Randomness Prediction of Brain Tumor by Analyzing EEG Signal Using Approximate Entropy and Regression Analysis

Md. Kamrul Hasan, Md. Osman Goni Nayeem, Md. Asif Ahamed, Maung Ning Wan, Mohiuddin Ahmad

Abstract*—Brain activity commonly known as the Electroencephalographic (EEG) signal is the measure of the brain state either normal or abnormal condition of the human brain. The brain contains about 10 Billion or more working brain cells. Brain tumor is life frightening disease of human brain. The brain tumor is the disease which neutralize the neuron day by day on the brain. The detection of brain tumor is one of the major problem by analyzing the brain signal (EEG Signal). The more the age of the tumor in the brain indicates the more randomness that is more unpredictable. In our research, we tried to find out the solution for the detection of tumor level that exist in the human brain. To complete this research, EEG data of the tumor patients having different age of tumor growth is analyzed and regression equation is determined for the prediction of the randomness. By using this regression equation, clinical person may provide the treatment for the tumor affected persons.

***Index Terms*—EEG Signal, Approximate Entropy (ApEn), Brain Tumor, Regression Analysis.**

I. INTRODUCTION

Electroencephalogram (EEG) can be defined as a representative signal containing of information about the electrical activity produced by the cerebral cortex nerve cells [1]. EEG recorded by the scalp electrodes is a superposition of a large amount of electrical potentials produced various sources like brain cells, neurons, artifacts [2]. EEG test results are obligate in identifying central nervous system disorders, brain tumors, and cerebrovascular disorders, metabolic and toxic encephalopathies [3-4]. Detection of brain tumors is an important application of EEG signal. Brain normallyproduces new cells only when they are needed to replace old or damaged ones and generally this process takes place in an orderly and controlled manner.If the processgets out of control, the cells will continue to divide, developing into a lump, which is called a tumor [5]. Brain tumor is the uncharacteristic accrual of cells inside the brain or the skullthat can either be cancerous or non-cancerous [6].In 69% of the brain tumor cases diagnosis or early treatment are either missed or delayed because the most of the brain tumor symptoms are highly misleading according to the survey [7].

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The most commonly used imaging methods for diagnosis of brain tumor are Computerized Tomography (CT), Magnetic Resonance Imaging (MRI), positron emission tomography (PET), single-photon emission computed tomography (SPECT), and functional MRI (fMRI) [8-9]. CT imaging technique is often used for diagnosis of brain tumors because of its high accuracy in initial diagnosis of primary pathology [10]. However, those advanced neuroimaging techniques such as MRI and CT or biopsy are costly, invasive and involve risks like hazardous radiation [3]. As EEG is a non-invasive low cost procedure, it is a mutable tumor diagnosis method [11].In brain tumor diagnosis, EEG is most conversant in measuring how the brain responds to treatments. In this research, our goal is to develop an automated tool which can easily analyses the EEG signal and relative information of the brain tumor. We use approximate entropy and regression analysis for analyzing the EEG signal containing brain tumor.

II. MATHEMATICAL CONTEXTUAL

1. Approximate Entropy (ApEn)

Approximate entropy can be defined as a measure that quantifies the regularity or randomness of a time series data [12]. Approximate entropy algorithm summarizes the time series in to a single non negative number. A high value of approximate entropy signifies more irregularity, on the contrary a low value signifies that the time series is deterministic [13]. Approximate entropy reflects the intra-cortical information flow in the brain when applied to EEG signals [14]. Mathematical procedure of approximate entropy (ApEn) calculation are described below step by step [15], [16]. If N data points form a time series {u(n)} = u(1), u(2), u(3)………u(N), the steps to compute approximate entropy are

Step-1: Form a time series of data u(1), u(2)…….u(N). These are N raw data values from measurement equally spaced in time.

Step-2: Fix m, an integer, and r, a positive real number. The value of m represents the length of compared run of data, and r specifies a filtering level.

