T.C.
FATIH UNIVERSITY
INSTITUTE OF BIOMEDICAL ENGINEERING

THE DETECTION OF NON-SEIZURE AND SEZIURE EEG CONDITION WITH CURVE LENGTH METHOD

AGAMYRAT AGAMBAYEV

MSc. THESIS
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FATİH ÜNİVESİTESİ
BİYOMEDİKAL MÜHENDİSLİK ENSTİTÜSÜ

NORMAL VE İNME EEG DURUMLARININ EĞRİ UZUNLUK ANALİZ METODUYLA TESPİT EDİLMESİ

AGAMYRAT AGAMBAYEV

YÜKSEK LİSANS
BİYOMEDİKAL MÜHENDİSLİĞİ PROGRAMI

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İSTANBUL, HAZİRAN/ 2014

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FATIH UNIVERSITY

INSTITUTE OF BIOMEDICAL ENGINEERING

Agamyrat AGAMBAYEV, a **MSc** student of Fatih University **Institute of Biomedical Engineering** student ID 520112003, successfully defended the **thesis** entitled "The detection of Non-Seizure and Seziure EEG condition with Curve length method", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my lovely wife,

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June 2014 Agamyrat Agambayev

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LIST OF SYMBOLS

Hz	Hertz
μ	Mean
σ	Standart Deviation
Σ	Sum

ABBREVIATIONS

CL : Curvelength
N : Length of sliding window
App : Appendix
D : Overlap
EEG : Electroencephalogram

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SUMMARY

THE DETECTION OF NON-SEIZURE AND SEZIURE EEG CONDITION WITH CURVE LENGTH METHOD

Agamyrat AGAMBAYEV

Biomedical Engineering Programme
MSc Thesis

Advisor: Prof. Dr. Sadık KARA
Co-Advisor:Asst.Prof. Şükrü OKKESİM

Around 50 million of people world poplulation affected by Epilepsy which characterized by recurrent seizures

A seizure is an abrupt, impermanent aberration in the brain's electrical activity that produces disruptive symptoms. This symptoms can be lapse in attention or whole body convolution. According to the Clinic and EEG data, Seizures can either be generalized or partial. Detection of Non-seizure, and Seizure condition of EEG data take an important role for understanding the behavior of disease. The best solution for this is EEG signals from patients should be processed.

Curve length analysis method which calculate the total length of given time interval. During seizure, because of EEG data depend on both frequency and amplitude, both ampliute and frequency will affected. So total length of curve between given interval will definetly different from non eizure part.

Keywords: Epilpetic Seziure, Curve length, EEG seizure detection.

ÖZET

NORMAL VE İNME EEG DURUMLARININ EĞRİ UZUNLUK ANALİZ METODUYLA TESPİT EDİLMESİ

Agamyrat AGAMBAYEV

Biyomedikal Mühendisliği Programı

Yüksek Lisans Tezi

Danışman: Prof. Dr. Sadık KARA

Eş Danışman: Yard.Doç.Dr. Şükrü OKKESİM

Dünyada yaklaşık 50 milyon üzerinde Epilepsi hastalığından etkilenen hasta sayısının olduğu tahmin edilmektedir

Beyin hücrelerinde geçici anormal elektrik yayılması sonucu ortaya çıkan klinik bulgu nöbet olarak tanımlanmaktadır. Epilepsi birden çok inmelerin aniden ortaya çıkması şeklinde tanımlanmakta olup dikkat dağınıklığı vey a tüm vücüt tutulamsı gibi semptomların görülmesine neden olmaktadır. Klinik veya EEG verilerine göre Epilepsi Genel vey Kısmı olarak iki gruba ayrılabilmektedir. Inmeli EEG ve normal EEG'nin tespiti Epilepsi çalışmalarında önemli rol oynamaktadır

Normal ve İnme EEG durumlarının tespiti Birçok yöntemle yapılabilmektedir. Eğri analizi yöntemi sinyalin belirlenen zaman dilimindeki eğri uzunluklarını hesaplamaktadır. EEG sinyallleri frekansa ve genliğe bağlı olduğundan yöntem sinyaldeki değişimleri kolayca tespit edebilmektedir. Bu tezin ana fikri eğri analizi metoduyla Normal ve İnme EEG durumlarının tespitini yapmaktır.

Anahtar kelimeler: Epileptik inme, Eğri Analizi, EEG inme tespiti.

FATİH ÜNİVERSİTESİ -BİYOMEDİKAL MÜHENDİSLİK ENSTİTÜSÜ

CHAPTER 1

INTRODUCTION

Epilepsy is one of the major brain disorder in the worldwide and more than 50 million people about 1% of world population suffer from Epilepsy and Epilepsy related disease. [1]

1.1 Literature Survey

Epilepsy is derived from Latin and Greek word which meaning “to seize upon” and one of the ancient disorder that have seen the trace since 40000 years. In the 20th century within the advance of technology, studies move forward faster [2]. For almost 40 years many studies were done to examine the detection of non-seizure, onset seizure and seizure EEG conditions. The aim of studies are try to classify the epilepsy, seizure accurately and prediction before the seizure or epilepsy event occur. For precise seizure detection deep mathematical and engineering approach is required. Lyapunov Exponent had been used for the first mathematical and engineering approach with nonlinear system [3]. They found that there are significant decrease in EEG behavior before seizure starts. Later different methods had been used and obtained various results. One of them is Kat’z Algorithm. After Esteller conducted the theoretical Fractal Dimensional analysis, the Katz developed algorithm which had been frontier seizure detection on Intracranial EEG [4] But in this case it so computational. For reducing Computational burden Olsen [5] eliminated the logarithmic computations then analyze the curve length of signal which defined the sum of length of segments between samples of signal. Coolen group applied this algorithm for Automatic burst detection [6] and Guo group use this method to automatically epileptic seizure detection [7]. But they first decompose with wavelet transform then applied Curve length analysis method and their number of patient is limited with 5.

1.2 Purpose of the Thesis

The purposes of this thesis was detect the non-seizure and seizure EEG condition of signal that were recorded from Epilepsy disorder patients. The Shoeb's [8] group recorded pediatric EEG signals and created open source databank. Signals provided from open source: 22 patient's EEG signal will be examined. Curve analysis method will be directly applied to the raw signal.

1.3 Hypothesis

Because of frequency and amplitude changing in seizure condition, Curve length algorithm would sense this activity and the average Curve length value of seizure condition EEG should be greater than Non-Seizure condition. Analyzing before seizure condition may give us opinion about the seizure onset for further studies.

CHAPTER 2

BRAIN, NEURON EPILEPSY and EEG

2.1 Brain

Human brain control the all body of human and process of brain contain a huge amount of information in a significant efficient manner. Think about driving a bicycle. Almost all of people can drive it without any difficulty. But doing it properly we must perform a lot of task orderly. First, we have to sure that our body is in working order: Breathing, heart rate and temperature. Should be properly regulated and also should not fall asleep. Despite of Multiple complex tasks we can perform it properly without consciousness and there are also certain things that we have to aware: we should see the road, traffic and also using information from feet, legs and hands, body movements we can control the way and speed of driving. Addition to the these we can listen music, sing a song or talking to the someone on the telephone(not good idea).Despite the controlling balance of magnitude and speed of bicycle is difficult in theory, most of us consider that driving bicycle is such an easy task. So, how does our brain handle such a complex multitasks at once?

The answer is simple. Our brain splits the big tasks into smaller ones. In our example big task is driving bicycle and smaller parts are performed activities during driving bicycle like: seeing, moving, hearing checking and etc. Those smaller parts also can be split into smaller tasks. So one part of human brain analyze seeing however, other pars recognize them. By doing so part of brain specialize on some specific tasks.

On the other hand, if one part of brain damaged, other parts of brain could not perform activities. For instance, at the back side of our brain has occipital lobe and damage to this lobe can cause blindness. However, it does not any effect on a person's ability to hear or move. Because the big task: Seeing; divided into different compartments in the brain, anyone who have lost one aspect of sight like ability to see colors or to recognize faces, shapes, can still able to do other compartmented tasks. We can easily imagine someone's face by hearing their sounds without seeing their faces.

This localization of functions help when a big task parceled out through the brain, they can be completed all at once. "Division of task" accelerate to recognizing, analyzing and responding to what is happened on our surrounding. Dealing with problems such a way called Parallel processing [9]. Especially Computer Engineers or Scientist have use same concept in the development of Computers.

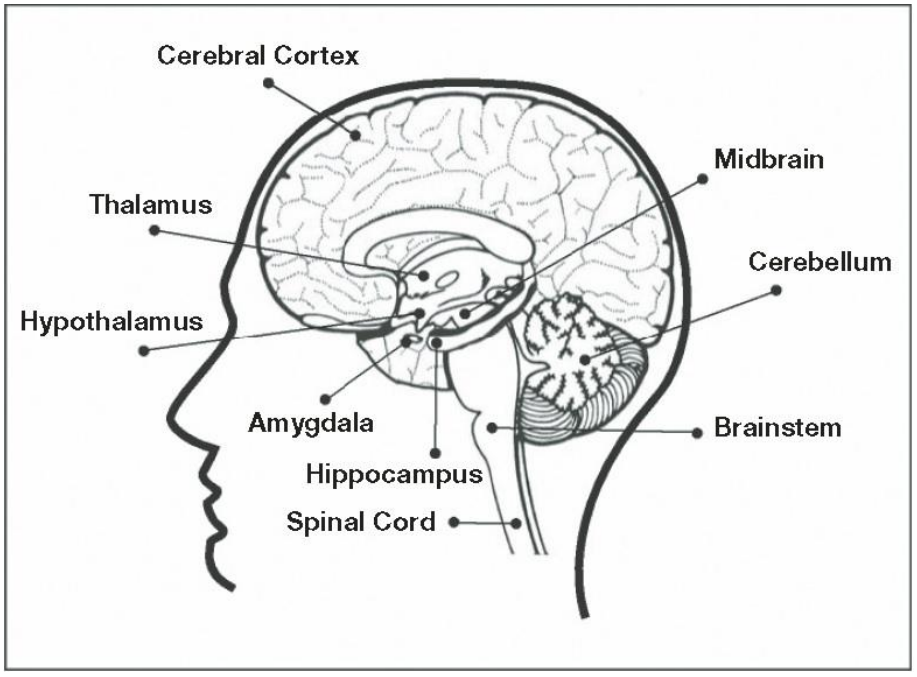

Figure 2.1. Half cut brain show the major regions of the brain. [10]

The brain of Human has a specific regions, which are required for necessary activities for life [11, 12]. These are:

1-Brainstem: connects the brain and spinal cord as shown in Fig-2.1 and take a role in coordinating many basic functions such as breathing, eating heart rate and sleeping.

2-Cerebellum: in Latin means "little brain" play key role in motor control and also in some other cognitive functions like fear and pleasure response, focusing. [13]

3-Limbic system: Very complex system, occupied in two sides of the thalamus just under the right side of Cerebrum. It is not a separate system itself but the combination of different structures from telencephalon, diencephalon, and mesencephalon the limbic system takes role in regulating motivations, emotions, and movement and also for memory. [14-16].

4-Diencephalon- also called Interbrain. It located between cerebrum and brain stem. The diencephalon has 4 different components: the thalamus, the subthalamus, hypothalamus and epithalamus which take a role in regulation of visceral activities [17]

5-Cerebral cortex: also called grey matter and contain the largest part of the brain mass and lies over and around most of the other brain structures. It takes role in thinking, perceiving, and producing and understanding language. [16]

2.2 NEURONS

For Information receiving and analyzing processes the human brain uses Conventional Electrical signal. But the Electrical signal itself are only symbols which do not imitate their real world representation and our important and necessary task is decoding their meaning [20]

Like other organs of body, brain is also composed of billions of cells. In the Nervous system there are two distinct class of cells: neurons and glia. Unlike other cells of body, brain cells are geometrically is different.

