# Bio-Signals in Medical Applications

Subjects: Health Care Sciences & Services

Contributor: M. Swapna

Artificial Intelligence (AI) has broadly connected the medical field at various levels of diagnosis based on the congruous data generated. Different types of bio-signal can be used to monitor a patient's condition and in decision making. Medical equipment uses signals to communicate information to care staff. AI algorithms and approaches will help to predict health problems and check the health status of organs, while AI prediction, classification, and regression algorithms are helping the medical industry to protect from health hazards. The early prediction and detection of health conditions will guide people to stay healthy.

artificial intelligence | signal processing | bio-medical signal processing | smart health devices | sensors | bio-signals

## 1. Role of Bio-Signals in Medical Applications

### 1.1. Bio-Signals with Artificial Intelligence

There have been great success stories about the reach and advancements of Artificial Intelligence (AI) technology in the medical area. Some of the applications, such as smart watches and wearable devices, are used to sense the pulse rate and irregularity in monitoring through algorithms and in the prediction of heart stroke. They will monitor the activity of a person. As per the authors, it was proven that the size of the brain is larger than the common size for those with heart stroke. The life of the brain will also reduce by 1.1 years of the average lifetime of the brain. It will work one hour more than the regular brain capacity. Echocardiography examination can predict a person's cardiac attack up to two weeks prior to the event [1].

Sleep detection with a bio-signal AI application is used to detect the sleep stages of the person using AI with asleep analysis algorithm, which uses the concepts of pattern recognition and rule evaluation [2]. Bio-signals help in perceiving the emotions of a person while they are returning home from the office. It is possible to know the pulse rate of a person while walking. If at all the pulse rate crosses a limit, only then will the device send a message to the person's family. It also helps us to know the actual mindset of a person's emotions [3].

Another application with bio-signal recognition is to know the emotions of a car racer while driving a car in a car racing competition. It can be evaluated using the intelligent emotion reorganization algorithm. This system will read the values from the wearable device to send the signals to the reorganization module and then classify the results based on an adaptive neuron fuzzy inference system [4]. A severe infection, such as cancer, can easily be identified with blood investigation using the total tally counter to count the first leucocytes and then parasites under high power fields (HPF).

This count is directly recorded in CSV files, having no scope for human error. TTC counts outside of the range signify that some infection or cancer exists in the blood. It is a very simple, easy, and low-cost investigation [5].

AI in wearable devices use bio-signals, and literature work reveals that AI concepts can be used to predict heart diseases at early stages, but applying AI on wearable devices is the proposed model by the author. Cardiovascular-related diseases can be monitored through a digital setting on devices. Atrial fibrillation detection was performed using a forest plot using the R Package. Deep learning methods are used on the bio-signal values recorded by wearable device data, such as ECG and PPG Bio-signals [6].

Bio-signals Processing Architecture: Bio-signals are used in the medical field to assess the environment. This technology is used for the better detection, diagnosis, and treatment of many life-threatening diseases. **Figure 1** will explain the signal processing flow. The steps include selecting the dependent variables, analysis, type of sensor that needs to be used, observing input signal, collecting the data, and visualizing. Finally, the input can be analyzed using technical and efficient algorithms to classify, predict, and find a correlation or covariance, etc.

