precipitated by factors such as the excessive consumption of alcohol, the use of recreational drugs, adverse reactions to prescribed medications, fevers from acute illnesses, metabolic conditions such as diabetes or very recent head injury (Hauser and Annegers, 1993; Kraemer, 2005). An individual may experience frequent daily seizures or just a few seizures over a lifetime (Shorvon, 2000). The lifetime risk of an individual having a seizure is about five percent (Trostle, 2005). People with epilepsy may experience many different types of seizures. The International League against Epilepsy (ILAE) has developed a classification system for epilepsy related seizures (DeLorenzo, 1991), based on the initial system proposed by Gastaut (1970).

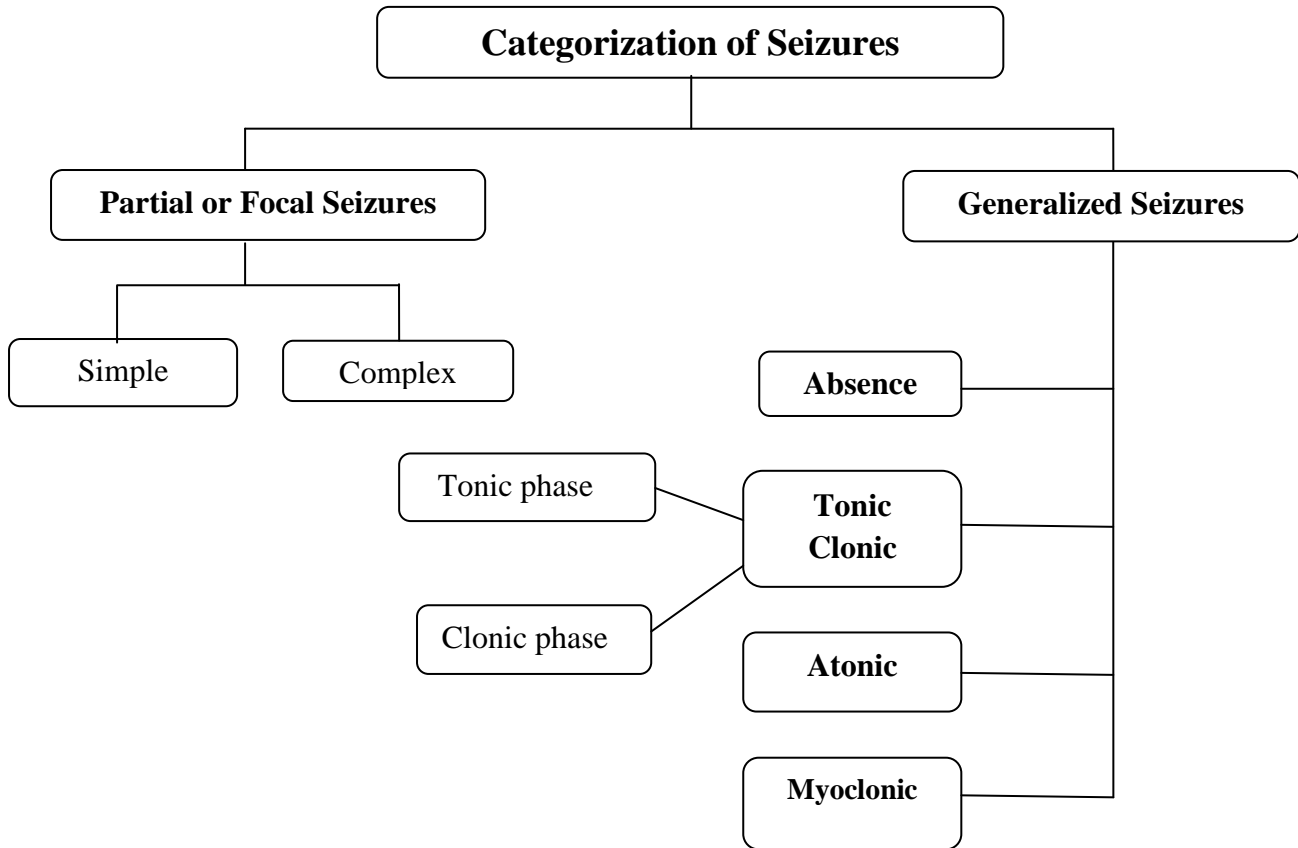


Figure.1.7 Taxonomy of Seizure Types

According to the system suggested by ILAE, seizures are broadly categorized into partial or focal and generalized seizure, which is represented in Figure. 1.7. Partial Seizures are further classified into simple and complex seizures. Likewise Generalized seizures are classified into absence, tonic clonic, atonic and myoclo seizures.

Partial seizures: It is a condition when the neuron activations are limited to a part of cerebral hemisphere and may result in unusual muscle movements, sensory experiences, speech problems, emotional experiences or distorted perceptions depending on the location of the neurons are activated during the seizure.

Simple Partial Seizures: This is a situation when the consciousness is not altered.

Complex Partial Seizures: The scenario found here is an alteration in consciousness; the person does not recall having the seizure and may be very

confused and fatigued with the repercussions of aberration in behaviour patterns. Simple partial seizures may evolve into complex partial seizures and complex partial seizures may evolve into generalized seizures as more neurons are activated.

Generalized seizures: It is also referred to as “grand mal” seizure, where neurons are aggravated in both the hemisphere (<http://brain.oxfordjournals.org/content/129/5/1281.long>). The initial manifestations could be an impaired consciousness.