A neuron is also the difference from other cells because of its property of electrically excitable. Human brain has contained around 100 billiard neurons and each nerve cells

connections with other 50000-250000 neurons and also other sensory receptors, and muscle cells. They can process and transmit electrical excitation via electrical signals or chemical signals. The interactions between neurons enable people to think, move and feel emotions.

While there are ten thousand specific types of neurons, generally there are three kinds of neurons:

1-Motor neurons: for conveying motor information

2-Sensory neurons: for conveying sensory information

3-Interneurons: for conveying information between different types of neurons.

Typically neurons has 4 main components: the cell body (soma), dendrites, axons, and presynaptic, or axon, terminals. [18-19], [21-23].

1. Cell body (Soma): Control center of neuron and contain nucleus. Therefore the protein synthesis occurred in Soma.

2. Dendrite: because of similarity to dendritic tree the name is given and it is extension of cell branches. Income signals received via dendrite.

3. Axon: The outcome of signals to the other neurons held via Axon.

4. Axon terminals: Lies in the end of axon and contain neurotransmitters which signal flow to another neuron had been held at chemical synapses. [19]

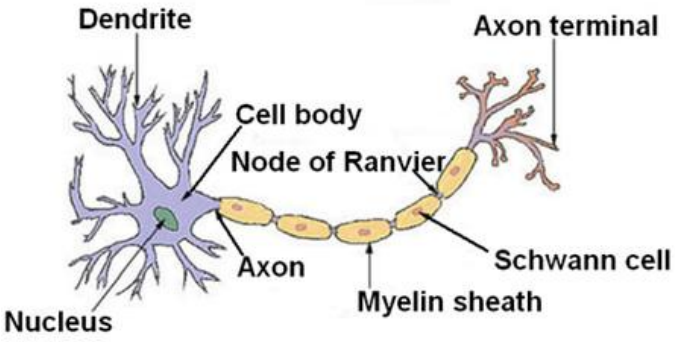

Figure 2.2 Structure of Typical neuron. [24]

Neuronal Signaling.

When the input signal reach to the neurons through chemicals (Also called Neurotransmitter), it will be passed to the downstream neurons. This transmission from Dendrite to axon terminals held by opening and closing of potential gated ions. This process cause occupation of the action potential (AP) in the cell body. Within the traveling down to the axon of AP, Polarity changes within the membrane. In the end Signal reaches the axon terminal, it cause the other neuron's stimulation. [25]

2.3 EPILEPSY & SEIZURE:

EPILEPSY

Human brain disorders are responsible for many pathophysiological diseases, especially epilepsy. The word "Epilepsy" is derived from Greek words which the meaning of "to be seized, surprise to be attacked" and it is the second most common chronic disorder of Central Nervous system observed by the neurologist. Also International League Against Epilepsy-ILAE classified "Epileptic seizure as a temporary symptoms which caused by excessive or synchronized neuronal activity in the brain" [30]

Epilepsy is characterized by unprovoked recurrent (two or more) seizures. A seizure is an abrupt, impermanent aberration in the brain's electrical activity that produces disruptive symptoms. This symptoms can be lapse in attention or whole body convulsion.

Epilepsy can be start any age of human life and occur frequently or occurring in randomly and suffer to whole life or periodically. May be some of them can be limits with certain ages groups [26]

On the other hand epilepsy can be progress after serious recognizable life, traumas event like head injury, a stroke, a cerebral infection, or a brain malignancy or without any recognizable events, just result of inheriting a mutation in a molecular mechanism that regulate neuron behavior, migration, or organization. First called Symptomatic epilepsy, second type called idiopathic epilepsy

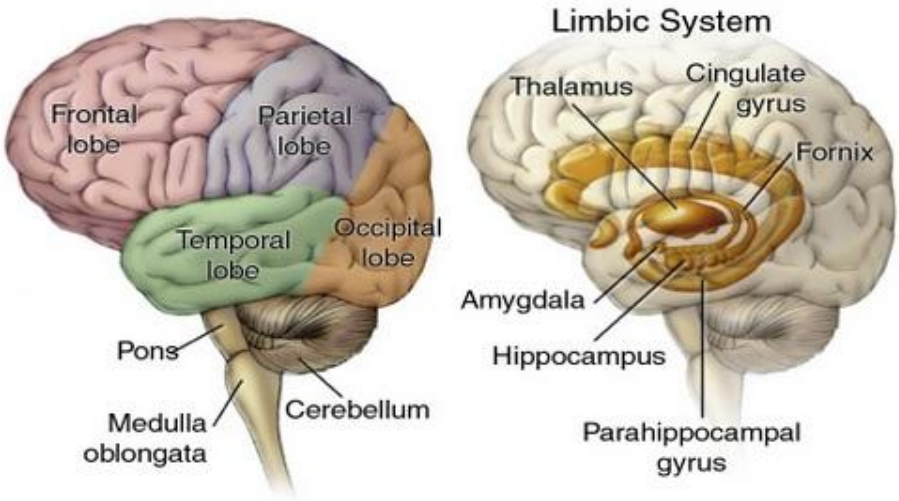

Figure 2.3: Brain anatomy [27]

SEIZURE

The process of excessive nerve cell discharge occurrence or neuronal excitation called Seizure. The process of The Excitation or the Excessive discharge can be occurred only in some part of brain or whole brain or start first at some part of brain then spread out to whole brain.

As a result of Seizure, Suddenly consciousness loss, abnormal functional body and extra muscular activities can be occur. A seizure sometimes also allude to attack, fit or convulsion. But fit and convulsion refer to types of seizure.

2.3.1 CLASSIFICATION OF SEIZURE

Since 1960, Neurologists try to classify the epilepsy in international conferences. According to the Clinic and EEG data, Seizures can classified as generalized or partial [41]. In generalized seizures, almost all brain cells evolved that may cause to complete consciousness loss or some period of fixed staring.

In partial seizures also known as focal seizures, in only one part of brain has irregular functioning. Symptoms and signs depend on part of brain that affected. As a result "automatic behavior" may be seen and change consciousness, like look somewhere deeply or nibble some object. In some cases this may be repetitive [42].

I. PARTIAL SEIZURES (seizures beginning locally)
A. Simple partial seizures (consciousness not impaired)
1. With motor symptoms
2. With somatosensory or special sensory symptoms
3. With autonomic symptoms
4. With psychic symptoms
B. Complex partial seizures (with impairment of consciousness)
1. Beginning as simple partial seizures and progressing toimpairment of consciousness
(a) With no other features
(b) With features as in A 1–4
(c) With automatisms
2. With impairment of consciousness at onset
(a) With no other features
(b) With features as in A 1–4
(c) With automatisms
C. Partial seizures secondary generalized
II. GENERALIZED SEIZURES (bilaterally symmetrical and without local onset)
A. 1. Absence seizures
A. 2. Atypical absence seizures
B. Myoclonic seizures
C. Clonic seizures
D. Tonic seizures
E. Tonic-clonic seizures
F. Atonic seizures
III. UNCLASSIFIED EPILEPTIC SEIZURES (inadequate or incomplete data)

Table 2.1. International Classification of Seizures.

2.3.2 SIGNS AND SYMPTOMS

Signs and symptoms in seizures depend of types. Each type has its specific signs.but the majority of signs are seen as convulsion.

Signs in Partial seizures: a person can be dazed or confused In general there are six types of this seizures and all involve during consciousness loss and observed no warning.

1.Tonic-clonic seizures: a person will lose consciousness, muscles will stiffen and jerky movements will be observed. Seizure period can be 1-3 minutes and recovering will be take much time.

2.Tonic: involve Constant Muscle contraction. In the case of impairment on breathing, person can be turn to blue.

3.Clonic: involve limb shaking in harmony.

4.Myoclonic : Spasm in Muscles

5.Absence seizures: Slight turn head or eye blinking.

6.Atonic: Loss of muscle activity more than one second [43-44].

2.3.3 EPIDEMIOLOGY

Epidemiology is the science which studies and give information about the dynamics of certain disease in the population and help to improvement of the health system. Prevalence is the ratio of population which had certain disease to the entire interested population in given period. Incidence is the rate of occurring new disease in a given period (e.g. Year) in an interested population.

In all over the world the prevalence and incidence studies had been held. According to the Who Epilepsy Atlas 2005, epilepsy affect 50 000 000 of peoples in Worldwide [28]. The epilepsy had been seen more in developing countries rather than developed countries and also social and environmental differences could be key factor but the significant difference is not observed between racial differences. Figure 2.4 show us that 1 of every 20-30 people has an epilepsy in countries with low income and 1 of every 200-300 people has an Epilepsy in countries which had higher income.

According to the studies in Europe the prevalence rate of Epilepsy is 8.2 per 1000 people and it means that currently 6 million people in Europe affected by the Epilepsy and 15 million people will have Epilepsy at least once in their whole life [29]. Also the prevalence of Urban and rural states of Turkey had been done and the crude prevalence rate in rural place was 8.8/1000 and in urban areas was 4.5/1000 [30] and lifetime prevalence of Epilepsy in rural state of Istanbul had been studied and the rate was 8/1000 [31] and also the prevalence of Epilepsy among children was again 8/1000 [32]. Similar studies had been also studied in my home country Turkmenistan and Post-Soviet countries and similar results had been obtained [33].

Age adjusted incidence rate also have been studied for dozen of years and range from 18 to 69 [34-37]. The graph of incidence to the specific ages for Europe and comparison for the global had been plotted in Figure 2.5

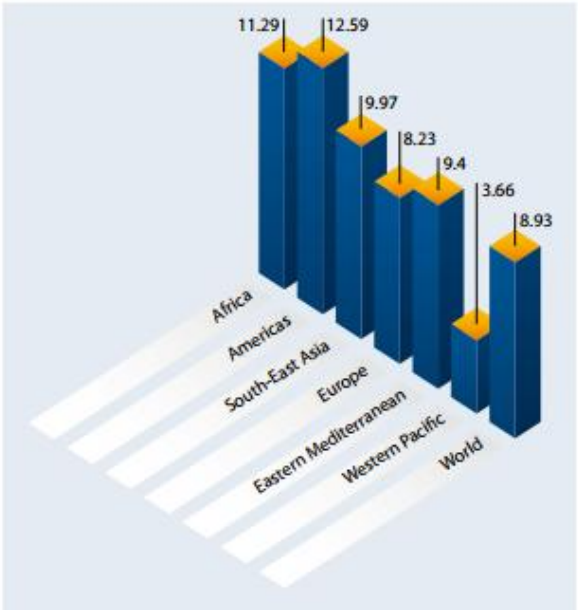

Figure 2.4 Mean number of people with epilepsy per 1000

Population in WHO Regions and in the world [28]

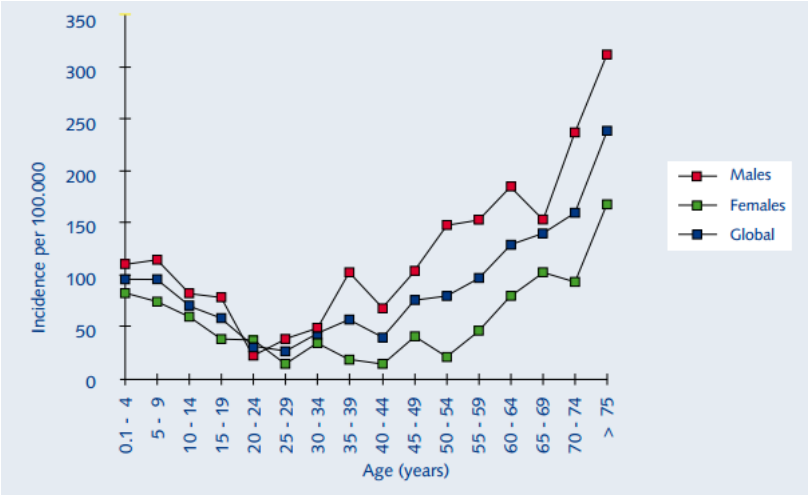

Figure 2.5 The age specific incidence of Epilepsy in Europe [28]