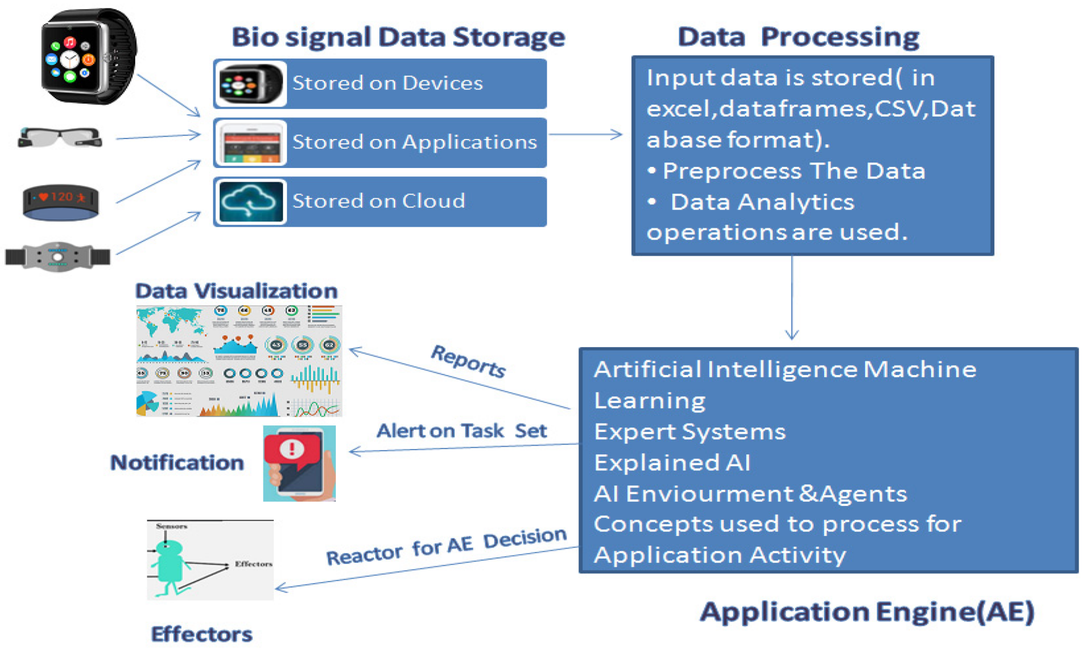


**Figure 1.** Architecture diagrams of bio-signals processing environment.

The data have been collected from various types of biosensor wearable devices. Different types of Bio-signals are recorded through these devices and stored on the device. The simulator/application use dynamic data that can be updated on the cloud. The data storage format can be in different modes, but the researchers preprocess the data and perform different analytics or statistical approaches. The processed data are sent to the application engine to apply AI concepts and the results are extracted. The generated reports are viewed over different report generation tools such as data visualize, tabular tool, mat plots, etc. The notification is generated on the event generator, effectors are reacted to the environment, and agents perform assertion.

## 1.2. Basic Concepts and Applications in the Medical Industry

AI has taken the lead over the biomedical discipline in the detection of various diseases. Accurate identification of medical and health complications can be completed. The most common approaches in medical imaging are used for preliminary suspects and investigation. This method will process images with the help of different AI techniques and as per the observations made concerning the applications, results are found. A three-dimensional brain MRI scan is used to create a three-dimensional image view of the brain to detect lesions and find any faults that exist on the tissue (such as tissue stiffing, infection on tissue, nerve damage, etc.). The segmentation of lesions using the concept analysis will observe images of the white and gray matter and cerebrospinal fluid. It computes the feature using SVM, where lesions exist only in white matter, and the result was observed that there is an increase in performance in compression with previous methods. Sensitivity is 99%, specificity is 80% and accuracy is 99% [7].

Medical Imaging is a highly active field of research in the biomedical industry. AI algorithms are used to process digital images and classify various diseases. In a previous study, 80 MRI images were referred from the Harvard Medical School database. The study was on various methods to classify diseases such as Pick’s, Huntington’s, cerebral calcinosis, and Alzheimer’s using Otsu’s thresholding. The researchers use Euclidean distance methods to analyze the clusters of classes with the histogram binning approach. The similarity can be measured using a base of Euclidean distance value. The classifications of classes are carried out using the binary threshold method and dendrograms [8].

Bio-signals are used in various applications using intelligent devices such as the electrocardiogram (ECG). This ECG can have low power consumption and low data loss features. It can not only work with low-energy wireless communication protocols, but also use a smart phone for the display of ECG output. ECG is used for synthetic waveform, which monitors the heart behavior, such as excitement assessment, recovery rate, etc. The author’s latest intelligent proposal is that an ECG waveform is given as input, and with the help of ADS, the researchers convert an analog signal to a digital signal. MSP is used for data processing, BLE is used for transmission, and data are collected on a smart phone using Bluetooth technology. The results obtained in the above process are that the loss rate of ECG packets has reduced from 13.26% to 0.63% and no packet transmission over time has risen from 98 to 633 packets with the new intelligent ECG system [9].