Step-3: Form a sequence of vectors x(1), x(2)…..x(N-m+1), in Rm, real m-dimensional space defined by

$$x(i) = [u(i), u(i+1) \dots\dots\dots\dots\dots\dots\dots u(i+m-1)]$$

Step-4: Use the sequence x(1), x(2)……………x(N-m+1) to construct, for each i, $1 \le i \le N-m+1$

$$c\_i\^m = (number\ of\ x(j)\ such\ that\ d[x(i), x(j)] < r)\ /\ (n - m + 1)$$

$$in\ which\ d[x, x^\wedge *]\ is\ defined\ as$$

$$d[x, x^\wedge *] = (\_a\ \ {}^\wedge max)|u(a) - u^\wedge * \ (a)|$$

Where u(a) are the m scalar components of x, d represents the distance between the vectors x(i) and x(j), given by the maximum difference in their respective scalar components. Note that j takes on all values, so the match provided when i=j will be counted.

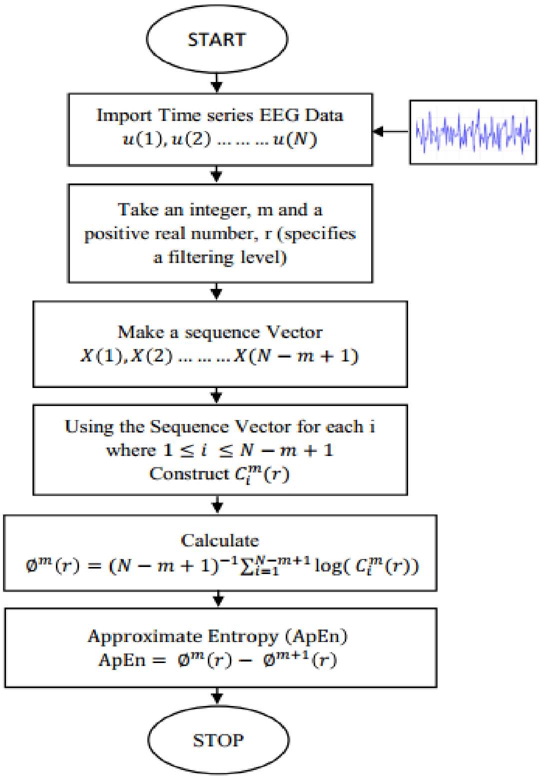

Figure 1. Flow chart for measuring approximate entropy.

Step-5: Define

$$\emptyset^m(r) = (N - m + 1)^{-1} \sum_{i=1}^{N-m+1} \log\left(c_i^m(r)\right)$$

Step-6: Finally determine the value of ApEn

$$ApEn = \emptyset^m(r) - \emptyset^{m+1}(r)$$

The overall flow diagram is shown in the Figure 1.

2. Regression Analysis

In mathematics, regression analysis is a statistical progression for approximating the relationships among variables. In a nutshell, it is the procedure to find out the mathematical relationship between a dependent variable with independent variable. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In limited conditions, regression analysis can be used to infer causal relationships between the independent and dependent variables [17], [18]. Regression analysis is widely used for prediction and forecasting of dependent variable. Regression models for prediction are often useful even when the assumptions are moderately violated, although they may not perform optimally. However, in many applications, especially with small effects or questions of causality based on observational data, regression methods can give misleading results [19], [20]. The function which fits a polynomial regression model to powers of a single predictor by the method of linear least squares is mention below in equation (2)

$$Y = b_0 + b_1 x^1 + b_2 x^2 + \cdots \dots\dots\dots + b_k x^k$$

Where Y represents predicted outcome value for the polynomial model with regression coefficients b1 to bk for kth order polynomial and Y intercept b0. Graphical representation is in Figure 2.