The Incidence is higher in two lifecycle of human as it given in the graph: Childhood and elderly. There is an evidence decreasing in children and increasing in elderly people. And also the incidence rate of Epilepsy in woman is less than males. These epidemiological data show that the seriousness of Epilepsy in worldwide

2.3.4 ETIOLOGY

All of us may develop a seizure in our certain circumstance of life. As mentioned before seizure is a symptom of an abnormal functional condition of body and it have a number of causes. The major portions of those (Approximately 25%) are Epilepsy [38]. Alcohol and alcohol related problems, trauma, CNS infections are can be one of the causes during the adulthood [39] and in older group cerebrovascular diseases are one of the major causes of Seizure[40]. The other causes which are not directly related with Epilepsy is given in Table 2.2

Metabolic	Hypoglycaemia	Pyridoxine deficiency/dependency
	Hypocalcaemia	Uraemia
	Electrolyte imbalance	Phenylketonuria
	Hypomagnesaemia	Porphyria
	Hyperbilirubinaemia (kernicterus)	
Infections	INTRACRANIAL	EXTRACRANIAL
	— meningitis	— febrile illnesses (febrileconvulsions)
	— encephalitis	— pertussis
	— AIDS	— pertussis immunization
	— Neurosyphylis	— tetanus
	— cerebral malaria	
	— rabies	
	— toxoplasmosis	
	— cysticercosis	
	— encephalopathy (SSPE)	
Trauma	Birth trauma	Cold injury in newborns
	Head injury in later life	Hypothermia
Anoxia	Birth asphyxia	Conditions later in life
Toxic	Alcohol and withdrawal from alcohol*	
	Carbon monoxide poisoning	
	Drugs (high dose i.v. penicillin, strychnine, etc.)	
	Lead poisoning	
	Organo-phosphorus insecticide poisoning	
Space-occupying lesions	Haemorrhage	Tuberculoma*
	Abscess	Cysticercosis
	Tumour	Toxoplasmosis
Circulatory disturbances	Cerebro-vascular accident (stroke)	Sickle-cell crisis
	Vascular anomalies	
Cerebral oedema	Hypertensive encephalopathy	Eclampsia
Congenital	Malformations of the brain	
	Tuberous sclerosis	
	Neurofibromatosis	
	Encephalo-trigeminal facial angiomatosis	
Degenerative diseases	Niemann-Pick disease	Dementias
	Cerebromacular degeneration**	
Epilepsy		

Table 2.2. The brief information about the Causes of Seizure.

2.3.5 DESCRIPTION OF EPILEPSY IN INDIVIDUALS

Some of individuals describe what is look like a seizure in the “Brainstorms: Epilepsy in our world” book:

I have come face to face with the combination of Deja vu and fear. I could not find the anything which take me far from déjà vu. The experienced feeling you are in front of tarin which you could not escape from it.

The worst side of having seizures is you cannot imagine the time it would happen. It can be any time and drugs help me that after seizure was break. [45]

CHAPTER 3

MATERIALS AND METHODS

Information about the subjects, the procedure of research, and the physiological signals that were investigated in the research, the measurement system that used to gathering signal and signal processing methods constitutes this chapter.

3.1 SUBJECTS

Case	Gender	Age (years)	Case	Gender	Age (years)
chb01	F	11	chb13	F	3
chb02	M	11	chb14	F	9
chb03	F	14	chb15	M	16
chb04	M	22	chb16	F	7
chb05	F	7	chb17	F	12
chb06	F	1,5	chb18	F	18
chb07	F	14,5	chb19	F	19
chb08	M	3,5	chb20	F	6
chb09	F	10	chb21	F	13
chb10	M	3	chb22	F	9
chb11	F	12	chb23	F	6
chb12	F	2			

Table 3.1. Subject Information.

Used EEG signals in this study were provided from open source database [1] which data collected at Children Hospital's Boston. It contain EEG signals which collected from Pediatric subjects with unyielding seizures. For characterizing their seizures and checking necessity for surgery intervention, the subjects withdrawal from anti-seizure medication and monitored for several days

23 different pediatric EEG signal package collected from 22 pediatric patients. Each Signals package represent with numbers. The data packet 21 obtained from the same patient numbered data packet 1 but 1.5 year later. The subject information is given the above Table-3.1.

The ages range from 1.5 to 22 (5 male subjects from 3to 22 and 17 female subjects from 1.5 to 19) with 9.98 average age and 5.67 standard deviation.

3.2 EEG SIGNALS

From 9 to 42 .edf files included in each data package or case (chb01, chb02, etc.) from single subject. The 10 or less second gap during non-measuring time had been occurred due to the Hardware limitations. In some cases this gap were much more than 10 seconds. For privacy of the subject protection, Protected Health Information (PHI) had been replaced with related information without losing their meaning in .edf files. Recorded dates had been replaced but the time relationship in each case were not changed.

Generally .edf files contain 1 hour EEG signals, but in some cases like chb10 contain 2 hours EEG signals and chb04, chb07, chb09 and chb23 contains 4 hours EEG signals. Generally in this cases seizures were too short.

Signals collected with 256 Hz sample rate with 16-bit resolution. Expect a few cases with 24 and 26 channels, most recordings contain 23 channels. This source contained total 664 edf recorded files and 129 edf files contain between from one and four seizures. The Standardized International 10-20 EEG System and Nomenclature had been used.

The Standardized International 10-20 System of EEG electrode position:

Spontaneous EEG recordings generally the internationally standardized 10-20 system is usually used. The electrodes are placed on the surface of scalp in this system as shown in Fig-3.1A, 3.1B and 3.1C.

Reference points: Nasion and Inion used for determining reference points. In the transverse and median planes, from this reference points the skull perimeters are measured. So these perimeter divided into 10% and 20% intervals for Electrode locations. Other three electrodes also placed equidistant from the points like in Fig-3.1B.

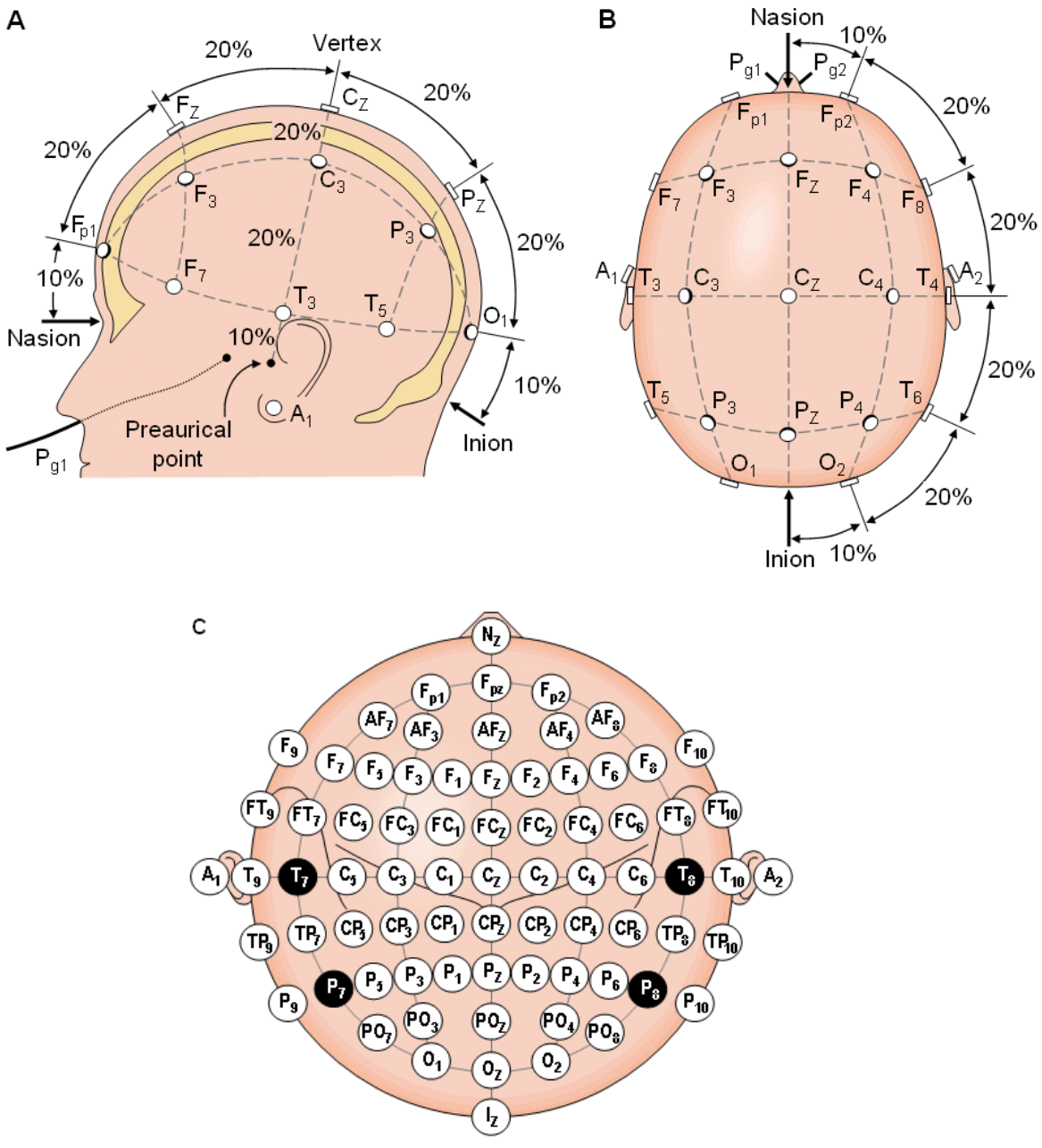

Figure 3.1. The international 10-20 system seen from (A) left and (B) above the head. A = Ear lobe, C = central, Pg = nasopharyngeal, P = parietal, F = frontal, Fp = frontal polar, O = occipital.

(C) Location and nomenclature of the intermediate 10% electrodes, as standardized by the American Electroencephalographic Society [46].

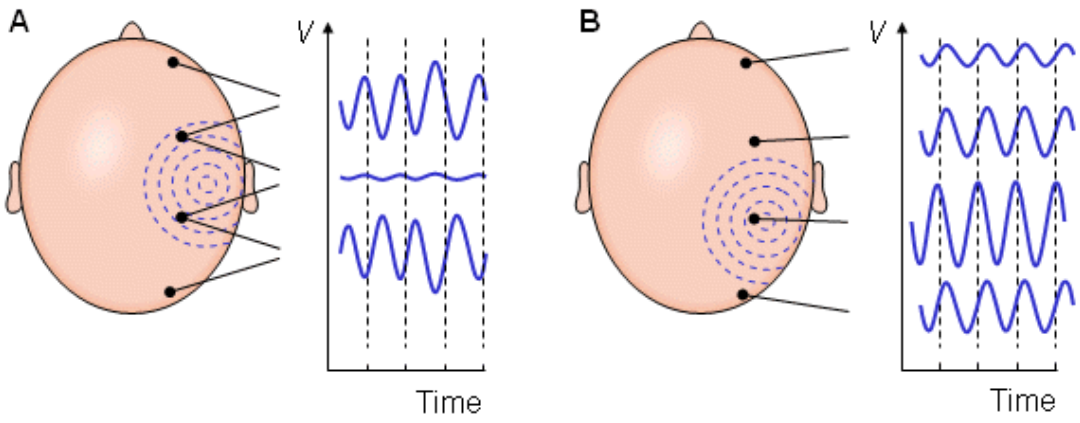

Figure 3.2. (A) Bipolar and (B) unipolar measurements. Note that the waveform of the EEG depends on the measurement location [47].

In the EEG measurement, 2 kinds of measurements: Bipolar or Unipolar electrodes can be used. Bipolar: the potential difference among two pair of electrodes is measured As Shown in Fig-3.2A. Unipolar: the potential difference between each electrode and neutral electrode (Reference) or Potential difference between each electrode and average value of all electrodes as shown in Fig-3.2B. In this recordings first method-Bipolar measurement had been used.