Absence Seizure: When the impairment of consciousness is extremely brief, it is classified as a form of absence seizure.

Tonic-Clonic Seizure: If the alteration in consciousness is associated with specific movements, it is classified under tonic-clonic seizures. During a tonic-clonic seizure, the person can experience two distinct types of movements. During the **tonic phase**, the body becomes rigid. In the **clonic phase**, the individual suffers from rhythmic jerking movements.

Atonic seizure: Here the person suddenly loses muscle tone and may fall to the ground suddenly or may slump in a rhythmic step-by-step fashion or display only brief nodding of the head or sagging of the body.

Myoclonic seizure: In case of myoclonic seizure, the person experiences sudden muscle jerks, usually in the arms and legs (Arzimanoglou, Geurrini, and Aicardi, 2004; DeLorenzo, 1991; Porter, 1993).

1.4.3. Epidemiology of Epilepsy

Epidemiology is a term used in medical parlance, which relies heavily on scientific methodologies to isolate factors which affect prevalence of diseases in a certain area. Once epidemiologists identify factors, the risks a certain population faces due to a particular disease can be anticipated. Epidemiologists can prevent

the widespread outbreak of diseases by identifying the disease and finding possible ways of curbing it and thereby minimizing casualties. They employ a scientific method against diseases by conducting experiments, and performing analysis to identify the cause of diseases and execute preventive measures. It is characterized by incidence and prevalence rates. The incidence rate is the number of new cases of a disease that occurs during a specified period of time in a population. Prevalence is the number of affected persons present in the population at a specific time (Gordis, 2004). There are 40 to 50 million people with epilepsy across the world, and at least 50 percent of cases begin in childhood or adolescence (World Health Organization, 2002a). The incidence and prevalence of epilepsy appear greater in underdeveloped countries in contrast to developed countries (Senenayake *et al.*, 1993). The probable reasons for such a discrepancy includes deficient public healthcare systems; lack of conformity on epilepsy and its diagnosis; divergence to conceal the condition for fear of stigma and detest ; miscellany in the understanding of epilepsy among the people; possibly higher rates of head trauma due to traffic and work related accidents; and widespread poverty.

1.4.4. Diagnosis and Prognosis

A person diagnosed with epilepsy, is most commonly treated with an anticonvulsant medication. Remission of Seizure is the ultimate goal of imbibing anticonvulsants. Despite good drug compliance, patients who still continue to have seizures may sooner require the surgical option. A division of the corpus callosum was occasionally performed to prevent spread of seizure discharges from one hemisphere to the other. Stimulation of the cerebellum has been reported to suppress seizures, but this has not gained acceptance in clinical circles. Ketogenic diets have been occasionally used in the management of intractable epilepsy since Wilder's original report in 1921. The classical diet is based on an estimated daily requirement of 75 kilocalories per body weight; 50% of calories is given as fat, and the remaining as protein and carbohydrates.

1.4.5. Factors Causing Seizures

A number of factors have been identified as a potentially precipitate of seizures in people with epilepsy. Some of the more common triggers include stress, sleep deprivation and fatigue, alcohol and alcohol withdrawal, toxins and drugs, metabolic disturbances, caffeine, and, for women, the menstrual cycle (Bonilha and Li, 2004; da Silva Sousa, Lin, Garzon, Sakamoto, and Yacubian, 2005; Hart, 2004; Shorvon, 2000; Spinella, 2001). Furthermore, it is possible that stress may interact with some of these triggers to amplify their effect (Kaufman and Sachdeo, 2003; Lester, 1995). Each person is unique, and some people with epilepsy will have identifiable and unique triggers. The avoidance of such triggers may result in greater seizure control but cause various lifestyle restrictions. The potential for sustaining injuries when having a seizure can increase the concerns of both affected individuals and their family about the possibility of there being further seizures (Fisher *et al.*, 2000a). Epilepsy is a potentially life-threatening condition and when people with epilepsy focus on the prospect of death, it may lead to increased anxiety and depression. Researchers have consistently shown that people with epilepsy, despite an overall good prognosis for seizure control, have a small increased risk of untimely death compared with those without it (Caamfield, Camfield, and Veugelers, 2002; Forsgren *et al.*, 2005b; Gaitatzis, Johnson, Chadwick, Shorvon, and Sander, 2004a; Lhatoo and Sander, 2001; Mohanraj *et al.*, 2006; Rafnsson, Hauser, and Gudmundsson, 2001).

1.5. EEG Artifacts

Artifacts are unwanted signals arising from sources other than cerebral area, which exacerbates the performance of the biological signals. The major confrontation in monitoring EEG is artifact recognition and elimination, as observation of seizures is hampered by the existence of physiological and extraphysiological artifacts. The patient related artifacts are the physiological artifacts (e.g. Muscle movement, sweating, ECG, eye movements) and technical artifacts are the extra-physiological artifacts such as (50/60 Hz artifact, electrode popping), which have to be handled

differently. Some tools like Electro-Oculogram (EOG), Electromyogram (EMG) and Electrocardiogram (ECG) aid in finding artifacts like ocular, myogenic and cardiac respectively.

1.5.1 Physiological artifacts

The most common type of physiological artifacts are delineated as follows:

Eye Movement Artifact: They are the major source of contamination of EEG signals, due to the reason that eye-movements cause a change in the electric field that surrounds the eye and correspondingly distort the electric fields over the scalp enormously.

