International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

A Short Review on Biomedical Signals

Gajbe R. J.

Department of Electronics, Vidya Bharati Mahavidyalaya, Amravati, M.S., India-444 602
Corresponding Author Mobile No.: +919423649592 Email: rjgajbe[at]gmail.com

Abstract: ***This paper is briefly reviewed on types, examples, objective of Biomedical signals , which are observations of physiological activities of organisms, ranging from gene and protein sequences, to neural and cardiac rhythms, to tissue and organ images. Biomedical signal processing aims at extracting significant information from biomedical signals. With the aid of biomedical signal processing, biologists can discover new biology and physicians can monitor distinct illnesses.***

Keywords: Biomedical signals; examples, objectives; difficulties encountered

1.Introduction

The human body is a system which includes the nervous system, the cardiovascular system, and the musculoskeletal system, among others. The cardiac system performs the important task of rhythmic pumping of blood throughout the body to facilitate the delivery of nutrients, as well as pumping blood through the pulmonary system for oxygenation of the blood itself. Every system is consisting of several subsystems that carry on many physiological processes. Physiological processes are complex phenomena, including nervous or hormonal stimulation and control; inputs and outputs that could be in the form of physical material, neurotransmitters, or information; and action that could be mechanical, electrical, or biochemical. Most physiological processes are accompanied by or manifest themselves as signals that reflect their nature and activities. Such signals could be of many types, including biochemical in the form of hormones and neurotransmitters, electrical in the form of potential or current, and physical in the form of pressure or temperature [1-3].

Diseases or defects in a biological system cause alterations in its normal physiological processes, leading to pathological processes that affect the performance, health, and general well-being of the system. A pathological process is typically associated with signals that are different in some respects from the corresponding normal signals. If we possess a good understanding of a system of interest, it becomes possible to observe the corresponding signals and assess the state of the system.

In intensive-care monitoring, the ear drum temperature may sometimes be measured using an infra-red sensor. Occasionally, when catheters are being used for other purposes, a temperature sensor may also be introduced into an artery or the heart to measure the core temperature of the body. It then becomes possible to obtain a continuous measurement of temperature, although only a few samples taken at intervals of a few minutes may be stored for subsequent analysis [4, 5]. Let us now consider another basic measurement in health care and monitoring: that of blood pressure (BP). Each measurement consists of two values - the systolic pressure and the diastolic pressure. BP is measured in milli-meters of mercury (mm of Hg) in clinical practice, although the international standard unit for pressure is the Pascal [6-8].

2.Examples of Biomedical Signals

The preceding example of body temperature as a signal is a rather simple example of a biomedical signal. Regardless of its simplicity, we can appreciate its importance and value in the assessment of the well-being of a child with a fever or that of a critically ill patient in a hospital. The origins and nature of a few other biomedical signals of various types are described in the following subsections, with brief indications of their usefulness in diagnosis.

2.1 The action potential

This is the electrical signal that accompanies the mechanical contraction of a single cell when stimulated by an electrical current**.** Which cause by the flow of sodium**,** potassium, chloride and other ions across the cell membrane. It is the basic component **of** all bioelectrical signals. It provides information on the nature of physiological activity at the single-cell level. Recording an action potential requires the isolation of a single cell, and microelectrodes with tips of the order of a few micrometers to stimulate the cell and record the response [9].

2.2 The Electroneurogram (ENG)

The ENG is an electrical signal observed as a stimulus and the associated nerve action potential propagate over the length of a nerve. It may be used to measure the velocity of propagation (or conduction velocity) of a stimulus or action potential in a nerve [lo]. ENGs may be recorded using concentric needle electrodes or silver - silver-chloride electrodes (Ag - AgCl) at the surface of the body [10].

