Journal of Neurodevelopmental Cognition

JJournal of Neurodevelopmental Cognition 6(2) (2025) 77-86 10.48308/jncog.2025.239360.1016
ISSN: 2645-565X
http://www.jncog.sbu.ac.ir

EEG Analysis for Estimating of BIS Using Neural Network

Mohsen Najafi,[1,2*], Mohammad Reza Arab[3]

[1*] *Independent Researcher, Intelligent Signal Processing and Cognitive Sciences Research Laboratory, Arak University of Technology, Arak, Iran*
[2] *Assistant Professor, The Institute for Cognitive and Brain Sciences (ICBS), Shahid Beheshti University, Tehran, Iran*
[3] *Independent Researcher, Intelligent Signal Processing and Cognitive Sciences Research Laboratory, Arak University of Technology, Arak, Iran*
Communicated by Hamidreza Mahdiani

Abstract

Designing a system that can accurately notify the doctor of the patient's level of consciousness in the operating room and ICU departments, has always been one of the challenges of the treatment team in hospitals. The usual method of measuring the depth of anesthesia in operating rooms is to use hemodynamic criteria, which is not satisfactory. Using bispectral index (BIS) is an advanced and reliable method to measure the depth of anesthesia, and its number has an inverse relationship with the depth of anesthesia. In this article EEG signals have been used for estimating of BIS using Time Delay Neural Network (TDNN). Using the designed software, all parameters of the extraction time domain, such as brain signal, Burst Suppression Ratio (BSR), frequency range of the bi spectrum, 95% spectral edge frequency (95%SEF), median frequency (MF), and relative delta power (RDP) have been extracted. These parameters are feed to the as input of a neural network for estimating the BIS. EEG signals during anesthesia were saved by BIS XP monitor (Aspect medical system Inc.).

Keywords: Bispectral Index, EEG Signal, Neural Network.

* Corresponding author

Email addresses: nadjafi43@gmail.com *Received: March 2025* *Accept: May 2025*

1. Introduction

Bispectral index (BIS) measurement is one of the important tasks for estimating the dose of drug for Anesthesia (1). There is ample evidence that hemodynamic parameters such as blood pressure and heart rate lack acceptable correlation to the adequacy of the anesthetic state, leaving the clinician to infer the state of consciousness from an assessment of cardiovascular system reactivity. A reliable technology that would allow the clinician to monitor brain status directly during anesthesia would greatly assist in patient management. Such a technology would provide a direct measurement of the hypnotic effect of the agent(s) used - reflecting the state of consciousness,

EEG signal processing has been used for extraction of BIS.The electroencephalographicbispectral index (EEG BIS) has been shown to be a quantifiable measure of the hypnotic effect of anesthetic drugs on the central nervous system (1-3).

In the recent years many researchers have been worked in this area. Such as: Sigl JC et al, described bispectral analysis, a method of signal processing that quantifies the degree of phase coupling between the components of a signal such as the EEG [2], J Liu et al, designed a system to evaluate the effectiveness of the BIS index and 95% spectral edge frequency(95%SEF)for assessing the level of propofol-induced sedation and amnesia during regional anesthesia [3], Pomfrett, CJD et al determined whether Delta sleep-inducing peptide (DSIP) could be used as an adjunct to volatile anesthesia in human subjects, their hypothesis being that DSIP is a natural hypnotic that would increase anesthetic depth(4) , C.-S. Degoute, designed an algorithm to evaluate the correlation between the electroencephalographic bispectral index (BIS) and the hypnotic component of anesthesia (CA) induced by sevoflurane in 27 children and 27 adult patients (5).

Rakesh Kumar Sinha et al presented an effective application of back propagation artificial neural network (ANN) in differentiating electroencephalogram (EEG) power spectra of syncopic and normal subjects (6). Esmaeili estimated the depth of anesthesia using fuzzy soft computation applied to EEG features (7).

2. EEG Analysis for estimating of BIS [8]

Signal processing of an EEG is done to enhance and aid the recognition of some aspect of the EEG that correlates with the physiology and pharmacology of interest (8). Many parameters and features of EEG signal have been used in the extraction of BIS (9):

1-The means of amplitude of EEG:

Mean amplitude is calculated from EEG waves with amplitude of more than 5μV.

