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APPLICATIONS OF NANOTECHNOLOGY IN BIOMEDICAL SIGNAL PROCESSING SUCH AS ECG EEG & EMG TO GAIN REQUIRED INFORMATION FOR DIAGNOSIS

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ABSTRACT

There are three different levels at which biomedical signals can be acquired from the body: the organ level, the cell level, and the molecular level. There are different biomedical signals including the electroencephalogram (EEG), which is the electrical activity from the brain; the electrocardiogram (ECG), which is the electrical activity from the heart; the electro-myogram (EMG), which is the electrical activity from the muscle sound signals; the electro-neurogram; the electro-retinogram from the eye; and so on. Biomedical signals are typically utilized for the purpose of diagnosing or detecting particular physiological or pathological states. Furthermore, these signals are utilized in the field of healthcare for the purpose of statistically analyzing biological systems. signal denoising, exact detection of signal model through analysis, feature extraction and dimension reduction for definitive function or dysfunction, and prediction of future functional or pathological events by utilizing machine learning techniques are the goals of signal processing. Signal processing is also known as signal processing. The purpose of this chapter is to provide an overview of the various applications of biomedical signals in the medical field, as well as the various stages involved in the process of biomedical signal analysis.

Keywords: *diagnosis, nanotechnology, biomedical, processing*

INTRODUCTION

Over the course of the past several years, a multitude of significant advancements in the fields of microprocessor technology and biological signal detection have been made. For the purpose of in vivo measurement, new sensors that are not only biocompatible but also free from ionizing radiation have been developed. Examples of such sensors include optical sensing devices of this type. Some examples of such revolutionary sensors are sensors that are based on optical fiber and small sensors that are implanted in the bloodstream. During the same time period, multi-core microprocessors and field-programmable gate arrays (FPGA) have become accessible and affordable for a wide variety of applications. Because of these enabling technologies, opportunities have arisen to develop and deploy noise decontamination methods that are more complex and effective to biological signals in order to extract information that is clinically meaningful in real time. Because there are so many different biological signal processing approaches, both traditional and modern, there is a growing demand to determine which methods are the most effective for certain therapeutic applications.

Biological Signals—Basic Definition

The term "biological signal" will be used throughout this article to refer to any signal that originates from a human body. Naturally, such signals may be present within an organ as a result of the homeostatic processes that are taking place within it, or they may be generated by the application of an external stimulus. Within the realm of biological signals, it is feasible to categorize them according to the physical features that are naturally generated by stimulation. The biological signals that are utilized in everyday clinical practice are the ones that are employed the most frequently. Generally speaking, these are as follows:

- Biologically induced electric signals, which are derived from the electric events that occur on the membranes of cells;
- The measuring of noises that are produced by certain organs as a result of fluidic or mechanical motions within the body is what is referred to as bio-acoustic signals;
- The measurements of biomechanical signals, which include the deflections in position, pace, acceleration, flow rates, and pressures, are included in this category;
- There are biochemical signals that provide information about the concentration of chemicals in the body as well as their pH;
- Body temperature, which reflects the metabolic interactions within the body.

There are, of course, other kinds of biological signals, such as bio-impedance and bio-magnetic signals, which are typically not utilized because of the complexity of their accompanying measurements and the limited clinical utility they offer. Clinical uses of bioelectrical signals are, in fact, the most common kinds of applications for these signals. Because of this, the processing of bioelectrical signals is going to be the primary focus of this work. A comprehensive diagram of the many different types of biosignals is shown in Figure 1.

