Proceedings of the International MultiConference of Engineers and Computer Scientists 2013 Vol II,
IMECS 2013, March 13 - 15, 2013, Hong Kong

Examination of Temporal Characteristic of Wavelet Subbands of Scalp Epileptic EEG Based on the Local Min-Max

Suparerk Janjarasjitt

***Abstract*—In this paper, the temporal characteristic of wavelet subbands of scalp EEG of an epilepsy patient associated with different states of the brain is examined using the so-called number of local min-max. The computational results show that during the seizure onset the number of local min-max of the D_1 subband extremely increases while the number of local min-max of the A_3 subband remarkably drops. In addition, there are significant differences in the number of local min-max of epileptic EEG during the epileptic seizure event compared to other brain states. This suggests that the number of local min-max may be used as a useful feature for epileptic seizure detection.**

***Index Terms*—electroencephalogram, seizure, epilepsy, subband local min-max.**

I. Introduction

Epilepsy is a common brain disorder in which clusters of neurons signal abnormally [1]. More than 50 million individuals worldwide, about 1% of the world's population are affected by epilepsy [2]. In epilepsy, the normal pattern of neuronal activity is disturbed, causing strange sensations, emotions, and behavior, that sometimes include convulsions, muscle spasms, and loss of consciousness [1]. There are many possible causes for seizures ranging from illness to brain damage to abnormal brain development [1], and epileptic seizures are manifestations of epilepsy [3]. The electroencephalogram (EEG) is a signal that quantifies the electrical activity of the brain, usually from scalp recordings and is commonly used to assess and detect brain abnormalities, and is crucial for the diagnosis of epilepsy [1].

Temporal patterns of EEG signals can provide important information and such features can be obtained by visual inspection/analysis and using computational tools. Concepts and computational tools derived from the study of complex systems including nonlinear dynamics have gained increasing interest for applications in biology and medicine [4]. The correlation integral and dimension are common nonlinear dynamical analysis techniques that have been applied to EEG signal analysis [5] to study various aspects. Epilepsy is an important application for nonlinear EEG analysis [6], [7].

In this paper, the temporal characteristic of sleep EEG quantified in terms of *local minima* and *local maxima* is examined. Local minima and maxima may be defined in various manners. In general, local min-max detection algorithms rely on thresholding the magnitudes in a specified time window. In this study, the local minima (local maxima) is defined as a point whose amplitude is less (greater) than its neighbors. The local minima and maxima thus specify extreme points of the signal where the magnitude changes direction [8]. This computational analysis technique was previously applied to analyze epileptic EEG and sleep EEG data using measures based on various characteristics of the local min-max [9]–[12].

The temporal characteristic of scalp epileptic EEG is quantified from the total number of both local minima and local maxima, referred to as the number of local min-max N_λ. In addition, rather than analyzing the full spectral band of epileptic EEG, the computational analysis is applied to wavelet subbands of epileptic EEG signal that are reconstructed from detail and approximate coefficients of epileptic EEG signal. From the computational results, it is observed that for various wavelet subbands there are distinguishable temporal characteristics of the epileptic EEG associated with different pathological brain states as measured using the number of local min-max N_λ. Furthermore, the most remarkable temporal characteristics of the epileptic EEG signal can be noticed in the lower and highest frequency subbands where as the number of local min-max N_λ of the epileptic EEG signal during epileptic seizure is significantly different from that associated with other brain states.

II. Methods

A. Data and Subjects

The EEG data analyzed in this study were obtained from the CHB-MIT scalp EEG database [13]. This database consists of EEG recordings from pediatric subjects with intractable seizures at the Children's Hospital Boston [13]. The EEG data were recorded using a sampling frequency of 256 Hz with 16-bit resolution A/D. In addition, these recordings used the international 10-20 systems of EEG electrode positions and nomenclature [13].

B. Local Min-Max and Local Min-Max Feature

As defined in [9]–[12], the local minima λ_{min} of the signal x are defined as point whose amplitude is less than that of its consecutive preceding and succeeding points while the local maxima λ_{max} are defined as point whose amplitude is greater than that of its consecutive preceding and succeeding points.

Let $x[n]$ be a sequence of EEG samples where $n = 0, 1, \ldots, N?1$, and N denotes the length of signal. Computationally, the local minima λ_{min} and maxima λ_{max} are given

Manuscript received December 7, 2012. This work is supported by Ubon Ratchathani University.