2-Burst Suppression Ratio (BSR):

As previously mentioned, "BSR" defined Burst Suppression as amplitude less than 5μV lasts more than 0.5 sec in the processed wave. BSR is calculated in the periods lasts more than 0.5 sec which used for calculation of SynchFastSlow and β Ratio. When the effective period is less than 20% of total BSR value will be calculated . It is shown in figure 1(10, 11).

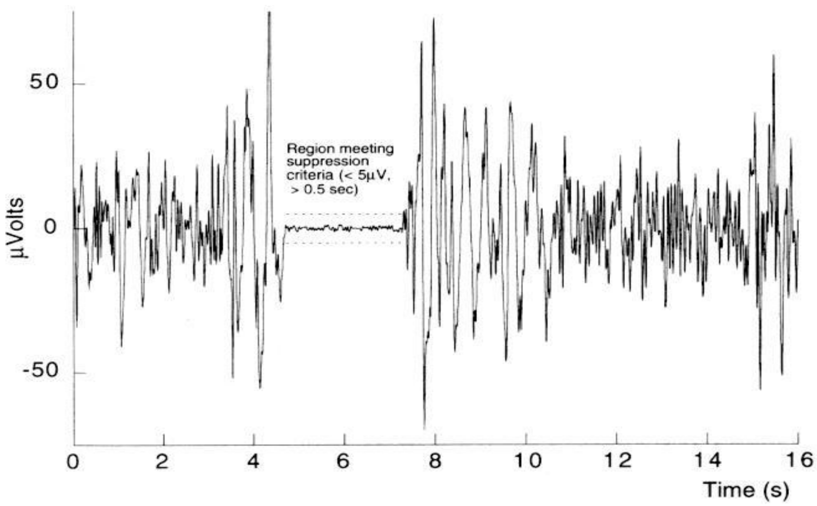

Figure 1 EEG burst suppuration (11)

BSR is used to detect deep anesthesia in the BIS Index. It is quite natural that when the suppression progresses, EEG waves become almost flat and frequency analysis becomes less meaningful.

one of the important signal analyses is the frequency domain analysis. Fourier analysis generates a frequency spectrum, which is simply a histogram of amplitudes or phase angles as a function of frequency. in this Analysis we used the fast Fourier transform for recognizing of EEG frequency analysis such as (12):

3- the range of frequency: gamma, beta, alpha, theta and delta.

In EEG signals Delta Band is the frequency range up to 4 Hz and is often associated with the very young and certain encephalopathy and underlying lesions. Theta is the frequency range from 4 Hz to 8 Hz and is associated with drowsiness, childhood, adolescence and young adulthood. Alpha (Berger's wave) is the frequency range from 8 Hz to 12 Hz. It is characteristic of a relaxed, alert state of consciousness. Alpha rhythms are best detected with the eyes closed. Alpha attenuates with drowsiness and open eyes, and is best seen over the occipital (visual) cortex. Beta is the frequency range above 12 Hz up to 30Hz. Low amplitude beta with multiple and varying frequencies is often associated with active, busy or anxious thinking and active concentration. Gamma is the frequency range approximately 30–45 Hz. Gamma rhythms appear to be involved in higher mental activity, including perception, problem solving, fear, and consciousness (1,3).

In this paper we used fast Fourier transform for generating of an EEG frequency spectrum. Figure 2 shows the alpha, beta, delta and theta waves of EEG signal. figure 3 shows the EEG frequency spectrum(6).

