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Prediction of Epileptic Seizures with the Use of Biomedical Sensors and Internet of Things

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M. Sc. Thesis

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Prediction of Epileptic Seizures with the Use of Biomedical Sensors and Internet of Things

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

ALLA FIKRAT ALWINDAWI

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ABSTRACT

Prediction of Epileptic Seizures with the Use of Biomedical Sensors and Internet of Things

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The biosensors became most important for monitoring patient status; the seizure epilepsy is taken into consideration to monitor the patients and predict their status before the seizure happen. The epilepsy is the 4th most common neurologic disorder affecting people of different ages which about 65 million people affected around the world, this disease is happen randomly and may be caused a sadden unexpected death. The standard monitoring epileptic seizures system involves video/EEG (electro-encephalography), which is bothersome for the patient, as EEG electrodes are attached to the patient head. Seriously, help and alert patient before the seizure is one of the issue that the researchers and designers attention. For that there are spectrums of portable seizure detection systems available in markets which are based on non-EEG signal.

This study is conducted to use the combined a portable wrist-band, together with smartphone which can easily carried by the patients. The portable wrist-band integrated four sensors to read the signal of three physiological parameters such as: Electromyography (EMG), Heart rate (HR), oxygen level (SpO_2) and accelerometer (ACM) biosensor; for facilitate in providing separable signal variation to recognize the status of patients.

The study applied on the Iraqi’s patients whom visit the Department of Neurology at Baghdad Hospital, almost all the patients had no-seizure during the EEG-Video recording which was one of the problems was faced during the trials of device, according to this problem the work change from real monitoring into virtual study.

In this study was incorporated Arduino platform ‘wrist-band” as a component part of the system. From the applied test it showed that the fixed wrist-band is confortable to use by the patient hand. Also, the used sensors were reflected a good signals of the studied parameters. The proposed system provide difference services such as heart rata tracking and oxygen level , user tracking location and emergency notification.

The Arduino-wear and android-smartphone side of the proposed system is implemented by the Android studio using java programming, while the portable written by Arduino programing language. The results of the proposed system response show a promising outcome that can depend on for predicting the seizure.

Keyword: Biosensors, Wearable sensors, Epilepsy, Seizures, Non-EEG, EMG, Autonomic Alterations in Epilepsy

ÖZET

Biyolojik ve İnternet Sensorlarının Kullanımı ile Epilepsi Nöbetlerinin/ Krizlerinin Tahmin Edilmesi

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Epilepsi hastaların gözetilmesi için biyolojik sensorları oldukça önemlidir. Söz konusu sensorlar, epilepsi nöbetinin meydana gelmesinden önce tahmin edebilir. Epilepsi hastalığı, dünya çapında çeşitli yaşlardaki insanların yakalandığı 4. nörolojik hastalıktır. Dünyada yaklaşık olarak 65 milyon kişi epilepsi hastalığından şikayet etmektedir. Rastgele meydana gelen bu hastalık ani ölüme sebebiyet verebilir. Epilepsi nöbetlerini tahmin etme sistemi, beyin için bir video/ elektroencefalogram cihazını içermektedir. Söz konusu cihaz hastalar için rahatsız edici olup, hastanın beynine bağlanır.

Araştırıcı ve tasarımcılar, epilepsi nöbetlerinin meydana gelmesinden önce hastalara yardım etme ve onları uyarma meselesine oldukça önem vermektedir. Dolayısıyla piyeslerde nöbeti keşfetmek için asılı spektrum sistemleri bulunmaktadır. Bunlar beyine, elektrikli çizim sinyalleri olmaksızın çalışmaktadır.

Araştırıcılar, bileklikte taşınan bir bileklik ve akıllı telefonları kullanarak bu incelemeyi yapmışlardır. Bileklik, "elektrik", "kalp atışları ortalaması", "oksijen seviyesi" ve hastanın durumunu belirtmek üzere ayrılabilir bir sinyalin sağlanması için "biyolojik sensor cihazını hızlandırma" olmak üzere dört sensordan oluşmaktadır.

Araştırıcılar, incelemeyi Bağdat'ta bulunan Nöroloji Hastalıkları Bölümü'ne gelen Iraklı hastalar üzerine uygulamışlardır. Neredeyse hastaların tamamı beyine elektrikli resim videosu kaydı sırasında epilepsi nöbetine maruz kalmamıştır. Bu durum da araştırıcıların karşılaştıkları sorunlardan biri olmuştur. Bu sorun yüzünden çalışma gerçek gözetlemekten tezli bir incelemeye dönüşmüştür.

Bu incelemede, sistemi oluşturan bir paça olarak Arduino programı birleştirilmiştir. Sabit bilekliğin kullanımı hasta için daha rahat olduğu testlerden gözlemlenmiştir. Bununla birlikte test sırasında incelenen bilgiler için sensorlar iyi sinyal sağlamıştır. Sistem ayrıca, kalp atışlarının ortalamasını izleme, oksijen seviyesi, hastanın bulunduğu yeri takip etme ve olağanüstü durumlarda alarm verme gibi değişik hizmetler sağlamıştır.

Java ve Android'den dil yazılımları kullanılarak Android Stüdyo'sunda sunulan akıllı telefonların Android ve Arduino yazılımları uygulanmıştır. Sistem sonucunda, nöbetlerin tahmin edilmesine ilişkin esas alınabilecek sonuçlar elde edilmiştir.

Anahtar Sözcükler: Biyolojik Sensorlar, Epilepsi, Nöbetler, Elektroencefalogram, Epilepsi hastalığı için otomatik alarm .

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LIST OF ABBREVIATIONS

SoC	System on Chip
ILAE	International League Against Epilepsy
SUDEP	sudden unexpected death in epilepsy
AEDs	Anti-Epileptic Drugs
SVD	Singular Value Decomposition
KCNQ1	**Potassium Voltage-Gated channel subfamily Q member 1**
SCN5A	Sodium Voltage-Gated channel Alpha subunit 5
HERG	Human Ether-a-go-go related gene
KCNH2	**Potassium Voltage-Gated channel subfamily H member 2**
GTCS	Generalized tonic-clonic seizure
EEG	Electroencephalography
CPS	complicated partial seizures
PDA	personal digital assistant
ECG	Electrocardiography
ACM	Accelerometer
HRV	Heart Rate Viability

Gyro	Gyroscope
EKG	Electrocardiographic
WSN	Wireless Sensor Network
KNN	K-Near Neighbors
EDA	Electro-dermal activity
EMG	Electromyography
GPS	Global Positioning System
BSNs	Body Sensor Networks
EMU	Epilepsy Monitoring Unit
HR	Heart Rate
SpO2	Arterial Oxygenation
TEMP	Temperature
MCDS	Multi Criteria Decision System
BR	Breathing Rate
WBAN	Wireless Body Area Network
NoC	**Network on Chip**
FAR	False Alarm Rate

FDR	False Discovery Rate
FPR	false prediction rate
FP	**False Positive**
PPV	Positive Predictive Value
SNE	Sensitivity
Avg	Average
SVDD	support vector data description
WLAN	Wireless Local Area Network
ANS	The autonomic nervous system
RRI	R to R Interval
Hz	Hertz
HF	High Frequency
LF	Low Frequency
SC	skin conductance
SCL	Skin Conductance Level
SCR	Skin Conductance Response
AC	Alternating Current

DC	Direct Current
ADC	Analog to Digital Converter
IR	Infrared
PANs	Personal area networks
FPGA	Field Programmable Gate Array
IDE	Integrated Development Environment
PC	Personal Computer
SDL	Serial Data Line
SCL	Serial Clock Line
GND	Ground

1. IMPORTANCE OF PREDICTING EPILEPTIC SEIZURES

1.1 INTRODUCTION

Medical experts, policy-makers, payers, and customers think of health information methods like e-health records and computerized provider order entry as crucial in transforming the industry of health care. Managing data is important for the delivery of healthcare. Taking into consideration how fragmented medical care is, the huge system transactions, the necessity of integrating fresh scientific evidence for practicing, and other complicated data management actions, restrictions of paper-based information management are obvious. Whereas advantages of technologies concerning the health information are theoretically evident, the adaptation of fresh information schemes to medical care has appeared hard and rates of utilization were limited. The majority of applications concerning information technology focused on administrative and financial transactions instead of the delivery of medical care [1].