S. Janjarasjitt is with the Department of Electrical and Electronic Engineering, Ubon Ratchathani University, Ubon Ratchathani 34190 Thailand e-mail: ensupajt@ubu.ac.th. He also serves as an adjunct assistant professor at the Department of Electrical Engineering and Computer Science, Case Western Reserve University, Cleveland, Ohio 44106 USA.

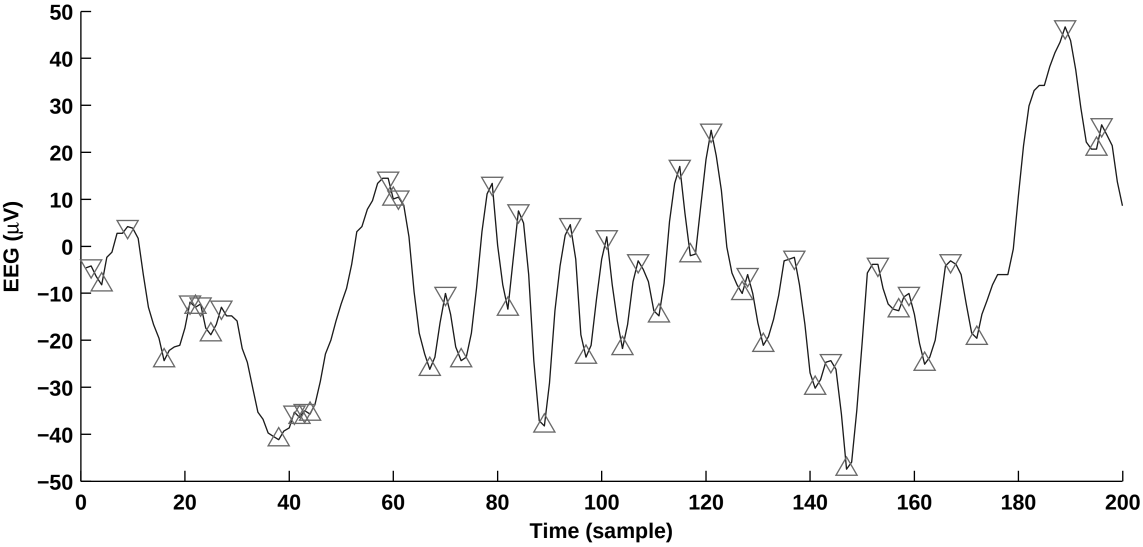


Fig. 1. Local minima λ_{min} plotted in '△' and local maxima λ_{max} plotted in '▽' of an EEG signal.

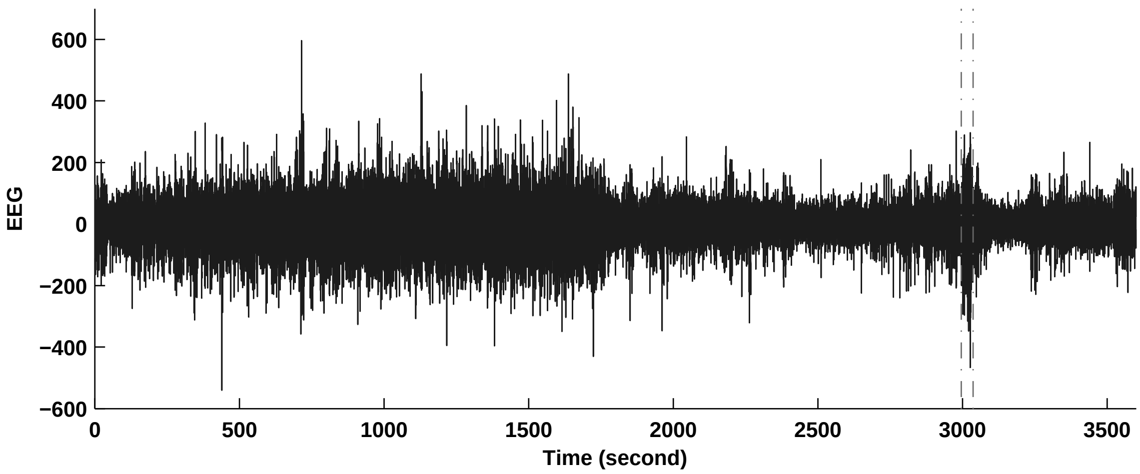


Fig. 2. The scalp epileptic EEG (plotted in solid line), and the begining and the end of epileptic seizure (plotted in dashed line).