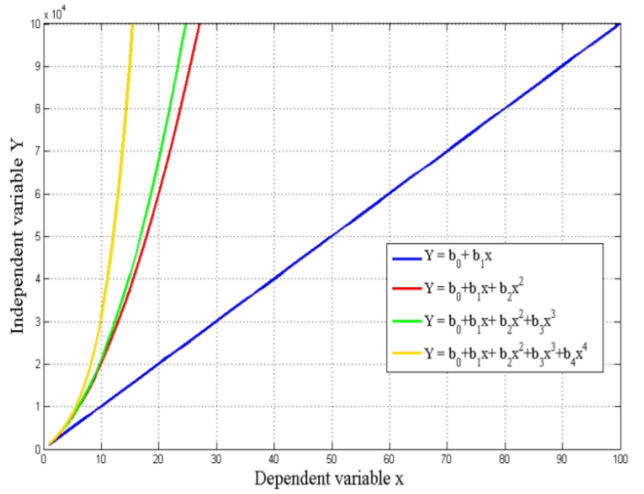

Figure 2. Graphical representation of different order polynomial model with regression coefficients.

III. EEG Signal Extraction

EEG recording is the sophisticated process in clinics, BCI research as well as biomedical research. The quality of EEG signal depends on its extraction from the brain and the noise on this signal depends on the electrode position on scalp as shown in Figure 3.

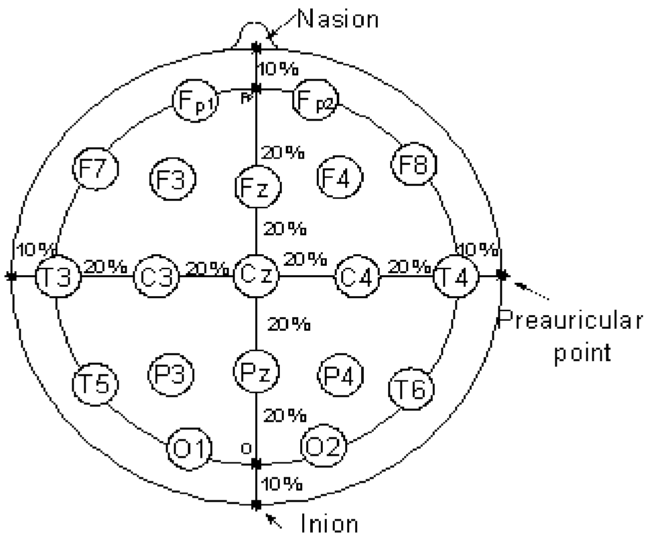

Figure 3. Graphical 10-20 electrodes placement scheme.

There are some key stage which should be performed for the extraction of EEG signal from the human brain [21]. These are mentioned below-

i. Subject should be relaxed during the extraction
ii. Electrodes should place at right position

iii. Subjects should be seated in front of visual stimulator as shown in Fig. 4.
iv. Reference electrode should be properly select
v. Calibration of extraction unit should be proper
vi. Artifacts are removed by using various filter (NF, LPF or HPF)

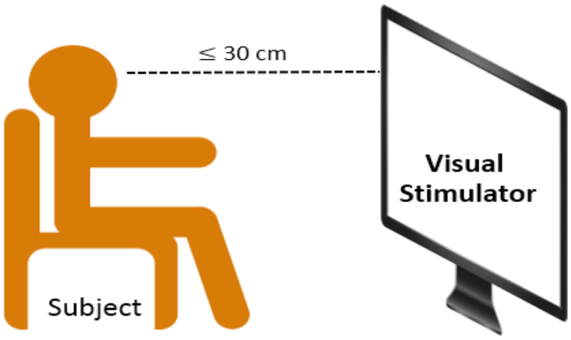

Figure 4. Visual Stimulator in front of Subject

The most common types of electrodes are wet electrode for the EEG scalp recording, they should require contact gel (Ag-AgCl) which avoid potential shift due to electrode polarization. To get a good (i. e., with impedance below 5 Kilo-Ohms) contact between electrode and skin surface, the skin has to be cleaned with ether or alcohol for fat or dirt removal.