Eye Blink Artifact: It is another important source of artifact which produces high amplitude signals.

Muscle Artifact: It is one of the common forms of artifact and is caused by the electrical activity in the muscles caused due to activity in the neck or facial muscles. Muscle artifacts are of shorter duration and have a frequency much higher than the cerebral activity.

ECG Artifact: These artifacts are caused by muscles in the heart which pumps blood to the whole of the body. These artifacts are rhythmic in nature and relatively easily recognized in the EEG activity.

Spit swallowing Artifact: Swallowing of saliva produces spikes or short burst activity.

Jaw Clenching Artifact: It is a high frequency muscular activity which can be further propagated at low frequencies (Samuel Boudet *et al.* , 2007).

1.5.2. Extraphysiological artifacts

Line Noise: Strong signals from A/C power supplies can corrupt EEG data as it is transferred from the scalp electrodes to the recording device. This artifact is often

altered by notch filters, but for lower frequency line noise and harmonics this is often undesirable. If the line noise or harmonics occur in frequency bands of interest they interfere with an EEG that occurs in the same band (James. K. Knight, 2003). Line noise can corrupt the data from a few or all the electrodes depending on the source of the problem.

Electrode pop: This artifact is caused by a sudden change in the impedance of an electrode, which appears as a single or multiple sharp change in the EEG.

AC Artifacts: These artifacts are caused by the alternating current (AC) either in the recording equipment or in the other equipment accessories such as lamps or medical equipment and can be eliminated by grounding the connection appropriately.

Other artifacts: Other types of artifacts include movement of other people around the patient, the electroencephalographer himself, infusion motors, ventilators, radio, TV, mobile phones and other electronic devices to have an impact over the patients recording.

1.6. Basic Concepts of Signal Processing

As the main part of the research work deals with Signal processing, some vital fundamentals are being discussed in this section. Signal processing is the analysis, interpretation and manipulation of signals like speech, sound, images, sensor data and any time varying measurement data. It has become an important tool in a multitude of diverse fields of science and technology. Any signal obtained from a biologic system or originating from a physiologic process i.e. from a human or animal is called a biomedical signal. Figure 1.8 shows glimpses of signal processing.

Signals are broadly categorized as Deterministic and Stochastic or random signals. A signal is said to be deterministic if it is predicted exactly with the specified time period. Signals which are generated by processes are enormously complex such that it is extremely undesirable to make precise descriptions within the specified time period and are characterized as Stochastic or random signals. They are characterized by a set

of probability density functions and statistical properties. Biological signals are an essence of both deterministic and stochastic components.

The signal intensity of any biomedical signal is very feeble and needs amplification to augment the amplitude of a signal. Amplification is usually accomplished by using several stages of electronic circuits to gradually increase the signal to the desired level of amplitude. As the amplified signal is often contaminated with noise, some sort of filtering is required.

In order to analyze signals on a digital computer, the signal must be transformed into a form digitized, by which a signal is defined only by a particular set of values of time and amplitude. The field of digital signal processing encompasses and provides firm theoretical backgrounds in a large number of biomedical application areas and has paved a way for its massive growth. A signal which is defined for continuous amplitude but at discrete time intervals is defined as discrete time signal, but when defined for discrete amplitude is called discrete amplitude signals. A signal defined for both discrete time and amplitude is a digital signal. The operations that are crucial to convert an analog signal into a discrete time are called sampling and discrete amplitude signal is called quantization.

Digital signal processing consists of three stages: a sampling process, an Analog to digital conversion process (ADC), and a Digital filtering process.

Digital processing of analog signals proceeds in three stages:

1. The analog signal is digitized, such that, it is sampled and each sample quantized to a finite number of bits. This process is called A/D conversion.
2. The digitized samples are processed by a digital signal processor.
3. The resulting output samples may be converted back into analog form by an analog reconstruction (D/A conversion).

Some of the important concepts to be pondered while performing ADC are Sampling frequency, Sampling range, Nyquist frequency and Aliasing.