3.3 SIGNAL PROCESSING

Curve length method.

After Esteller conducted the theoretical Fractal Dimensional analysis, the Katz developed algorithm which had been frontier seizure detection on Intracranial EEG [3.4]. But in this case it so computational. For reducing Computational burden Olsen [3.5] eliminated the logarithmic computations then analyze the curve length of signal which defined the sum of length of segments between samples of signal. The mathematical expression is

$$CL[n] = \sum_{ik=1+(n-1)(n-d)}^{n(N-D)+D} (|x(i-1) - x(i)|) \quad (3.1)$$

Here

- $CL[n]$: The curve length of time series $x(n)$

- N : Length of sliding window which had been expressed in number of points.

- n : Discrete Time Index.

- D : is the overlap

This expression give nearly same results with Katz algorithm but provide less computational burden. It is useful in frequency and amplitude change observations. Furthermore FD may add nonlinearity and give negative value but CL it is not possible [47].

ALGORITHM APPLICATION ON MATLAB

So this mathematical expression had been transform on algorithm on MATLAB and applied to the signals.

Since the sampled rate 256 Hz, 1 hour measurement will have total 921600 measurements. So we set up the variables in order to process time efficiently.

- N : 5000

- D : 4900

The raw EEG signal draw in Fig-3.3A and the black window express our window (D=5000) lie at 50000 and 55000. Since it is not easily observable Fig-3.3B show zoomed version of 3.3A. So algorithm sum up the all signal values between 50000 and 55000 and record it in corresponding (here 50000/100=500) point new obtained signal.

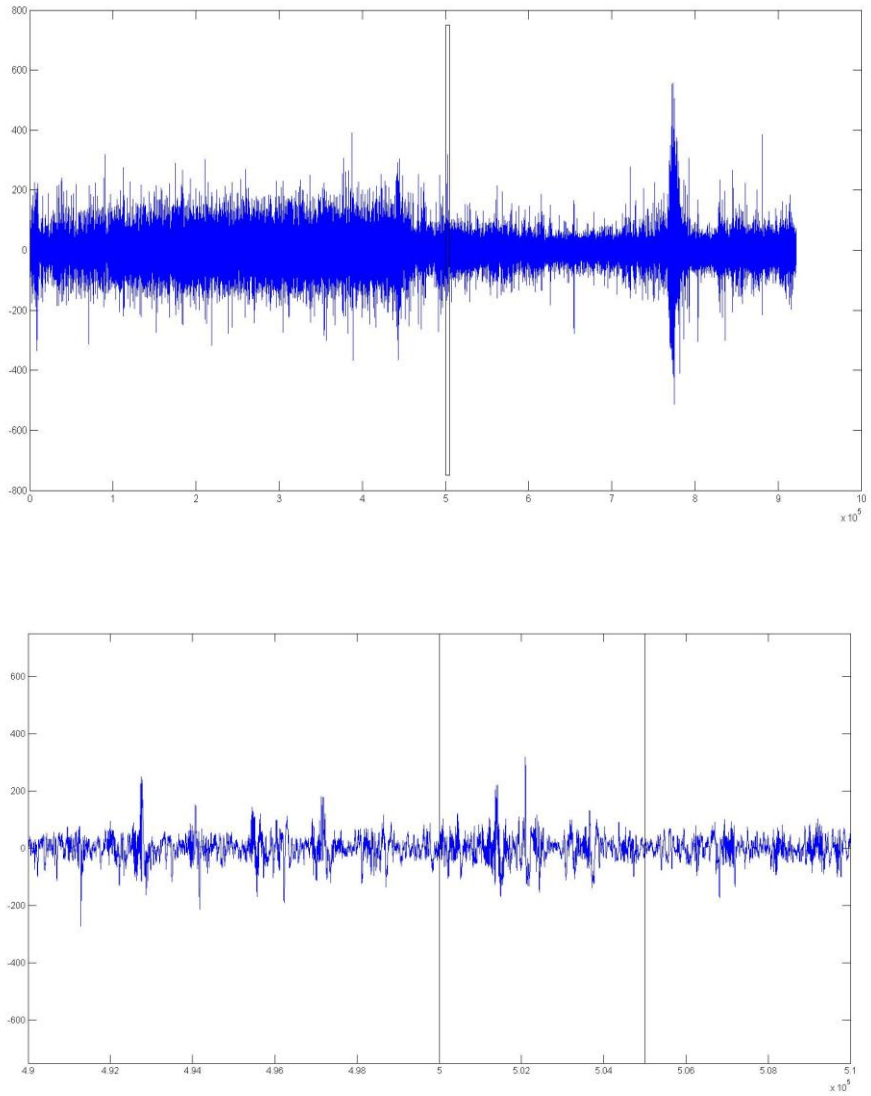

Figure 3.3 A) The Raw EEG and window (D=5000) B) Zoomed version of Same Raw EEG and window (D=5000)

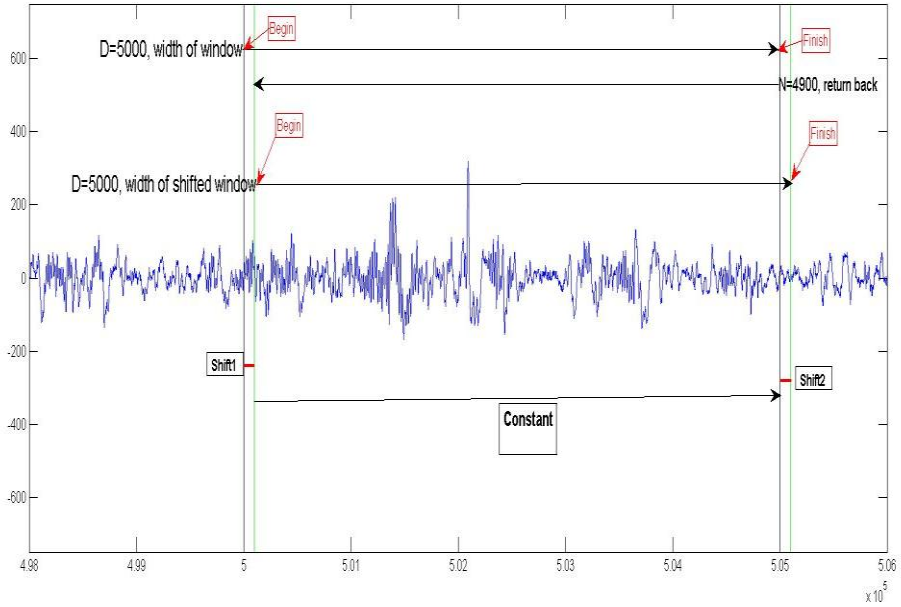

Figure 3.4. Shifting window

After record it window will be shift D=100 point to 50100 then start to sum up all value still 55100. The total value record to 501 on new data as shown in Fig.3.4. This process repeated until the window reach at the end point of processed data. The new obtained data has 100 times less point and thousands time great values.

By doing so,

1.Differences of Seizure regions and Non-seizure regions examined

2.The regions before Seizure and after seizure will be examined for significant difference and relation

3. 5 channels from 5 different regions of brain will be examined and try to select the best channel and compare with Shoeb's et all. Study[48]

CHAPTER 4

RESULTS

In this chapter, results of analyzing Nonseziure, seizure onset and seizure condition of EEG signals will be explained. For signal processing, algorithms in MATLAB® (v. 7.8.0 R2011a) software was used for signal processing. The differences between Non-seizure, Seizure Onset and Seizures were detailed briefly.

The first signal obtained from the 11 years old female patient coded as Chb01_01 which the measurement continue around 1 hour between 11:42:54 and 12:42:54 The Total Number of Seizures in measurement was 0.

Figure 4-1 Show that EEG signal obtained from patient1 without any seizure event occurred.

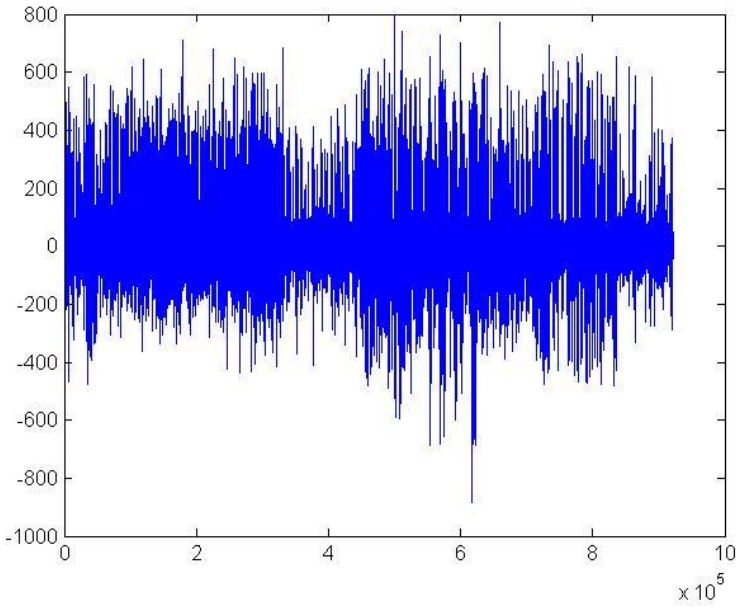

Figure 4.1 Raw EEG data without any Seizure

Since the graph is so complicated, it is very difficult to make a comment about behavior of EEG data from this figure. Hence, The EEG data depend on both frequency and amplitude, the curve length analysis method can sense both tiny changes (frequency and amplitude). After the application of Curve Length method to the same EEG data, the graph of new obtained signal was plotted in Fig-4.2. In this graph EEG Signals were randomly distributed and there is no corresponding spikes or big changes.

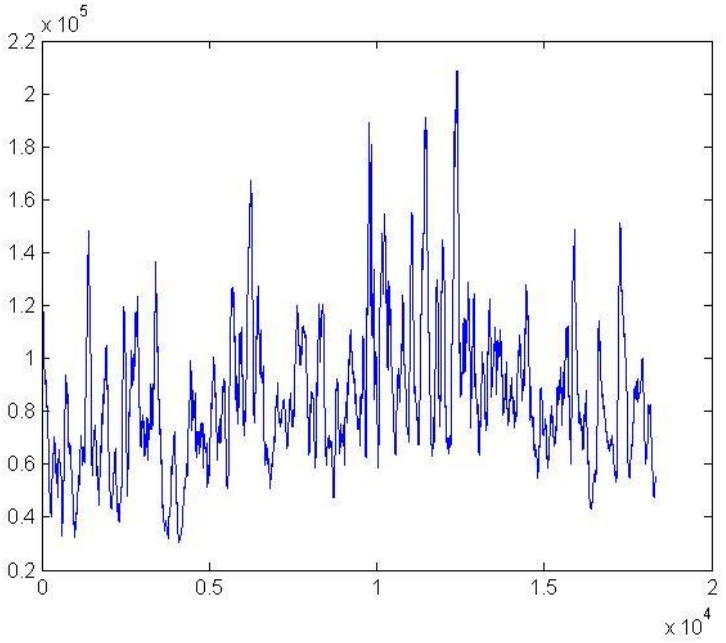

Figure 4.2 After application of curve length method to the same EEG data in Fig-4.1.

The difference between this two graph: Raw EEG graph and after Curve Length analysis method applied graph are explained briefly in Chapter 3.

