International Journal on Advanced Science Engineering Information Technology

Vol.9 (2019) No. 3
ISSN: 2088-5334

Implementation of The Variable Data Transmission System of Abnormal ECG with Activity State

Yun-Hong Noh[1], Ji-Yun Seo[2], Hosoo Nam[3], Do-Un Jeong[4]

[1]*Department of Computer Engineering, Busan Digital University, 57 Jurye-ro, Sasang-gu, Busan, 47011, Korea*
E-mail: yhnoh@bdu.ac.kr

[2]*Ubiquitous IT Engineering Graduate School, Dongseo University, 47 Jurye-ro, Sasang-gu, Busan, 47011, Korea*
E-mail: 92sjy02@naver.com

[3]*Division of Mechatronics Engineering, Dongseo University, 47 Jurye-ro, Sasang-gu, Busan, 47011, Korea*
E-mail: hsnam@dongseo.ac.kr

[4]*Division of Computer Engineering, Dongseo University, 47 Jurye-ro, Sasang-gu, Busan, 47011, Korea*
*E-mail: *4dujeong@dongseo.ac.kr*

***Abstract*— The cause of death among modern people are the highest death rate from heart disease and monitoring and management of ECG signals to cope with these heart diseases is necessary. ECG is a bio-signal that is an important criterion for determining the presence or absence of cardiac activity states. Recently, an attempt has been made to analyze and compare biological signals and physical activity information for accurate analysis and diagnosis. However, in order to measure the ECG data for a long time, a storage space of several Mbytes and a wide bandwidth for wireless transmission are required. To solve this problem, cost, time, and high-performance systems are additional required. The implemented system minimizes the amount of packets generated during wireless data transmission as well as abnormal heartbeat detection and activity information, and enables monitoring of heart activity status and activity information in real time through a smart phone. In order to evaluate the data packet transmission and restoration performance of the system implemented in this research, the MIT / BIH Arrhythmia Database 100 record was embedded in the system controller section and the packet was transmitted to the smartphone. In addition, ECG evaluation experiments were conducted according to the activity status during daily life. As a result of the performance evaluation, both experiments confirmed the data packet generated and signal restoration performance.**

***Keywords*— pattern matching; state classification method; abnormal heartbeat detection.**

I. INTRODUCTION

The cause of death among modern people is the highest death rate from heart disease and monitoring and management of electrocardiogram signals to cope with these heart diseases is absolutely necessary [1], [2]. ECG (Electrocardiogram) is a Bio-signal that plays an important role in the diagnosis of heart disease, one of the chronic diseases. In order to measure ECG in daily life, it is unilateral to attach to the body and measure it. For this purpose, researches are being conducted to analyze various health information such as wearable, garment type, and non binding measurement system [3]-[6]. Recently, an attempt has been made to analyze and compare bio signals and physical activity information for accurate analysis and diagnosis. In addition, data processing and analysis techniques using big data and data mining are used for bio signal processing for precise diagnosis [7], [8]. However, in order to measure the ECG data for a long time, a storage space of several Mbytes and a wide bandwidth for wireless transmission are required. Various data processing techniques and analysis techniques have been studied, but long-term ECG examinations using Holter are still common in hospitals for abnormal ECG diagnosis. ECG monitoring using a Holter requires 24 hours of measurement, and there are many problems to be used in daily life because of the additional cost and time required. In this research, we implemented a real time ECG monitoring system using pattern matching and state classification method to provide not only continuous cardiac activity monitoring during daily life but also multiple heart health analysis based on abnormal heartbeat detection and activity classification. State classification method consists of a fuzzy classification system for classifying the activity state from the acceleration signal and implemented to classify 4 activity states. Also, data packet structure was designed to transmit only minimal information for health analysis by being embedded in the system controller section.

II. Material and Method

A. System configuration

In this research, implemented a real-time ECG monitoring system using pattern matching and state classification technique to provide not only continuous cardiac activity monitoring during daily life but also multiple heart health analysis based on abnormal heartbeat detection and activity classification. The implemented system minimizes the number of packets generated during wireless data transmission as well as abnormal heartbeat detection and activity information and enables monitoring of heart activity status and activity information in real time through a smart phone as shown in Figure 1. For this purpose, a belt type electrode was used to minimize the inconvenience of measurement and implemented a measurement section using a 2-lead ECG measuring instrument for ECG measurement and 3-axis acceleration for extracting activity information. System controller section converts the analog signal measured by the ECG and 3-axis acceleration measurement circuit into a digital signal using an internal A/D converter. Also, a signal processing unit employing the activity state classification method for extracting pattern matching and activity information for abnormal heartbeat detection is built in.

