ISTANBUL UNIVERSITY –
JOURNAL OF ELECTRICAL & ELECTRONICS ENGINEERING
YEAR : 2006 (41 - 44)
VOLUME : 6
NUMBER : 1

INVESTIGATION OF THE INTERACTION BETWEEN CHAOTIC MUSICS AND HUMAN'S BRAIN

Mehmet Engin[1] **Tayfun Dalbastı**[2] **Emre Ertuğrul**[3]
Sinan Öz[4] **Erkan Zeki Engin**[5]

[1,3,4,5] Ege University, Faculty of Engineering, Electrical&Electronics Engineering Department

[2]Ege University, Medical Faculty, Neurosurgery Department

[1] E-mail: mengin@bornova.ege.edu.tr

ABSTRACT

In this paper, we examined methods for analysing EEG (Electroencephalogram) during music listening and the relationship between EEG and music cognition. We especially focused on non-linear signal analysis for EEGs. We calculated correlation dimension (CD) and Lyapunov exponents (LE) signals of interest for two healthy subjects. Thus, we try to obtain the experimental results from the beginnings works about the possibility of medical treatment by music.

Keywords: *Music cognition, chaotic analysis, EEG, medical treatment.*

1. INTRODUCTION

Listening to music plays an important role among higher brain functions [1]. However, only few studies based on EEG were dedicated to this question. There is no consensus about the contribution of distinct areas of the brain to the processing of music. The complex behaviour of the neural network at various levels strongly emphasizes the non-linear nature of interactions in human's brain. Music and sound processing rely on widely distributed cortical neural networks involving superior temporal and dorsolateral frontal lobes, and also parietal brain regions [2].

Listening to music however is much more than processing acoustics patterns; music can be powerful tool to elicit emotions. Little is known about the neurobiological basis of these emotions. The brain system consists of dozens of functional subsystems and their cooperative process enables high-level recognition such a music listening. On the other hand, in recent years the progress of the musicotherapy is remarkable. Also, the importance of the musicotherapy has been more closely evaluated [3]. Linear methods that have been used in the field of biomedical signal processing. It seems that these techniques cannot always be powerful enough to analyse signal that originate from very complex non-linear living systems such as human's brain. Recent developments in the

Received Date : 02.03.2005
Accepted Date: 02.12.2005

theory of non-linear dynamics have highlighted some methods for analysis of the series representing signals measured from non-linear segments.

In this study, we investigated of the mathematical analysis of different kinds of artificial chaotic music forms by using chaotic parameters such as correlation dimension and Lyapunov exponent. In order to establish the interaction between any kind of chaotic music and human's brain, EEG signals taking from two subjects are evaluated respect to same chaotic parameters. Thus, it is purposed to obtain some proofs about treatment by chaotic structured music.

2. METHODS

The description of non-linear systems or processes starts with usually an attempt to reconstruct its state-space portrait. One possible way of doing this can be the Takens method of delays [4]. This method explains how to construct an attractor of dynamic systems in k-dimensional state-space from only of a one-dimensional time sequence. But often necessary to use a simple parametric representation such as correlation dimension. There are other tools; e.g., Lyapunov exponent, Point correlation, Kolmogorov entropy, etc. We have used Correlation dimension and Lyapunov exponent on the analysis of music and EEG's.

A. Correlation Dimension

The CD is given based on pairs of points in the phase-space set that are separated by a distance of less than r . CD is computed from [5];

$$CD = \lim_{r \to 0} \frac{\log C(r)}{\log r} \qquad (1)$$

where the correlation integral $C(r)$ is;

$$C(r) = \frac{1}{N^2} \sum_{i=1}^{N} \sum_{\substack{j=1 \\ i \neq j}}^{N} \theta\left(r - \left|X_i - X_j\right|\right) \qquad (2)$$

where X_i , X_j are the points of the trajectory in the phase space. N is the number of data points in the phase space, the distance r is a radius around each reference point X_i , and θ is the Heavyside function which excludes values outside of radius r . CDs correspond to the properties of the physiological process investigated. Those properties could be regular deterministic, chaotic, or stochastic behaviour.