by [9]–[12]

$$\lambda_{\text{min}} = \left\{ n = \left\lceil \frac{s+t}{2} \right\rceil \;\middle|\; x[s-1] > x[n] \text{ and } x[t+1] > x[n] \right\} \tag{1}$$

and

$$\lambda_{\text{max}} = \left\{ n = \left\lceil \frac{s+t}{2} \right\rceil \;\middle|\; x[s-1] < x[n] \text{ and } x[t+1] < x[n] \right\} \tag{2}$$

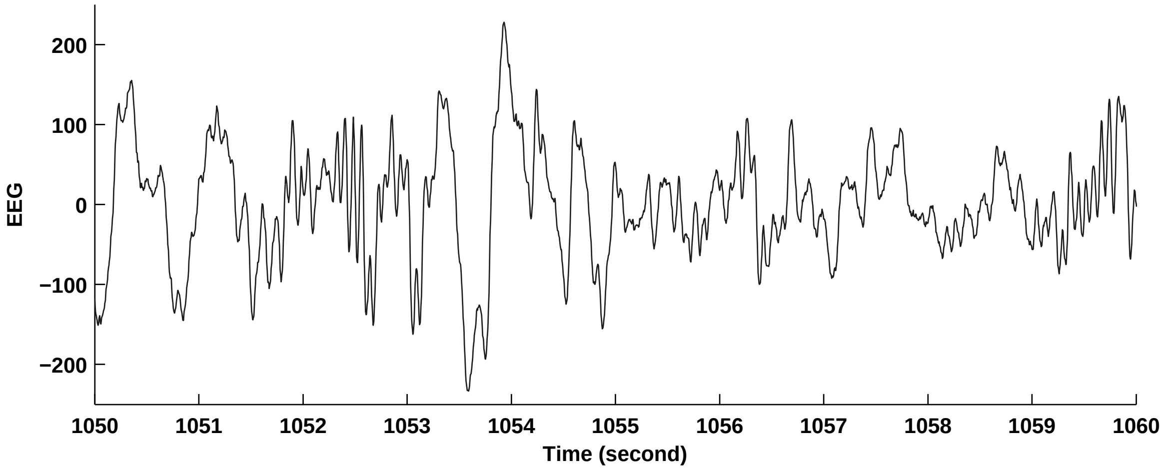
where $x[s] = x[s+1] = \ldots = x[n] = x[n+1] = \ldots = x[t]$. The local minima and the local maxima of the EEG signal are depicted in Fig. 1.

In this study, the temporal characteristic of EEG signal is measured using the total number of local minima λ_{min} and local maxima λ_{max} that is referred to as the number of local min-max N_λ.