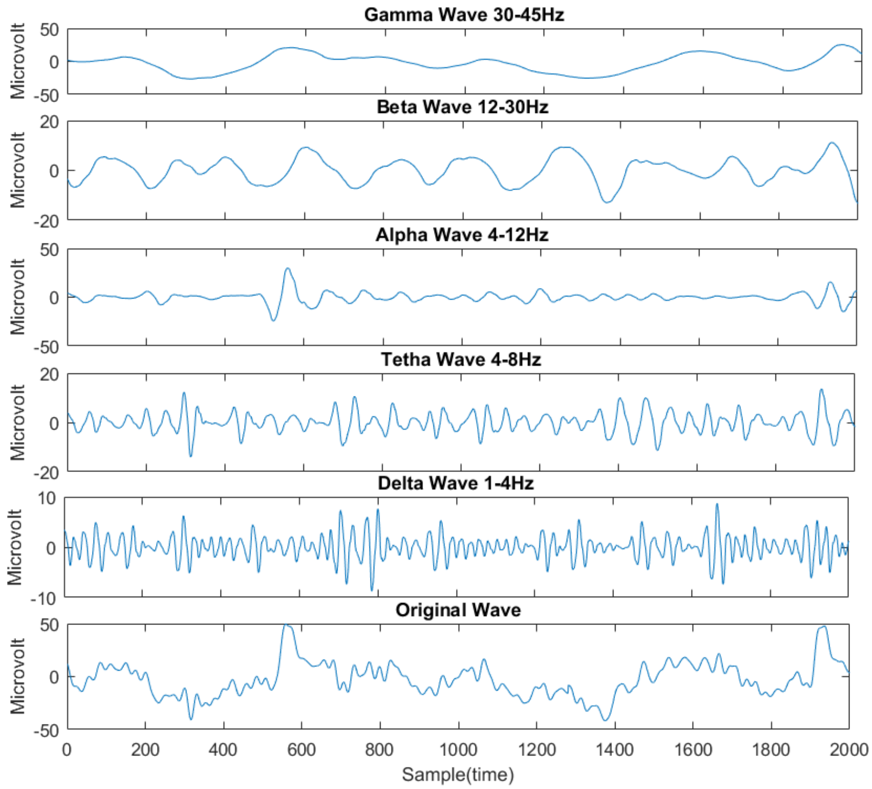

Figure 2 EEG frequency subbands

2- SEF95 and SEF90: the spectral edge frequency (SEF95) is the frequency below which 95% of the power in the spectrum resides. SEF95 becomes small in the state of anesthesia as figure 3 and is according to equation 1

.

Find the frequency (f_{SEF95}) such that:

$$[P\_\{cumulative\}(f\_\{SEF95\}) \;=\; 0.95 \;\backslash times\; P\_\{total\}] \qquad (1)$$

This means (f_{SEF95}) is the frequency below which 95% of the total power resides.

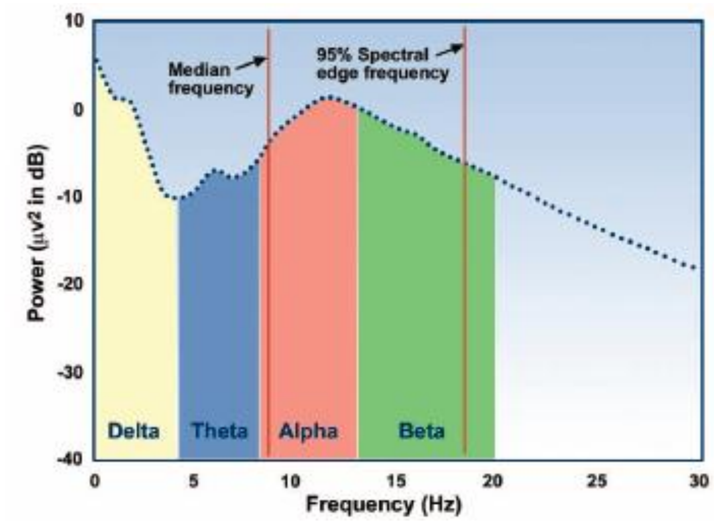

Figure 3 power spectrum display and analysis of a typical EEG segment (13)

3- SynchFastSlow parameter: According to the review by Rampil (14), SynchFastSlow parameter is computed by following equation.

SynchFastSlow=log(B0.5-47.0Hz/B40.0-47.0Hz) (2)

He describes bispectrum as Bx-y (the sum of the bispectrum activity in the area subtended from frequency x to y on both axes in the frequency versus frequency bispectral space is shown in Figure 4). That BIS calculates SynchFastSlow from bispectrum values of f1+f2<48Hz. The precise method of SynchFastSlow calculation (14).