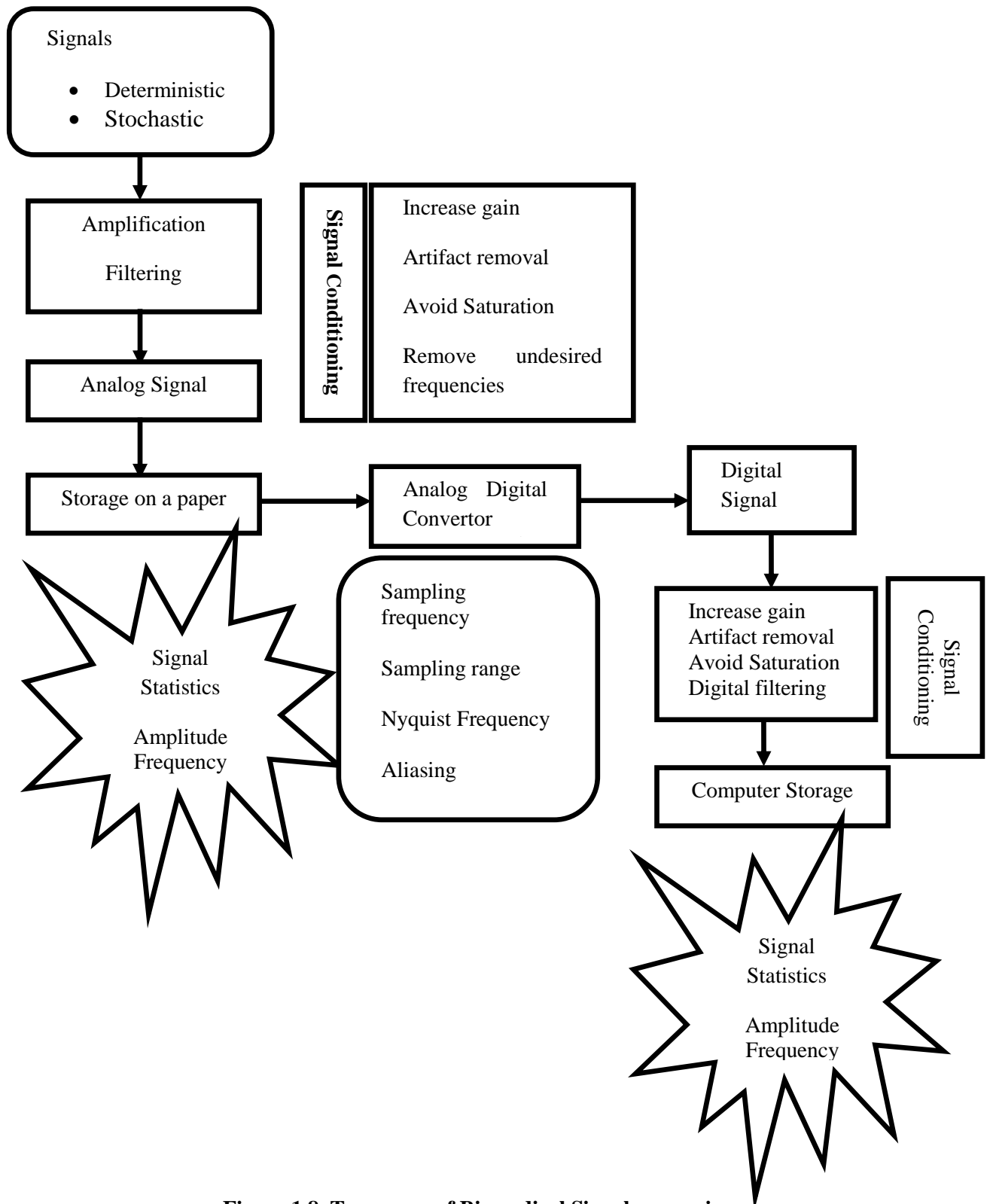


Figure 1.8. Taxonomy of Biomedical Signal processing

(<http://s3.amazonaws.com/docuun/attachments/6246/biomedsignal/Willsky> ,1997)

The sampling frequency is the frequency at which the analog signals are converted into digital signals over a discrete time period, which is usually the number of samples per second. Sampling range is the range between the minimum and maximum values at which the signals are sampled. Nyquist Sampling Rate is the value of the sampling frequency which is equal to twice the maximal frequency of the signal that is acquired. Aliasing is a condition which arises when a signal is discretely sampled at a rate that is insufficient to capture changes in the signal.

Contemplating over the other important features which are also essential in studying the basics of signal processing are discussed below:

Gain and amplification: Gain is a measure of the ability of a circuit to increase the power or amplitude of a signal. If a gain is 1, the signal remains unchanged, if the gain is higher than 1, the signal is amplified, if it is lower than 1, the signal is attenuated.

Amplitude saturation: Saturation in amplitude occurs when the intensity of a signal exceeds the values of the sampling range. Signals are distorted when the signal acquired crosses the sampling range.

Spectral analysis: It is the process of decomposing a signal in different frequency components by plotting the intensity of each component as a function of its frequency.

Fourier analysis: It is a mathematical technique that allows performing a spectral analysis of the biological signal.

Filters:

A filter is a device or process to remove unwanted characteristics from the signal of interest. Signals of interest linger around a particular frequency range or bandwidth. Bandwidths are determined by filters, which are devices that alter the frequency composition of the signal. There are five types of filters which are described below:

Low pass filters: This electronic circuit pass low frequency signals and attenuates high

frequency signals.

High pass filters: This electronic filter pass high frequency signals and attenuates low frequency signals.

Notch filter: Filters one frequency, usually 50 Hz or 60 Hz from the power lines.

Hardware filters: These filters alter the frequency composition of the signal and it is impossible to recover the frequencies that have been filtered.

Digital filters: These filters alter the frequency of the signal by performing computation on the data and thereby eliminating the unwanted frequencies. It is possible to recover the filtered frequencies if a record of the original signal is still available. Reasons for preferring digital signal processing to analog signaling processing are delineated below:

Accuracy: The analog circuits are prone to temperature and external effects. Due to the tolerance rate in analog circuit's components, it is difficult for the designer to control the accuracy, but the digital filters have no such problems and fetch accurate results.

Flexibility: Reconfiguring analog filters is very tedious which involves redesign of hardware circuits, which ought to be tested and verified further before usage, whereas the digital filters can be reconfigured easily by changing the program coefficients.

Storage facility: Digital signals can be easily stored on any magnetic media or optical media without deterioration or signal fidelity; as a result, signals can be hauled and can be processed off-line in a remote laboratory.