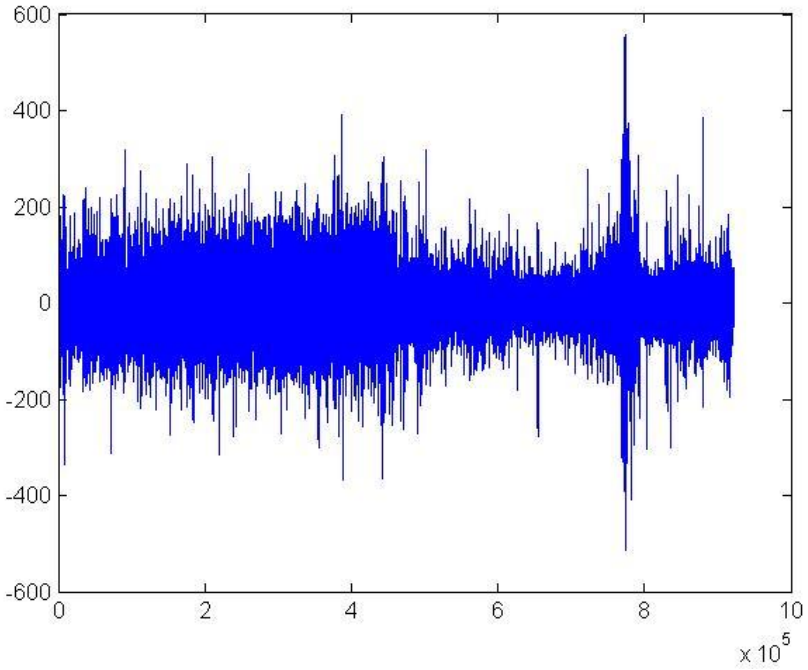

Figure 4.3 Raw EEG with Seizure from same patient in Fig- 4 .1 but in different measurement.

From same patient but different data codes as Chb01_03 which continue around 1 hour between 13:43:04 and 14:43:04 and raw EEG data was plotted in Fig 4.3. The Neurologists interpreted and denoted that Chb01_03 EEG file contain Seizure event between 2996 seconds and 3036 seconds. These region has quite different as in amplitude and frequency in Fig- 4.3.

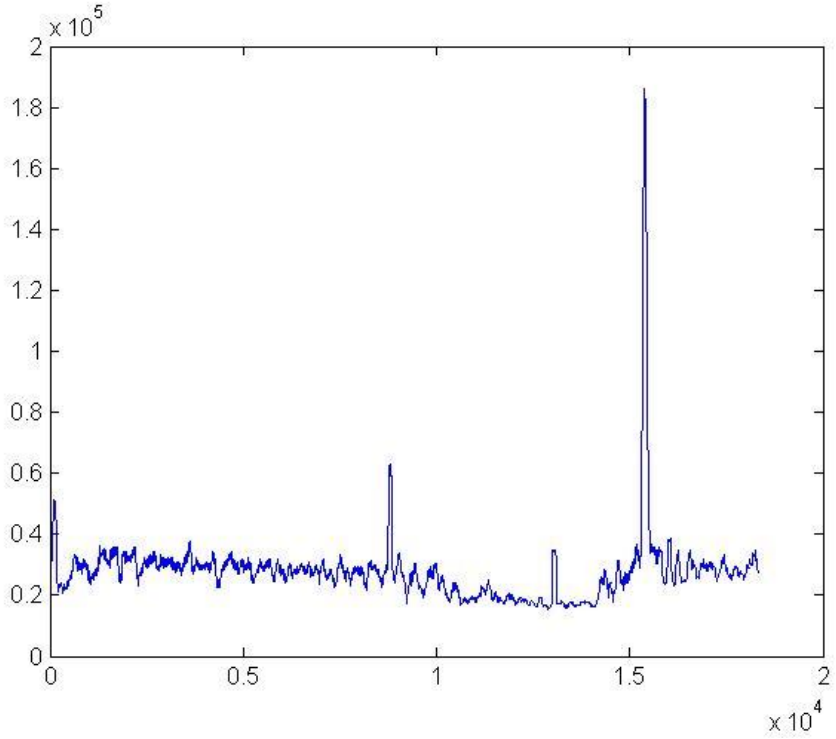

Figure 4.4 The graph of Curve length of same patient in Figure 4.1-4.3 with seizure.

After applied curve length method, the new signal had been obtained and Figure 4.4 show the Graph of new signal. By naked eye observation, it can easily observed that Seizure part of EEG has higher value than rest one. The 2996 seconds and 3036 seconds in Fig- 4.3 corresponded to 7669.76 and 7772.16 points in new signal in Figure 4.4. The Fig- 4.5 focused only to seizure part region. The blue line which inside the green rectangle were the seizure part of EEG data. The left side of rectangle was matched with 7669 and right side matched with 7773 which the beginning and end point of seizure event. The ratio of seizure part of EEG signal's value to the rest part's value would discuss in further parts of this chapter.

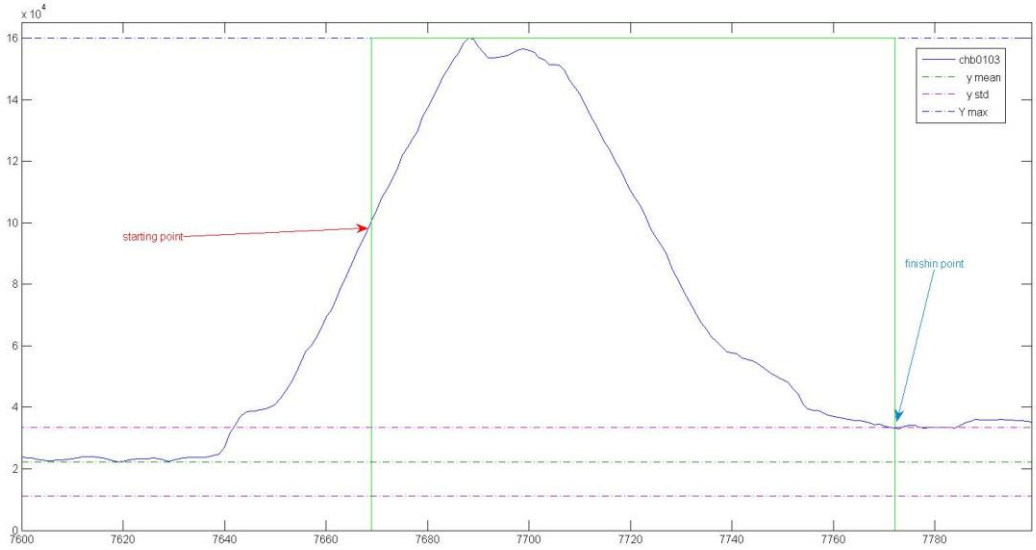

Figure 4.5 Focusing to the seizure part of Chb01_03 EEG data.

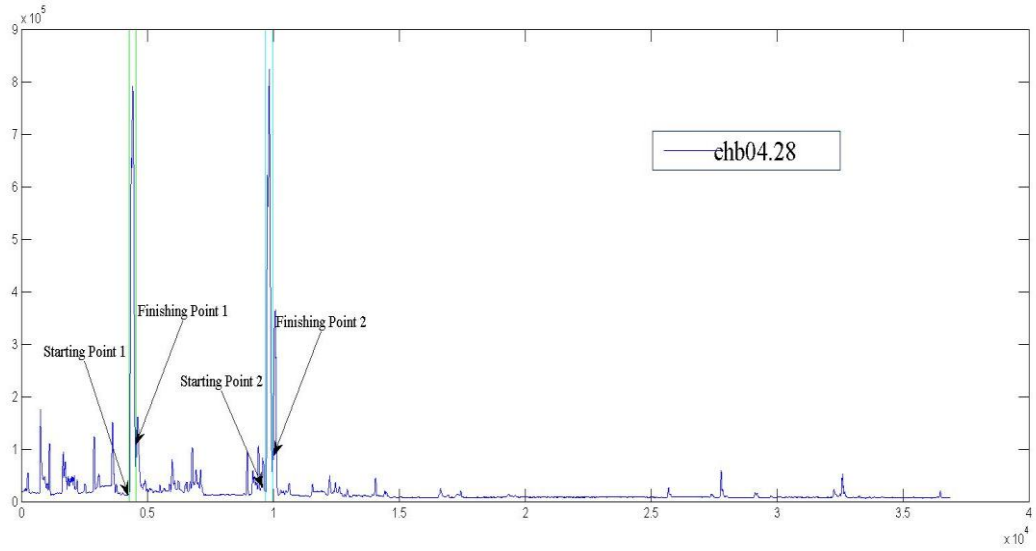

Figure 4.6 Two seizures in single signal Chb_04_28

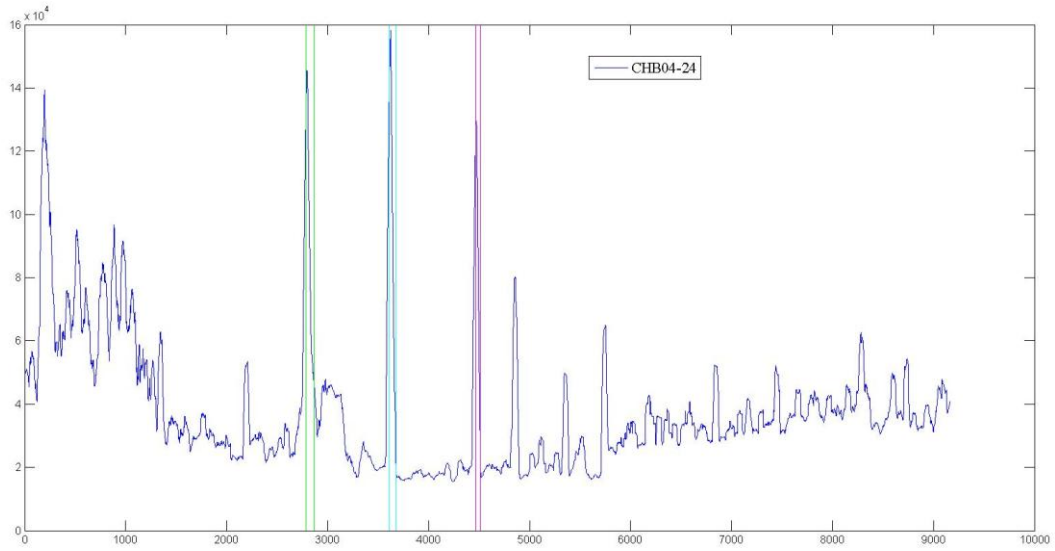

Figure 4.7 Three seizures in single signal Chb_04_28

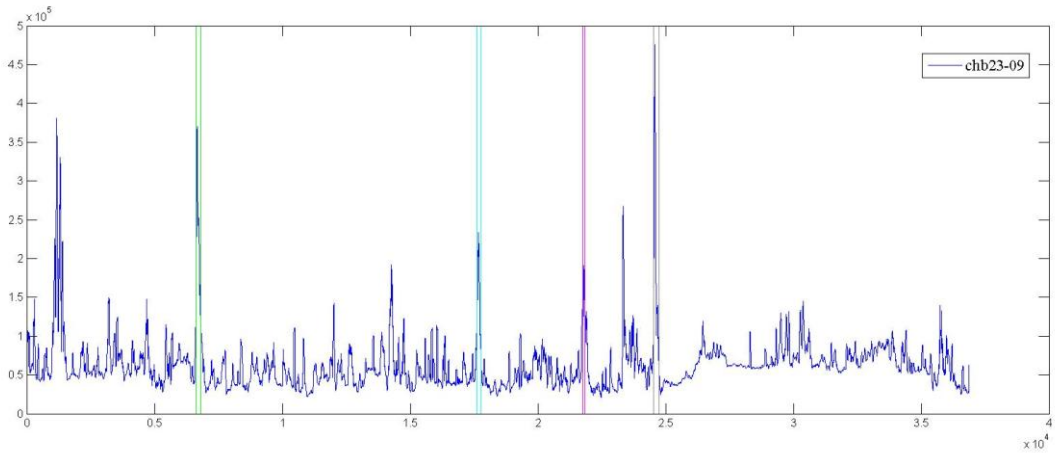

Figure 4.8 Four seizures in single signal Chb_23_09

As briefly explained in Chapter 3, the signals had been collected from 23 different channels from different parts of brain. Some of these channels could easily effected from noise and some of them did not much. Shoeb and et all [48] examined three different regions of brain's channels to finding the most sensitive to the seizure:

Frontal Central Channels:

FP2-F4. Channel Number: 9;

F4-C4. Channel Number: 10;

The right frontal and posterior channels

FP2-F8. Channel number: 13;

F8-T8. Channel Number 14;

T8-P8. Channel Number 15;

P8-O2. Channel number 16;

The Central Channel

FZ-CZ. Channel number 17;

Found that the most prominent activity region among them was frontal central channels, second one was central channels and third one was central and posterior channels. However they had used different method. Signals from total five channels: three from regions described above and other two from frontal and occipital regions would examined for detecting the best channel. The examined channels are:

Channel 1: (Frontal Channel)

Channel 10: F4-C4 (Frontal Central)

Channel 13: FP2-F8 (The right frontal and posterior)

Channel 17: FZ-CZ (The Central Channel)

Channel 23: (Occipital Channel)

This five channels from 5 different patient EEG had been examined. The average Curve Length value of Seizure evolved EEG and Non-Seizure part of EEG before and after seizure had been calculated and given in the Table 4.1. Since each patient had several seizure included EEG, the only one measurement for each patient randomly selected.