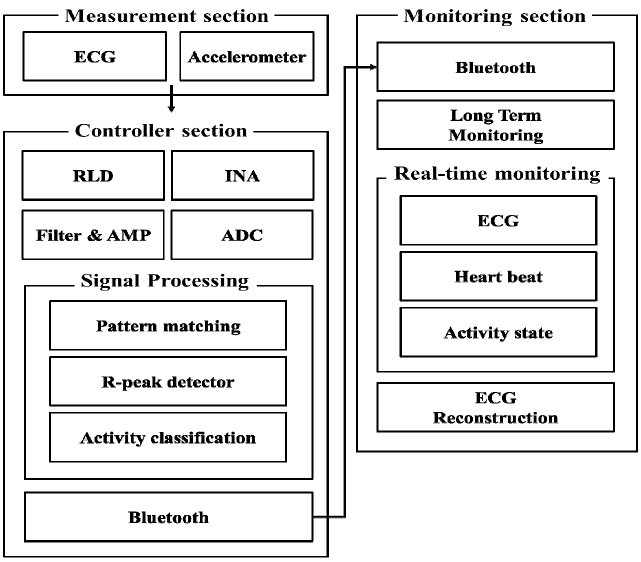


Fig. 1 System configuration

B. Pattern matching to detect abnormal heartbeat

In this research, we implemented a pattern matching method to detect abnormality abnormal heartbeats. Pattern matching method generates a pattern for a normal ECG and matches a pattern of the inputted ECG to detect an abnormal heartbeat. It is a suitable method to apply to limited system such as microprocessor because morphological anomaly can be analyzed and input signal can be processed in real time. In order to apply the pattern matching method, the time required to generate a matrix for normal ECG was set to 30 seconds, and the measured signal was divided into PQRST intervals based on the R-peak in the initial 30 second signal. In the case of normal ECG, normalization process using Min-Max technique was performed to minimize the error rate since a slight difference occurs in amplitude. To reduce the amount of computation, the microprocessor uses a 10 bit ADC to convert the decomposed original signal into 5 bits and extract the PQRST pattern for 30-seconds. Figure 2 shows the pattern extraction procedure for normal ECG.