IV. RESULTS AND DISCUSSION

With the help of the modern EEG instrumentation techniques the brain electrical activities which is normal and abnormal can be recorded with high accuracy. The typical EEG signal is shown in the Fig. 5 in which the upper signal is for the normal healthy subjects and lower portion is for the tumor patients. This extracted EEG signal can easily be used for the diagnosis of brain tumor or can be used for the tumor level prediction

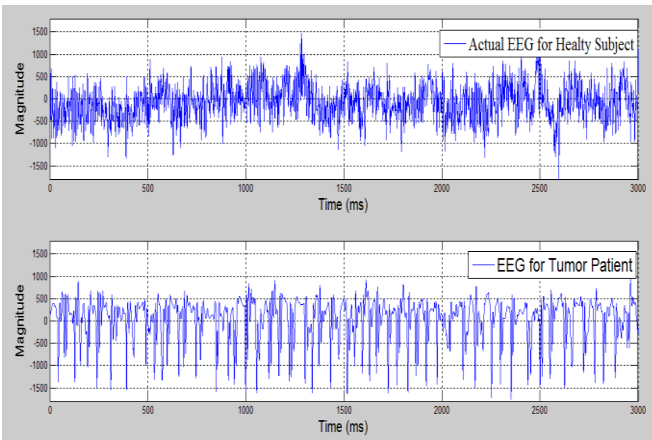

Figure 5. Typical representation of EEG signal one is for normal condition (Up) another is for tumor patients (Down)

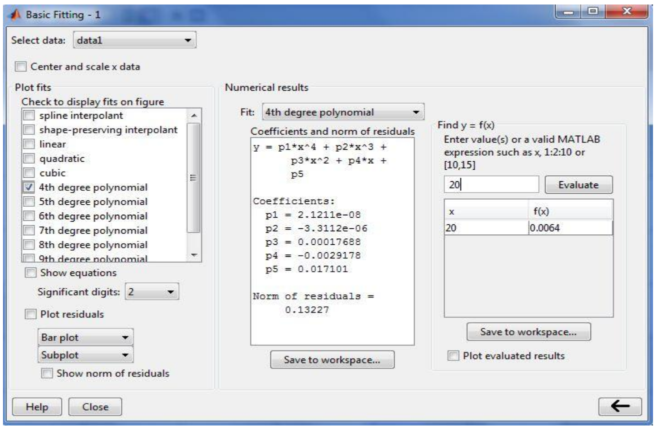

Figure 6. Curve fitting Toolbox for ApEn fitting (4th Order)

Fig. 6 shows the MATLAB Toolbox for the curve fitting. In this toolbox the approximate entropy, a feature which determine the degree of randomness is fitted corresponding to different age of tumor growth of brain tumor. Here 4th order fitting is used for the greater accuracy and less computational complexity. From this regression, a corresponding regression equation (Eq. 2) is determined which predicts the behavior of randomness of brain signal viz EEG signal mathematically. The regression equation is mentioned in the Eq. 2. In this equation the dependent variable is Y which indicate the ApEn and independent variable X which indicate the tumor growth time. Form this equation, one can predict the randomness of tumor affected EEG signal by selecting any value of growth time, X. Fig. 7 is the fitting of ApEn with the different age of growth.

$$Y_{ApEn} = 2.1211 \times 10^{-08} x^4 - 3.3112 \times 10^{-06} x^3 + 0.00017688 - 0.0029178 x^1 + 0.017101 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