2.3 The Electromyogram (EMG)

Skeletal muscle fibers are considered to be twitch fibers because they produce a mechanical twitch response for a single stimulus and generate a propagated action potential. Skeletal muscles are made up of collections of motor units**,** each of which consists of an anterior horn cell (or motoneuron or motor neuron), its axon, and all muscle fibers innervated by that axon. **A** motor unit is the smallest muscle unit that can be activated by volitional effort. The constituent fibers of a motor unit are activated synchronously. Component fibers of a motor unit extend lengthwise in loose bundles along the muscle. In cross-section, the fibers of a given motor unit are interspersed with the fibers of other motor units [11-12].

2.4 The electrocardiogram (ECG)

The ECG is the electrical manifestation of the contractile activity of the heart, and can be recorded fairly easily with surface electrodes on the limbs or chest. The ECG is perhaps the most commonly known, recognized, and used biomedical signal. The rhythm of the heart in terms of beats per minute may be easily estimated by counting the readily identifiable waves. More important is the fact that the ECG wave shape is altered by cardiovascular diseases and abnormalities such as myocardial ischemia and infarction, ventricular hypertrophy, and conduction problems [13].

2.5 The electroencephalogram (EEG)

The EEG (popularly known as brain waves**)** represents the electrical activity of the brain. A few important aspects of the organization of the brain are as follows: The main parts of the brain are the cerebrum, the cerebellum, the brain stem (including the midbrain, pons medulla, and the reticular formation), and the thalamus (between the midbrain and the hemispheres). The cerebrum is divided into two hemispheres, separated by a longitudinal fissure across which there is a large connective band of fibers known as the corpus callosum. The outer surface of the cerebral hemispheres, known as the cerebral cortex, is composed of neurons (grey matter) in convoluted patterns, and separated into regions by fissures (sulci). Beneath the cortex lie nerve fibers that lead to other parts of the brain and the body [14-16].

2.6 Event-related potentials (ERPs)

The term **event-related potential** is more general than and preferred to the term **evoked potential,** and includes the ENG or the EEG in response to light, sound, electrical, or other external stimuli. Short-latency ERPs are predominantly dependent upon the physical characteristics of the stimulus, whereas longer-latency ERPs are predominantly influenced by the conditions of presentation of the stimuli.

2.7 The Electrogastrogram (EGG)

The electrical activity of the stomach consists of rhythmic waves of depolarization and repolarization of its constituent smooth muscle cells **[17-19].** The activity originates in the mid-corpus of the stomach, with intervals of about 20 s in humans. The waves of activity are always present and are not directly associated with contractions; they are related to the spatial and temporal organization of gastric contractions. External (cutaneous) electrodes can record the signal known as the electrogastrogram (EGG). Chen et al. [20] used the following procedures to record cutaneous EGG signals.

2.8 The Phonocardiogram (PCG)

The heart sound signal is perhaps the most traditional biomedical signal, as indicated by the fact that the stethoscope is the primary instrument carried and used by physicians. The PCG is a vibration or sound signal related to the contractile activity of the cardio hemic system (the heart and blood together) and represents a recording of the heart sound signal. Recording of the PCG signal requires a transducer to convert the vibration or sound signal into an electronic signal: microphones, pressure transducers, or accelerometers may be placed on the chest surface for this purpose. The normal heart sounds provide an indication of the general state of the heart in terms of rhythm and contractility. Cardiovascular diseases and defects cause changes or additional sounds and murmurs that could be useful in their diagnosis [21-25].

2.9 The carotid pulse (CP)

The carotid pulse is a pressure signal recorded over the carotid artery as it passes near the surface of the body at the neck. It provides a pulse signal indicating the variations in arterial blood pressure and volume with each heart beat. Because of the proximity of the recording site to the heart, the carotid pulse signal closely resembles the morphology of the pressure signal at the root of the aorta; however, it cannot be used to measure absolute pressure [21].

2.10 Signals from catheter-tip sensors

For very specific and close monitoring of cardiac function, sensors placed on catheter tips may be inserted into the cardiac chambers. It then becomes possible to acquire several signals such as left ventricular pressure, right atrial pressure, aortic pressure, and intra cardiac sounds. While these signals provide valuable and accurate information, the procedures are invasive and are associated with certain risks [22, 23].