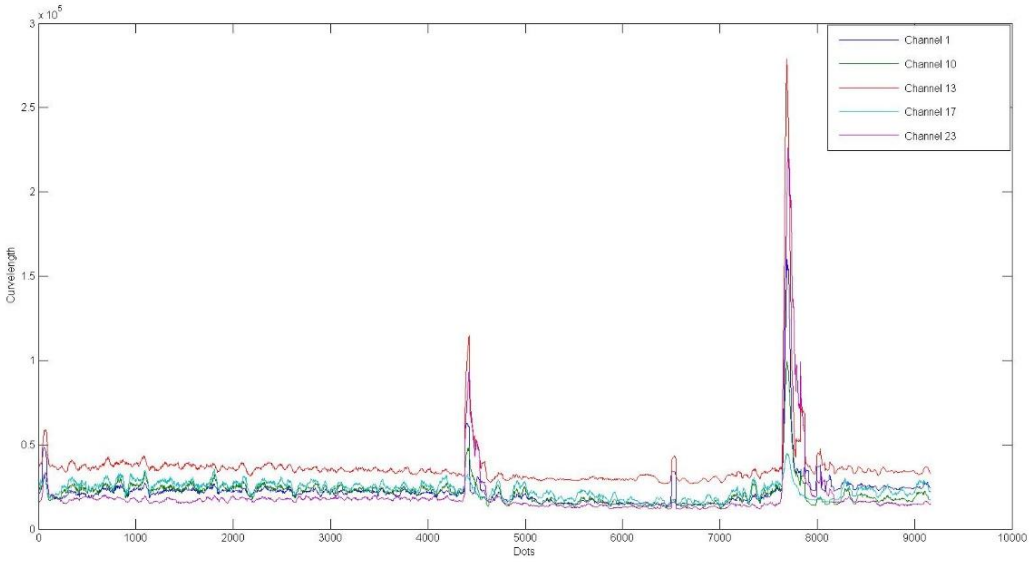

Figure 4.9 The graph of Curve Length Chb_01_03 in five channel.

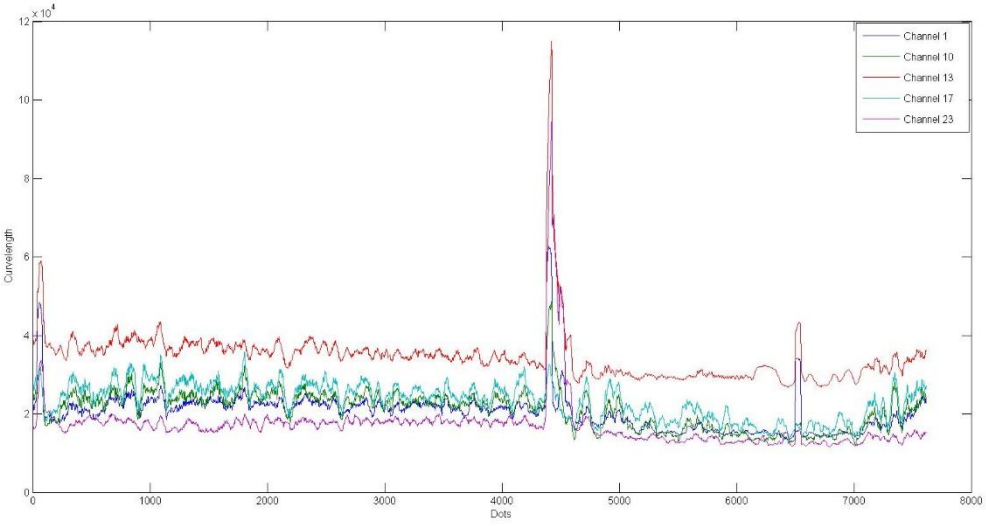

Figure 4.10 The graph of Curve length of Chb_01_03 before Seizure.

	Channel 1					Channel 10				
	S	B	A	av	R	S	B	A	av	R
ch.01.03	136470	20345	17214	18779	7,27	87941	21145	18717	19931	4,41
ch.02.16	61085	29258	39899	34579	1,77	67099	20471	21859	21165	3,17
ch.03.03	158650	45181	61943	53562	2,96	82236	24564	30005	27285	3,01
ch.04.18	67322	46157	30898	38528	1,75	45170	35469	22733	29101	1,55
ch.05.13	185810	34945	38942	36944	5,03	182910	25820	24455	25138	7,28
	Channel 13					Channel 17				
	S	B	A	av	R	S	B	A	av	R
ch.01.03	230480	34723	37157	35940	6,41	41612	23487	21669	22578	1,84
ch.02.16	82616	26701	52051	39376	2,10	47634	17429	31464	24447	1,95
ch.03.03	141080	40585	52258	46422	3,04	36639	11134	13787	12461	2,94
ch.04.18	48490	41021	23848	32435	1,49	26882	16550	12450	14500	1,85
ch.05.13	201270	36221	34785	35503	5,67	151770	25198	23077	24138	6,29
	Channel 23									
	S	B	A	av	R					
ch.01.03	191010	26263	21811	24037	7,95					
ch.02.16	108950	125760	53851	89806	1,21					
ch.03.03	224560	65598	66965	66282	3,39					
ch.04.18	72988	67065	25862	46464	1,57					
ch.05.13	379500	39218	49688	44453	8,54					

Table 4.1 Channel specific quantative CL values S-Average Curve length of Seizure Region, B- Average Curve length of Before Seizure Region, A- Average Curve length of After Seizure Region, av- Average Curve length of before and after Seizure part, R- Ratio S to Av

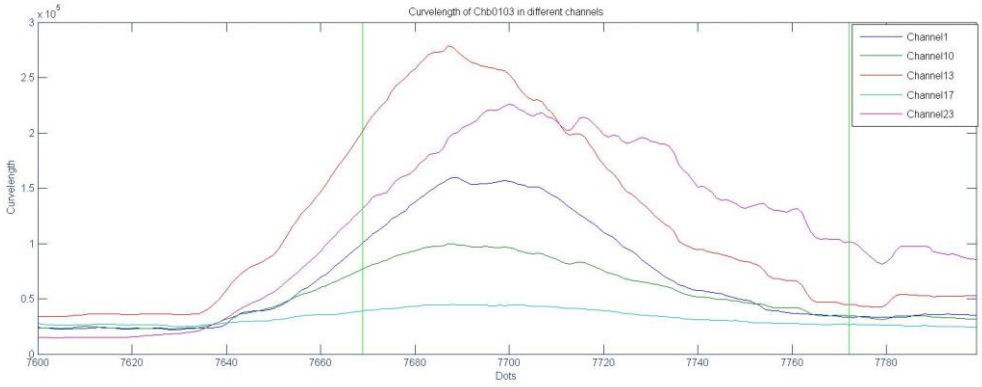

Figure 4.11 The graph of curve length of Chb_01_03 during Seizure.

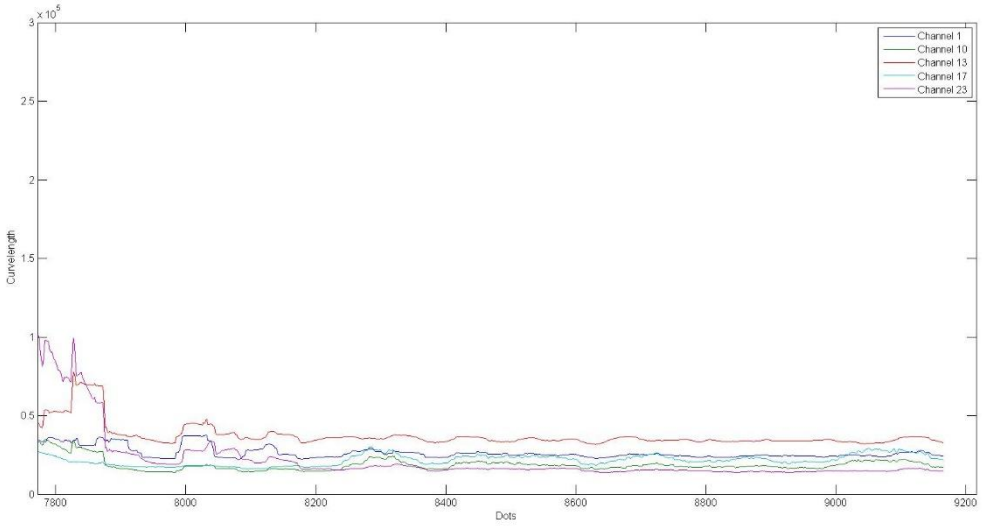

Figure 4.12 The graph of curve length of Chb_01_03 after Seizure event.

Fig 4.9- 4.12 Show correspondence the graph of curve length of full Signal Chb0103 and before the seizure, during seizure and after the Seizure part of signals. The Average value of each part had been recorded to the table.

From this table we tried to correlation those three regions value. As it showed in Table 4.1, we could not able to find any correlation among this three regions. So, rest of meausrments these individual three region had been not calculated.

Measurement Informations					Channel 1			
Seizure	**Total Sample**	**Total S.Sample**	**S.S.Points**	**S.F.Points**	**Sav**	**Tav**	Rav	Ratio
chb01_03	921600	10240	766976	777216	136470	22254	20971	6,507659
chb02_16	245504	20992	33280	54272	61085	40009	38038	1,605878
chb03_03	921600	17664	110592	128256	158650	76440	74834	2,120039
chb04_08	3686400	28416	1650176	1678592	67322	38010	37782	1,78184
chb05_13	921600	28160	278016	306176	185810	43191	38696	4,801807
chb06_13	3686400	3328	129536	132864	31277	36224	36228	0,863327
chb07_13	953856	24576	840960	865536	279710	50581	44521	6,282598
chb08_02	921600	43776	683520	727296	66776	45964	44926	1,486351
chb09_19	1459200	15872	1356544	1372416	328180	91856	89257	3,676791
chb10_38	1843200	22784	1182208	1204992	76869	67432	67314	1,141949
chb11_82	921600	5632	76288	81920	78912	37103	36846	2,141675
chb12_36	921600	6912	167168	174080	15565	20551	20589	0,755998
chb13_19	921600	5632	163328	168960	19470	15067	15040	1,294554
chb14_11	921600	10496	470528	481024	16097	16233	16235	0,991526
chb15_62	921600	27648	192256	219904	32563	14979	14435	2,255811
chb16_11	921600	2304	286720	289024	83225	49664	49580	1,678604
chb17a_04	921600	29440	774400	803840	67638	40807	39922	1,69427
chb18_36	921600	11776	118528	130304	65028	17487	16872	3,854272
chb19_29	921600	19712	758784	778496	404000	43623	35746	11,30182
chb20_12	921600	7424	24064	31488	74777	14435	13945	5,362294
chb21_19	921600	14336	329728	344064	73341	65955	65838	1,113957
chb22_25	921600	18944	803584	822528	200780	59651	56689	3,541772
chb23_06	1923584	28928	1014272	1043200	192540	41840	39539	4,869612