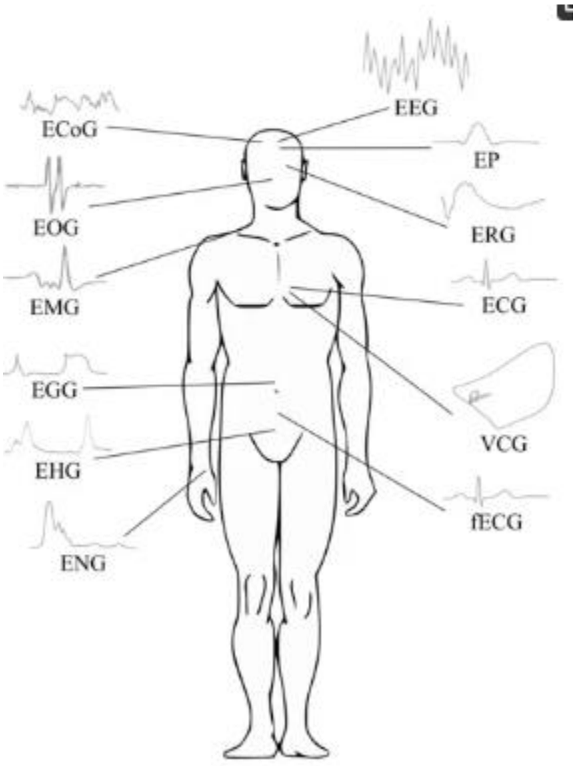

Figure 1. Bio-signals general scheme.

Bioelectrical Signals

In reality, a bioelectrical signal is formed by adding up the action potentials of cells that are located at a particular anatomical location, such as the heart, the brain, or the skeletal muscle. The action potential is a signal that is produced by an electrical current that is activated by an electrical current that is either neuronal or external. This signal is produced in conjunction with a mechanical contraction of a single cell. This electrical signal is a result of the movement of ions across the cell membrane, including sodium (Na+), potassium (K+), chloride (Cl−), and other ions.

Both depolarization and repolarization are stages that may be distinguished from one another in terms of the electrical activity of the cell. The depolarization phase is the beginning of the action potential, and the highest value of the action potential is approximately 20 millivolts for the majority of cells. When Na+ ions enter the cell, it causes a change in the concentration of Na+ in the cell, which is the cause of this condition. It can be stated that the interior of the cell achieves a positive potential in comparison to the exterior of the cell. After a specific duration of being in the depolarized state, the cell undergoes a process known as repolarization, which ultimately results in the cell becoming polarized once more and returning to its resting potential, which can range from -60−60 to -100−100 mV. This is in contrast to the depolarization process, in which the permeability of the membrane is significantly slower for K+ ions than it is for Na+ ions. The repolarization process is characterized by the predominant membrane permeability for K+ ions. Because the concentration of potassium ions (K+) inside the cell is significantly larger than the concentration outside the cell, there is a net outflow of potassium ions (K+) from the cell. This makes the inside of the cell more negative, which in turn affects repolarization back to the resting potential. It is important to note that the duration of the action potential varies depending on the kind of cell. For instance, the duration of time for nerve and muscle cells is approximately one millisecond, whereas the duration of time for cardiac muscle cells is between one hundred fifty and three hundred milliseconds.