2.11 The speech signal

Human beings are social creatures by nature, and have an innate need to communicate. We are endowed with the most sophisticated vocal system in nature. The speech signal is an important signal, although it is more commonly considered as a communication signal than a biomedical signal. However, the speech signal can serve as a diagnostic signal when speech and vocal-tract disorders need to be investigated [25].

2.12 The Vibroarthrogram (VAG)

Considerable noise is often associated with degeneration of knee-joint surfaces. The VAG is the vibration signal recorded from a joint during movement (articulation) of the joint. Normal joint surfaces are smooth and produce little or no sound, whereas joints affected by osteoarthritis and other degenerative diseases may have suffered cartilage loss and produce grinding sounds. Detection of knee-joint problems via the analysis of VAG signals could help avoid unnecessary exploratory surgery, and also aid

Paper ID: SR22429215651 DOI: 10.21275/SR22429215651

better selection of patients who would benefit from surgery. The VAG signal, however, is not yet well understood, and is a difficult signal to analyse due to its complex non stationary characteristics [26-32].

2.13 Oto-acoustic emission signals

The oto-acoustic emission (OAE) signal represents the acoustic energy emitted by the cochlea either spontaneously or in response **to** an acoustic stimulus. The discovery of the existence of this signal indicates that the cochlea not only receives sound but also produces acoustic energy. The OAE signal could provide objective information on the micromechanical activity of the preneural or sensory components of the cochlea that are distal to the nerve-fiber endings. Analysis of the OAE signal could lead **to** improved noninvasive investigative techniques to study the auditory system. The signal may also assist in screening of hearing function and in the diagnosis of hearing impairment [33].

3.Objectives of Biomedical Signal Analysis

The representation of biomedical signals in electronic form facilitates computer processing and analysis of the data. Figure 1.1 illustrates the typical steps and processes involved in computer-aided diagnosis and therapy based upon biomedical signal analysis.

The major objectives of biomedical instrumentation and signal analysis [10-12] are:

- **Information gathering** - measurement of phenomena to interpret a system.
- **Diagnosis** - detection of malfunction, pathology, or abnormality.
- **Monitoring** - obtaining continuous or periodic information about a system.
- **Therapy and control** - modification of the behaviour of a system based upon the outcome of the activities listed above to ensure a specific result.
- **Evaluation** - objective analysis to determine the ability to meet functional requirements, obtains proof of performance, perform quality control, or quantify the effect of treatment.

Signal acquisition procedures may be categorized as being invasive or non invasive, and active or passive.