Easy operation: Complex mathematical operations can be performed easily using computers, whereas intricacies exist with analog processing. Sophisticated signal processing algorithms can also be implemented with ease.

Cost effective: The digital implementation is always cheaper than its counterpart due to its flexibility in modifications. Due to advent of Large Scale Integration (LSI) the size

of the components is reduced with increasing speed.

One practical limitation lies in the speed of A/D convertors. A swift performance requires fast sampling rate A/D convertor.

The recording of electrical signals which emanate from human brain can be composed from the scalp of the head using (a device called) Electroencephalogram (EEG). These signal's parameters and patterns indicate the health of the brain. EEG is a vital area of biomedical data analysis. Using Digital Signal Processing functions EEG signals can be analyzed to properly diagnose the patient.

1.7. Basic Concepts of Soft Computing

As soft-computing based matching is adopted in the seizure detection system, the concepts are reviewed and discussed in this section. "Soft computing is a collection of methodologies that aim to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness, and low solution cost" (Zadeh, 1994). Its major components are fuzzy logic and neuro computing. Soft computing is performing an increasingly imperative role in many application areas. The role model for soft computing is the human mind."(Zadeh 1994). It is a multidisciplinary field proposed by Dr Lofti Zadeh, wherein the main objective was to construct a new generation of Artificial Intelligence called Computational Intelligence. Problem solving approaches used here have an analogy to biological reasoning and are also referred to as cognitive computing. Since the evolution of soft computing, approaches used here are the incarnations of blending the following fields of Fuzzy Logic, Neurocomputing, Evolutionary and Genetic Computing, in order to develop an intelligent machine to solve non-linear and mathematical models.

Soft computing sustains its presence even today, as it has its own advantages which are discussed below. 1) Solutions are derived to solve non-linear problems, which do not possess mathematical model 2) As it considers the human Knowledge such as cognition, recognition, understanding and learning in the field of computing it is possible to model systems such as autonomous tuning systems and self designed

systems by exploiting the tolerance for approximation, uncertainty, and imprecision.

1.7.1. Fuzzy Logic

In the real life situation there exists much of fuzzy information or knowledge which is a knowledge that is vague, imperfect, ambiguous, uncertain or probabilistic. Such is the type of information used by human and the information specified is fuzzy in nature, as the human thinking and reasoning frequently involve inherent, inexact human concepts. The computing systems based on classical set theory and two valued logic cannot answer to the real life situation questions because they do not have completely correct answers. It is needed that the computer systems not only give human like the answer but also describe them with reality levels and these levels are calculated using imprecision, uncertainty of facts and rules.

Classical set theory: Set is defined as an element with certain property belonging to a particular set or not. When Set A is contained in a Universal space X then we can state explicitly that each element x in the space X is “is or not” an element of A. A is described by a function called characteristic function. This function defined on Universal space X assumes a value of 1 for those elements of x that belong to set A and a value of 0 for those elements of x that do not belong to set. The notation used to represent set A by using a characteristic function as $\mu_A(x)$ for all elements $x \in X$ $\mu_A(x) = \{ 1 \text{ if } x \in X \text{ and } 0 \text{ otherwise} \}$ $\mu_A(x)$ has only values 1 “true” and 0 “false” and hence called crisp sets. For a non-crisp set the characteristic function $\mu_A(x)$ can be defined and it is generalized. The generalized characteristic function is called membership function and such non crisp sets are called fuzzy sets. Fuzzy sets are able to provide adequate data which are otherwise not provided by crisp sets. Instead of ignoring or avoiding uncertainty Fuzzy set theory captures uncertainty. Crisp sets are \subset fuzzy sets.

Fuzzy Sets: Fuzzy sets are an extension of classical set theory, where the elements possess degrees of membership. Dubois and Prade (1996; 1997) have specified three

interpretations for the degrees of membership $\mu_A(x)$ in a fuzzy set and could be defined as the degree of similarity, the degree of preference and degree of uncertainty. This degree of uncertainty shows the complexity of any system or fuzziness of a system.

Fuzzy operation: Fuzzy set operations are operations on fuzzy set. They are generalizations of crisp set operations. Standard fuzzy set operations are Union, Complement, Intersection and Difference.

1.7.2. Neural Computing

Artificial Neural Networks (ANN) are massively connected networks of computational neurons which represent parallel-distributed processing structures. The inspiration for ANN has come from the biological architecture of neurons in the human brain. A key characteristic of neural networks is their ability to approximate arbitrary nonlinear functions.

An epilepsy detection system using ANN highly depends on one of the key factors:

Data: The data which are acquired for seizure detection should be valid, authentic and in proper format.

Variables: ANN relatively depends upon the input training set which in turn relies on the data variables. The variables used in the study depend upon Minimum value of PSD, Maximum value of PSD, Mean of PSD and Standard Deviation of PSD in each of the bands delta, theta, alpha and beta.

Dataset: The data that are acquired for training, plays a critical role in detecting the accuracy of seizures. Hence the volume of data acquired for training the proposed model is of consideration i.e. whether the acquired dataset is a 10 second data or a 10 minute data.

Training set: The training set is the most essential which acts as the backbone of ANN based Seizure Detection system. It comprises of the input matrix and target

matrix which is a compilation of unit input and unit output for ANN. A better training set would result in better results.

Architecture of ANN: One of the most significant points under consideration is the architecture of ANN. The architecture of ANN is highly dependable on the number of layers, the number of neurons etc. The existence of different types of architecture to model seizure detection systems is available in the literature, but best suited model depends on excavating the following key points when developing a seizure detection model.