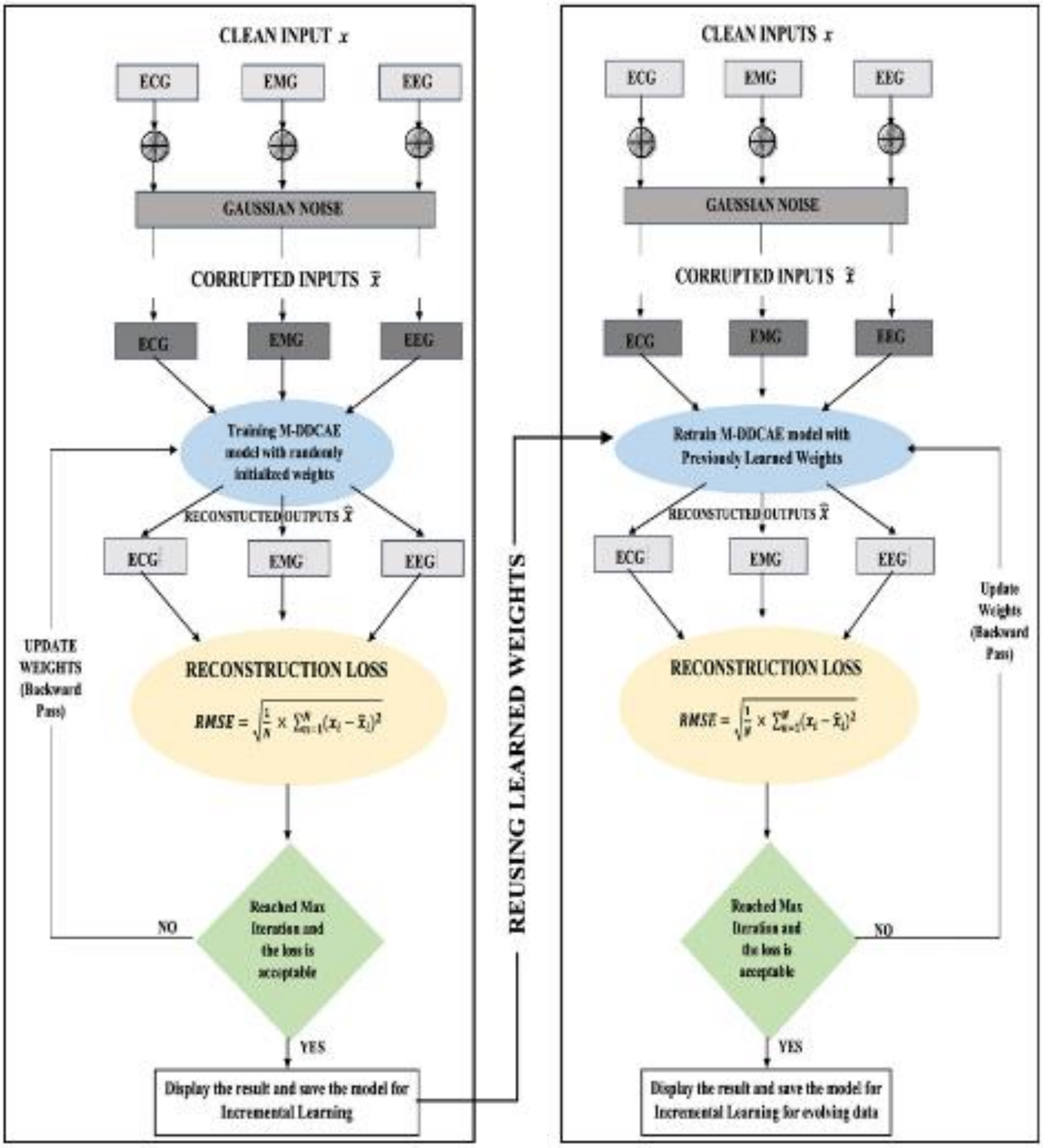

Figure 2 Signal processing flow diagram

At the level of the single cell as well as the level of the organ, bioelectrical signals offer a substantial amount of information regarding the nature of physiological activity.

Noise and Interference

There are numerous sorts of noise and interference that originate from the patient's body or the surroundings, and these factors cause each bioelectrical signal to become contaminated. When these noise signals superimpose on the signal, they cause the signal to become distorted in both the temporal and frequency domains. This frequently leads to the complete loss of the modest biological signal that is contained within the noise. Therefore, it is vital to eliminate these interferences in order to correctly analyze the signal that was detected and to acquire diagnostic information.

- **Power line interference (PLI)** It is the electromagnetic field that is dispersed throughout the power supply that is responsible for power line interference, often known as PLI. As the most prevalent form of noise in bioelectrical signals, it is characterized by the superposition of sinusoidal harmonic components at a frequency of fifty hertz in European countries and sixty hertz in the United States of America and Japan.

- **Baseline wander** The addition of the harmonic sinusoidal component to the signal with frequencies lower than 1 Hz is the result of baseline wander, which is caused by breathing and changes in the contact between the electrode and the skin. Both the baseline instability drift and the gradual shift in the signal waveform are caused by it. Because of their amplitude of 200–300 mV, which reflects the multiple amplitude of the biological signal that was detected, the electrode–skin interface artifacts that are induced by electrode movement constitute a considerable source of noise.

- **Slight movement artifacts** The movement of neighboring bodily parts (such as the limbs, tongue, eyes, and neck, among others) can often result in the formation of artifacts. Over a frequency range of up to 30 Hz, these artifacts are responsible for a distortion in the signal that is not harmonic.

- **Myopotentials and motion artifacts** are examples of random broadband signals that are overlaid on the measured signal. These signals are either by the muscle activity of the body part to which the electrode is attached, or they are caused by the bulk motion of the patient (for example, when they are exercising or walking).