Attempts for the effective management of chronic care have been restricted by different elements, such as fragmented health care system also the necessity to get extra coordination across the settings of medical care; the shortage of interoperable medical information schemes that could be helpful in supplying easily available, all-inclusive information regarding patient to the ones delivering supervision, the ones managing care, and the ones receiving it, and lastly, the ongoing mainly fee for service payment system rewarding fragmentation and volume, and doesn’t efficiently line up incentives with the aims of managing chronic care. Introducing health IT, such as e-health records also the health data exchange, offers great potential in addressing several of limitations, for the efficient chronic care management, via supplying necessary medical data concerning the patients whenever and wherever it’s required, in precise time and insecure way. Owning data from the care delivery procedure easily is accessible over the health information exchange, health IT at the local, state also at the national levels help in main elements of managing operation for chronic care, even the ones that are associated with clinical decision support, measurement, customer activation, coordination, and collaboration **[2].**

Healthcare organizations around the world are transforming themselves into more efficient, coordinated and user-centered systems. This tendency implies more integrated interoperable and ubiquitous healthcare services, a greater and easier access to health records and related information, and to engage patients in their own healthcare. With this purpose, the data and communication technology should play a more central part in achieving efficiencies and enhancing distributed healthcare systems that should fulfill diverse and frequent update demands.To address health issues, Internet of Things that is abbreviated as (IoT) suggests a networked device all over the world, services, and applications based on the cloud, together with different cooperation approaches where big-data analytics allow obtaining information and objective data, also acquiring well-grounded decision making. Health-IoT eco-systems today depend on a network of devices which connect in a direct manner with one another for capturing and sharing vital data, and significant information, via a secure service layer connecting to a central command and control server in the cloud. The future success of IoT mainstream will depend on the confluence of a right standardization, efficient wireless protocols, enhanced sensors, less expensive and low-power microprocessors, advanced SoC, and the support of communities and established corporations for the important improvement of cloud-based implementations [3]. The researchers reported different technologies to improve the human health such as “wearable sensor, actuators, and modern communication ". One of common diseases which we will focus on is Epilepsy.

1.2 EPILEPSY

Epilepsy can be defined as a brain disorder identified via an enduring pre-disposition for the generation of epileptic seizures and via the physiological, neuro-biological, cognitive, and social results of this disorder. Defining epilepsy needs the occurrence a minimum of one epileptic seizure [4].

This condition is the 4th most common neurologic disorder affecting people of different ages **[2]**.There are about 65 million people affected all around the world, with a high and dramatic impact not only on the patient’s quality of life but also on the professional development and social behavior; the health system budget is highly affected as well[5].

Epilepsy may have an effect on people of any age but it is most widespread among children and elderly. A few kinds of epilepsy are inherited and are caused by genetic factors. Other probable epilepsy causes involve the brain injuries because of oxygen deprivation at birth or head traumas. In several of the situations, the reason behind epilepsy is simply not known [18]

1.2.1 Seizure

A seizure is unusual behaviors (with symptoms or signs) that result from unusual discharges of cortical neurons. This phenomenon is observable, which is finite in time. Epilepsy is a definition of a chronic state which is defined by repeated occurrences of seizures. A syndrome is a set of symptoms and signs occurring combined, however, not like a disease, have no single known cause or pathology [6]. Seizures occur, in the majority of the patients, suddenly with no external symptoms. The sudden occurrences of those seizure pose a serious concern and account for mortality in patients that have uncontrolled epilepsy. Thus, timely predicting seizures provides a sufficient time for reducing risks of seizures and thereby improve the quality of life of the affected [7].

A seizure could seem to happen in a spontaneous way, with no external cause, even though in a great deal of patients a cause like a flashing light, redundant sounds or stressful cases are easily characterized as triggers of seizure. While seizures often happen during sleep, a seizure during the waking time could be a cause for the patient to harm themselves when they suddenly lose consciousness. The danger that faces to the epileptic patient and others are obvious. They could fall and harm their head, fall into moving machinery or lose control of a car.

1.2.2 Seizure Types

Until the past few years, seizures were categorized based on 1981 the international classification of seizures, which has been suggested by the "International League Against Epilepsy (ILAE)" [17]**.** In 2017, ILAE announced a new classification of seizures according to the onset of the seizure (i.e. focal or generalized), the state of consciousness at the time of seizure (complete or impaired awareness), and on the symptoms that occur at the time (motor or otherwise) [52].

- Focal onset seizures (previously known as partial seizures).

  This type of is more widespread than generalized seizures and happen in one or more certain locations in the brain. In some of the situations, they could spread to wider areas in the brain. They typically happen as a result of some injuries, but in the majority of the cases, the specific origins are not known (idiopathic).

- Generalized onset seizures.

This type usually occurs in each of the brain sides. Those seizures are combined with the loss of consciousness. Many types of those seizures are genetically based. People typically have normal neurologic functions between episodes.

- Unknown onset seizures.

  In some of the cases, the seizure onset happens unobserved and it is difficult to determine if it started out as focal or generalized.

1.3 SUDDEN UNEXPECTED DEATH (SUDEP)

SUDEP in epilepsy is a rare cause of death. Sudden unexpected death in epilepsy means the sudden death of rather a healthy person with epilepsy typically happens in the time of, or immediately following, a tonic-clonic seizure. In recent decades, a lot of interest was focused on "sudden unexpected death in epilepsy (SUDEP)" [8]. This expression means a death that happened in an unexpected way of what appears as a healthy person with epilepsy, typically, related to "tonic-clonic" seizure, where that there is no reason of death could be known. Even though this expression has been recognized from the 19th century, but just in last 20 years when the entire range and risk of this matter was determined [9].

SUDEP appears to be the most common category of sudden deaths that are related to the central nerve system . the SUDEP has been defined as "sudden, unexpected, witnessed or unwitnessed, non-traumatic and non-drowning death in patients with epilepsy with or without evidence for a seizure and excluding documented status epilepticus, in which postmortem examination does not reveal a toxicologic or anatomic cause of death"[8].

SUDEP typically happen outside the hospital and aren't usually observed by physicians. They'll usually be brought to the attention of a medical examiner or coroner, whose responsibility is determining the reason and the way of death and for the generation of a death certificate [10].

1.3.1 Risk Factors of SUDEP

The characterization of risk factors differs according to the study method. In researches that us non-SUDEP deaths as controls, age, a seizure that precedes death, being in bed, and subtherapeutic medication levels are the most commonly recorded risk factors. In studies that use live patients having epilepsy as controls, age, common seizure occurrence, polytherapy, and long durations of epilepsy are characterized as risk factors, combined with the use of psychotropic drugs [11].

Those differences could be explained by the fact that comparing SUDEP deaths to non-SUDEP deaths as controls reveal the circumstances that surround those deaths while comparing patients who died from SUDEP to living people that have epilepsy focuses on clinical variables and lifestyle problems which could be one of the reasons of death. In general, SUDEP appears to have an influence on younger people with intractable epilepsy and people having learning difficulties who take numerous AEDS, each one of whom get frequent seizures. Death typically happens during sleep. Low concentrations of AED have been recorded in some of the researches. Patients that await epilepsy surgery or who keep having seizures after surgery appear to be specifically under risk.

Some of the other risk elements are not discovered yet. Familial long QT syndrome (LQTS) recently captured the interest due to its association to sudden cardiac death, syncope, and seizures. LQTS is associated with mutations on over ten genes, eight of which encodeion channels, with 80 percent of those mutatioss found on 3 genes that encode sodium or potassium channels (KCNQ1, SCN5A, HERG or KCNH2) [12].

An analysis of collected data from four case-control studies utilizing living persons that have epilepsy as controls known the next risk elements: AED poly-therapy, increased convulsive seizure frequency, longer epilepsy duration, male sex, young age at onset, symptomatic causes and lamotrigine treatment(in people that have idiopathic generalized epilepsy) [13].

The SUDEP risks were 1.4 times more in male than females patients, 1.7 times more in patients that have start of epilepsy prior to reaching age of sixteen than in patients that have onset of age between (16 to 60), and it’s as twice as high in patients who had been suffering from epilepsy for over fifteen years. Almost all prominent of the risk factors was the repetitiveness of generalized “tonic-clonic” seizures that is abbreviated as (GTCS). Compared to people who have no GTCS, between 1 and 2 GTCS annually were related with an odds ratio of 2.94, between 3 and 12 GTCS each year with an odds ratio of 8.28, and between 13 and fifty GTCS each year with an odds ratio of 9.06, this ratio reached 14.51 for patients who have over 50 GTCS annually. The patients on combination treatment (i.e. poly-therapy) with anti-epileptic drugs that can be abbreviated as (AED) had 3 times higher danger factors of SUDEP than did the ones on monotherapy. It is when the redundancy of AED and GTCS treatment were put to studying combined in interaction analysis, each of GTCS and poly-therapy had a contribution as a danger factor of SUDEP, even though high-frequency of GTCS had more risk [9].

1.4 SEIZURE DETECTION USING WEARABLE BIOSENSORS

In a clinical setting, electro-encephalo-graphy (EEG) in combination with video monitoring is the optimal standard for the detecting and diagnosing different neuro-logical cases including epilepsy. The capability for the automatic detection of seizures is crucial for different diagnostic, safety, and treatment causes. For example, the diagnosis of a patient that has epilepsy needs capturing ictal episodes with the use of multi-channel EEG. Which could be time-consuming and costly at the same time, and requires either a clinic stay or wearing ambulatory devices for a number of days [10]. With the continuous need from the patients to remain in normal life while being observed for their physiological activities, wearable biomedical sensors are playing a significant part. To achieve this, new adhesive tape type wearable sensors enable sensor integrations [14].