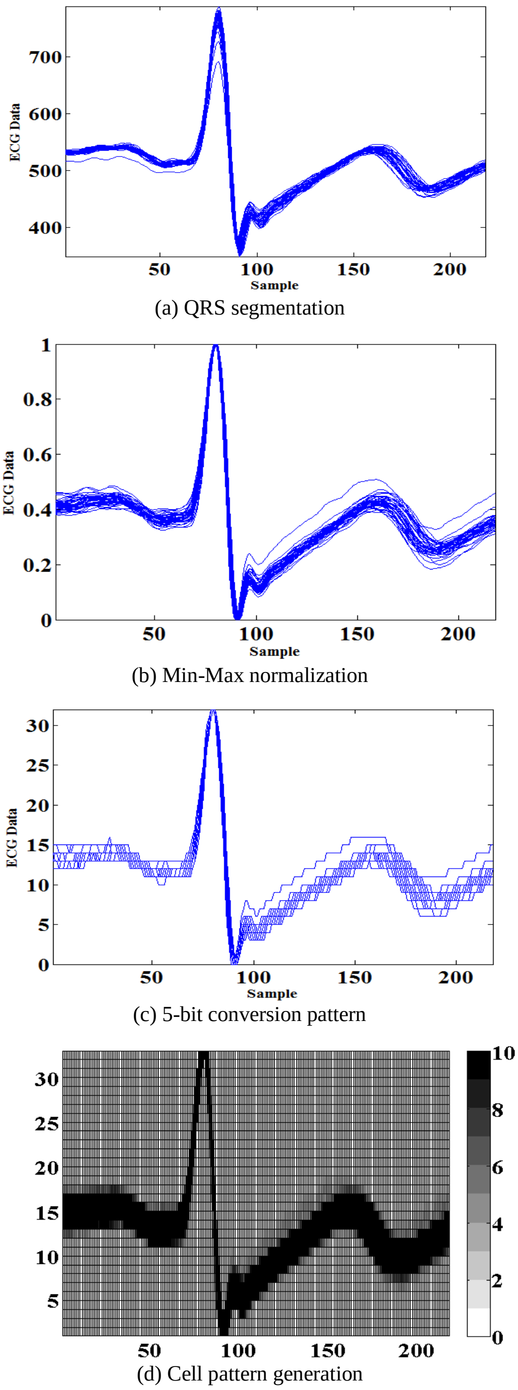


Fig. 2 pattern extraction procedure for normal ECG

C. State classification method using 3-axis acceleration

Recently, to accurately and efficiently measure the various activities of the human body, a signal processing technique researches has been carried out to attach the sensor to various parts of the human body and to discriminate the posture change and the activity state [9],[14]. In this research, we tried to perform extra reliable health monitoring by simultaneously analyzing ECG signals and acceleration signals. For this purpose, we have implemented an activity state classification method to classify the change of activity state using 3-axis acceleration in the measurement section. To classify the activity states, the measured 3-axis acceleration signal was passed through a high-pass filter with a cut-off frequency of 1 Hz, and the SVM (Signal Vector Magnitude) was calculated after eliminating the acceleration offset by the geomagnetic. The SVM is the sum of the acceleration vector values in all directions and is shown in Equation 1 below.

$$\mathrm{SVM} = \sqrt{\mathrm{x_i^2} + \mathrm{y_i^2} + \mathrm{z_i^2}} \qquad (1)$$

Here, x_i, y_i, z_i is the acceleration i sample of each axis. In order to distinguish more active states, ISVM (integral signal vector magnitude) was calculated by integration SVM at 1-second intervals and equation of ISCM is shown in Equation 2.

$$\mathrm{ISVM} = \int_{t=0}^{T} (SVM)dt \qquad (2)$$

To classify the activity state, 3-axis acceleration signals according to the activity pattern such as posture change, walking, and running were measured, and SVM and ISVM were calculated. When the reference value of ISVM has a value greater than 10, the activity state is classified into four stages through the implemented activity state classification method. If the value of ISVM is larger than 10, the fuzzy classifier effectively processes the ambiguous information and classifies it into the appropriate activity state.

D. Real-time monitoring

A smartphone based real-time monitoring section is implemented to monitor the ECG and activity status in real time from the data packet transmitted through the system controller section. Real-time monitoring was designed as an Android-based smartphone application with built-in Bluetooth. The structure of the application is composed of View Classes that are displayed on the framework based screen, Communication Management Classes which are communication setting and application setting of Bluetooth data, Pattern Data Management which stores pattern data, and Data Management Classes which manage all data. In particular, the Data Manager distinguishes wirelessly transmitted data packets and saves them in each of the connection list objects. The Pattern Data Manager Loads the data of the standard stored ECG patterns in case of normal heartbeat according to the type of heartbeat, loads the ECG data of the transmitted data packet in case of abnormal heartbeat and transmits it to the Monitoring Graph Section, Perform real-time monitoring. Figure 3 shows a conceptual configuration of ECG signal restoration in the Data Management Classes, and the overall configuration of the implemented monitoring application is shown in Figure 4.