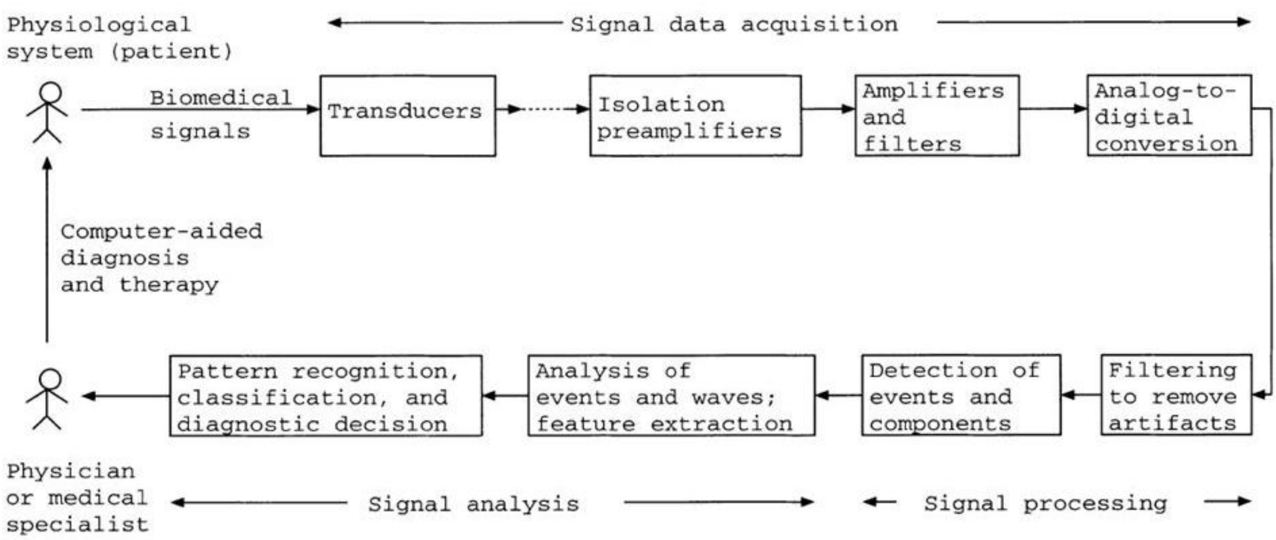

Figure 1.1: Computer-aided diagnosis and therapy based upon biomedical signal analysis

3.1 The human - instrument system:

The components of a **human** – **instrument system** [10-12] are:

- **The subject or patient:** It is important always to bear in mind that the main purpose of biomedical instrumentation and signal analysis is to provide a certain benefit to the subject or patient.
- **Stimulus or procedure of activity** Application of stimuli to the subject in active procedures requires instruments such as strobe light generators, sound generators, and electrical pulse generator.
- **Transducers:** electrodes, sensors.
- **Signal-conditioning equipment:** amplifiers, filters.
- **Display equipment:** oscilloscopes, strip-chart or paper recorders, computer monitors, printers.
- **Recording, data processing, and transmission equipment:** analog instrumentation tape recorders, analog-to-digital converters (ADCs), digital-to-analog converters (DACs), digital tapes, compact disks (CDs), diskettes, computers, telemetry systems.
- **Control devices:** power supply stabilizers and isolation equipment, patient intervention systems.

The science of measurement of physiological variables and parameters is known as biometrics**.** Some of the aspects to be considered in the design, specification, or use of biomedical instruments [13-17] are:

- **Isolation of the subject or patient** - of paramount importance **so** that the subject is not placed at the risk of electrocution.

- **Range of operation** - the minimum to maximum values of the signal or parameter being measured.
- **Sensitivity** - the smallest signal variation measurable. This determines the resolution of the system.
- **Linearity** - desired over at least a portion of the range of operation. Any nonlinearity present may need to be corrected for at later stages of signal processing.
- **Hysteresis** - a lag in measurement due to the direction of variation of the entity being measured. Hysteresis may add a bias to the measurement, and should be corrected
- **Frequency response** - represents the variation of sensitivity with frequency.
- **Stability** - an unstable system could preclude repeatability and consistency of measurements.
- **Signal-to-noise ratio (SNR)** - power-line interference, grounding problems, thermal noise, and so on, could compromise the quality of the signal being acquired. A good understanding of the signal-degrading phenomena present in the system is necessary in order to design appropriate filtering and correction procedures.
- **Accuracy** - includes the effects of errors due to component tolerance, movement, or mechanical errors; drift due to changes in temperature, humidity, or pressure; reading errors due to, for example, parallax; and zeroing or calibration errors.

4. Difficulties Encountered in Biomedical Signal Acquisition and Analysis

4.1 Accessibility of the variables to measurement:

Most of the systems and organs of interest, such as the cardiovascular system and the brain, are located well within the body (for good reasons!). While the ECG may be recorded using limb electrodes, the signal so acquired is but a projection of the true 3D cardiac electrical vector of the heart onto the axis of the electrodes. Such a signal may be sufficient for rhythm monitoring, but could be inadequate for more specific analysis of the cardiac system.

4.2 Variability of the signal source:

It is evident from the preceding sections that the various systems that comprise the human body are dynamic systems with several variables. Biomedical signals represent the dynamic activity of physiological systems and the states of their constituent variables. The nature of the processes or the variables could be deterministic or random (stochastic); a special case is that of periodicity or quasi-periodicity.