4- Relative β Ratio: According to the review by Rampil (14), "Relative β Ratio" sub-parameter is the log ratio of power in the two empirically derived frequency bands: log(P30-47Hz/P11-20Hz) is according following equation. The parameter is most heavily weighted when the EEG has characteristics of light sedation in the BIS index.

$$\text{Relative } \beta \text{ Ratio} = \log\left(\text{P30} - \frac{47\text{Hz}}{\text{P11}} - 20\text{Hz}\right) \quad (3)$$

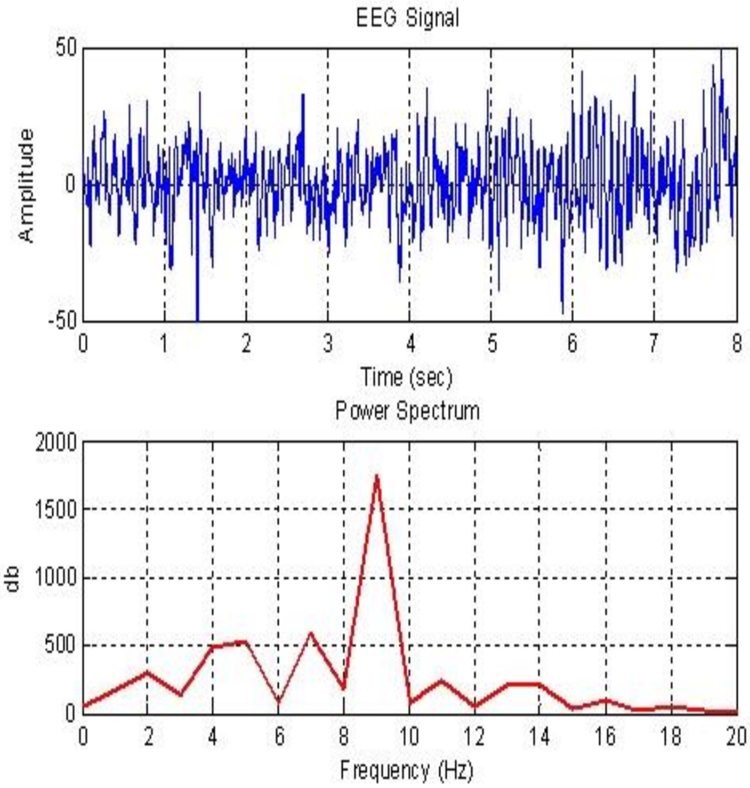

Figure 4 EEG frequency spectrum

Signals in the EEG that are of non-cerebral origin are called artifacts. The EEG is nearly always contaminated by such signals. This is one of the reasons why it takes considerable experience to interpret EEGs clinically. The most common types of artifacts are (15):

Eye artifacts (including eyeball, ocular muscles and eyelid)

EKG artifacts

EMG artifacts

Gloss kinetic artifacts

Figure 5 shows some of the prevalent artifact that there is in EEG signal:

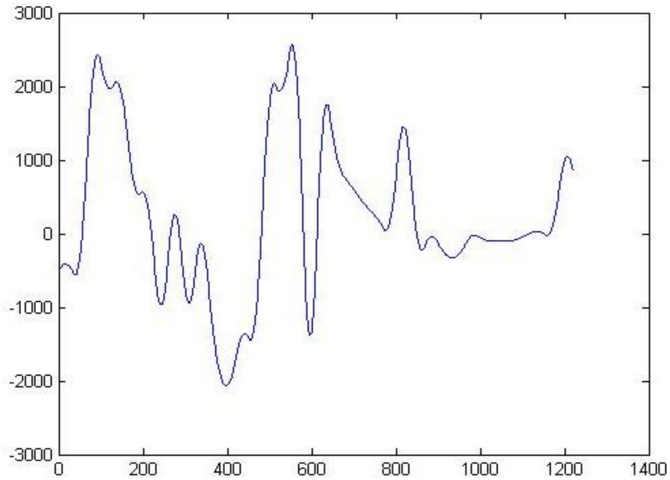

Figure 5 Blinking artifact

3. Subjects and data recording and processing

The EEG data used in this study with segments of 1024 samples (8 second duration) were sampled at 128 Hz [8]. To prepare a database of raw EEG during anesthesia the raw EEG signal was saved during anesthesia by BIS XP monitor (Aspect medical system Inc.) through contact electrodes placed on the patient's forehead. The noise free intervals of the signal were selected for further analysis. We used MATLAB software version 2017 for simulating and data processing.