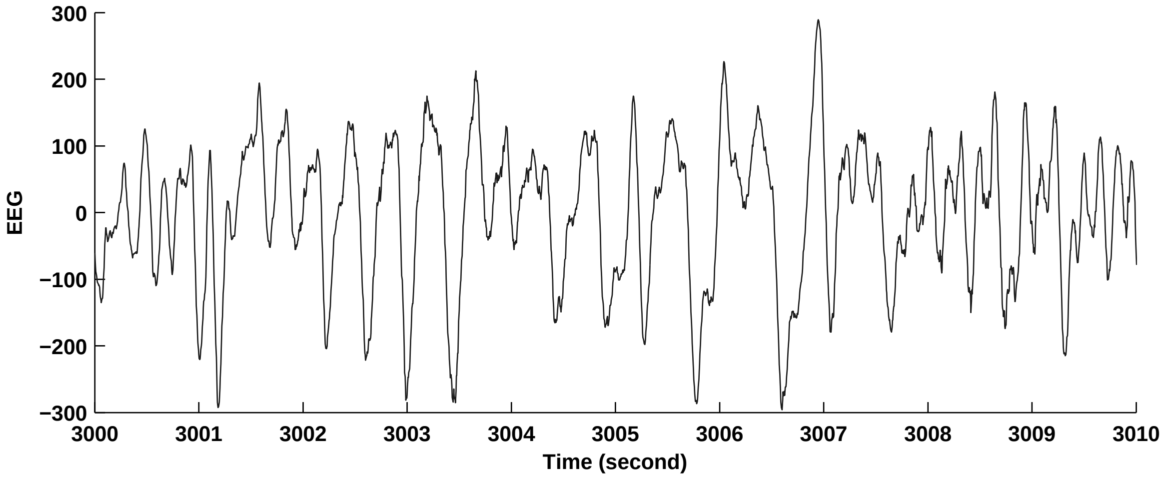
C. Analytical Framework

The EEG recording chb01_03 was used in this study. This recording is one hour long. Further, only the Fz-Cz channel of the epileptic EEG data was examined. Fig. 2 illustrates the corresponding scalp epileptic EEG signal. In this EEG recording, there is one epileptic seizure event occurs between 2,996 and 3,036 seconds where the dashed lines in Fig. 2 indicate the beginning and the end of the epileptic seizure. In addition, exemplary sections of scalp EEG during a non-seizure period and during an epileptic seizure event are compared in Fig. 3.

The epileptic EEG signal is divided into non-overlapped 10-second epochs. The epileptic EEG epochs are subsequently decomposed into four levels using the discrete Meyer wavelets. There are thus four wavelet subbands: D_1, D_2, D_3 and A_3 that correspond to 64–128Hz, 32–64Hz, 16–32Hz and 0–16Hz subbands, respectively. The number of local min-max N_λ of the wavelet subbands of epileptic EEG reconstructed from the detail and approximate coefficients is examined. The temporal characteristic of the wavelet subband of epileptic EEG signal as measured using the



(a) A section of scalp EEG during a non-seizure period



(b) A section of scalp EEG during an epileptic seizure event

Fig. 3. Sections of scalp EEG corresponding to different pathological brain states.

number of local min-max N_λ is examined by classified into three states of the brain: pre-ictal, ictal and post-ictal states.