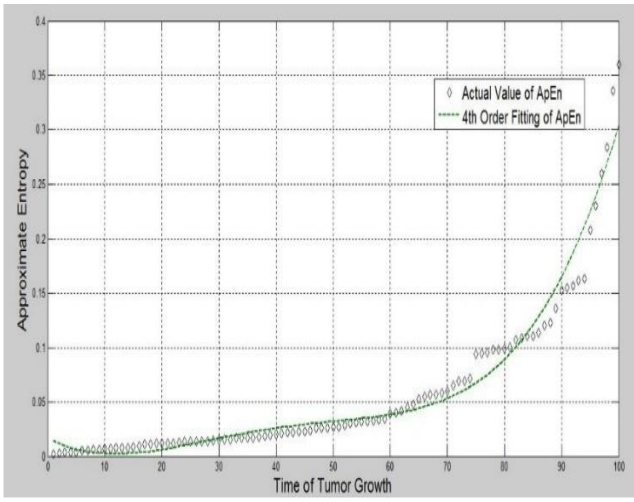

Figure 7. 4th order fitting of ApEn with growth time

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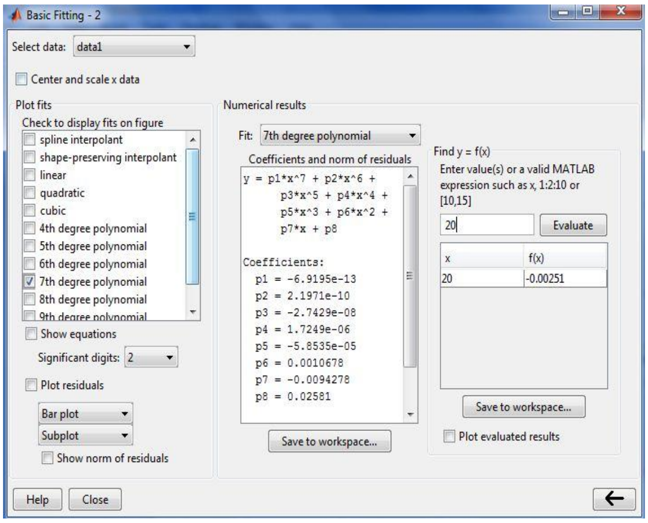

Figure 8. Curve fitting Toolbox for regression fitting (7th Order)

$$Y_{Residual\ (ApEn)} = -6.9195x^{-13} + 2.1971 \times 10^{-10}x^6 - 2.7429 \times 10^{-08}x^5 + 1.7249 \times 10^{-06}x^4 - 5.08535 \times 10^{-05}x^3 + 0.0010678x^2 - 0.0094278x^1 + 0.02581 \quad (3)$$

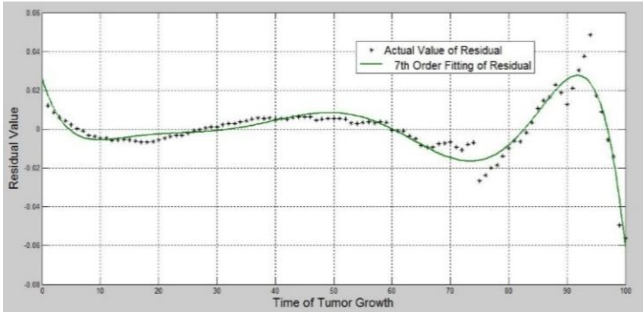

Figure 9. 7th order fitting of residual with growth time

TABLE I. PREDICTION OF RANDOMNESS AND CORRESPONDING ERROR

Age of tumor growth	Actual Value of ApEn (x_a)	Predicted Value of ApEn (x_p)	Error (%) $(\frac{x_a - x_p}{x_a}) \times 100$	Avg. Error
1	0.0022	0.0024	9.09 %	7.01 %
5	0.0041	0.0046	12.20 %	
10	0.0071	0.0076	07.04 %	
15	0.0085	0.0090	05.88 %	
20	0.0119	0.0120	0.85 5	

The modification between the predicted value and actual value of the independent value is called the residual which is the measure of accuracy of prediction. In Fig. 8 the Toolbox for fitting of residual is shown. The residual of tumor randomness prediction (7th Order) is shown in Fig. 9 and its regression equation is Eq. (3). From this equation, we may find the error of prediction at any age of the Tumor growth. In the Table I, the residual or error calculation is shown. Here, it is noticeable that the error level of randomness prediction is too low (average value 7.01 %). The smaller value of residual or error is found at the age of 20 years that indicate at the 20th age of tumor growth the curve is best fitted. The larger value of error indicate less fitting of the ApEn with time of tumor growth.

V. CONCLUSION

The scalp signal of living animal that is human being known as EEG signal can be analyzed for the diagnosis of various cerebral disorders which is progressively increasing. The modern advanced neuroimaging techniques such as MRI and CT-SCAN are the most reliable for the detection of the brain disorder. In our manuscript, a simple statistical approach is clearly described using Approximate Entropy (ApEn) and regression analysis. The regression equation from the regression analysis can be used for the prediction of tumor level.

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