4. Bis estimating using Neural Network

We use the means of Amplitude of EEG, Burst Suppression Ratio, SEF95 and SEF90, Synch Fast Slow, Relative Ratio and is according to equations 1, 2, 3 as input of a Neural Network and the output of the Neural Network is BIS. Neural Network that used in this paper is Time delay Neural Network (TDNN). The TDNN used in this study are feed forward multilayer Perceptrons with the taped delay line at the input. That is called the time delay neural network (FTDNN), that Levenberg- Marquardt method is employed as learning (16). Figure6 shows that construction of neural network.

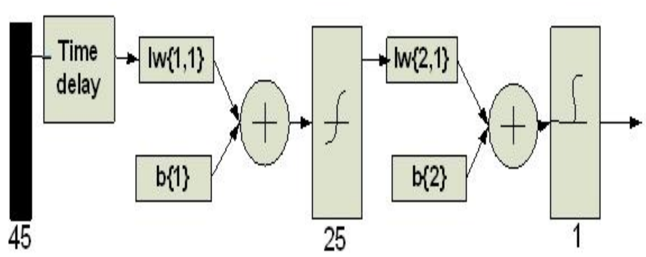

Figure 6 Schematic of applied neural network

5. Simulation Result

In this paper we use actual measured data for learning the neural network. We apply one part of data for learning (70%) and other part is used for test (30%). Figure 7 shows the result of neural network test. Neural network calculates the Bispectral Index (BIS). For approving out puts of neural network we used BIS are calculated by monitoring deep anesthesia (BIS XP monitor). These out puts of BIS monitoring were extracted by special software [11].

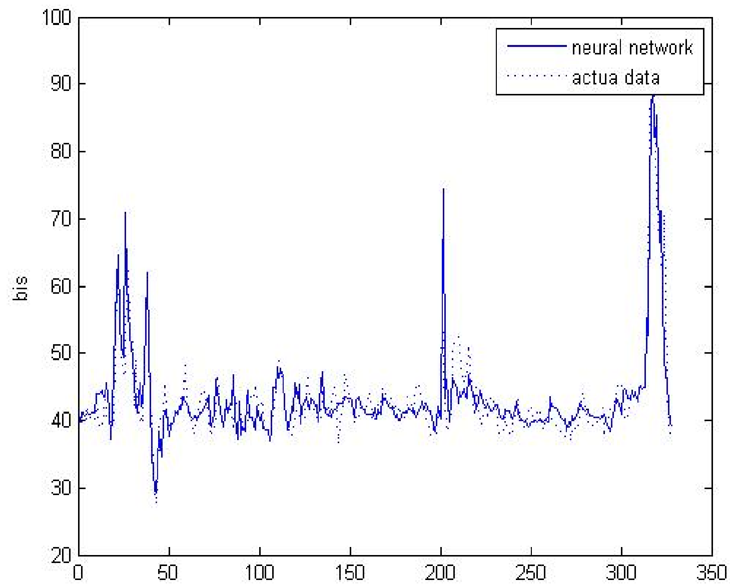

Figure 7 Schematic of applied neural network

6. Conclusion

In this paper we compared performance of our neural network with outputs resulted from monitoring system. As shown in figure 7, outputs original data are very similar to each other. Comparing original patient data with data estimated by the neural network with error of neural network near to 0.01 is shows in Figure 7.