4.3 Inter-relationships and interactions among physiological systems:

The various systems that compose the human body are not mutually independent; rather, they are inter-related and interact in various ways. Some of the interactive phenomena are compensation, feedback, cause-and-effect; collateral effects, loading, and take-over of function of a disabled system or part by another system or part.

4.4 Effect of the instrumentation or procedure on the system:

The placement of transducers on and connecting a system to instruments could affect the performance or alter the behavior of the system, and cause spurious variations in the parameters being investigated. The experimental procedure or activity required to elicit the signal may lead to certain effects that could alter signal characteristics. This aspect may not always be obvious unless careful attention is paid. may need some rest between procedures or their repetitions.

4.5 Physiological artefacts and interference:

One of the pre-requisites for obtaining a good ECG signal is for the subject to remain relaxed and still with no movement. Coughing, tensing **of** muscles, and movement of the limbs cause the corresponding EMG to appear as an undesired artefact. In the absence of any movement by the subject, the only muscular activity in the body would be that of the heart. When chest leads are used, even normal breathing could cause the associated EMG of the chest muscles to interfere with the desired ECG.

4.6 Energy limitations:

Most biomedical signals are generated at microvolt or millivolt levels at their sources. Recording such signals requires very sensitive transducers and instrumentation with low noise levels. The connectors and cables need to be shielded as well, in order to obviate pickup of ambient electromagnetic (EM) signals. Some applications may require transducers with integrated amplifiers and signal conditioners so that the signal leaving the subject at the transducer level is much stronger than ambient sources of potential interference.

4.7 Patient safety:

Protection of the subject or patient from electrical shock or radiation hazards is an unquestionable requirement of paramount importance. The relative levels of any other risks involved should be assessed when a choice is available between various procedures, and analyzed against their relative benefits. Patient safety concerns may preclude the use of a procedure that may yield better signals or results than others, or require modifications to a procedure that may lead to inferior signals. Further signal-processing steps would then become essential in order to improve signal quality or otherwise compensate for the initial loss.

References

[1] Lathi BP. Signal Processing and Linear Systems. Berkeley-Cambridge, Carmichael, CA, 1998.
[2] Oppenheim AV, Willsky AS, and Nawab SH. Signals and Systems. Prentice- Hall, Englewood Cliffs, NJ, 2nd edition, 1997.
[3] Papoulis A. Signal Analysis. McGraw-Hill, New York, NY, 1977.