- **Equipment-related artifacts** • An example of an equipment-related artifact is a high-frequency noise that is produced by the amplifiers, recording system, electromagnetic impulses throughout the environment that are transmitted through power lines, or the electro-surgical unit. The quality of the signal and the frequency resolution are both significantly diminished as a result of these abnormalities, which also result in the formation of signals with a high amplitude. These signals have the potential to obscure minor characteristics of biological signals, which are essential for a variety of applications, including clinical monitoring and diagnostics. In addition to this, it is essential to bring up the quantization noise that is introduced by the hardware that processes analog-to-digital signals, as well as the electronic noise that is coupled on the biosignals as a result of the analog front-end hardware. The utilization of a variety of data converters, which results in an increase in the bandwidth of the transceiver, causes these aberrations. There are problems with the nonlinearity of the data which arise due to the fact that the data converters are often mixed-signal components. The quantization noise is generally considered to be one of the most frequently simulated impairments that are associated with data converters. Conversion of a continuous random variable into a discrete form or conversion of a discrete random variable into a form with fewer levels are both examples of situations that can result in this phenomenon. When it comes to images or signals, quantization noise is something that comes up rather regularly during the acquisition process. When employing analog-to-digital converters, which often compress bioelectrical signals (especially the electrocardiogram), there is a possibility of experiencing some noise or quality loss that is associated with the equipment.

- **Impulse noise** • Artifacts from electrical stimuli employed for measuring the evoked activity of the cells that were researched are included in the category of impulse noise. Such artifacts include high-amplitude artifacts that are caused by digitizing and switching other electrical equipment, sharp changes of baseline that are caused by the loss of electrode–skin contact, and many others.

- **Biological signals** It is possible for biological signals that originate from other structures to be considered noise as well, given that they may overlap in time and frequency with the signal that is being sought for. Because of this, the extraction of individual components can be a difficult process.

When it comes to the design, characterization, manufacturing, and applications of materials, structures, devices, and systems, nanotechnology is a word that is used to designate areas of science and engineering in which phenomena that occur at nanoscale dimensions are utilized. In 1959, physicist Richard Feynman gave a talk on the subject of producing things at the atomic and molecular levels. This was the first time that the idea of nanotechnology was exposed to the public. Nanotechnology is currently considered to be the most promising technology of the twenty-first century, and researchers have explored it as a fresh tool in the field of medical research. As evidenced by the steadily growing amount of public investment allocated to nanotechnology research and development over the course of the past decade, nanotechnology will usher in a new era of improved productivity and wealth. The application of nanotechnology has the potential to stimulate economic growth while also improving a sector's capacity and quality. It has made a significant contribution to the well-being of today's society and has shaped the character of contemporary existence. There is a possibility that it will dramatically impact the dynamics of society, the conditions of the economy, and the lives of individuals.

Since the beginning of time, people have been searching for magical treatments that may alleviate the agony associated with illness and injury. Numerous academicians are of the opinion that the uses of nanotechnology in the medical field could be crucial in accomplishing this goal. Among these applications are comprehensive surveillance, control, creation, repair, and defense of all biological human systems. These applications make use of nanodevices and nanostructures that are designed to act on a molecular level. Nanotechnology has the potential to generate a new field of human betterment and bring about a profound transformation in medical research. There is a promising future for the diagnostic, therapeutic, and prophylactic applications of nanotechnology. This technology has the potential to purposely alter the body, which is just one of several issues. The nanoparticles that were utilized have showed that the bioavailability of the medication is improved, that the adverse effects are minimized, and that the therapeutic medicine is absorbed more efficiently.

Nanotechnology gives up new possibilities for the life sciences business, particularly in the field of healthcare. Many aspects of medical care, including diagnosis, monitoring for diseases, operating equipment, regenerative medicine, producing vaccinations, and medication distribution, could be significantly altered by the application of nanotechnology, which has a great deal of promise in terms of its ability to manipulate objects at the atomic level. In addition to this, it paves the way for the development of medications that can improve therapies for a variety of illnesses by taking advantage of advanced research instruments. It is possible to use nanotechnology to deliver medication to specific cells within the body, which can reduce the likelihood of the medication being rejected or not working properly.