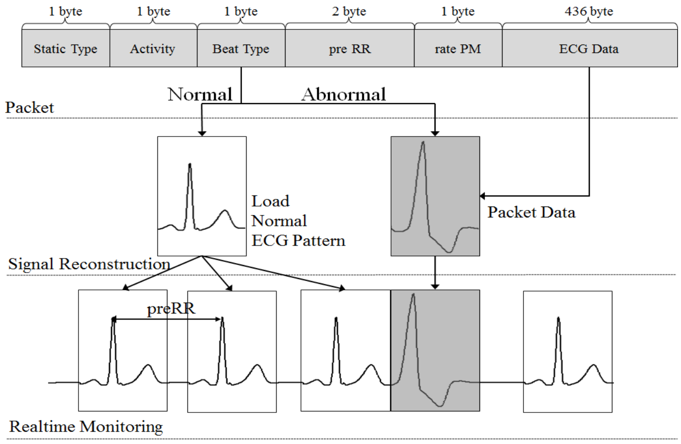


Fig. 3 Conceptual configuration of ECG signal restoration

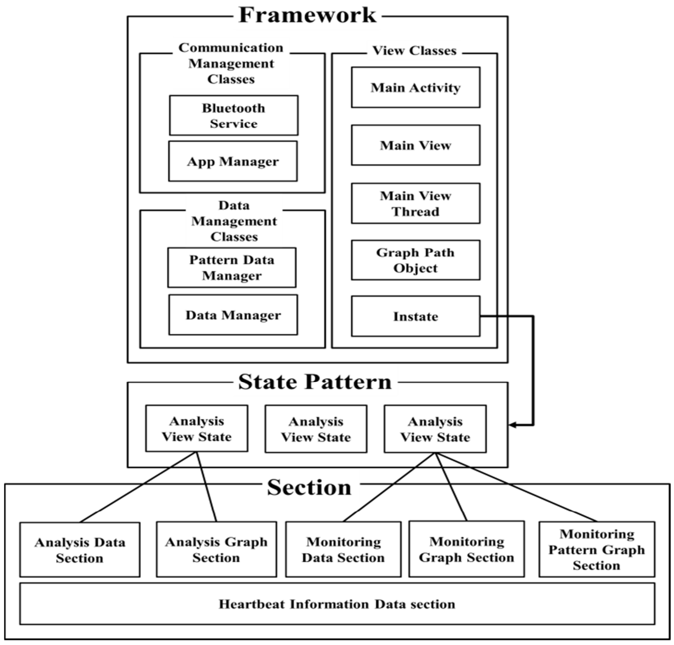


Fig. 4 Monitoring section configuration

III. Results and Discussion

A. Data packet transmission and restoration performance evaluation

The real-time ECG monitoring system implemented in this research can classify abnormal heartbeat detection and activity status. In addition, in case of a normal heartbeat, only simple information about heartbeat and activity state is transmitted, and in case of abnormal heartbeat, data transmission packet can be minimized by transmitting information about the whole heartbeat. To evaluate the data packet transmission and restoration performance of the system implemented in this research, the MIT / BIH Arrhythmia Database 100 record was embedded in the system controller section, and the packet was transmitted to the smartphone. Generally, when data is transmitted, ECG requires a packet of 2 bytes per sample to transmit 1 sample of 10 bits when the sampling frequency is 360 Hz. Therefore, the total number of samples of 100 records in 30 minutes is 650,161, and a total of 1,300,322 bytes of packets are transmitted.

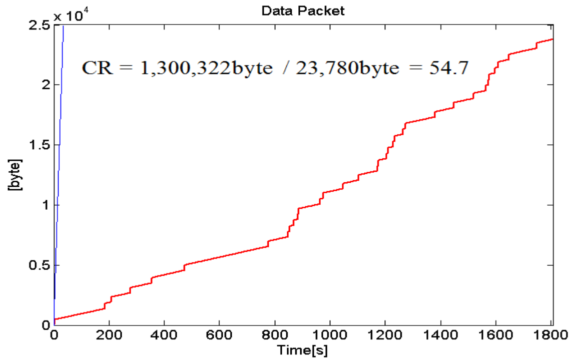
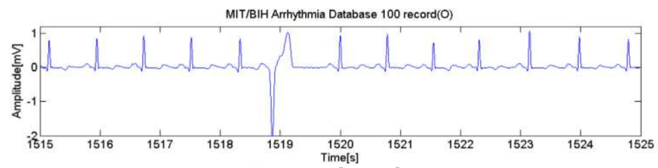
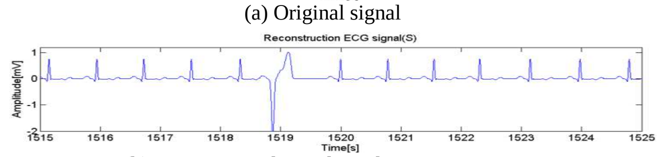


Fig. 5 Amount of wireless transmission packets generated by 100-record

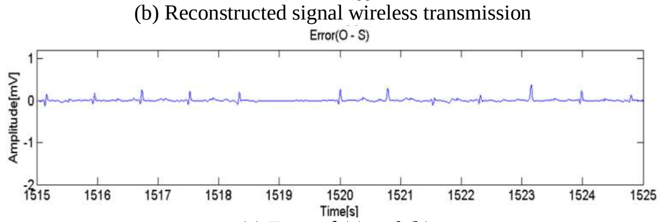
Experimental results show that the system generated 23,780 bytes of the packet by packetizing and transmitted the entire data only when the incipience normal data according to the heartbeat detection of the measured ECG data is the cell pattern data and the abnormal heartbeat. Figure 5 shows the number of wireless transmission packets generated by 100-record. At this time, the compression ratio (CR) was 54.7: 1, which confirmed the high performance. In the case of a normal ECG, the signal for the final normal ECG is loaded from the memory of the smartphone and displayed and in case of an abnormal heartbeat, the signal is reconstructed by displaying based on the transmitted data. Therefore, the transmitted ECG signal and the reconstructed ECG signal may be the difference from each other, and experiments were performed to confirm the restoration performance. The results of signal restoration of 100 records are shown in Figure 6. (a) is the original signal, (b) is the reconstructed signal by wireless transmission, and (c) is the error of (a) and (b).