There are several devices on the market which are designed for the detection of convulsive seizures with the use of extra-cerebral (non-EEG) signals. The majority of those devices use motion sensors due to the fact that convulsive movement is identical amongst patients, and therefore readily identifiable. On the other hand, there isn’t any wearable device available for the detection of complicated partial seizures (CPS), as they are non-convulsive [15].

Designing and developing of wearable bio-sensor systems for monitoring health has captured a great deal of focus in the industry also in scientific association through past few years. Primarily motivated by the increase in health-care expenses and powered by recent improvements in the technology of miniature bio-sensing devices, wireless communications, smart textiles, and micro-electronics, the constant development concerning wearable sensor-based schemes will have a great potential in transforming the future of health-care via allowing ubiquitous monitoring of a patient's’ health and permitting proactive management for personal health. Those systems may include different kinds of small physiologic sensors, transmission modules, and processing abilities, and therefore is capable of facilitating wearable low-cost unobtrusive results for constant day-round and anyplace health, also monitoring activity and mental status [16].

Wearable-systems for the purpose of monitoring health could include different kinds of little sensors, implantable or wearable. Those bio-sensors can measure important physiologic parameters such as hearts rate, oxygen saturation, blood pressure, the temperature of body and skin, the rate of respiration, electrocardiogram, and others. The measurements that were gained are being communicated by a wired or wireless linked to the centralized node, for instance, a personal digital assistant that is abbreviated as (PDA) or a micro-controller board that can afterward display the associated data on the user interface or transfers aggregated important signs to the health center. The previous depicts that a wearable system could include many different components: wireless communication modules and links, user interface, smart textiles, power supplies, sensors, wearable materials, software, control and processing units, decision-making algorithms and advanced data extraction [16].

In most countries in the Middle East, epileptic patients are feared to be known by the community because of their stigma because of social stigmatization. Therefore, it is necessary to find a way to detect cases of epilepsy before using modern technology.

1.5 LITERATURE SURVEY

Since the 70’s, medical specialists have envisioned intelligent, implantable devices for predicting seizures and triggering abortive treatment to aid many people all over the world who have medically intractable epilepsy. The most of the researcher used the seizure detection method based on the EGG –recordings require, either an invasive recording (intra-cranial electrodes) or placing numerous scalp electrodes, which is less stable over time. Moreover, the patient can get uncomfortable wearing electrodes on their scalp, due to the fact that they are very obvious for the others. Despite the EEG approach being the established standard; it does not necessarily seem as the optimal choice for a seizure alarm outside the hospital. So the other research tries to find a new different method to predict the seizure [19].

Throughout the years, different researchers adopted different techniques for intelligent devices, some of them focused on developing the ECG methods, while others went in the direction of the ACM, while some researchers went on merging those two techniques in their researches and studies, bellow is a wide range of researches that have been conducted, categorized according to the used approach:

Researches based on ECG:

Most of the epilepsy patients severed a SUD due to neurogenic cardiac arrhythmias, for that one study suggest using Electrocardiograms (ECG) to monitor implantable loop recorder (Rugg-Gunn et al., 2004). The method showed effective automatic detection of bradycardia and tachycardia.

Van Elmpt et al. [20] in 2006 held an investigation which developed an algorithm based on analysis of heart rate pattern by using ECG, this method can determine the heart rate patterns for automatic detection of seizures in epilepsy patients.

Malarvili et al.[21] applied a method in 2009 that contains a sequence of processing to monitor the epilepsy patients and used a supervised statistical classifier for HRV classification, the suggested method showed the sensitivity of HRV to the changing in cardio regulatory system of the heart, which helped detecting seizures in patients with epilepsy .

Recent development in miniaturizing ultra-low power elements offer more intelligent wearable health monitors. The evolvement and evaluation of a wireless wearable electrocardiogram (ECG) monitor for the detection of epileptic seizures from variations in the cardiac rhythm is described. The ECG data is analyzed with the use of embedded algorithms: a robust beat-detection algorithm in combination with a real-time epileptic seizure detector [22].

An investigation has been held to test the ability of algorithm based on Electrocardiographic EKG- based seizure detection [23]. The results of EKG obtained a good quality that reached (91%), which was acceptable and promising using these for further analysis.

Behbahani et al. [7] also developed an algorithm based on heart rate analysis (HRV) analysis by predicting when the seizures may occur according to dynamical variations of ECG during the pre-ictal period. The presented method showed a potential for monitoring epileptic patients and improving their life quality. The general efficiency of the algorithm is an important step for clinical implementations.

The study of Shamim et al. [24] showed that using electrocardiogram ECG is one of the best ways for detecting epilepsy seizures, because of it is comparatively easier compared to EEG. The results showed that the proposed algorithm detected epileptic seizures efficiently, and compared to other models it has been found to be more effective.

Researches based on ACM:

Whereas, Nijsen et al. [25] was used the visual analysis of 3-D accelerometer (ACM) and video/EEG recordings for predicted epilepsy. The study results showed good results showed good results 91% of the seizure with motor phenomena have been detected by using recorded data with these sensors and considered feasible for detecting seizures.

Cuppens et al. [19] suggested another detection systems applied with accelerometers ACM that are attached to wrists and ankles. This system used the development of an automatic detection algorithm. A detection system can solve unsuitable use problem of EEG in the daily lives of patients. By using the development of an automatic detection algorithm .This resulted in an algorithm of sensitivity of up to 91.67% and accuracy of up to83.92%.

While another study used ACM with a different algorithm based on a Bayesian approach and found that the patient in standing up status promotes a good detection close to 90% of seizures and 25% of false alarms [26].

Schulc et al. [27] used a dives Wii Remote® which encased an accumulator and Bluetooth antenna and by using this device achieved 100% temporary sensitivity and specificity of over 88% while a positive predictive value ≥75% of false alarm ratio.

Another study used wireless ACM sensor with some physiological parameters, the false alarms were reduced with realizing a high level of detection accuracy [28].

Borujeny et al. [87] revealed the benefit of WSN in the application of health monitoring to detect epilepsy seizures, this application can be used in a clinical environment or at the patient's home. They used ACM in the portable device. This study obtained 85% Sensitivity with 3FP, while another study got a high sensitivity of up to 90% and a low rate of false alarms (0.2/day) which used the same device with a different algorithm [30].

Helmy et al. [31] created the first mobile application which was called Seizario, This app offered a set of useful properties that help to provide assistance to Epilepsy patients. Seizario app. are introduced a new accelerometer-based learning algorithms with elaborate finite-state-machines for the automatic detecting of grand mal seizures and harmful falls. Seizario's detecting algorithms were designed to operate efficiently on mobiles and showed great potential with more than 95% detection rate for each of seizures and falls, with a minimum number of false alarms.

Whilst Ribeiro et al. [32] used the wearable device from ACM and embedded sensors by applying machine learning algorithms obtained kNN 99% and C4.5 & PART 98% and there was no valuable variation at the results between kNN, PART, and C4.5… An experiment showed that the user of wearable accelerometer sensor was found very efficiently with a limited number of false alarms [33]. Also Kusmakar et al. [34] used wearable ACM sensors and their results showed that the sensitivity 95:23% with 0:72=24h.

Researches based on mixed sensors (e.g. EDA, ACM, ECG, EMG, SpO_2 Video, audio skin, Temperature and BR)

Poh [35] was proposed an approach to monitor sympathetic nervous system activity during epileptic seizures with the use of a wearable sensor measuring electro-dermal activity (EDA) and ACM. The sensitivity of the method reached 94% tonic-clonic seizures with low rate of false alarms (<;1 per 24h).

Another study used a method to distinguish between ordinary movement and hyper motor seizures [36] The ACM in both wrist and ankle applied to get dataset with synchronized video, audio, EEG, ECG , upper arm EMG and ACM data. The results were achieved 100% sensitivity and Positive Predictive Values PPV which ranged from 34.91% to 100%.

Other researchers monitored the human health by observing some physiological signals such as electrocardiogram (ECG), respiration and electromyography (EMG) signals. The author promised to use these findings to monitor the epilepsy seizure [37]. Becq et al. [38] Used motogrogram to detect different types of epilepsy seizures and by collecting data from triaxis accelerometers and magnetometers.

Conradsen et al. [39] applied automatic multi-modal intelligent seizure acquisition (MISA) system to detect motor seizures from electromyographic data. Their results showed that MISA system is highly sensitive short detection latency and low rate of false detection. Moreover, the results have shown that the multimodal detecting system is superior when compared with uni-modal system. The proposed system has a potential to detect seizures according to multi-modal data.

A group of researchers developed a small medallion which is attached to the patient's neck with the use of a necklace type grip that consists of combining the spectral analysis method of anomalous currents with modern processors and mobile communications technology such as GPS and Bluetooth [40]. The device disassembles and amplifies only the primary brain currents, the ones of epileptic seizures, and warns the patient of possible danger The voice warning is used to connect the mobile to the patient with the use of a specified program, and to send an emergency text that the seizure reports are imminent and the current location with the use of GPS system for emergency service, the doctor, and the National Center for Epilepsy Monitoring and Communication in advance.