OBJECTIVES

(1) To study the applications of nanotechnology in biomedical signal processing;

(2) To identify & discuss associated features and characteristics of Nanotechnology for the medical domain;

Need for nanotechnology in the medical field

There is a huge and diverse range of discoveries that can be made in nanotechnology and nano medicines. The field of nanomedicine has witnessed remarkable advancements, which have brought the drug to a new level and resulted in substantial improvements in healthcare. It is necessary to do research into the major capabilities that nanotechnology possesses in the field of medicine. The field of medicine is currently conducting a substantial amount of research into the most effective techniques and approaches, such as nephrology, cardiovascular disease therapeutic gene management, and cancer therapy. At the same time that the quality of nanoparticles and nanotechnology has improved and demonstrated positive results, there has been a major development in the conventional treatment. Nanoparticles have also been important in the field of gene therapy. There have been multiple investigations that have focused on the applications of viral vectors, which are thought to be mechanisms for the delivery of medication.

Data is transmitted from nanobots that target specific cancer cells to smart tablets, which are then sent back to researchers to guarantee that patients receive the appropriate treatment. The use of nanotechnology has the potential to facilitate in-vitro diagnostics by allowing for the replacement of conventional methods with alternatives that are both more cost-effective and simpler to implement. Nanoparticles have the potential to function as molecular imaging agents within these devices, allowing them to gain insight into cancer-related genetic mutations as well as the functional characteristics of tumor cells. In addition, coatings that are based on functional nanotechnology usually contain the following nanomaterials, depending on the function that is desired: titanium dioxide, silicon dioxide, carbon black, iron oxide, zinc oxide, and silver. Physiochemical characterization assessments, safety evaluations, and efficacy evaluations of nanomaterials and nanosurfaces that are integrated into medical device engineering are achieved through the utilization of instruments and techniques. Scientific research is an essential component in the production of a wide range of products, including innovative materials, sensors, and energy storage devices.

Electrocardiography

Electrocardiography, also known as ECG, is a diagnostic technique that allows for the recording of the electrical activity being produced by the heart muscle. The electrocardiogram (ECG) is measured by utilizing surface electrodes that are affixed to the chest or the limbs. Electrodes that are attached to the electrocardiogram are used to record the electrical activity of the heart, which is necessary for the heart to perform its pumping function correctly. The detection of arrhythmia, myocardial infarction, various cardiovascular diseases, and problems of the autonomic nervous system are only some of the situations that can be uncovered through the use of these electrical recordings, which provide information that is of great value.

Due to the fact that certain electrodes are part of two pairs and hence offer two leads, a standard 12-lead electrocardiogram (ECG) is obtained in clinical practice with a total of ten electrodes, which includes four limb electrodes and six thorax electrodes. A reference electrode, also known as a grounding electrode, is put to the right foot in order to form the chest leads. This electrode is formed by connecting the limb electrodes. AVR stands for "right hand," aVL stands for "left hand," and aVF stands for "left foot." These are the typical names for the limb leads. The leads I, II, and III, also referred to as Einthoven's triangle, are comprised of these three limb electrodes as individual components. One of the Wilson reference terminals can be found in the middle of this triangle. It is denoted by the letters V1–V6 that the chest leads are directed towards the Wilson terminal.

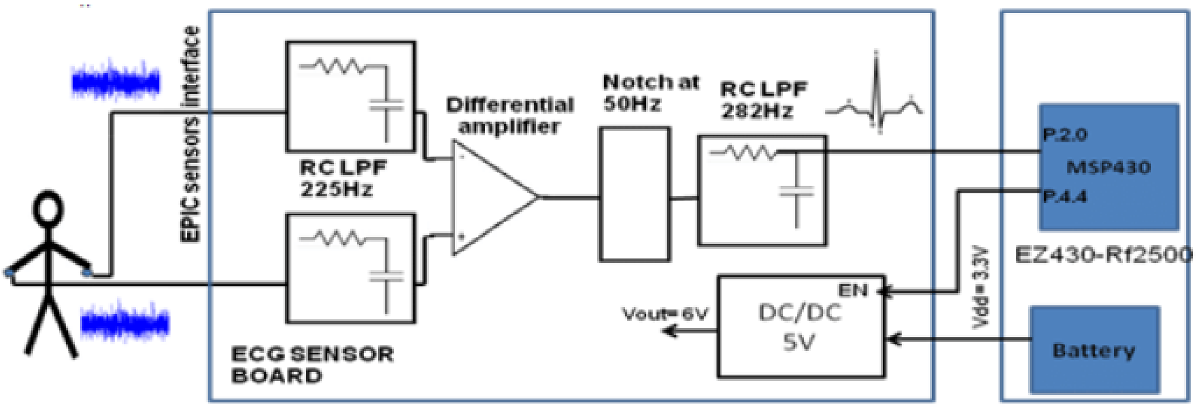

Figure 3 ECG sensor board block diagram and interfaces.