Types of Network: Choosing an appropriate type of network plays a crucial role in faster detection of seizures. The training and detection is dependent upon the types of the network e.g. Multi Layer Perception (MLP), Multi Layer Feed Forward Network (MLFFN) etc.

No of hidden layers: Determining the number of hidden layers also contributes to the accuracy of the system. A single layer network is appropriate for solving any problem with ease and rapidity, but might lead to results, which are less accurate. A multilayer network could produce better results, but could end up being slow due to its complexity. Hence a cautious selection is to be done in the occurrence of trade-off.

Algorithms: Number of training algorithms are available but an appropriate selection of training algorithms should be performed, so as to achieve fast and accurate results.

Activation function: A vast number of activation functions are available for training the network but selecting a suitable activation function may lead to better results. TANSIG, LOGSIG, SIGMOID etc. are some of the examples of activation function.

Weights/Bias: Another important factor that contributes to the working of a network is the initialization of weights and bias. Proper initialization of weights and bias would lead the network in a proper direction.

Learning Rate: Learning rate is another factor that leads to the training of the network with a given constant factor. Higher the learning rate faster is the conversion and lower the learning rate slower the conversion. A small learning rate may lead to a smooth conversion for better results with slow convergence and a high learning rate tends to a faster but less accurate results. Initially any random value is taken as learning rate.

Threshold: If an output is needed based on any particular condition than the threshold value is set and when the threshold value is achieved the output is generated or else is not being generated.

Momentum: For a smooth conversion of network, momentum could be set with a factor <1 .

Figure 1.9 shows a broad categorization of Neural Networks.

Broad Classification of Neural Networks

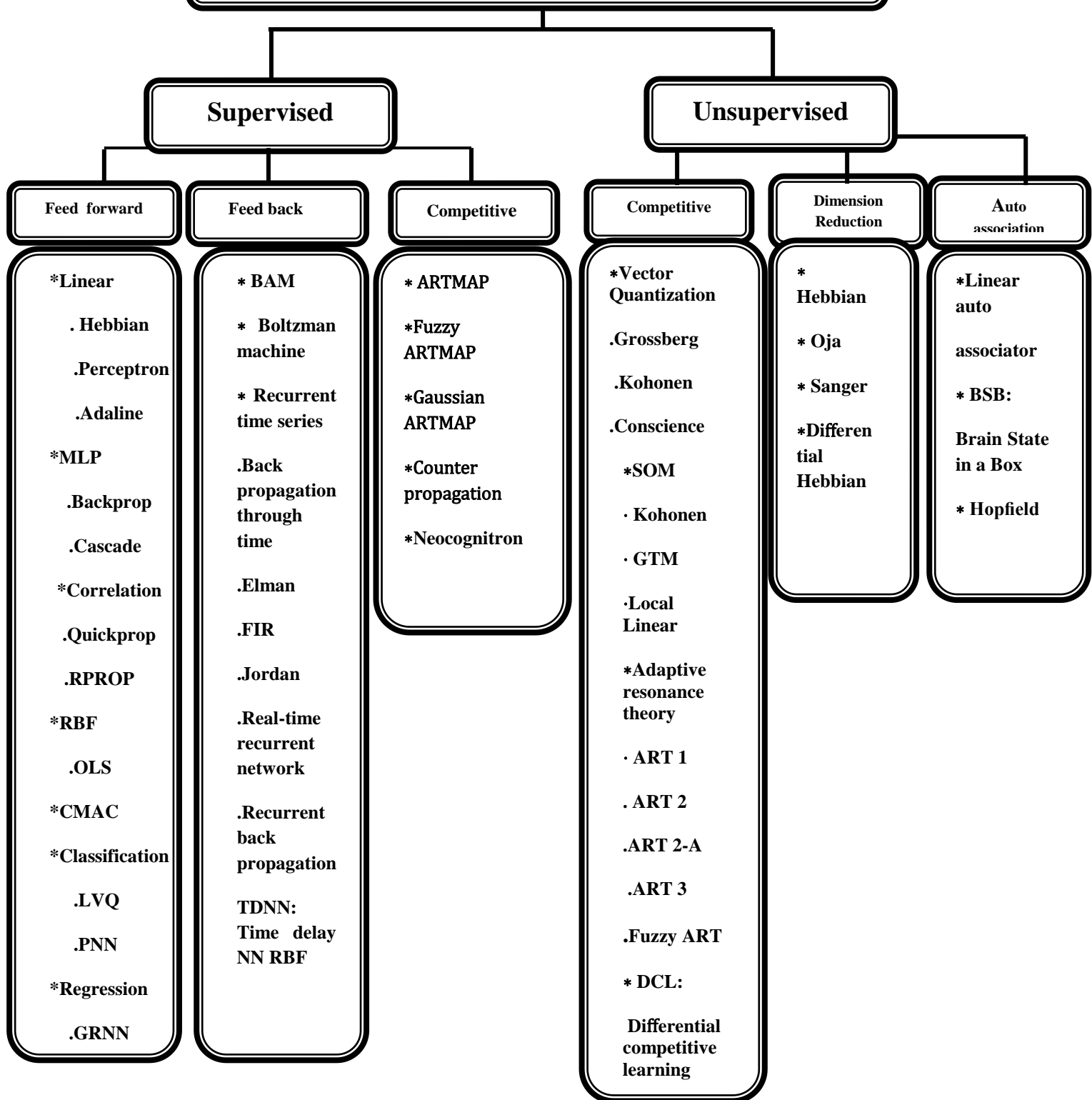


Figure. 1.9. Categorization of neural networks (Jaroslav Ramík(2001))