(a) Original signal



(b) Reconstructed signal wireless transmission



(c) Error of (a) and (b)

Fig. 6 Signal restoration of 100 record

To compare the signal restoration rate between the original signal of 100-record and the measured all data for 30 minutes, we calculated CC(correlation coefficient) that can detect the correlation of the signal and RMSE(root mean square error) which represents the error of the two signals. CC showed a high correlation coefficient of 0.964, and RMSE showed a low error of 0.039. Therefore, when the proposed method is used, it is possible to minimize the packets generated in the wireless transmission and to have the same effect as compressing and transmitting the ECG data.

B. Performance evaluation of abnormal heartbeat detection using pattern matching

To evaluate the overall performance of the proposed abnormal heartbeat detection technique, a detection experiment was performed using eight records, including various abnormal heartbeats in the MIT / BIH Arrhythmia database. The results are shown in Table 1. From the results of the experiments, the success rate of heartbeat detection was 99.9% and the abnormal heartbeat detection using pattern-matching method was 95.4% with excellent performance was confirmed.

TABLE I
HEART BEAT AND ABNORMAL HEART PEAK DETECTION RESULTS

MIT/ BIH record	MIT/BIH		Proposed algorithm		A	B
	R-peak	Arrhythmia	R-peak	Arrhythmia		
100	2273	1	2272	1	99.9	100
102	2787	4	2187	5	100	75
119	1987	444	1987	439	100	98.9
121	1863	1	1861	1	99.9	100
123	1518	3	1518	3	100	100
124	1619	47	1619	52	100	89.4
230	2256	1	2256	1	100	100
231	1573	2	1571	2	99.9	100
Avg.					99.9	95.4

A : R-peak detection accuracy [%]
B : Abnormal detection accuracy [%]

C. Performance evaluation in everyday life

In this research, the real time ECG monitoring system using pattern matching and state classification method is implemented. In order to evaluate the performance of the implemented system in everyday life, the ECG measurement experiment was performed in the active state. Activity state was performed an experiment by setting a travel route of about 2Km in the school. Table 2 shows the ECG measurement results in the active state.

TABLE II
MEASUREMENT RESULTS FROM ACTIVITY STSAYE

Section	Activity type	Time [s]	Activity Accuracy (%)	R peak	Number of abnormal heartbeat
1	1	342	100	535	1
2	2	243	98	445	4
3	3	151	87	349	8
4	0	181	99	268	0
5	1	28	99	242	4
6	2	62	93	114	3
7	1	103	98	168	2
8	4	22	87	55	21
9	1	85	98	128	2
10	0	177	99	256	1
11	4	16	90	40	18
12	1	185	94	286	3
13	0	182	100	239	2
14	1	175	100	264	5
15	3	35	93	58	9
Total		1987	96	3448	83
CR	2,861,280byte / 48,384byte = 59.14				

Experimental results show that the activity discrimination performance of arbitrarily designated activity state is 96%. The reason is that is considered to be an error caused by difficulty in maintaining the exact speed of the test subject during the activity state. Then, the performance of the data packet generated rate was evaluated through the activity state experiment. When the activity state data is measured at a sampling frequency of 360Hz for 1,987 seconds, it is assumed that a packet of 2,861,280 bytes is generated, and CR was derived by calculating the ratio of the amount of data packets generated in the experiment. Therefore, since 83 abnormal heartbeats occurred in the data packet, the total packet generated 48,384 bytes of packet also, CR was calculated as 59.14.

IV. CONCLUSIONS

In this research, we implemented a real-time ECG monitoring system using pattern matching and state classification method to provide not only continuous cardiac activity monitoring during daily life but also multiple heart health analysis based on abnormal heartbeat detection and activity classification. The implemented system minimizes the number of packets generated during wireless data transmission as well as abnormal heartbeat detection and activity information and enables monitoring of heart activity status and activity information in real time through a smartphone. For this purpose, a belt type electrode was used to minimize the inconvenience of measurement.