The amplitude of the electrocardiogram (ECG) signal falls within the range of 10μ10V to 4 mV, indicating that it is extremely smaller and weak. As a result, it is highly susceptible to a variety of disturbances or additional activity in other areas of the heart. There are a number of them that, in addition to the SA node, have its own rhythms and features. Some examples of these include the AV node, Purkinje fibers, and ventricularity. Within the range of 0.05–100 Hz, this signal's frequency that is considered to be the most significant is located. When it comes to diagnostic reasons, it is advised that the sample frequency be set at 500 Hz. In order to facilitate long-term monitoring, the frequency range that is being evaluated may be narrowed down to 0.5–50 Hz. Additionally, during stress tests, the frequency range may be increased to 30–50 Hz, with a sampling frequency of 100 Hz. On the other hand, the high-resolution electrocardiogram necessitates a wider frequency band, which falls the range of 0.050.05 to 500 Hz.

Electroencephalogram

An electroencephalogram, often known as an EEG, is a diagnostic procedure that involves attaching small metal discs, known as electrodes, to the scalp in order to assess the electrical activity in the brain. Even when they are sleeping, brain cells are constantly active and communicate with one another through the use of electrical impulses. On an electroencephalogram recording, this activity is represented as wavy lines.

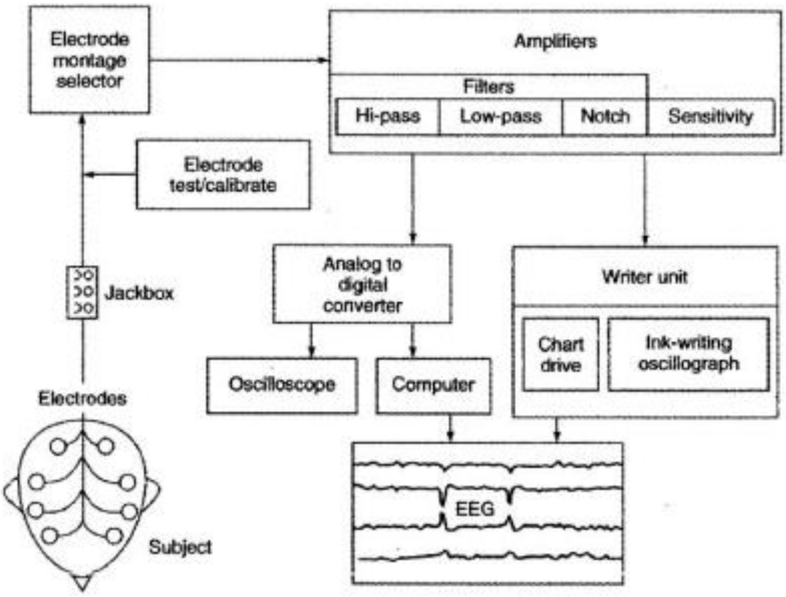

Figure 4 Schematic diagram of an EEG Machine

Another important diagnostic test for epilepsy is an electroencephalogram (EEG). An electroencephalogram (EEG) can also be utilized in the process of identifying different types of brain diseases. The electroencephalogram (EEG) has the capability to detect alterations in brain activity that could be of assistance in the diagnosis of brain illnesses, particularly epilepsy or another seizure disorder. An electroencephalogram (EEG) could also be useful in diagnosing or treating:

- Brain tumors
- Brain damage from head injury
- Brain dysfunction that can have a variety of causes (encephalopathy)
- Sleep disorders
- Inflammation of the brain (herpes encephalitis)
- Stroke
- Sleep disorders
- Creutzfeldt-Jakob disease

An EEG might also be used to confirm brain death in someone in a persistent coma. A continuous EEG is used to help find the right level of anesthesia for someone in a medically induced coma.