Vital signals are important parameters to check the basic health profile of the subject, which includes blood pressure, blood oxygen, respiration rate, and temperature and pulse rate being the basic biomarkers to check the fitness of a subject. Electrodes and pulse sensors are used to sense the ECG signals, pulse rate, humidity and temperature. This information is sent to an app, web browser or the local web browser [10].

Bio-signals are used in electrocardiogram (ECG) for cardiology examination used for heart regularization. It helps us to find out the damage in the heart and the size and location of holes in the heart. These signals may have noise issues, or they have unacceptable ECG waveforms for the investigation process. Deep learning methods are used to classify the ECG waveform as acceptable or not. Four conventional neural networks are used to be defined with a different number of layers, kernels, learning rate, etc., in architecture models. The results in the above models with a cutoff value of 0.05 have an 88% success rate in the detection of unaccepted ECG waveforms [11]. Takumi Toya et.al. [12] use a 12-lead ECG in the medical area of peripheral micro vascular endothelial function for an index of vascular ageing. An AI algorithm is trained to estimate age and sex, determining age and chronological age (Δ age). Additionally, the hazard ratio was 4.72; 95% CI, 1.24–17.91; $p$ = 0.02AI. Δ age was significantly associated with an increased risk, which is consolidated in **Table 1**.

**Table 1.** The different data sources of medical applications using bio-signals.

| Data Source Details | URL |
|---|---|
| The eICU Collaborative Research Database [13] | https://eicu-crd.mit.edu/gettingstarted/access (accessed on 27 December 2021). |
| Ajou University Hospital Biosignal database [14] | https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7921576/ (accessed on 27 December 2021). |
| The Munich BioVoice corpus (MBC) [15] | https://sipl.eelabs.technion.ac.il/projects/heart-rate-measurement-from-human-voice (accessed on 27 December 2021). |
| VitalDB database [16] | https://github.com/vitaldb (accessed on 27 December 2021). |

Electroencephalogram (EEG) is a bio-signal used to observe brain activity by attaching a small disc of electrodes to the scalp of the head. The brain cells communicate with an outside monitoring system using electrical impulses at all times, even while sleeping. This examination is used to know the patterns of the brain and test any head injuries, tumors, dizziness, seizures, and sleeping disorders. EEG investigation will not have any side effects. EEG bio-signal methods will assess the sleep stage scoring, seizure detection, mental workload, and emotional detection. The motor imaginary movement method will find the movement of the tongue/limbs. CNN architecture was designed as an efficient method in comparison with LSTM and RNN networks. EEG data are used to measure mental stress and complexity task performance. The SAE model with new architecture is doing well in comparison with other models. Sleeping stages are stage 1, 2, 3, and 4 [17].

Tremors and epileptic seizures are disorders of the neural system. Early diagnosis always helps in giving better treatment and results. EEG signal capture will help to monitor the functionality of the brain. This author uses the Bonn dataset; the Tunable Q wavelet transform (TQWT) method preprocesses the EEG signal. The feature extraction is performed using fuzzy entropy methods, feature reduction is used in auto encoders, and classifications are performed using fuzzy and non-fuzzy algorithms, ANFIS-BS, able to achieve an accuracy of 99.79% [18].

Electroencephalogram (EEG)bio-signals are used in real-time applications to know whether a person addresses questions with positive or negative mental pressure. The analysis of mental pressure helps us to know the facts of problem solving. This approach uses unsupervised learning in the classification of the classes. The preprocessing of EEG signals is performed based on the division of data, and feature selections are applied. The classification of the obtained dataset is applied. Feature selection is obtained using forward greedy attribute selection and gain ratio feature selection methods. Clustering analysis is conducted using two approaches; one is personal data analysis and the other is channel data analysis. The survey gives solutions for two problems. One of the most effective features is classification, and extra knowledge is used to classify the classes [19]. Another application is predicting children's grade failures using an ML model, which is used to classify (KNN algo) based on three variables, and the results showed that poor performance in math is 55% and language is 74%. The overall failure rate depends on the above reasons, discussed in **Table 1**.