In addition, we implemented a measurement section using a 2-lead ECG measuring instrument for ECG measurement and 3-axis acceleration for extracting activity information. Moreover, we implemented the system controller section to convert the analog signal to digital and wirelessly transmit heartbeat and activity information. The implemented system has a merit that it can analyze it by various kinds of activity state classification even when an abnormal heartbeat detection error occurs due to a change of ECG signal due to excessive activity in daily life. To evaluate the data packet transmission and restoration performance of the system implemented in this research, the MIT / BIH Arrhythmia Database 100 record was embedded in the system controller section, and the packet was transmitted to the smartphone. Also, ECG evaluation experiments were conducted according to the activity status during daily life.

As a result of the performance evaluation, both experiments confirmed the data packet generated and signal restoration performance. In future research, it is necessary to develop advanced diagnostic parameters through correlation analysis between activity information and ECG and to provide health analysis considering user environment such as temperature, humidity, altitude, topographical information as well as activity information.

ACKNOWLEDGMENT

Basic Science Research Program supported this research through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No.2018R1D1A1B07045337/No.2016R1D1A1B03934866).

REFERENCES

[1]. D. Mozaffarian et al., “Heart disease and stroke statistics-2016 update: A report from the American Heart Association”, Circulation, vol. 133, pp. e38, 2016.

[2]. Naghavi, Mohsen, et al., “Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the Global Burden of Disease Study 2016.” The Lancet, pp. 1151-1210, 2017.

[3]. Shimauchi, Suehiro, et al., “An analysis method for wearable electrocardiogram measurement based on non-orthogonal complex wavelet expansion.” Engineering in Medicine and Biology Society (EMBC), 2017 39th Annual International Conference of the IEEE. IEEE, pp. 3973-3976, 2017.

[4]. Zheng, Kaipei, et al., “Large Area Solution Processed Poly (Dimethylsiloxane)-Based Thin Film Sensor Patch for Wearable Electrocardiogram Detection.”, IEEE Electron Device Letters 39.3, pp. 424-427, 2018.

[5]. Zhang, Qingxue, et al., “Highly wearable cuff-less blood pressure and heart rate monitoring with single-arm electrocardiogram and photoplethysmogram signals.”, Biomedical engineering online 16.1:23, 2017.

[6]. Balasubramanian, et al., “A knowledge-driven framework for ECG representation and interpretation for wearable applications.”, Acoustics, Speech and Signal Processing (ICASSP), 2017 IEEE International Conference on, IEEE, pp. 1018-1022, 2017.

[7]. Lee, Seolhwa, et al., “Mining biometric data to predict programmer expertise and task difficulty.” Cluster Computing., Vol. 21(1), pp.1097-1107, 2018

[8]. So, Aram, et al., “Early diagnosis dementia form clinical data by machine learning techniques.” Applied Sciences Vol. 7(7):651, 2017.

[9]. Li, Zhijun, et al., “Adaptive impedance control for an upper limb robotic exoskeleton using biological signals.”, IEEE Transactions on Industrial Electronics 64.2, pp. 1664-1674, 2017.

[10]. Tacchino, Giulia, et al., “EEG Analysis during active and assisted repetitive movements: Evidence for differences in neural engagement.”, IEEE Transactions on Neural Systems and Rehabilitation Engineering 25.6, pp. 761-771, 2017.

[11]. Singh, Balbir, et al., “A Removal of Eye Movement and Blink Artifacts from EEG Data Using Morphological Component Analysis.”, Computational and mathematical methods in medicine 2017, 2017.

[12]. Yang, Bo, et al., “Motion prediction via online instantaneous frequency estimation for vision-based beating heart tracking.”, Information Fusion 35, pp. 58-67, 2017.

[13]. Hicks, Robert A., et al,. “Frontal alpha asymmetry and aerobic exercise: are changes due to cardiovascular demand or bilateral rhythmic movement?.”, Biological psychology 132, pp. 9-16, 2018.

[14]. Gaudet, et al,. “Classification of Upper limb phantom movements in transhumeral amputees using electromyographic and kinematic features.” Engineering Applications of Artificial Intelligence 68, pp. 153-164, 2018.