[4] Papoulis A. Probability, Random Variables, and Stochastic Processe. McGraw-Hill, New York, NY, 1965.
[5] Bendat JS and Piersol AG. Random Data: Analysis and Measurement Procedures. Wiley, New York, NY, 2nd edition, 1986.
[6] Aufin JI and Chandrasekar V. Introduction to Probability and Random Processes. McGraw-Hill, New York, NY, 1997.
[7] Ramsey FL and Schafer DW. The Statistical Sleuth -A Course in Methods of Data Analysis. Wadsworth Publishing Company, Belmont, CA, 1997.
[8] Riffenburgh RH. Statistics in Medicine. Academic, San Diego, CA, 1993.
[9] Bailar 111 JC and Mosteller F, editors. Medical Uses ofStatistics. NElM Books, Boston, MA, 2nd edition, 1992.
[10] Webster JG, editor. Medical Instrumentation: Application and Design. Wiley, 489 New York, NY, 3rd edition, 1998.
[11] Goodgold J and Eberstein A. Electrodiagnosis of Neummuscular Diseases. Williams and Wilkins, Baltimore, MD, 3rd edition, 1983.
[12] de Luca CJ. Physiology and mathematics of myoelectric signals. IEEE Trunsactions on Biomedical Engineering, 26:3 13-325, 1979
[13] Rushmer RE Cardiovascular Dynamics. WB Saunders, Philadelphia, PA, 4th edition, 1976
[14] Cooper R, Osselton JW, and Shaw JC. EEG Technology. Butterworths, London, UK, 3rd edition, 1980.
[15] Kooi KA, Tucker RP, and Marshall RE. Fundamentals of Electroencephalography. Harper & Row, Hagerstown, MD, 2nd edition, 1978.
[16] Hughes JR. EEG in Clinical Practice. Butterworth, Woburn, MA, 1982.
[17] Verhagen MAMT, van Schelven LJ, Samsom M, and Smout AJPM. Pitfalls in the analysis of electrogastrographic recordings. Gastroenterology, 1 17:453-460, 1999.
[18] Mintchev MP and Bowes KL. Capabilities and limitations of electrogastrograms. In Chen JDZ and McCallum RW, editors, Electrogastrography: Principles and Applications, pages 155-169. Raven, New York, NY, 1994.
[19] Mintchev MP and Bowes KL. Extracting quantitative information from digital electrogastrograms. Medical and Biological Engineering and Computing, 34244-248, 1996.
[20] Chen JDZ, Stewart Jr. WR, and McCallum RW. Spectral analysis of episodic Rhythmic variations in the cutaneous electrogastrogram. ZEEE Transactions on Biomedical Engineering, 40(2): 128-1 35, 1993
[21] Rangayyan RM and Lehner RJ. Phonocardiogram signal processing: A review. CRC Critical Reviews in Biomedical Engineering, 15(3):211-236, 1988.
[22] Tavel ME. Clinical Phonocardiography and External Pulse Recording. Year Book Medical, Chicago, IL, 3rd edition, 1978.
[23] Luisada AA and Portaluppi F. The Heart Sounds - New Facts and Their Clinical Implications. Praeger, New York, NY, 1982.
[24] Shaver JA, Salerni R, and Reddy PS. Normal and abnormal heart sounds in cardiac diagnosis, Part I: Systolic sounds. Current Problems in Cardiology, lO(3): 1-68, 1985.
[25] Reddy PS, Salerni R, and Shaver JA. Normal and abnormal heart sounds in cardiac diagnosis, Part 11: Diastolic sounds. Current Problems in Cardiology, lO(4):l-55, 1985.
[26] Frank CB, Rangayyan RM, and Bell GD. Analysis of knee sound signals for non-invasive diagnosis of cartilage pathology. IEEE Engineering in Medicine and Biology Magazine, pages 65-68, March 1990.
[27] Tavathia S , Rangayyan RM, Frank CB, Bell GD, Ladly KO, and Zhang YT. Analysis of knee vibration signals using linear prediction. IEEE Transactions on Biomedical Engineering, 39(9):959-970, 1992.
[28] Moussavi ZMK, Rangayyan RM, Bell GD, Frank CB, Ladly KO, and Zhang YT. Screening of vibroarthrographic signals via adaptive segmentation and linear prediction modeling. IEEE Transactions on Biomedical Engineering, 43(1): 15-23, 1996.
[29] Krishnan S, Rangayyan RM, Bell GD, Frank CB, and Ladly KO. Adaptive filtering, modelling, and classification of knee joint vibroarthrographic signals for non-invasive diagnosis of articular cartilage pathology. Medical and Biological Engineering and Computing, 35(6):677-684, 1997.
[30] Rangayyan RM, Krishnan S, Bell GD, Frank CB, and Ladly KO. Parametric representation and screening of knee joint vibroarthrographic signals. IEEE Transactions on Biomedical Engineering, 44(1 1): 1068-1074, 1997.
[31] Kernohan WG, Beverland DE, McCoy GF, Hamilton A, Watson P, and Mollan RAB. Vibration arthrometry. Acta Orthopedica Scandinavia, 61 (1):70-79, 1990.
[32] Chu ML, Gradisar IA, and Mostardi R. A noninvasive electroacoustical evaluation technique of cartilage damage in pathological knee joints. Medical and Biological Engineering and Computing, 16:437-442, 1978.
[33] Probst R, Lonsbury-Martin B, and Martin GK. A review of otoacoustic emissions. Journal of the Acoustical Society of America, 89(5):2027-2067, 1991