Electromyography (EMG) is a bio-signal used to examine if the muscles respond to the nervous system properly or not. It helps in the detection of diseases, disorders, neural problems, or damages in the neural system. The various diseases used to detect using EMG include nerve injuries, degenerative conditions of the nerve. The procedure for the EMG test will use a needle electrode inserted into the muscles, which is used to record the muscles' functionality. EMG examination is carried out in COVID-19 patients after detecting negatives to discover any blocks in the nervous system and to check whether they have been exposed to fatigue, dizziness, calf cramping, or exhaustion under stress. This study was a study of three COVID-19 patients kept under observation with mild health issues. Cases 1 and 2 could tolerate but case 3 was not able to tolerate the needle electrodes in the muscles. The result of the EMG examination was able to find an inference pattern. Case 1 and case 2 were able to perform due to the short duration, low amplitude of motor unit action potential, and myalgia. In case 3, the EMG test was unable to be performed due to muscle pain while going through the procedure [20].

Hand recognition and gesture recognition are more challenging, especially in contactless health treatments such as for COVID-19. Contactless treatment, service in the hospital and quarantine need some actions for basic needs and response to the doctors. Some gestures, such as feeling good or require something, can be standardized by the hospital. EMG signals are used to recognize the gestures of hands or fingers. Electrodes are fixed to the hand, wrist and fingers. The time division features are extracted and machine algorithms are used for the classification of type of gesture. An ANN-based classifier achieved 0.940 accuracy [21].

Tele rehabilitation is a traditional treatment that will be used to monitor the muscular activities of the patients and the effectiveness of home exercise. This application is most effective in physiotherapist treatments. The electromyography biofeedback system device helps to monitor the patients at remote places. It helps to monitor muscular activity after injuries and major surgeries. AI is added to support the medical industry with technology. This device has five module roles Module1: accept the input through EMG electrodes for sensors; Module2: biofeedback device gadgets are designed along with two mobile phones with designed applications, and Modules 3,4, and 5 are used to implement a check of EMG signal [22].

Electroencephalograms (EEG) are used in the medical industry to identify disorders and changes in behavior and to monitor the activity of the brain. It is observed generally in liver transplant and heart transplant patients. EEG is an examination performed through an external metal disc attached to the scalp. It has no side effects. EEG is also used to authenticate a person's identity. There are many biometric methods used to identity authentication, such as DNA, face reorganization, fingerprint, hand geometry, typing rhythm, and voice. In biometric reorganization, many considerations should be satisfied; for example, every person should have distinct characteristics, invariant over time, and this should be measurable. This examination has three stages of study. Stage one—the researchers perform four tasks: person to relax, close eyes, and be still. The next task is to take the observation of limb movement activity without moving the limbs. Another task is to generate finger rotation activity. The next stage is feature extraction and finally, classification rules are applied using a support vector machine algorithm to calculate the false acceptance rate and false rejection rate, and 100% accuracy has been improved using the voting rule [23].

AI is used to classify the EEG collected data for application in very short-term memory assessment. Short-term memory can remember the small visual details of an image or picture at one sight. Some details include color, shape, location, and characteristics of the image. Short-term memory has two limitations: capacity of memory and time limit. The brain will see, observe and try to store in the memory. This experiment was conducted with 12 patients showing two images, A and B. Later, the researchers asked a few questions and calculated the order of display image, type of the image, and correctness of the answer, and classification was obtained using four methods of AI, which are SVM, KNN, Navi Bayesian, and Random Forest. The classification result declares that 90.12% of correct answers in the orders of the image shown are drawn from the persons. A total of 90.51% of emotional people can answer the time and type questions correctly [24].

Electrooculography (EOG)is a bio-signal used to observe eye movements and to record the cornea–retina potential difference. The electrodes are placed above and below the right side or left side of the eyes. Of two electrodes, one is positive and another one is negative. The eyes will move to either side, and the researchers can record the position of potential difference between the electrodes. The real-time applications are implemented to guide wheelchair patients and HCI applications for people who suffer from brainstem strokes, injuries to the brain and spine, etc. The spectrum of studies is carried out on EOG bio-signals in medical areas such as cranial nerves (CN) to record the positive and negative waveforms. In this study, 18 patients who had brain surgery have kept practicing this technology [25].