Electromyography

The technique known as electromyography (EMG) is a method used in electro-diagnostic medicine that involves analyzing and recording the electrical activity that is generated by skeletal muscles. The electromyogram (EMG) is produced by utilizing a device known as an electromyograph, which results in the production of a record known as an electromyogram. When muscle cells are electrically or neurologically activated, an electromyograph is able to detect the electrical nerve signals (potentials) that are created by these muscle cells. Detecting medical problems, activation level, or recruitment order can be accomplished through the analysis of the signals, as can the analysis of the biomechanics of movement in either humans or animals.

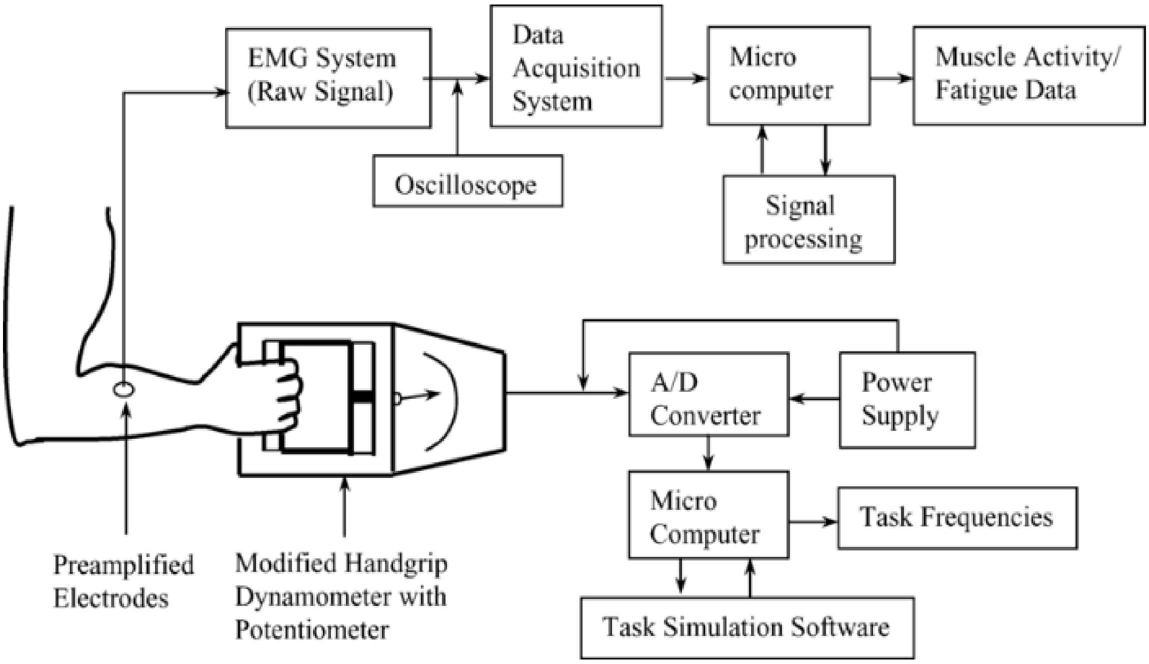

Figure 5 Block diagram of force and electromyography (EMG) system.

Electrical impulses are the driving force behind the actions of neurons and muscles. A series of electrical discharges that transport information in a pulse repetition frequency are responsible for the transmission of information along nerves. A range of one to one hundred pulses per second could be considered for this. In addition, the contraction of muscle fibers in electromyography is coupled with an electrical discharge. This discharge can be detected by measuring electrodes or it can be brought about by electrical stimulation.

When a person exhibits signs of weakness and an examination reveals that they have diminished muscle strength, electromyography (EMG) is administered. It is possible to get a better understanding of the differences between primary muscle problems and muscle weakness brought on by neurological illnesses. In order to discern between genuine weakness and limited utilization as a result of pain or a lack of enthusiasm, electromyography (EMG) can be utilized.

Recording electrodes, preamplifiers (which are typically positioned very close to the patient in order to prevent the pick-up of electrical interference), amplifiers that provide the correct gain, calibration, and frequency characteristics, a display system (typically a CRT), a variety of integrators and averagers - in part to achieve some data compression (chart records may be very long and difficult to read), and a recording medium, which is typically a photographic (fibre-optic) system, are the components that make up electromyography equipment.