B. Lyapunov Exponent

Lyapunov exponents quantify the average growth of infinitesimally small errors in initial points. Chaotic and stochastic processes are characterized by positive LEs, which means that neighbouring points of trajectories in the phase space diverge [5].

$$LE = \frac{1}{N\Delta k} \sum_{k=1}^{N} \log_2 \frac{L(k + \Delta k)}{L(k)} \qquad (4)$$

where $L(k + \Delta k)$ is distance between the developed points in the phase space. $L(k)$ represents distance between starting point and the nearest Euclidean neighbour and Δk is prediction time interval. LE is negative, zero, positive finite and infinite for stable fixed point, stable limit cycle, chaos and noise, respectively.

3. EXPERIMENTAL STUDIES AND RESULTS

In the first step, we would like to choose chaotic musical recordings. For this aim, we downloaded nine artificial chaotic music recordings from different web sites [6]. These recordings are called; gingerbread2, lamdafnfn2, Jetson lo,Blade, Ghostbusters,Apocalyptical NothingsElse,Dondesem,DumanHerseyiYak, Dussokagisevdanates, respectively. In order to investigate interaction between these musical recordings and human's EEG, we choose two healthy male subjects. Both subjects were undergraduate students aged 23 years old. The mental condition of subjects during the experiments should be identical and subjects must pay attention to music. To satisfy these requirements, we choose persons with musical experience as subjects. The EEG data of two subjects were recorded under relaxing condition; relaxing with eyes closed for 2 minutes and music listening condition; listening to music for nine songs with eyes closed for 2 minutes.

EEG's were recorded continuously during relaxing and listening conditions for both subjects, with electrodes positioned according to the International 10/20 Electrode System at Ege University Medical School, Department of Neurosurgery. In the signal analysis step for EEGs and musical recordings: we compute auto mutual information function, Embedding dimension, Correlation dimension by Takens estimator [4]. For calculating Lyapunov exponent, we have used prediction error.

Figure 1 shows an example of relaxing EEG signal for subject 1 and corresponding strange attractor.

Under listening to music recording 1, strange attractor of subject 1's EEG as shown in Figure 2.

Table 1 shows, Correlation dimensions and Lyapunov exponents for all musical recordings. As shown in Table 1: Since Correlation dimension and Lyapunov exponent values are positive and finite numbers, we can say that corresponding EEG signals are low dimensional chaotic number. Only music recording 2 increases chaotic property of EEG for subject 2 (i.e. LE=4.05 under listening while LE=3.7 under relaxing). However, music recordings 1, 2, 3, 4 increase chaotic property of EEG for subject 1 (i.e. LE=4.5, 4.2, 4.3, 4.1 under listening, while LE=3.7 under relaxing). From these results, we can say that chaotic structure of the EEGs is dependent on subjects, as well. On the other hand, Correlation dimensions values are decreasing for all musical recordings expect for recordings 7. Thus, these values lead to low complexity of investigated non-linear physiological system regarding to relaxing state.

4. CONCLUSIONS

As a method to studying music recognition by using human's EEGs analysis, we have reported on the non-linear analysis using chaotic parameters. We observed that chaotic parameters such as CD and LE of the EEG's for both subjects are changing according to musical structure.

This paper reports mainly on the comparison conditions between relaxing and listening to music. But stricter evaluations are possible by improving the control parameter of the contrastive experiments. However, the main goal of this study is proving the experimental results obtain from the beginning works about the possibility of medical treatment by music.

REFERENCES

[1] Bhattacharya J., Petshe H., and Pereda E., "Interdependencies in the spontaneous EEG while listening to music", Elsevier International Journal of Psychophysiology, 42 (2001), pp. 287-301.

[2] Altenmüller E., Schürmann K., Lim V.K., and Parlitz D., "Hits to the left, flops to the right: different emotions during listening to music are reflected in cortical lateralization patterns", Pergamon, Neuropsycholigia 40 (2002), pp. 2242-2256.

[3] Kawamura K., "New supporting system for musicotherapy using computer processing", 18th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Amsterdam 1996.