Table 4.2. Channel1 CL values Total Sample-Signal contained samples; Total S.Samples, Signal contained seizure samples; S.S.Points- Seziure start point; S.F.Points-Seziure finishing point Sav-Seziure average value after curve length applied; Tav-Total signal average value after curve length applied; Rav- Total average value of Remain part(except seizure) after curve length applied; Ratio-ratio of Seziure average value to Remain average value

Measurment Informations					Channel10			
Seizure	Total Sample	Total S.Sample	S.S.Points	S.F.Points	Sav	Tav	Rav	Ratio
chb01_03	921600	10240	766976	777216	87941	21440	20693	4,101726
chb02_16	245504	20992	33280	54272	67099	24947	21006	2,689662
chb03_03	921600	17664	110592	128256	82236	38417	37561	2,140615
chb04_08	3686400	28416	1650176	1678592	45170	28635	28507	1,57744
chb05_13	921600	28160	278016	306176	182910	29770	24943	6,144105
chb06_13	3686400	3328	129536	132864	29730	41577	41588	0,715059
chb07_13	953856	24576	840960	865536	300650	62143	55835	4,838035
chb08_02	921600	43776	683520	727296	83184	56050	54697	1,484103
chb09_19	1459200	15872	1356544	1372416	245780	49320	47160	4,983374
chb10_38	1843200	22784	1182208	1204992	64560	35789	35429	1,803906
chb11_82	921600	5632	76288	81920	28220	20601	20554	1,369836
chb12_36	921600	6912	167168	174080	47466	28419	28275	1,670221
chb13_19	921600	5632	163328	168960	17252	20620	20641	0,836663
chb14_11	921600	10496	470528	481024	18767	26177	26262	0,716927
chb15_62	921600	27648	192256	219904	22389	18570	18452	1,205654
chb16_11	921600	2304	286720	289024	33223	28107	28094	1,182019
chb17a_04	921600	29440	774400	803840	32095	33313	33353	0,963438
chb18_36	921600	11776	118528	130304	55623	15404	14883	3,610945
chb19_29	921600	19712	758784	778496	157440	27043	24193	5,821839
chb20_12	921600	7424	24064	31488	35675	22883	22779	1,559018
chb21_19	921600	14336	329728	344064	27233	25578	25552	1,064704
chb22_25	921600	18944	803584	822528	143340	56802	54986	2,523503
chb23_06	1923584	28928	1014272	1043200	115670	35650	34428	3,2446

Table 4.3. Channel10 CL values Total Sample-Signal contained samples; Total S.Samples, Signal contained seizure samples; S.S.Points- Seziure start point; S.F.Points-Seziure finishing point Sav-Seziure average value after curve length applied; Tav-Total signal average value after curve length applied; Rav- Total average value of Remain part(except seizure) after curve length applied; Ratio-ratio of Seziure average value to Remain average value

Measurment Informations					Channel13			
Seizure	Total Sample	Total S.Sample	S.S.Points	S.F.Points	Sav	Tav	Rav	Ratio
chb01_03	921600	10240	766976	777216	230480	36840	34664	6,648921
chb02_16	245504	20992	33280	54272	82616	50409	47398	1,743041
chb03_03	921600	17664	110592	128256	141080	75246	73960	1,90753
chb04_08	3686400	28416	1650176	1678592	48490	31737	31607	1,534161
chb05_13	921600	28160	278016	306176	201270	41150	36103	5,574846
chb06_13	3686400	3328	129536	132864	36417	51245	51258	0,710459
chb07_13	953856	24576	840960	865536	236290	49478	44538	5,305415
chb08_02	921600	43776	683520	727296	59297	38789	37766	1,570104
chb09_19	1459200	15872	1356544	1372416	359090	67581	64375	5,578068
chb10_38	1843200	22784	1182208	1204992	92787	71456	71189	1,303389
chb11_82	921600	5632	76288	81920	79552	40601	40362	1,970987
chb12_36	921600	6912	167168	174080	20355	23697	23722	0,858055
chb13_19	921600	5632	163328	168960	15870	16040	16041	0,989337
chb14_11	921600	10496	470528	481024	29663	18071	17937	1,65369
chb15_62	921600	27648	192256	219904	25474	19903	19731	1,291084
chb16_11	921600	2304	286720	289024	50339	40390	40365	1,247093
chb17a_04	921600	29440	774400	803840	89707	45732	44281	2,025863
chb18_36	921600	11776	118528	130304	71846	20003	19332	3,716431
chb19_29	921600	19712	758784	778496	392050	40313	32625	12,01675
chb20_12	921600	7424	24064	31488	146290	16843	15792	9,263689
chb21_19	921600	14336	329728	344064	65525	56996	56861	1,152367
chb22_25	921600	18944	803584	822528	149520	61168	59314	2,520832
chb23_06	1923584	28928	1014272	1043200	244520	56411	53539	4,567145

Table 4.4. Channel13 CL values Total Sample-Signal contained samples; Total S.Samples, Signal contained seizure samples; S.S.Points- Seziure start point; S.F.Points-Seziure finishing point Sav-Seziure average value after curve length applied; Tav-Total signal average value after curve length applied; Rav- Total average value of Remain part(except seizure) after curve length applied; Ratio-ratio of Seziure average value to Remain average value

Measurment Informations					Channel17			
Seizure	Total Sample	Total S.Sample	S.S.Points	S.F.Points	Sav	Tav	Rav	Ratio
chb01_03	921600	10240	766976	777216	41612	23404	23199	1,793666
chb02_16	245504	20992	33280	54272	47634	30708	29125	1,635479
chb03_03	921600	17664	110592	128256	36639	16595	16203	2,261204
chb04_08	3686400	28416	1650176	1678592	26882	14397	14300	1,879858
chb05_13	921600	28160	278016	306176	151770	27417	23498	6,458967
chb06_13	3686400	3328	129536	132864	24245	33890	33899	0,715219
chb07_13	953856	24576	840960	865536	133820	21936	18977	7,051663
chb08_02	921600	43776	683520	727296	34728	19409	18645	1,862584
chb09_19	1459200	15872	1356544	1372416	228660	38315	36222	6,312771
chb10_38	1843200	22784	1182208	1204992	85256	42628	42094	2,025349
chb11_82	921600	5632	76288	81920	20589	13760	13718	1,500874
chb12_36	921600	6912	167168	174080	27192	23004	22972	1,183684
chb13_19	921600	5632	163328	168960	16938	21727	21756	0,778528
chb14_11	921600	10496	470528	481024	13759	22446	22546	0,610261
chb15_62	921600	27648	192256	219904	21400	16302	16144	1,325543
chb16_11	921600	2304	286720	289024	25359	23909	23905	1,060808
chb17a_04	921600	29440	774400	803840	18742	116780	120015	0,156164
chb18_36	921600	11776	118528	130304	24843	13289	13139	1,890718
chb19_29	921600	19712	758784	778496	136930	24186	21722	6,303798
chb20_12	921600	7424	24064	31488	28001	27485	27481	1,018929
chb21_19	921600	14336	329728	344064	17858	15098	15054	1,186232
chb22_25	921600	18944	803584	822528	45430	19031	18477	2,458737
chb23_06	1923584	28928	1014272	1043200	37976	14237	13875	2,737098

Table 4.5. Channel17 CL values Total Sample-Signal contained samples; Total S.Samples, Signal contained seizure samples; S.S.Points- Seziure start point; S.F.Points-Seziure finishing point Sav-Seziure average value after curve length applied; Tav-Total signal average value after curve length applied; Rav- Total average value of Remain part(except seizure) after curve length applied; Ratio-ratio of Seziure average value to Remain average value

Measurment Informations					Channel23			
Seizure	Total Sample	Total S.Sample	S.S.Points	S.F.Points	Sav	Tav	Rav	Ratio
chb01_03	921600	10240	766976	777216	191010	19856	17933	10,65136
chb02_16	245504	20992	33280	54272	108950	67484	63607	1,712864
chb03_03	921600	17664	110592	128256	224560	83191	80428	2,792046
chb04_08	3686400	28416	1650176	1678592	72988	44697	44477	1,641019
chb05_13	921600	28160	278016	306176	379500	57516	47368	8,011821
chb06_13	3686400	3328	129536	132864	50040	68039	68055	0,735285
chb07_13	953856	24576	840960	865536	275490	77176	71931	3,829903
chb08_02	921600	43776	683520	727296	113720	136130	137248	0,828576
chb09_19	1459200	15872	1356544	1372416	542040	156330	152088	3,563979
chb10_38	1843200	22784	1182208	1204992	170160	95870	94940	1,792286
chb11_82	921600	5632	76288	81920	68776	55156	55072	1,248832
chb12_36	921600	6912	167168	174080	43171	44238	44246	0,975703
chb13_19	921600	5632	163328	168960	15641	21267	21302	0,734264
chb14_11	921600	10496	470528	481024	24540	23115	23099	1,062403
chb15_62	921600	27648	192256	219904	20993	12881	12630	1,662139
chb16_11	921600	2304	286720	289024	51134	81692	81769	0,62535
chb17a_04	921600	29440	774400	803840	190370	54452	49967	3,809922
chb18_36	921600	11776	118528	130304	77573	25115	24436	3,174534
chb19_29	921600	19712	758784	778496	408730	38736	30649	13,33572
chb20_12	921600	7424	24064	31488	119690	18495	17673	6,772402
chb21_19	921600	14336	329728	344064	53352	49262	49197	1,084448
chb22_25	921600	18944	803584	822528	326010	91570	86650	3,762385
chb23_06	1923584	28928	1014272	1043200	150410	38968	37266	4,036067

Table 4.6. Channel23 CL values Total Sample-Signal contained samples; Total S.Samples, Signal contained seizure samples; S.S.Points- Seziure start point; S.F.Points-Seziure finishing point Sav-Seziure average value after curve length applied; Tav-Total signal average value after curve length applied; Rav- Total average value of Remain part(except seizure) after curve length applied; Ratio-ratio of Seziure average value to Remain average valu

The curve length values of each selected channels had been recorded in Table 4.2-4.6. In Channel 1 the average value ratio is 3.09 anwith standart deviation 2.76. It contain 3 ratio smaller than 1 which means the the average curvelength value of normal part of EEG signal is greater than seizure contained part of signal's curve length value and also there 6 ratios which is between 1 and 2. The maximum ratio in this table is 11.32.

In Channel 10 the average value ratio is 2.44 and with standart deviation 1.68. It contain 4 ratio smaller than 1 which means the the average curvelength value of normal part of EEG signal is greater than seizure contained part of signal's curve length value and also there 9 ratios which is between 1 and 2. The maximum ratio in this table is 5.8.

In Channel 13 the average value ratio is 3.26 and with standart deviation 2.96. It contain 3 ratio smaller than 1 which means the the average curvelength value of normal part of EEG signal is greater than seizure contained part of signal's curve length value and also there 9 ratios which is between 1 and 2. The maximum ratio in this table is 12.01.

In Channel 17 the average value ratio is 2.35 and with standart deviation 2.05. It contain 3 ratio smaller than 1 which means the the average curvelength value of normal part of EEG signal is greater than seizure contained part of signal's curve length value and also there 11 ratios which is between 1 and 2. The maximum ratio in this table is 6.31.

In Channel 23 the average value ratio is 3.38 and with standart deviation 3.34. It contain 4 ratio smaller than 1 which means the the average curvelength value of normal part of EEG signal is greater than seizure contained part of signal's curve length value and also there 7 ratios which is between 1 and 2. The maximum ratio in this table is 6.31.

Finally the average values and standart deviations given in Table 4.7 and the graph of average values of ratio given in Figure 4.14. Conclude all the result, the second Channel 10 has a most effective channel among them with less average but the minimum standart deviation and this result is consistence with Shoeb's studies.