III. Results

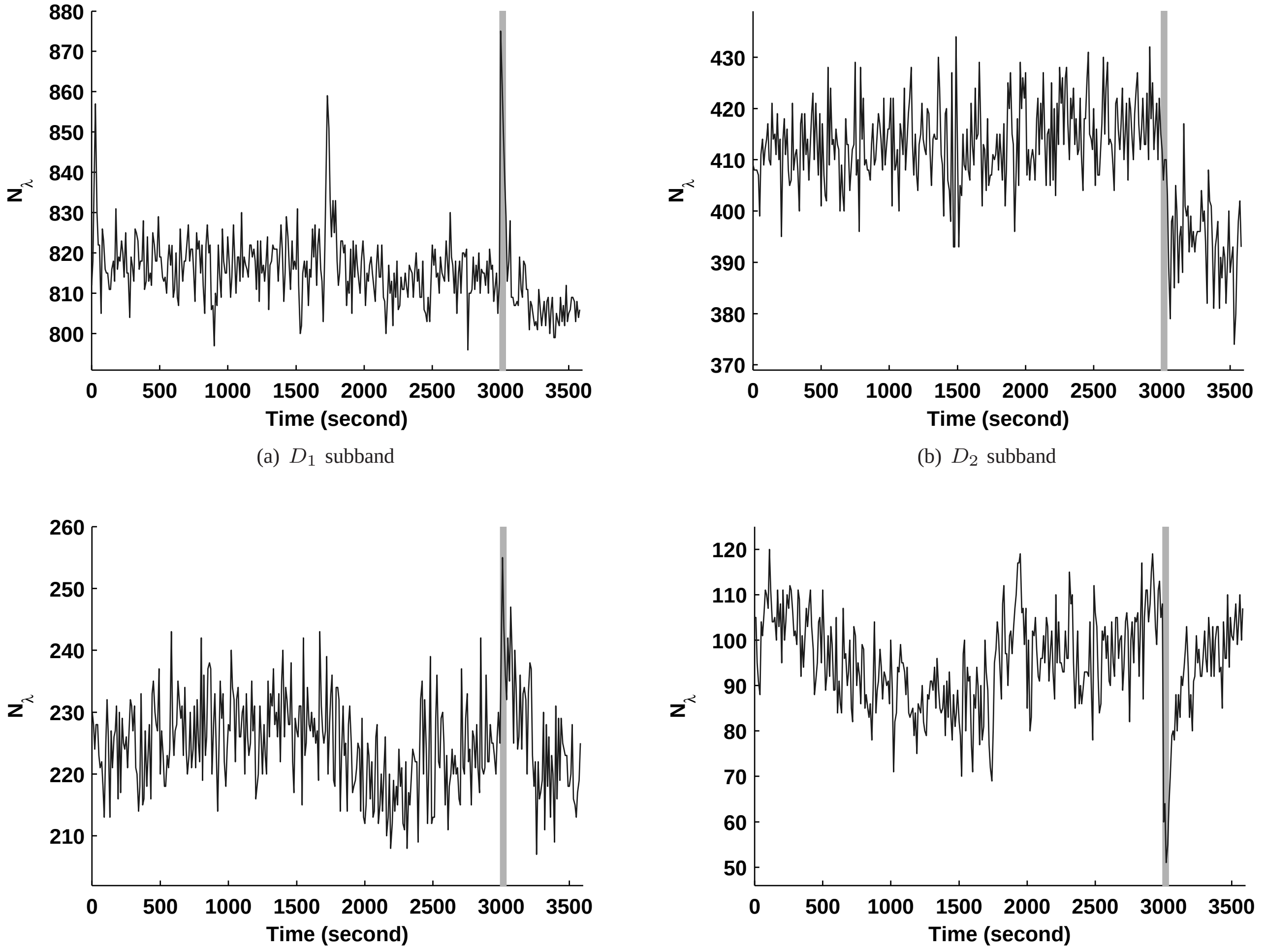
The number of local min-max N_λ of the D_1, D_2, D_3 and A_3 subbands of epileptic EEG signal is illustrated in Fig. 4(a), Fig. 4(b), Fig. 4(c) and Fig. 4(d), respectively. In Fig. 4(a), Fig. 4(b), Fig. 4(c) and Fig. 4(d), the epileptic seizure event is indicated in a shaded area. It is clearly shown that the number of local min-max N_λ of epileptic EEG has distinguishable characteristics corresponding to different states of the brain for all four wavelet subbands, i.e., D_1, D_2, D_3 and A_3. In particular, note that for the D_1 subband the number of local min-max N_λ instantaneously increases during the seizure onset while the number of local min-max N_λ sharply decreases during the seizure onset for the A_3 subband.

Furthermore, when the number of local min-max N_λ of the wavelet subbands of epileptic EEG signal is classified into the states of the brain, i.e., pre-ictal, ictal and post-ictal states, the mean, median and standard deviation of the number of local min-max N_λ of the wavelet subbands of epileptic EEG signal are summarized in Table I. The number of local min-max N_λ of the D_1 and D_3 subbands of epileptic EEG signal

TABLE I
STATISTICAL VALUES OF THE NUMBER OF LOCAL MIN-MAX OF WAVELET SUBBANDS OF THE SCALP EPILEPTIC EEG SIGNAL.

Subband	Brain State	Mean	Median	S. D.
D_1	pre-ictal	816.70	816.00	7.78
D_1	ictal	857.25	858.00	15.90
D_1	post-ictal	807.75	807.00	6.13
D_2	pre-ictal	413.66	413.00	7.61
D_2	ictal	409.50	410.00	2.52
D_2	post-ictal	394.04	395.00	7.90
D_3	pre-ictal	224.72	225.00	7.14
D_3	ictal	244.00	242.50	8.04
D_3	post-ictal	224.76	224.00	8.83
A_3	pre-ictal	95.53	95.00	10.15
A_3	ictal	57.50	57.50	5.69
A_3	post-ictal	94.33	95.00	9.76

ISBN: 978-988-19252-6-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)



(a) D_1 subband

(b) D_2 subband

(c) D_3 subband

(d) A_3 subband

Fig. 4. The characteristics of the number of local min-max of the wavelet subbands of the scalp epileptic EEG associated with different pathological brain states.

during the epileptic seizure event tends to be higher than that associated with other states of the brain. On the contrary, the number of local min-max N_λ of the D_2 and A_3 subbands of epileptic EEG signal during the epileptic seizure event tends to be lower than that associated with other states of the brain, i.e., the pre-ictal and post-ictal states.