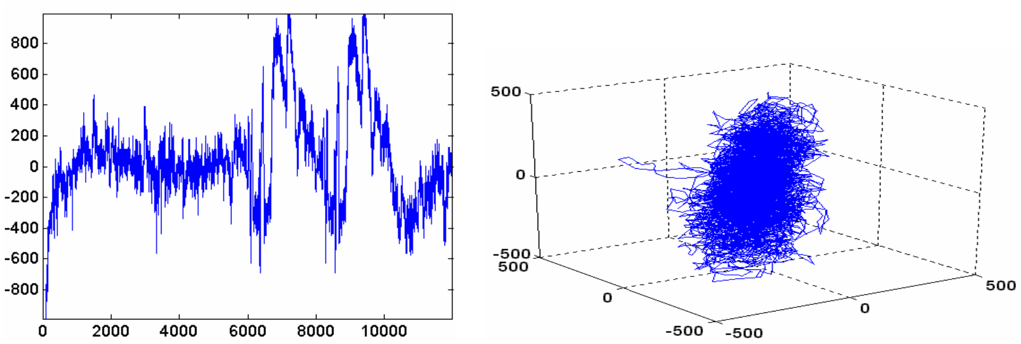
[4] Fojt O. and Holcik J., "Applying non-linear dynamics to ECG signal processing", IEEE Eng. In Med. And Biology Magazine, pp. 96-101, March/April 1988.

[5] Hoyer D., Schmidt K., Bauer R., Zwiener U., Köhler M., Lüthke B., and Eiselt M., "Non-linear analysis of heart-rate and respiratory dynamics", IEEE Engineering in Medicine and Biology Magazine, pp. 31-39, Jan/Feb. 1997.

[6] WebSites:
http://www.gweep.net/~rocko/sufficiency/node27.html
http://arttech.about.com/library/bl_chaos_music.htm
http://www.math.pitt.edu/~gartside/math0450/chaos/studentReports/ HeatherElko.html
http://members.aol.com/dspondike/fractal.html
http://members.aol.com/dspondike/mnr/linknav.html#navfractal
http://members.aol.com/dspondike/mnr/mnrfractal.html#linkfractal
http://hometown.aol.com/strohbeen/fml.html
http://www.pjbmusic2.freeserve.co.uk/
http://www.elucida.com/TranslatingSpace.html

Table 1. Correlation dimensions and Lyapunov exponents.

	Correlation dimension (CD)		Lyapunov exponent (LE)	
	Subject 1	Subject 2	Subject 1	Subject 2
Relaxing condition	2.9497	3.0277	3.7	3.7
1. Gingerbread2	2.7320	2.4929	4.5	3.4
2. Lamdafnfn2	2.8440	2.3585	4.2	4.05
3. Jetson_lo	2.1570		4.3	
4. Blade	2.8165	2.6520	4.1	3.5
5. Ghostbusters		2.9459		3.4
6. ApocalypticaNothingElse	2.7870	2.5849	3.5	3.3
7. Dondesem	4.5050		2.8	
8. DumanHerseyiYak	2.8479	2.0602	3.4	3.1
9. Dussokagisevdanates		2.4067		3.2



(a) **(b)**

Fig. 1. An example of EEG its strange attractor:
(a) EEG signal for subject 1 and (b) its strange attractor.

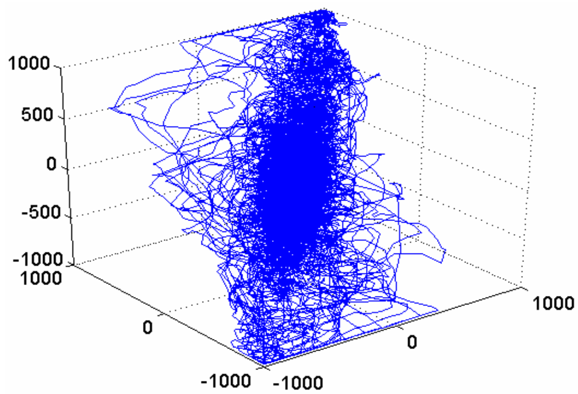


Fig. 2. Strange attractor of subject 1' EEG under listening to music recording 1.