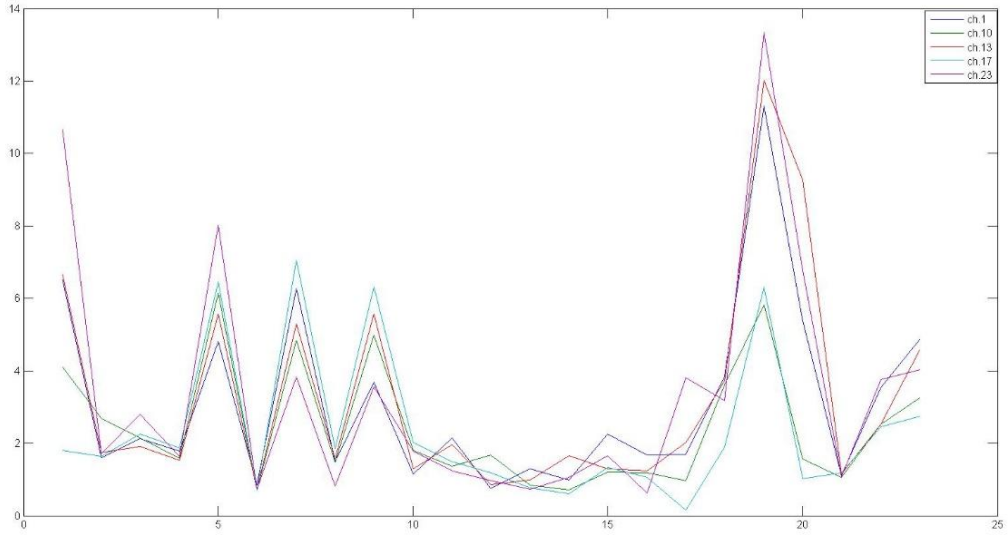

Figure 4.13 The graph of ratios to the different patients in different channels.

Channel #	Mean	STD
Channel01	3,092365246	2,526
Channel10	2,445538795	1,687
Channel13	3,267358873	2,946
Channel17	2,356875378	2,056
Channel23	3,384491486	3,348

Table 4.7 The mean value of ratio's and standard deviation of ratios in five channels.

DISCUSSION

Epilepsy disorder are common neurological disorders and epileptic seizure is the one of the most known disorder in nowadays. Epilepsy affects individuals' life Quality negatively and besides it also influences patient's relatives and family. This change in life quality like randomly movements, become angrier in predictable time else causes decrease in work performance and this costs more than treatment of epilepsy.

Delay in diagnosis of Epilepsy or ignorance of signs and symptoms of illness are important reasons of high prevalence of epilepsy. In this case the researches about epileptic seizures taking important role.

In this study, the detection of seizure and non-seizure condition had been examined with curve length analysis method. Results are given there. But there are several average ratio values which is smaller than normal EEG. Since the signals are provided from open acess source the deeply investigation about details of seizure were not possible.

On the other hand channel 23 has the maximum ratio values but at the same time it has maximum standart deviation value in ratio. So the results are not consistence which each other. At the same time from Fig- 4.13 the, the consistence of all channels could be observable.

Last but not least, the windows values had been hold constant during all processing. But it can be more changeable.

CONCLUSIONS AND RECOMMENDATIONS

All signals had been collected from children. But in the case of collecting signals from non age justified patients, results could be more effective

REFERENCES

[1]-Brian Litt and Javier Echauz. Prediction of Epileptic seizures. The Lancet. Neurology. Vol 1. May 2012.

[2] Kale R. Bringing epilepsy out of the shadows. BMJ. 1997; 315:2-3

[3] Iasemidis LD, Sackellares JC, Zaveri HP, Williams WJ. Phase space topography and the Lyapunov exponent of electrocorticograms in partial seizures. Brain Topogr. Spring. 1990; 2(3):187-201.

[4] R. Esteller, G. Vachtsevanos, J. Echauz, and B. Litt, "A comparison of fractal dimension algorithms using synthetic and experimental data," presented at the IEEE Int. Symp. Circuits and Systems, Orlando, FL, 1999.

[5] R. Esteller et al., "Adaptive method and apparatus for forecasting and controlling neurological disturbances under a multi-level control," US Patent filed, 2000.

[6] Ninah Koolen, Katrien Jansen, Jan Vervisch, Vladimir Matic1, Maarten De Vos Gunnar Naulaers and Sabine Van Huffel "Automatic Burst Detection based on Line Length in the Premature EEG" BIOSIGNALS 2013 - International Conference on Bio-inspired Systems and Signal Processing

[7] Ling Guo, Daniel Rivero, Julián Dorado, Juan R. Rabu˜nal, Alejandro Pazos "Automatic epileptic seizure detection in EEGs based on line length feature and artificial neural networks" Journal of Neuroscience Methods 191 (2010) 101–109

[8] Goldberger AL, Amaral LAN, Glass L, Hausdorff JM, Ivanov PCh, Mark RG, Mietus JE, Moody GB, Peng C-K, Stanley HE, PhyioBank, PhysioToolkit, and Physionet: Components of New reseearch Resource for Complex Physiological Signals, Cirulation 101(23):e215-2-220 [Circulatiın Electronics pages; http://circ.ahajournals.org/cgi/content/full/101/23/e215]; 200(June 13)

[9]. Friedman, D.P., and Rusche, S1999. *FalsMessengers: How Addictive Drugs Change the Brain*. Amsterdam: Harwood Academic Publishers.

[10]National Institute on Drug Abuse (1997). Mind Over Matter: The Brain's Response to Drugs, Teacher's Guide.

[11] National Institute on Drug Abuse. 1997. Mind Over Matter: The Brain's Response to Drugs. NIH Publication No. 98-3592. Retrieved November 14, 2007.

[12] Kandel, E.R.1991. Brain and behavior. In E.R. Kandel, J.H. Schwartz, and T.M. Jessell (Eds.), Principles of Neural Science, 3rd edition (pp. 5–17). Norwalk, CT: Appleton & Lange.

[13] Wolf U, Rapoport MJ, Schweizer TA (2009). "Evaluating the affective component of the cerebellar cognitive affective syndrome". J. Neuropsychiatry Clin. Neurosci. **21** (3): 245–53

[14] Schacter, Daniel L. 2012. Psychology.sec. 3.20

[15] Princeton Review (29 July 2003). Anatomy Coloring Workbook, Second Edition. The Princeton Review. pp. 120–

[16] Markowitsch, H.J.; Staniloiu, A (2011). "Amygdala in action: Relaying biological and social significance to autobiographical memory". Neuropsychologia **49** (4): 718–733

[17] Shipp, Stewart (2007-06-17). "Structure and function of the cerebral cortex". Current Biology **17** (12): R443–9

[18] Davies, Melissa (2002-04-09). "The Neuron: size comparison". Neuroscience: A journey through the brain. Retrieved 2009-06-20

[19]- John G.Nicholls, A.Robert Martin , and Bruce G.Wallace. Introduction to Neuron to Brain: A cellular and Molecular Approach to the Function of the Nervous System. Sunderland, MA: Sinauer,1992

[20] Chudler, Eric H. "Brain Facts and Figures". Neuroscience for Kids. Retrieved 2009-06-20.

[21] Friedman, D.P., and Rusche, S. 1999. False messengers: How addictive drugs change the brain. Amsterdam: Harwood Academic Publishers.

[22] National Institute on Drug Abuse. 1997. Mind Over Matter: The Brain's Response to Drugs. NIH Publication No. 98-3592. Retrieved November 14, 2007.

[23] Kandel, E.R. 1991. Nerve cells and behavior. In E.R. Kandel, J.H. Schwartz, and T.M. Jessell (Eds.), Principles of Neural Science, 3rd edition (pp. 18–32). Norwalk, CT: Appleton & Lange.

[24]National cancer Institute webside - http://training.seer.cancer.gov/brain/tumors/anatomy/neurons.html

[25] Barnett MW, Larkman PM (June 2007) "The action potential". Pract Neurol **7** (3): 92–7

[26] Bernard S. Chang and Daniel H.Lowenstein. Epilepsy. The new England Journal of Medicine, 349(13):1257-1266

[27] http://www.ahaf.org/alzheimers/about/understanding/anatomy-of-thebrain.html

[28] World Health Organization World Health Organization. Atlas: Epilepsy Care in the World.: http://www.who.int/mental_health/neurology/Epilepsy_atlas_r1.pdf. Published 2005, Geneva Switzerland. Accessed May 10, 2014.

[29] 1. EUCARE. European white paper on epilepsy-call to action. Epilepsia, 2003, 44(Suppl 6): 4-8.

[30] Aziz H et al. Comparative epidemiology of epilepsy in Pakistan and Turkey: population-based studies using identical protocols. Epilepsia, 1997; 38:716-722.

[31] Onal AE, Tumerdem Y, Ozturk MK, et al. Epilepsy prevalence in a rural area in Istanbul. Seizure. 2002 Sep;11(6):397-401.

[32]. Serdaroglu A et al. Prevalence of epilepsy in Turkish children between the ages of 0 and 16 years. Journal of Childhood Neurology, 2004; 19:271-274.

[33]. Guekht (Gekht) AB. Epidemiology and economic aspects of epilepsy (article in Russian). Zhurnal Nevrologii i Psikhiatrii Imni S S Korsakova, 2005; 105:63-65.

[34] Crombie DL et al. A survey of the epilepsies in general practice: a report by the research committee of the College of General Practitioners. British Medical Journal, 1960, ii:416-422.

[35]. Forsgren L, Nystrom L. An incident case-referent study of epileptic seizures in adults. Epilepsy Research, 1990; 6:66-80.

[36]. Forsgren L et al. Incidence and clinical characterization of unprovoked seizures in adults-a prospective population-based study. Epilepsia, 1996; 37:224-229.

[37] Juul-Jensen P, Foldspang A. Natural history of epileptic seizures. Epilepsia, 1983, 24:297-312

[38]- Stasiukyniene, V.; Pilvinis, V.; Reingardiene, D.; Janauskaite, L. (2009). "[Epileptic seizures in critically ill patients]". Medicina (Kaunas) **45** (6): 501–7.

[39] Martindale, JL; Goldstein, JN; Pallin, DJ (February 2011). "Emergency department seizure epidemiology." Emergency medicine clinics of North America **29** (1): 15–2

[40] Harrison's Principles of Medicine. 15th edition

[41] Cascino GD (1994). "Epilepsy: contemporary perspectives on evaluation and treatment". Mayo Clinic Proc 69: 1199–1211. http://en.wikipedia.org/wiki

[42] Engel J Jr.(1996). "Surgery for seizures". NEJM 334 (10): 647–652

[43] Hammer, edited by Stephen J. McPhee, Gary D. (2010). "7". Pathophysiology of disease: an introduction to clinical medicine (6th ed. ed.). New York: McGraw-Hill Medica

[44] Simon, David A. Greenberg, Michael J. Aminoff, Roger P. (2012). "12". Clinical neurology (8th ed. ed.). New York: McGraw-Hill Medical

[45] Steven Scha hter. Brainstorms: epilepsy in our Words. Personal Accounts of Living with seizures. Raven Press, 1993

[46] Cooper R, Osselton JW, Shaw JC (1969): EEG Technology, 2nd ed., 275 pp. Butterworths, London

[47] Gilmore RL (1994): J. Clin. Neurophysiol RL Gilmore (ed.): American Electroencephalographic Society guidelines in electroencephalography, evoked potentials, and polysomnography, J. Clin. Neurophysiol. 11:(1, January) 147 pp

[47] R. Esteller, J. Echauz, T. Cheng, B. Litt, and B. Pless, “Line length: An efficient feature for seizure onset detection,” Proc 23rd Int. Conf. IEEE Engineering Medicine Biology Soc., vol. 2, pp. 1707–1710, 2001.

[48] A.Shoeb et al./Epilepsy & Behavior 5(2004) 483-498

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