References

Ahmadi, B., Negahbani, E., Amirfattahi, R., Zaghari, B., & Mansouri, M. (2008). Extraction of BIS™ index sub-parameters in different anesthetic and sedative levels. In Proceedings of the 9th International Conference on Signal Processing. IEEE. https://doi.org/10.1109/ICOSP.2008.4697697

Aho, A., Kamata, K., Jäntti, V., Kulkas, A., Hagihira, S., Huhtala, H., et al. (2015). Comparison of Bispectral Index and Entropy values with electroencephalogram during surgical anaesthesia with sevoflurane. British Journal of Anaesthesia, 115(2), 258–266. https://doi.org/10.1093/bja/aev206

Aribowo, W. (2019). Focused time delay neural network for tuning automatic voltage regulator. EMITTER International Journal of Engineering Technology, 7(1), 34–43. https://doi.org/10.24003/emitter.v7i1.315

Degoute, C. S., Macabeo, C., Dubreuil, C., Duclaux, R., & Banssillon, V. (2001). EEG bispectral index and hypnotic component of anaesthesia induced by sevoflurane: Comparison between children and adults. British Journal of Anaesthesia, 86(2), 209–212. https://doi.org/10.1093/bja/86.2.209

Esmaeili, V., Assareh, A., Shamsollahi, M. B., Moradi, M. H., & Arefian, N. (2008). Estimating the depth of anesthesia using fuzzy soft computation applied to EEG features. IEEE Transactions on Information Technology in Biomedicine, 12(4), 393–407. https://doi.org/10.1109/IEMBS.2007.4353239

Flaishon, R., Windsor, A., Sigl, J., & Sebel, P. J. (1997). Recovery of consciousness after thiopental or propofol: Bispectral index and the isolated forearm technique. Journal of the American Society of Anesthesiologists, 86(3), 613–619. https://doi.org/10.1097/00000542-199703000-00013

Flandrin, P. (2018). Explorations in time-frequency analysis. Cambridge University Press. https://doi.org/10.1017/9781108363181

Liu, J., Dong, K., Sun, Y., Kakkos, I., Huang, F., Wang, G., et al. (2023). Progress of brain network studies on anesthesia and consciousness: Framework and clinical applications. Engineering, 20, 77–95. https://doi.org/10.1016/j.eng.2021.11.013

Pawar, N., & Barreto Chang, O. L. (2022). Burst suppression during general anesthesia and postoperative outcomes: Mini review. Frontiers in Neuroscience, 15, 767489. https://doi.org/10.1038/s41467-023-42721-5

Pomfrett, C. J., Dolling, S., Anders, N. R., Glover, D. G., Bryan, A., & Pollard, B. J. (2009). Delta sleep-inducing peptide alters bispectral index, the electroencephalogram and heart rate variability when used as an adjunct to isoflurane anaesthesia. European Journal of Anaesthesiology, 26(2), 128–134. https://doi.org/10.1097/EJA.0b013e32831c8644 Punjasawadwong, Y., Phongchiewboon, A., & Bunchungmongkol, N. (2014). Bispectral index for improving anaesthetic delivery and postoperative recovery (Issue 6). https://doi.org/10.1002/14651858.CD003843.pub3

Sanei, S., & Chambers, J. A. (2013). EEG signal processing. John Wiley & Sons. ISBN: 978-1-118-69123-6

Shoob, S., Buchbinder, N., Shinikamin, O., Gold, O., Baeloha, H., Langberg, T., et al. (2023). Deep brain stimulation of thalamic nucleus reuniens promotes neuronal and cognitive resilience in an Alzheimer's disease mouse model. Nature Communications, 14(1), 7002. https://doi.org/10.1038/s41467-023-42721-5

Sigl, J. C., & Chamoun, N. G. (1994). An introduction to bispectral analysis for the electroencephalogram. Journal of Clinical Monitoring, 10, 392–404. https://doi.org/10.1007/BF01618421

Sinha, R. K., Aggarwal, Y., & Das, B. N. (2007). Backpropagation artificial neural network detects changes in electro-encephalogram power spectra of syncopic patients. Journal of Medical Systems, 31, 63–68. https://doi.org/10.1007/s10916-006-9043-y

Siuly, S., Li, Y., & Zhang, Y. (2016). EEG signal analysis and classification. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 11, 141–144. https://doi.org/10.1007/978-3-319-47653-7