Basics of Neural Networks:

Neural networks are nonlinear signal processing devices interconnected by neurons and organized into layers. Neurons are responsible for processing information and the signals are transmitted by means of links. Interconnected 'nodes' contain an 'activation function'. Patterns are presented to the network via the 'input layer', which communicates to one or more 'hidden layers' where the actual processing is done via a system of weighted 'connections'. The hidden layers then link to an 'output layer' where the outputs are displayed.

Modification of weights in between the connections of network layers in order to achieve an expected output is called training the network. The internal process that takes place during training is called learning process. There are three types of training: Supervised, Unsupervised and Reinforcement. Likewise different learning rules exist and can be specified as Hebbian, Perceptron, delta, competitive, out star, Boltzmann and memory based learning rule, of which the most popular ones are delta and Perceptron learning rules. The simplest of the network is the Back Propagational Neural Networks (BPNNs) which uses delta as the learning rule. Training or learning is a process by which values are set for the weights.

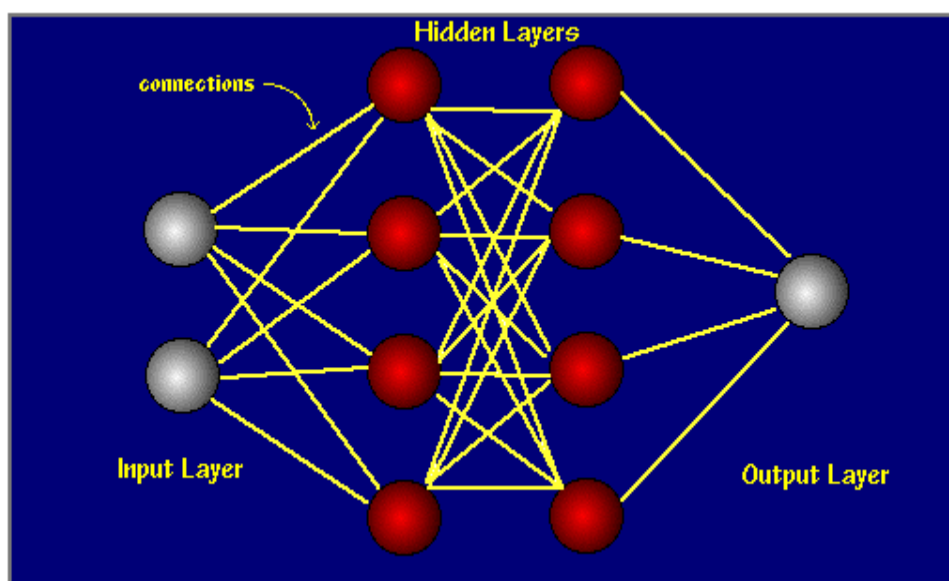


Figure. 1.10. Neural Network Architecture

Back propagation is a supervised process that aims to train the network to achieve a balance between the input patterns that are used for training and to provide better responses to the inputs that are similar. Each time the network is presented with an input pattern an output is computed from the net, and the total squared error of output is minimized by the gradient descent or generalized delta rule. Figure 1.10 represents the Network Architecture defined by the way neurons are connected (Sasikumar et al., 2006).

Each hidden layer node is a sigmoid activation function which polarizes network activity and helps it to stabilize. Once a neural network is 'trained' to a satisfactory level it may be used as an analytical tool for other data.

1.7.3. Machine Learning

Machine learning aims at building a computer system that adapts and learns from the experiences. A machine learning approach is constructed by collecting training samples, which is analyzed by learning algorithms with a purpose of classifying objects. The key intention is to perform either one of the following: supervised learning for a discrete decision making process and for continuous prediction, reinforcement learning for sequential decision making and unsupervised learning. Figure 1.11 shows different modes of machine learning.

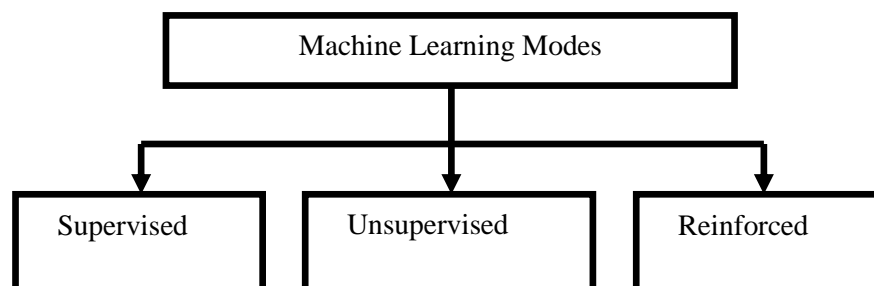


Figure. 1.11. Different modes of Machine Learning

1.8. Motivation

According to an article in Times of India Newspaper the current scenario discusses the following “There is a silent scourge sweeping through India, and our

society is ill prepared to deal with it (<http://articles.timesofindia.indiatimes.com>). From the study it is anticipated that about 3.5 million people will get afflicted by neurological disabilities, causing physical damage to the brain culminating in improper functionality of the brain. One of the major contributing causes of the epidemic is Epilepsy. India has an inadequacy in neurological and mental health facilities with a dearth of mental health professionals (fewer than 3 psychiatrists neurologists per million. Caregivers and attendants are also not trained to deal with such patients. This epidemic call for neurological disability in India mandates urgent changes in national health policy. Two types of brain related disabilities have deliberately been categorized by neurologists. One is epilepsy, which afflicts an overwhelming 10 to 12 million population according to the estimates. Three quarters of the population is not getting suitable treatment and they suffer from varying degrees of neurological disability which may aggravate with lack of treatment. The other is psychiatric disorders ". So one of the rationales of reckoning this particular disease is the affliction it has caused countrywide.