Mechanical devices such as wheel chair, mechanical arms, aerial vehicles, and toys cars are controlled by neuroscience. The real-time bio-signals (EEG) of the human brain are recorded. These signals are processed on a Raspberry Pi3 circuit board. The open-source code used to process the signals include brain flow, sLORETA and TAPEEG. The artificial intelligence and machine learning are used to control the robots [26].

## 2. Latest Trends in Bio-Signal Application in the Medical Industry

The latest medical applications are using bio-signals for speech rehabilitation. Bio-signals can capture the air vibrations below the audible speaking mode. The speech can be captured using articulator, respiratory and laryngeal activities, brain activities, acoustic activity, and muscle activity, and are observed by bio-signals. The speech can be converted into artificial voice or text. Non-contact sensors are used to capture the image to predict the human facial expression and human observations on objects. Bio-signals help us to observe the emotions of a person while answering in the house of judgment. Another application health checkup needs to be performed for pilots before they take a flight for flying. Clinical observations were performed to check for drug and alcohol use and check for depression or anxiety. The near-field communication is very important for sending children to field trips, forest tracking, missing ships, missing flights and searching for people in a dense forest. It is also used to estimate the emotion of a sports person while participating in car racing and estimate the pressure of a student while taking an exam. The latest application and industry applicable details are discussed in **Table 2**.

**Table 2.** Latest Trends in Bio-signal Applications.

| Latest Trends in Bio-Signal Applications in the Medical Industry | | | |
|---|---|---|---|
| **Author** | **Field of Application** | **Type of Signal** | **Concept of Application** |
| Tanja Schultz et al. [27] | Speech Rehabilitation | EMG, EEG, ECoG, fNIRS, US, PMA | Artificial Voice |
| Tourangeau et al. [28] | Facial Expression, Eye movement, and Skin Resistance | Video Camera<br>Eye-tracking<br>GSR measurements | Non-Contact Sensor |
| Akane Sano et al. [29] | Visual communication, automatic music selection, automatic metadata annotation | pulse wave, EMG, and acceleration sensors | Music play |
| Egon L et al. [30] | Unveiling Human Emotions through Bio-signals | EMG, EDA | classify the class of emotion |
| Suh, Y.A. et al. [31] | Existing Fitness for Duty: a worker's drug and alcohol level is taken, check for depression and anxiety | EEG indicators<br>EEG indicators, ECG indicators, BVP, GSR, | Multi-Criteria Decision Making |
| Eduardo Coutinho et al. [32] | Estimating bio-signals using the human voice | HR and skin conductance | audio recordings, video recording |
| Yushou Tang et al. [33] | Emotion Recognitions like sadness, disgust, neutrality, fear, happiness | nelectroencephalography (EEG) signals | eye movements or physiological signals |
| Ken Yamashita [34] | Bio-signal Monitoring System with Near Field Communication | Antenna for NFC, Acceleration/Electrodes | Smart phones using Near Field Communication (NFC) |

## 3. Challenges in Bio-Signals

Medical applications are designed with technology to detect the expected scenarios, monitor the human health system, and predict life hazards; brain readings, etc., are some of the generalized challenges in the medical industry. There is also usage of wheel sensors, inclinometers, voltage meters, gyroscopes, and torque sensors in the feedback process between the nervous system and the human body parts. These sensors help to find any biological changes that occur in the human brain and find how they are received and reflected in terms of behavioral changes. Medical applications need to be developed to correlate the sensors with human brain connectivity. COVID-19 has changed human lives and style of living, and global awareness has changed the mindsets, behavior and the utilization of devices or resources in people. Using hepatic technology, the researchers can eliminate human touch over resources and devices such as ATMs, lifts, etc. Another challenge in the COVID-19 pandemic is maintaining social distancing and creating an alarm system to give information to the police if social distancing is not maintained in a crowded area such as schools, colleges, parks, cinemas halls, etc., using a passive infrared (PIR) sensor with the geo tagging association. Doctors are facing medical challenges in treating COVID-19 patients; patients are isolated in a room and doctors and medical staff only visit patients for rotating checkups and emergency needs. COVID-19 patients are emotionally and mentally stressed and biofeedback monitoring is needed.

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