In the recent years, cloud computing in the area of health-care started gaining importance. Pandey et al. [41] presented a model for on-line monitoring of patient's health with the use of cloud computing technology.

Forkan et al. [42] presented a model which is based on a service-oriented model enabling real-time aided living services. It offers a flexible middle-ware layer hiding the complexity in managing sensor data from various types of sensors and contextual information as well.

Fortino et al. [43] presented a model which based on combining utilization of BSNs and the cloud computing. It performs monitoring of assisted living by wearable sensors which transmit data to the cloud using a mobile.

A study presented a method which is considered the first step in the direction of a reliable ambulatory monitoring system for epileptic seizures with or with no motor activities [44]. A hierarchical classification method has been implemented for the detection of various types of epileptic seizures utilizing data from wearable sensors (EDA and ACM). They obtained a general sensitivity of up to 89.1% and a general accuracy of up to 93.1% was obtained with motor activity By using a k-nearest neighbor (kNN). Whereas with no motor activity the sensitivity reached a percentage of 97.1% and the accuracy reached 92.9%

Single seizure detecting methods have the problem of high false positive rate [45]. A group of signals that may be easily monitored by a wrist -worn device have been found and which produced a distinctive pattern during the time of seizures for patients in epilepsy monitoring unit (EMU) A group of five bio-signals has been chosen, which may be monitored at the wrist and are known or believed to be affected by seizures: heart rate (HR), arterial oxygenation (SpO_2), accelero-metry (ACC), electrodermal activity (EDA) and temperature (TEMP) . several researchers have notices great HR changes at the beginning of some kinds of seizures, they needed to collect more data from epileptic patients in a day by day basis, in addition to EMU settings prior to being confident of having found a seizure detection method beneficial for a wide range of people. Data collection is continuing, so we will have opportunity to further evaluate our findings. WE expect that more sophisticated methodologies mentioned in Subsection.

Sasikala et al. [46] proposed the design; development and validation of a wrist-based wearable device that can not only detect seizure efficiently, but over time can also predict a seizure before the actual onset. The results concluded that seizure detection would primarily involve the measurement of the following parameters: (i) motion , (ii) electro-dermal activity (EDA), (iii) skin temperature and (iv) heart rate.

A new multi criteria decision system (MCDS) was proposed by Ahmed et al. [47]. They obtained a precision 96% with 90% recall over the synthetic data. In this study, they used parameters of Electro-cardiograph (ECG), Electrodermal activity (EDA), body motion and breathing rate (BR).

The study of Gheryani et al. [29] examined the Wireless Body Area Network (WBAN) to detect and identify seizures by the armband via a portable unit. The study used an inertial measurement unit and muscular activities acquisition sensors and from these signals was transmitted from the used device.

Different physical factors were applied to transmit the signals of seizures to a cell phone device Ramirez-Alaminos et al. [49]. These physical factors are temperature, heart rate, and extremities motion. The authors examined different temperature values, heartbeats and testing battery life of the used system.

Audio identification was applied on a group of epilepsy patient in the Netherlands **[50].** The used system was comprised of three stages; this system depended on a theory of Bayesian to classify the characteristics vector. This work included the proposal of a non-intrusive video analysis system for patient's body parts movement analysis in Epilepsy Monitoring Unit **[51]**, the system utilized skin colour modeling, head/face posture template matching and facial detecting for the analysis and quantification of the head motions. Epileptic patients' heads have been analyzed in a holistic way for inferring seizures and usual arbitrary motions. The patient is not required to wear any specific clothes, markers or sensors, therefore it is entirely non-intrusive.

Mohammad Saleh et al. **[52]** depended on EEG NoC concept to display and predict unstable brain waves. This well prevents the risks of seizure during the driving and childhood stage. Network on Chip(NoC).

Table 1.1: The review of different method, Algorithm and results for the detection of seizures

NO	Article	method	Algorithm	Results
1	Rugg-Gunn et al.[90] in2004	ECG	Device implantable loop recorders	Detected the beat per min of HR in seizure patients
2	Nijsen et al. [25] in 2005	ACM & video/EEG	visual inspection of the data	48% of seizures were detected by ACM. 91% of the seizures with motor phenomena were detected
3	van Elmpt et al.[20] in 2006	ECG	Tow Algorithm were used: i. Curve-fitting used to characterize the HR patterns. ii. A moving median filter to detect the change of HR	More than 10seizures of 2 patients out of 3 showed a sensitivity 90%
4	De Bruijne et al.[50] in 2009	audio signals	Bayesian decision theory	The sensitivity 95 to 98% and specificity 72 to 97% , depending on sound type PPV 2-40%
5	Malarvili et al.[21] in 2009	ECG	Used the Heart rate viability (HRV) to detect newborn seizures	The Sensitivity 85.7% and 84.6% specificity
6	Cuppens et al.[19] in 2009	ACM	development of an automatic detection algorithm	Sensitivity of 91.67% and a specificity of 83.92%.
7	Poh M et al. [92] in 2010	EDA	novel method for monitoring sympathetic nervous system	___
8	Jallon. [26] in 2010	ACM	based on a Bayesian approach using hidden Markov models	Able to find out 90% of seizures when FAR are 25% of alarms.

9	Poh, M .[35] in 2011	ACM & EDA	monitoring sympathetic nervous system activity	The sensitivity of the method reached 94% tonic-clonic seizures with low rate of false alarms (<;1 per 24h).
10	Van de Vel et al.[36] in 2011	ACM	Work on algorithm for distinguishing between normal movement and hypermotor seizures.	The results were achieved 100% sensitivity and Positive Predictive Values PPV ranged from 34.91% to 100%.
11	Schulc et al.[27] in 2011	(ACM)-based	dives Wii Remote®	Achieved 100% temporary sensitivity and specificity of over 88% while a positive predictive value ≥75% of false alarm ratio.
12	Becq et al.[38] in 2011	ACM & magnetometers	Artificial neural networks.	Sensitivity 90%, FDR per night 0.7
13	Altini et al. [37] in 2011	ECG , respiration and EMG signals	low-power, multi-modal, wearable sensor platform	The author promised to use these finding to monitor the epilepsy seizure
14	Conradsen et al.[39] in 2012	EMG , ACM & gyro	Automatic multi-modal intelligent seizure acquisition (MISA)	Sensitive short detection latency and low rate of false detection. A 100% sensitivity was observed with FDR per 0h and mean response 0.7s
15	Mandal et al .[93] in 2012	Video	The system utilized skin colour modeling, by using SMV to classify the seizure and normal movement	This method limited use in hospital to monitor the statues of the epilepsy patients.
16	Popescu et al .[40] in 2013	small medallion which is attached to the patient's neck	method of spectral analysis of abnormal cerebral currents with modern	—

		with the use of a necklace type grip	microprocessors and mobile telecommunication technologies	
17	Beniczky et al.[30] in 2013	ACM	—	High sensitivity of up to 90% and a low rate of false alarms (0.2/day).
18	Borujeny et al.[87] in 2013	ACM	Artificial Neural Network and K Nearest-Neighbor	Sensitivity85%,3FP.
19	Massé et al.[22] in 2013	ECG	a robust beat-detection algorithm in combination with a real-time epileptic seizure detector	The system obtained 75% of sensitivity and 70.4%specificity.
20	Osorio .[23] in 2014	EKG-based	Threshold	EKG obtained a good quality that reached (91%) a total of 241 out of 266 clinical seizures.
21	Salem et al .[28] in 2014	ACM	We use the exponentially weighted moving average algorithm	Highly level detection accuracy in against temporal variation.
22	Helderg et al.[44] in 2015	EDA and ACC	A hierarchical classification method has been implemented, by using a k-nearest neighbor (kNN) classifie.	Obtained a general sensitivity with motor activity: up to 89.1% and a general accuracy of up to 93.1% was obtained. Whereas with No-motor activity : the sensitivity reached 97.1% and the accuracy reached 92.9%
23	Helmy et al.[31] in 2015	ACM	Seizario app depending on ACM in smartphone	more than 95% detection rate for each of seizures and falls, with a minimum number of false alarms