When conducting a test, the most common procedure involves adhering an electrode to the skin directly above the muscle. The monitor displays the electrical activity that is detected by this electrode, and it is also possible to hear the activity audibly through a speaker (if one is present). Due to the fact that skeletal muscles are often huge units that are isolated from one another, each electrode only provides an average image of the activity of the muscle that is being picked. For the purpose of obtaining an accurate study, it may be necessary to position many electrodes in a variety of sites. It is possible that the patient will be requested to contract the muscle after the electrode(s) have been placed (for instance, by bending the arm).

Applications of Nanotechnology in Diagnostics

Nanodevices are currently being utilized by diagnostic sciences for the purpose of early and speedy disease diagnosis in order to provide further recommendations for medical procedures. Nanotechnology is also utilized for the purpose of determining the predisposition of disease at the cellular and molecular level in order to develop insights into potential treatment solutions. The application of nanotechnology has the potential to bring about a revolution in the field of healthcare diagnostics by enhancing the precision, sensitivity, and acceleration of medical examinations. One of the most significant applications is nanoparticle-based diagnostic imaging, in which nanoparticles can be attached to particular biomarkers in order to improve imaging modalities such as magnetic resonance imaging (MRI), computerized tomography (CT) scans, and positron emission tomography (PET) scans. This makes these imaging modalities more sensitive, accurate, and specific. In a similar vein, point-of-care diagnostic tests that are enabled by nanotechnology have the ability to detect infectious diseases, malignancies, and other ailments in a timely manner, hence enabling prompt treatment and prevention.

Nanotechnology has enabled the creation of highly sensitive biosensors that can detect even low quantities of biomolecules in physiological fluids such as blood and urine. This has made it possible to detect diseases at an earlier stage and to manage them more effectively. Biosensors are yet another application area that nanotechnology has enabled. Similar applications can be found in the form of microfluidic devices that integrate nanomaterials. These devices can be utilized to isolate and analyze particular cells, proteins, and genetic material, hence facilitating the detection of diseases in a timely and precise manner. Nanopore sequencing is a breakthrough technology that employs nanopores to detect the sequence of DNA or RNA molecules. This enables the speedy and precise diagnosis of genetic problems such as cancer and hereditary diseases. Another possible application of this technology is in the field of nanopore sequencing.

There have been recent developments that demonstrate nanomedicine has the potential to be utilized in the field of in vitro diagnostics sciences to enhance the effectiveness and dependability of illness detection. Nanodevices operating at the subcellular level are utilized to accomplish this goal, with samples derived from human tissue, cell culture, body fluids, and other natural sources. For the express aim of early diagnosis of any anomalies in the human body that could lead to toxicity or tumor formation events, the nanomedicine method is being employed in in vivo diagnostics to produce devices that are capable of working, responding, and altering within the human body. This is being done in order to develop in vivo diagnostics. Paramagnetic nanoparticles, nanocrystals, quantum dots, nanoshells, and nanosomes are some examples of the sorts of nanoparticles that are now being utilized for diagnostic reasons. The application of nanotechnology in the field of healthcare diagnostics is predicted to play an important role in the development of customized medicine. In general, nanotechnology possesses immense promise in this area.

CONCLUSIONS

The application of nanotechnology in the field of healthcare and medicine has the potential to bring about a significant transformation in the manner in which diseases are diagnosed, treated, and prevented. The field of nanotechnology entails the manipulation of materials on such a minute scale that the properties of the materials are markedly different from their bulk equivalents. This enables exact control of the materials' physical, chemical, and biological properties. New prospects for the development of novel medicines, tailored drug delivery systems, and sensitive diagnostic instruments are made available as a result of this revelation. In addition to drug delivery, targeted delivery, enhanced medications, limited dosages, and reduced systematic side effects, nanoparticles can also be used to increase the efficacy of existing drugs by increasing their solubility, stability, and bioavailability. This is in addition to the fact that nanoparticles can be employed during drug delivery. In addition, sensors and gadgets that are based on nanotechnology have the ability to monitor the health of patients in real time, which enables early identification and individualized therapeutic treatment regimens. It is also possible that in the future, nanotechnology will make it possible to create nanorobots that are able to traverse through the circulation in order to target and destroy cancer cells or deliver payloads of medications to specific areas.

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