Among the major achievements in India in the field of health sector, the most noteworthy are (i) The declining trend in vaccine preventable disorders due to improvement in immunization coverage and (ii) Sincere efforts being made for the eradication of poliomyelitis through countrywide pulse. The prevalence rate case of Epilepsy is extrapolated from the facts, is about 1.2 to 2 crore of the population (Ray *et al.*, 2002). Free camps could be conducted for the purpose of eradication of epilepsy or to create alertness among the people about the disease. The major reason for motivation of this thesis was a dream to reclude epilepsy away from India by providing firsthand information to the subject (patient) by adopting a software to report that seizures has sieged a person or not . Taking smaller steps will provide a giant leap and would be a gateway for widespread utilization of the therapeutic armamentarium for all other neurological diseases.

Neuropsychiatry, an amalgamated branch of medicine, considered neurology and psychiatry to be under a single tree for more than 2000 years in the West. Certain disorders had contradicting theories emerging about their etiology and

pathogenesis and were the major reasons for engendering negative attitudes among people, by exhibiting derision and incivility among themselves. Disdain among the civilians should be eradicated by creating awareness through conducting health programs and educating them. The social stigma is an authentic reason of botheration. Certain disorders though neurological were under the perception as being psychopathological in nature, as there is no definite schism between the disorders of psychopathology and neuropathology which were the major causes for patient's inharmonious nature toward treatment. Devoid of the confounding terms brain health and mental illness, it is expected that neurologists and psychiatrists must have a broad perspective in providing an accurate treatment. A simple diagnostic tool like an automated seizure detection system can be highly beneficial to resolve perplexity to a certain extent (Mary, 2005)

Epileptic Seizures are detected by executing a sequence of phases namely Signal acquisition, Artifact Removal, Feature Extraction and Classification. Already different algorithms exist for each of these phases, but as on date the studies are not contemplating on the problem of intending as to how integrate the appealing strategies and accomplish a better algorithm. Hence, it is very difficult to choose the best strategy for each of these phases in order to attain the best performance. This research work attempts to model a conglomeration of algorithms in each of the phases with a best and triumphant outcome by developing a suitable Automatic Seizure Detection System.

1.9. Problem Statement and Objectives of the research

Based on the motivation and the prevailing factors behind the disease the research problem is formulated with the following strategy: "To design an Automatic Seizure Detection system which would efficiently operate at the extremes of all the three axes simultaneously i.e. high accuracy, high scalability and ease of implementation with its utility". The above strategy is accomplished by designing and implementing an Automated Seizure Detection System using

Electroencephalogram (ASDEEG) by enhancing signal processing and soft computing techniques.

Following were the objectives formulated to design and implement ASDEEG.

- To design and develop preprocessing techniques that reduce the artifacts that obscure the underlying cerebral brain activity.
- To design and develop feature extraction technique to identify patterns to help the subsequent steps of ASDEEG.
- To design and develop classification phase that uses the features extracted to detect the presence or absence of seizure.
- To accomplish performance analysis of the three proposed techniques and comparing them with existing systems.

1.10. Organization of the Chapters

The underlying objective of this research work is to develop an effective and efficient Seizure Detection System based on EEG signals that can meet the demands of the medical field. The dissertation is organized as follows:

The Introduction chapter provides a brief outline of various types of Neurological Diseases while contemplating more on epilepsy. Different modalities of tracing the diseases are discussed and the rationale behind using EEG is also highlighted. Usage of EEG has an impact on the diagnosis of any form of brain disease, but is overlaid by the obnoxious artifacts. A brief outline of different types of artifacts superimposing the signals has been discussed in this section. An outlook transpiring signal processing and soft computing concepts are also presented in this section.

The Review of Literature chapter is a critical outlook at the existing research that is significant to the work that is carried out. In case of Seizure detection, several researchers have addressed the predicament in detecting Seizures and various elucidations required for overcoming these problems have also been

discussed. The work of several researchers is quoted and used as an evidence to support the concepts explained in this research work.

Chapter III explains the proposed methodology and explains various phases of research. The overall architecture is discussed here. This chapter elucidates an assortment of methods and techniques used during artifact removal, feature extraction and classification to detect seizures.

Chapter IV tabulates and discusses various results obtained while testing the proposed system. The results obtained are scrutinized and discussed in this chapter

Chapter V recapitulates the findings of the study with its limitations along with future directions.

Bibliography is used to substantiate the concepts explained in the research work. All these evidences used are listed in the reference section of this thesis.

1.11 Chapter summary

A panoramic view related to EEG and Epilepsy is elucidated. This chapter provides a gateway by making a smooth transition to the review of literature.