24	Cogan et al.[45] in 2015	Temp, HR, ACM , SpO_2, & EDA	versatile bio-signal activity recognition algorithm in which the physician received the seizure response time electronically	observed the change in $HR\uparrow \Rightarrow SpO2 \downarrow \Rightarrow EDA\uparrow$ by special algorithm in six out of 10 patients
25	Shamim et al.[24] 2016	ECG	by setting threshold and by using linear support vector machine	Obtained Accuracy 94.2%, SNE 84.1% and specificity 94.5%
26	Behbahani et al. [7] in 2016	ECG	The algorithm based on heart rate Analysis (HRV) analysis by prediction the occurrence of seizures based on dynamic changes of ECG	Result showed an Avg SNE of 78.59% and Avg FPR of 0.21/h false prediction rate
27	Sasikala et al.[46] in 2016	ACM ,EDA, HR & skin temperature	The paper proposes to design	—
28	Ribeiro et al.[32] in 2016	ACM and embedded sensors	Machine Learning	obtained kNN 99% and C4.5 & PART 98% and there was no valuable variation at the results between kNN, PART, and C4.5
29	Kusmakar et al.[34] in 2017	ACM	using machine learning approach kernelized support vector data description (SVDD)	Results showed that the sensitivity 95:23% with 0:72=24h.
30	Ahmed et al.[47] 2017	ECG , EDA and BR	A multi criteria decision system (MCDS)	obtained a precision 96% with 90% recall over the synthetic data
31	Gheryani et al.[29] in 2017	ACM, angular velocity (Gyro) and sEMG gyroscope	Their approach starts with Derivation of the root mean square for ACM and Gyro, followed by the normalization of	The result showed 100% of sensitivity with 5% of FAR

			whole signals in the same Range and aggregation to a signal.	
32	Mohammad Saleh et al.[51] in 2017	Network on Chip (NoC) ECG	—	the result present the EEG of NoC chip depends on the design of network , WLAN protocols , number of sensors and the packet size over the network
33	Ramirez-Alaminos et al.[49] in 2017	Temperature , HR and vibration sensor	By using device has Bluetooth module to connected wireless with smartphone.	Depending on the parameter that used in the device give sign when it get over the threshold and it's depended on the epilepsy type.
34	Snehal et al.[33] in 2017	ACM	Signal Conditioning and microcontroller.	The ACM sensor show reliable result that can detect seizure movement occurred in any direction.
35	Onorati et al.[53] in 2017	ACM and EDA	Used 3 different data of wristbands and test two new machine learning classifiers	Results of classifier (III) showed that the sensitivity 94.55% and FAR 0.2 events/day.
36	Fürbass et al.[56] in 2017	EEG ,ECG and EMG	Automatic multimodal detection	Obtained 86% sensitivity with Avg of false detection 12.8 in 24h
37	Sopic et al.[58] in 2018	ECG	**e-Glass** using 4 EEG electrodes	The Sensitivity 93.80% and 93.37% specificity
38	Elger et al.[54] in 2018	Heart Rate	Low Complex Novelty classifier detection	Results showed that sensitivity 77.6 % and Avg of FAR 2.56 false alarms per night
39	Geertsema et al.[55] in 2018	Video	Analyzing of Oscillatory motion pattern and set threshold	Obtained 97% sensitivity with median of false alarms 0.78 per night

40	Hurley, D.[57] in 2018	EMG	—	The result was detected 93.8% of seizures with 0.67 false alarms per 24 H

1.6 COMMERICAL DEVICES

There are different technologies developed for tracking seizure information. The developed devices and mobile application becomes a tool to help patients, families, and clinicians capture seizure data**.** The table below shows the commercial device with details.

Table 1.2: Review of different commercial devices

Commercial device	Used apparatus	Detection Method	Website
Advance Brain Monitoring	EEG with different NO. of channels	Wireless EEG	www.advancebrainmonitring.com
Emfit	ACM, bed motion sensor	Wireless transmission	www.emfit.com
Affectiva	Wrist-band	Bio-sensor for measuring EDA ,ACM and body TEMP	www.affectiva.com
Embrace	Wrist-band and mobile application	Multiple sensor: EDA, Gyroscope ,ACM and peripheral temperature sensor	www.empatica.com
EpDetect	Mobile Application (base on ACM of mobile)	Wireless transmission : sending SMS ,movement detection and GPS position location	www.epdetect.com
Smart belt	Chest-belt ,wearable	Respiration sensor and EDA sensor	—

Movisens	Electrodes	Raw signal of EDA , ACM TEMP and air pressure	www.movisens.com
Epi Watcher	ACM , bed motion sensor	Wireless alarm bell, wired version integrated and message to responsible person	www.vahlkamp.nl
Mio Alpha Streapless	Watch	Heart rate monitor	www.alphaheartrate.com
ADLX330	Wrist-band	ACM	www.sparkfun.com
Pulseguard	Wrist-band	Heart rate changing	www.pulseguard.org
SensAlert200	bed motion sensor	Detecting unusual movement	www.sensorium.co.uk
SAMI-sleep activity monitor	Video-Camera Night vision monitoring	Detecting unusual movement and send alarms and video records	www.samialert.com
Baby-Ping	Video-Camera Night vision monitoring with voice	Wi-Fi connection	www.babyping.com

1.7 OBJECTIVE OF THE STUDY

In order to avoid damage to epilepsy patients due to sudden seizures, it is necessary to find a means to reflect the bio-signal (physiological changes) before the seizure. For this purpose, this study amid the following:

1. Test the detection efficiency of some physiological changes such as oxygen saturation percentage changes in the blood, a sudden change in the heart rate and the movement of pattern body and Electromyography.
2. Apply sensors to transmit bio-signals to detect the possibility of a seizure of the patient and send an alarm to the person in charge or observer of the patient.
3. Select the suitable location of the body to detect these signals to comfortable for daily use to patients.

1.8 OUTLINE OF THE THESIS

- **Chapter 2:** Talking about the bio-signal and how its useful diagnostic tool in the biomedical application that helps medical experts and the autonomic nervous system.
- **Chapter 3:** This chapter contains details of Design and Setup of the proposed system.
- **Chapter 4:** Present results of the testing the portable device and check its efficiency of the performance of the proposed system.
- **Chapter 5:** Summarized the most important finding from the use of proposed system and suggested recommendations for future work.

2. BACKGROUND ON THE TOOLS AND DETECTION METHODS OF EPILEPSY

2.1 INTRODUCTION

Bio-signal classification is significant diagnosing tool in the bio-medical area which aids medical experts in the automatic classification of whether or not a sample of bio-signal under testing/monitoring is part of the normal type.

Bio-signal, an acronym of the biologic signal, is a general terminology for vital signals which may be assessed continually from living creatures. In the bio-medical area, the classification of the bio-signal is a valuable diagnosiing means for various physiological analyzing operations, for example, in the fields of neurology or cardiology. Typically, bio-signals are captured, measured and identified to be in the normal state or the opposite, via a computerized technology. Therefore, there's no straightforward method of accurately quantifying a bio-signal. One significant set of bio-signals is arbitrary signals whose tasks are the non-periodic or mostly periodical signals [61**].**

Principally, any mechanism attenuating or disturbing supplying oxygen to the brain and heart are of a high possibility of being lethal. SUDEP is possibly a seizure related state, because of the fatal respiratory failure or cardiac arrhythmia. Cardiorespiratory disturbances could be facilitated via inter-ictal adjustments of cardio and pulmonary functions which are related to redundant activities of seizures, antiepileptic drugs (AEDs) and genetic predispositions. Researches have studied states and patho-physiologies that are associated with the increased risks of sudden death in seemingly healthy individuals or in other medical cases; for example, certain ECG properties that predict an increased hazard of sudden cardiac death [62].

2.2 THE AUTONOMIC NERVOUS SYSTEM (ANS)

This is a group of neurons and nerves providing the innervation of blood vessels and the air-ways, intestines and urogenital organs. Those nerves are responsible for regulating and coordinating the functions of the body according to the gland secretory activity, on contracting and relaxing the smooth and the cardiac muscles, and on sensations that arise from deep viscera. ANS is far from voluntary controlling and includes efferent (i.e. motor) neurons, projecting mainly to and controlling the activities of the smooth muscle and the secretory cells, and afferent (or sensory) nerves, providing the system's sensory side and supporting each of the sensation and reflexes [63**].**

The most important role the autonomic nervous system plays is maintaining the balance of the body in different cases. The hypothalamus is capable of controlling 3 various systems. Aside from the ANS, the hypothalamus is responsible for controlling the system of endocrine and an ill-defined neuro-system that is concerned with motivating. The autonomic systems are visceral sensory and motor systems that are based on reflexes [64]

The external element of ANS includes 2 functionally and anatomically independent parts, which are - **the sympathetic** and **para-sympathetic** nervous systems. As the latter works on promoting energy restoration and conservation, the sympathetic system is responsible for stimulating maximized metabolic result for dealing with external issues. Therefore, increasing sympathetic activities elevate sweating, heart rate, and blood pressure, in addition to redirecting blood from the intestinal reservoir in the direction of the heart, lungs, skeletal muscles, and brain preparing for motor action. The brain is responsible for controlling the ANS using a complicated NN known as the "central autonomic network" [35].

Partial and generalized epilepsy types update autonomic functions throughout ictal, post-ictal, and inter-ictal cases. Every aspect of the autonomic functions may be under influence, such as the para-sympathetic system, the sympathetic system, and the adrenal medullary system. Autonomic alterations are the most widely known signs of simple partial seizures, however, they can pass by unrecognized. Seizures usually activate the activities of the sympathetic nervous system, accelerating the rate of heart and raising the pressure of blood, even though para-sympathetic activating or sympathetic inhibition could be predominant through partial seizures. Seizure-produced cardio-vascular dysfunctions, pulmonary edema, and post-ictal depression of autonomic respiratory reactions and cardio-vascular functions could play a role in the sudden, unexplained death in epilepsy [65].