IV. Conclusions

In this study, the temporal characteristic of wavelet subbands of the epileptic EEG signal is examined using the feature based on the local minima and maxima. The temporal characteristic is measured using the total number of both local minima and maxima, referred to as the number of local min-max N_λ. From the computational results, it is shown that the epileptic EEG signal has distinguishable characteristics corresponding to different pathological brain states for various wavelet subbands. The most remarkable characteristics of the number of local min-max N_λ can be observed in the D_1 and A_3 subbands of epileptic EEG signal.

The number of local min-max N_λ of the D_1 subband of epileptic EEG signal during the epileptic seizure event is signficantly higher than that associated with other states of the brain. On the other hand, for the A_3 subband the number of local min-max N_λ of epileptic EEG signal during the epileptic seizure event is significantly lower than that associated with other states of the brain. This implies that during the epileptic seizure event there is an increase of amplitude regularity in the highest frequency components (D_1 subband) of epileptic EEG while the amplitude regularity of the lower frequency components (A_3 subband) of epileptic EEG decreases.

These computational results suggest that the number of local min-max N_λ of various wavelet subbands reveals the distinguishing temporal characteristics of the epileptic EEG corresponding to different pathological brain states including ictal state. Therefore, the number of local min-max may be useful in detecting and identifying epileptic seizures from the scalp EEG signal.

References

[1] Seizure and Epilepsy: Hope through Research National Institute of Neurological Disorders and Stroke (NINDS), Bethesda, MD, 2004 [Online]. Available: http://www.ninds.nih.gov/disorders/epilepsy/detail_epilepsy.htm

[2] B. Litt and J. Echauz, "Prediction of epileptic seizures," *Lancet Neurology*, vol. 1, pp. 22–30, 2002.

[3] A. Subasi, "Epileptic seizure detection using dynamic wavelet network," *Expert Systems with Applications*, vol. 29, pp. 343–355, 2005.

[4] A. L. Goldberger, "Complex systems," *Proc. Am. Thorac. Soc.*, vol. 3, pp. 467–472, 2006.

ISBN: 978-988-19252-6-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

[5] W. S. Pritchard and D. W. Duke, “Measuring chaos in the brain: a tutorial review of EEG dimension estimation,” *Brain Cogn.*, vol. 27, pp. 353–397, 1995.

[6] C. E. Elger, G. Widman, R. Andrzejak, J. Arnhold, P. David, and K. Lehnertz, “Nonlinear EEG analysis and its potential role in epileptology,” *Epilepsia*, vol. 41(Suppl.), pp. S34–S38, 2000.

[7] C. E. Elger, G. Widman, R. Andrzejak, M. Dumpelman, J. Arnhold, P. Grassberger, and K. Lehnertz, “Value of nonlinear time series analysis of the EEG in neocortical epilepsies,” in *Advance in Neurology*, P. D. Williamson, A. M. Siegel, D. W. Roberts, V. M. Thadani, and M. S. Gazzaniga, Ed. Philadelphia: Lippincott Williams & Wilkins, 2000.

[8] S. Janjarasjitt and K. A. Loparo, “Temporal variability of the ECoG signal during epileptic seizures,” in *Proc. ECTI-CON*, 2010, pp. 332–336.

[9] S. Janjarasjitt and K. A. Loparo, “Comparison of temporal variability of epileptic ECoG signals,” in *Proc. ICEIE*, 2010, pp. V2259–V2263.

[10] S. Janjarasjitt and K. A. Loparo, “Investigation of temporal variability of epileptic EEG signals,” in *Proc. TENCON*, 2010, pp. 359–363.

[11] S. Janjarasjitt, “Investigation of temporal variability of sleep EEG,” in *Proc. ICICS*, 2011, pp. 1–5.

[12] S. Janjarasjitt and K. A. Loparo, “Examination of temporal characteristics of epileptic eeg subbands based on the local min-max,” in *Proceedings of The International MultiConference of Engineers and Computer Scientists*, 2012, pp. 1095–1099.

[13] A. H. Shoeb, “Application of machine learning to epileptic seizure onset detection and treatment,” Ph.D. Dissertation, Massachusetts Institute of Technology, Massachusetts, USA, 2009.

ISBN: 978-988-19252-6-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)