The majority of engineers and neuro-scientists are focused on the connection between brain and epilepsy rather that the link between the body and the brain. Extra-cerebral body signs are under cortical controlling and are also changed by seizures, therefore offering indirect but important information concerning the brain state [66]**.**

This study will focus out the extracerebral by using non-EEG devices depending on pathophysiological mechanisms that detect monitor cardiac, arterial oxygenation, respiratory rate temperature and electrodermal activity.

2.3 CARDIOVASCULAR CHANGES

2.3.1 Variability of Heart Rate

The heart is one of the most important organs the **ANS** targets**.** Redundant seizures could change the cardiac activity regulation via the ANS, and its dys-regulation is considered to be associated with higher morbidity and mortality in patients with epilepsy, especially from SUDEP [67].

“Heart rate variability” (HRV) is an appropriate parameter for assessing the neuronal effects on the cardiac pace-maker as one of the main functions of the “autonomic nervous system” (ANS). HRV is the variation of the length of neighboring RR-waves intervals. Those physiological variations raise from autonomic generators, also known as intrinsic oscillators, which represent the non-linear feed-back control systems that are produced by interacting between sympathetic and para-sympathetic input and represent the healthy body adaptability (Longin et al., 2005) [8].

Due to much neuronal activities in the pre-ictal time of epilepsy influence the autonomic nervous systems and functions influence the HRV, it’s presumed that seizures may be predicted via monitoring HRV [68].

Moreover, an ECG could be traced more easily than EEG. Holter monitoring could be utilized for measuring the long-term RR Intervals (RRI), and enabling monitoring the ECG signal of epilepsy patients. On the other hand, some drawbacks have been recorded on difficulties arising while using Holter at home, which includes high cost and required skills for operation. In past years different wearable HRV sensors were designed to enable measuring the RRI. The sensors were simple to utilize, produced less expensively and with the potential to be used in a daily manner. This technology could play a role in a wearable epileptic seizure predicting system [69].

Many experts have been generally studying heart rate features in epilepsy and in predicting epilepsy seizures. The HRV properties were computed with the use of complex and usually non-linear formulas that is potentially harnessing the usability of this type of property extracting methods in real time. In addition to that, a wide range of researches on predicting seizures utilize a “patient-specific” method, in which the predicting system must be trained for every one of the patients separately prior to predicting seizures. This needs many historical records with labeled seizure states, and that might not necessarily be available. Thus, there’s the need for developing nonpatient specific resolutions, and that will operate for groups of patients (with a similar diagnosis, epileptic focus localization, and so on) [70].

2.3.1.1 Detecting Heart rate changes

Each structure of living body has its activities varying through time. The rhythm of vital functions (such as breathing, heartbeats, and others) keeps continuously modifying by complicated approaches, because of external and internal stimuli. Thus, it is not possible identifying any of those rhythms as stable rhythms with a certain frequency.

Cardiac activity is accompanied with cardio-electric activities that can be measured from the surface of the body with the use of an electro-cardiogram (ECG). The ECG signal represents the resulting electrical vector of each electrically active heart cell carrying information on cardio-function or of its pathologic variations [71].

The change in the timing between cardiac cycle beats, referred to as “heart rate variability” (HRV), has shown to guarantee significant information concerning the balance between the two limbs of the autonomic nervous system, the sympathetic and para-sympathetic branches. This information has been popular for assessing the effect of the autonomic nervous system on cardio-vascular control.

Typical approaches of HRV estimation depend on measuring the intervals between heartbeats with the use of the R waves peaks in the electro-cardiogram (ECG) as markers. One of the benefits of HRV related methods lies in the fact that a wide range of the commercial devices which are available perform automated measuring of inter-beat intervals. And that refers to the fact that they permit rather a simple, non-invasive method to be implemented, therefore broadening the possible range of implementations for this type of measurements [72].

Extracting and evaluating physiologically useful data from HRV data are supported by each of the time and frequency domain approaches. The traditional frequency domain measurement is the HRV power spectrum. Consistently defined properties of this spectrum are a low frequency (LF) element which is centered **about 0.1 Hz** (frequency band in the range (**0.04 - 0.15)** Hz) and a high-frequency (HF) component that typically appears in the frequency band of the range (**0.15 - 0.5) Hz**. A wide range of literature sources suggest that HF spectrum could be a suitable sign of the Vagal heart rate control in the unstressed states and that LF could be a marker of sympathetic activities, or combined vagal and sympathetic activities, typically found in rather stressful situations [72].

2.3.2 Oxygen Saturation

Patients that have medically refractory epilepsy and have acute seizure-related hypoxemia and hyper-capnia found in epilepsy-monitoring units could be at a **high degree of danger of SUDEP** [73].

Oxygen saturation, “one of the most important vital sign”, has to be checked by pulse oximetry in each breathless and severely ill patient (when necessary, supplemented by blood gases) and the inspired concentration of oxygen has to be recorded on the observation chart with the result of the oximetry. (The rest of the vital signs are temperature, pulse, blood pressure, and rate respiration) [74].

Transferring oxygen from the lungs to the cells is mainly performed by molecules of hemoglobin in the red blood cells and merely 2 percent of the overall oxygen concentration undergoes dissolving in the plasma. Oxygen saturation in the blood can be defined as the ratio of the concentration of the oxygenated hemoglobin to the entire concentration of hemoglobin in the blood, and its degree in the arterial blood, SaO2, is of valuable clinic and physiologic importance due to the fact that it represents the efficiency of oxygen-delivering and respiration function. Acceptable values of SaO2 are in the range between 94% and 98% at sea level but those values can degrade to some extent after the age of 70 [75].

The possible advantages of other applications, like the home pulse oximetry monitoring with suitable alarms or constant positive airway pressure devices, can be useful to evaluate in patients that have recorded acute seizure-associated oxygen de-saturations who are in the waiting line for the potentially curative treatments [73].

2.3.2.1 Detecting the Oxygen Saturation

Oxygen saturation is a procedure of measuring the level of oxygen that has been dissolved in the blood, according to the Hemoglobin and De-oxyhemoglobin saturation in blood. The Oximeter probe includes a couple of components, which are, the “light emitting diodes” (LEDs) and light detectors (also known as photodetectors). A light beam is transferred via the tissues from a side of the probe to another. The blood and tissues ingest light which is eliminated by the probe; it differs based on oxygen saturation in the hemoglobin. Afterward, the photodetector captures the light that is transferred via blood pulses and the micro-controller procedure for the value of oxygen saturation (SpO_2) [76].

A pulse oximeter is a clamp that is connected to the finger-tip or the ear lobe (and that can be integrated to such things as rings or gloves). For infants, it may be integrated into a foot strap or body sticker. It includes a saturo-meter (using infra-red waves for sensing the concentration of blood–oxygen) and a plethysmo-graph [77].

2.4 RESPIRATION RATE

This is the vital sign that is minimum recorded and most often entirely neglected from the documentations of the hospital. An increased respiratory rate is a strong and certain indicator of serious reverse events like cardiac arrest [78].

Breathing is a vital physiological process in the living organism. For humans, this procedure produces air that contains oxygen inhaled to the lungs, in which the exchange of gas takes part across the alveolar-capillary membrane. Carbon dioxide is exhaled during this process, in the air that is emitted via the nose or mouth. The whole procedure from inhaling to exhaling is referred to as a breathing or respiration cycle. The rate of respiration is a vital sign which is utilized for monitoring the progress of the disease and an abnormal rate of respiration is a significant sign of a serious illness. There's some important evidence proving that changes in the rate of respiration may be useful in the prediction of possibly major clinical events like cardiac arrest or transferring to the ICU. Those researches have proven that respiratory rate is more efficient than the rest of the vital measurements like pulse and blood pressure in distinguishing between patients with stable conditions and ones under risk. The use of variations in respiratory rate measurements patients could be identified as high risk of about an entire day prior to the event with a certainty of up to 95%. **This vital sign can be used to detect the epileptic seizures** [79].

Cardiac arrhythmia and respiratory failure are commonly monitored throughout apparent ictal activities on EEG records, assuming that pathologic hypersynchronous cerebral activity is – by the disruption of the autonomic nets – the main reason of cardiorespiratory dysfunctions. In some of the observed SUDEP events, nevertheless, traces of EEG abruptly showed a generalized cerebral activity suppression before persons died due to gradual hypoventilation and bradyarrhythmia [13].

2.4.1 Detecting of Respiratory Rate

There is a wide range of approaches for respiration monitoring, which includes sensing the temperature of air-flow, pressure or velocity; chest motion or variations in volume.

A thermo-couple or thermistor put under the nose can the temperature of sense air-flow, a mask that covers the mouth and nose can sense the pressure of air-flow and a pneumotacho-graphy mask can sense the pressure or velocity of the air-flow. Even though those devices are popular, they’re associated with numerous drawbacks, such as their discomfort and effect on breathing [80].

Also, by sensing the movement of chest and abdominal wall for the sake of measuring the respiratory rate, depth or effort is typically done via measuring variations of volume between the upper and lower chest with the use of two straps (respiratory inducting plethysmo-graphy or RIP, two electrodes (impedance pneumo-graphy) or magneto-meters, even though it can as well be done with the use of one EMG (electromyo-graphy, on diaphragm or inter-costal muscles) or ACM sensor (on chest or bed), and even via remote measurement with the use of video or micro-waves [77].

2.5 OTHER AUTONOMIC CHANGES: ELECTRODEERMAL ACTIVITY

Throughout the past years, the areas of research of the affective sciences and computing have used a wide range of various modalities for measuring emotions, such as body posture, physiological signals, speech, and facial expressions. Among the physiological measures, “skin conductance” (SC) is popular for assessing emotional arousal. SC is one of the most widely utilized measurements in psychophysiological researches that involve emotional arousal and is typically measured at the fingers or the palms (the palm locations) [81].

Since the 1880s, when psychological factors which are related to electro-dermal phenomena have been first monitored, electro-dermal recording became one of the most common bio-signals in psychophysiology. The main reason for this is the ease of getting a certain electro-dermal response (EDR), the intensity of which appears related to the intensity of stimulus and/or its psychological importance. Electro-dermal recording is can be done with quite low-cost equipment, not exclusively in the lab but under less controlled field states as well. Despite the common usage of electro-dermal recording [82].

So we can simply say the Electro-dermal activity (EDA) is the umbrella term utilized to define autonomic alterations in the electrical skin properties. The most commonly researched feature is the skin conductance that may be measured via applying an electrical potential between a couple of points of skin contact and measuring the resultant current that flows between those two points [83].

2.5.1 Detecting of Electrodermal Activity

Since skin is the only organ that is affected by the sympathetic nervous system and not by the parasympathetic nervous system, electrodermal activity (EDA) can be used for seizure detection. When sweat glands are aroused, the electrical conductance's of the skin change. These changes can be detected by measuring EDA. EDA is measured with the use of electrodes that are connected to the strap/band of the device. Stainless steel/silver electrodes can be used for this purpose. A small alternating current is sent to the skin through these electrodes. The electrodes then measure change in skin conductance due to changes in the autonomic nervous system [46].

Medical experiments showed that the electrical conductance magnitude in the skin of human body is directly related to the emotional state. The short term variations in electric conductance are correlated with the individual's mental state as well. EDA meter has been used, which is designed for measuring skin conductance. EDA (Electrodermal Activity) signal is an electrical reflex on the person's skin. There are SCL ("Skin Conductance Level") and SCR ("Skin Conductance Response") in EDA. In general, SCL includes DC elements and SCR includes AC elements. Each of AC and DC signals may be utilized DC is the most widely known. It isn't important what kind of current is utilized due to the fact that the data is uniphastic (the current that is measured at the receptor is either minimized or maximized in comparison with the base-line) [84].

EDA measurement is taken of the eccrine sweat glands function. The preferable way to report EDA is typically as a measurement of conductance instead of resistance. This is due to the actual skin nature (it isn't merely one resistor, but rather, a set of resisters acting in parallel). Thus, the most popular measurement unit in EDA is the micro-siemen. EDA is linked to variations in hydration of the sweating glands [16].

2.6 TEMPERATURE

Seizures that are resulted from fever (i.e. febrile seizures) are the most widely spread kind of pathologic brain activity in infants and children. And the occurrence of unprovoked (i.e. spontaneous) seizures, usually unexpectedly [85].

In case of febrile seizures, temperature is an important parameter to be measured since the primary cause of seizure is the occurrence of fever. Since a child’s brain is more susceptible to fever than an adult brain, febrile seizures occur in children below 6 years of age, mostly between 12 and 18 months [46].

Febrile seizures are an optimal structure of abnormal network activity during development due to the fact that they don’t happen later in life. Moreover, they offer biologically useful instances of activity-dependent, enduring plasticity. The extra significance of those seizures is derived from the statistic associations of long term febrile seizures to human temporal-lobe epilepsy. Animal examples of those seizures provide opportunities for investigating possible causative correlations of those seizures and human epilepsy [85].

2.6.1 Detection the Temperature

The temperature sensor element can be considered a part of a temperature sensing unit which is, also a part of a controller for the regulation of the way the neuro-stimulation treatment is implemented on the neural model. The unit of temperature sensing performs a measuring and analysis of the temperature of the body for deriving temperature parameters which can be utilized for the initiation or alteration of a neuro-stimulation treatment when a temperature parameter is above a threshold value.

It’s still to be researched is a temperature measure is capable of detecting seizures. Even though it would be a proper approach for the detection of febrile seizures, the precise correlation of those seizures to epilepsy is typically unknown. Temperature variations may be measured with the use of thermometers existing as adhesive stickers or probes in watches, via radio-meters and via thermo-cameras which could also detect motion [16].

2.7 MOTOR ACTIVITY

Epilepsy seizures occur because of an asynchronous neurons firing. This burst in electric activity could be limited to a part or spread to the whole brain. Epilepsy seizures are identified by their unpredictability and could happen any time. Seizures could be spastic, which involve spasms of a part or the entire body, therefore, those seizures are of a higher danger of the patient getting injured or harmed during the seizure occurrence [34].

It is common that epilepsy seizures result in uncoordinated movements in the person's body. Those movements are relevant clinical elements in identifying seizures. On the other hand, quantifying this information hasn't been under that much of interest from science community. Typically, long-term video-electro-encephalogram (EEG) monitoring is used for studying those occurrences. Even though movement is of a high importance in diagnosing epilepsy, for decades, experts have focused on the development of quantifying algorithms for the extraction of EEG properties invisible to typical visual inspections. Identical methods haven't been performed on video data, in which doctors only carry out visual inspections. Doctors think of patient's uncoordinated seizure pattern of movement (or motor semiology) as important clue in identifying the existence of seizures and their source [86].

2.7.1 Accelero-meter, Gyroscope and Magneto-meter

ACM devices are responsible for measuring the translational accelerating. They are rather inexpensive and with their low consumption of energy, they provide the ability for ambulatory monitoring via a small device that has a large storage space, high processing speed and permits adding many properties. They're utilized in a wide range of medical uses for activity identification. For instance in Parkinson's disease, they're utilized for distinguishing normal motions from hypo-kinesia, brady-kinesia or dyskinesia [87].

Generalized epilepsy seizures involve the whole brain and produce bilateral motor signs typically with losing consciousness. Thus, seizures typically generate random limb and chest motions. The utilization of accelerometer (ACC) sensor is a suitable resolution for the quick detection of epilepsy seizures and result an alarm for the family (or surrounding people) for limiting the outcomes of the seizures, which will improve the efficiency of existing monitoring systems on the basis of the EEG analysis, via correlation and majority voting with raised alarms by ACC sensors [88].

Gyro sensors are responsible for measuring angular/rotational accelerating and are used to detect the versive seizures. They are more energy consuming than the ACM devices. Magneto sensors are capable of determining the location and direction variations of limbs or body and are valuable for the detection of tonic seizures, due to the “positioning” which happens in those seizures. Therefore, they can also be used to detect tonic–clonic seizures due to their ability of detecting the tonic state, in the beginning of the seizure. However, they have high degree of sensitivity to some of environment factors, and certainly affected by an external magnetic field [38].

An accelerometer is a device that is utilized for measuring suitable acceleration or g-force, which is the acceleration relative to a free-fall, or inertial observer who is at the time at rest based on the object measured and is different from coordinate acceleration. Accelerometers generally measure acceleration in 3 axes X, Y and Z and are used for detection of movements when placed on the patient’s extremities. They consume low power, come in small form factor and are low in cost. They may be utilized to detect clonic seizures which involve muscle spasms and jerky movements [46].

Gyroscopes are devices that can measure rotational acceleration or tilt. Thus they are used to detect seizures where the patient’s limbs suffer a rotational acceleration such as during a fall [46].

Attached to the patient, those sensors are advantageous by being directly connected to the motion (and that includes motor seizures) and by being capable of distinguishing between moving individual limbs, however in the case where a single ACM sensor is utilized, it requires being connected to the correct limb which is typically involved in the (motor) seizures of the patient. Connected to the bed or mattress, they offer more comfort for the patient and may even be of less susceptibility to dislocation over time.

2.7.2 Electromyography EMG

That is a diagnostic process for assessing the health of muscles and the nerve cells that control them (i.e. motor neurons). Those nerve cells carry electrical signals causing muscles to contract. An EMG converts those signals to graphs, sounds or numeric values which an expert is capable of interpreting. An EMG utilizes tiny devices known as electrodes for transmitting or detecting electric signals. A research on nerve conduction, another part of an EMG, utilizes electrodes that are taped on the skin (surface electrodes) for measuring the speed and strength of signals travelling between a couple or more points. EMG results may uncover nerve or muscle dysfunctions or issues with “nerve-to-muscle” signal transmitting [89].

Since they measure muscular activity or movement, they are used for the detection of the tonic stage of tonic-clonic seizures, helping in early detection [46].

According to the above, there are some bio-signals in patients which it can use in the application. Designing and successful implementation of epileptic seizure device is a challenging task. The use of the mobile application, the internet, and biomedical sensors may help to warn the patient family that’s the person having a seizure by sending them a mobile message if they are away from home. Four types of physiological measurements can be acquired in order to predict the seizure which includes heart rate (HR), arterial oxygenation (SpO_2), accelerometer (ACC), and Electromyography (EMG).

3. PROPOSED SYSTEM IMPLEMENTATION

3. 1 INTRODUCTION

After studying and extensively analyzing the existing systems and researches Justifications and reasons for the adoption of the suggested system are given in this chapter. Moreover, the design and the mechanism structure for epilepsy detection are described and illustrated as well.

3.2 DESCRIPTION OF THE STUDY PROPOSAL

As it has been mentioned earlier, the proposed detection and notification system is designed for epilepsy patients had to be constantly surveyed for safety and emergency response purposes. Moreover, for patients living alone temporarily or permanently and could be subject to an emergency situation. Therefore, the system is designed for providing some human related activities and specifications which would be helpful, in real-time, monitoring the abovementioned patients

3.3 OVERVIEW OF THE PROPOSED SYSTEM

Prior to the detailed exploring of the approaches utilized for precisely accomplishing the characteristics and the properties of the presented system. It is highly important to introduce the components of the proposed system (Figure 3.1) which take part in achieving the mechanism of the system. Every one of the component functions and their interrelated works with others are briefly overviewed as follows:

- **Wrist-band:** The wrist-band is fixed on the wrist and holds the responsibility for gathering data from their sensors, processing data for extracting predetermined features and sending them to the smart-phone by Bluetooth.
- **Smart-phone:** smartphones are carried by users and hold the responsibility for gathering data from their sensors and receiving wrist-band sensor data utilized for detection. Moreover, smartphones are responsible for the generation of emergency notifications and sending them to data-base centers and emergency contacts.

- **Web Server:** this is a system delivering content or services to the user via Internet. It is made up of a physical server, its OS and software that is utilized for the facilitation of the HTTP communication.
- **Data-base center:** it has the responsibility of storing the activities, locations, environment conditions and information of emergency notifications of the users.
- **Web Browser:** Anyone authorized is capable of using the web browser for contacting a web server and requesting web pages displaying users' locations, environment condition, activities and emergency notifications.

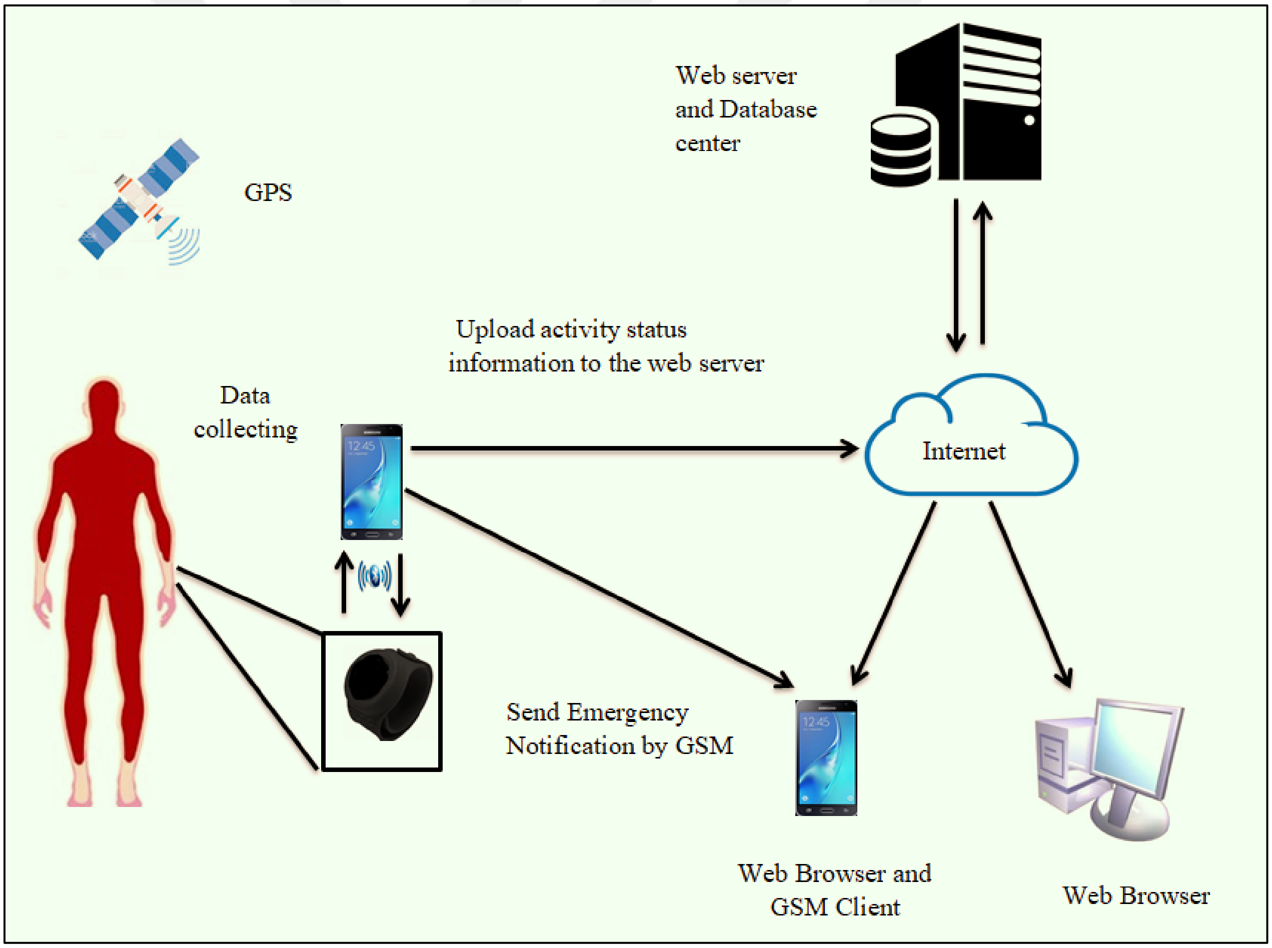


Figure 3.1: Illustrates the fundamental components of the system constituting the general architecture of the system.

Briefly, this chapter presents a discussion of the hardware and software implementation of the bio-medical sensor for monitoring patients with detailed circuits interfacing. Initially, the components that are utilized in the design of the system are overviewed. After that, the presented system structure, and detailed hardware implementation are discussed. Finally, the mobile application design and connecting it with the internet is discussed briefly.

1. hardware :
    - To gather the bio-sensors on portable devices ;
    - To gather the measurement data from the hospital ;
    - To check whether the study would be feasible ;
2. software :
    - To develop a detection algorithm based on the collected data;
    - Building the mobile application and connecting it to the internet ;

3.4 DESCRIPTION OF THE PROPOSED SYSTEM ELEMENTS:

Health monitoring sensors have been in use for many years on the traditional network of health-care. Whether being utilized to diagnose and prevent patients from being employed in situations where the patient is bedridden, those tools of signal sensing play an important role in modern health-care services. Until recently, those tools have been exclusively part of the hospitals and major private clinics. In spite of being relatively portable they had a certain function to monitor bedridden patients or those who are limitedly mobile. From the viewpoint of functionality, they have been and are still are utilized as static sensing tools. With increasing size reduction of silicon manufactured electronics chips, the design of dedicated ICs for health monitoring is presently feasible due to the fact that more and more functions are integrated to an extremely small silicon area that provides inexpensive advanced functionality [59].

There are five main components used to implement the system, these are:

3.4.1 Myoware sensor: the Figure 3.2 shows **MyoWare™**Muscle Sensor (AT-04-001). This muscle sensor from "Advancer Technologies" can measure a muscle's activity via monitoring the electric potential which is generated by the muscle cells. Which is known as electro-myography (EMG). The sensor amplifies and actions the complicated electrical activities of a muscle and converts it to a simple analog signal which is easily readable by any micro-controller with an "analog-to-digital converter" (ADC) such as Arduino. As the target set muscles flexes, the output voltage of the sensor increases. The precise correlation between the voltage and the muscle action may be fine-tuned with the use of an on-board gain potentio-meter. The sensor has traditionally been used for medical research and diagnosis of neuro muscular disorders. However, with the advent of ever shrinking yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into prosthetics, robotics and other control systems.

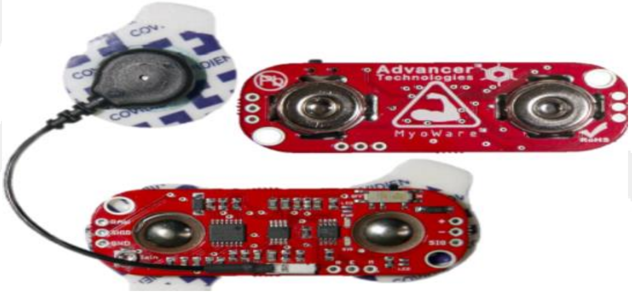


Figure 3.2: MyoWare™ Muscle Sensor

3.4.2 Pulse Oximeter & Heart Rate Sensor: the Figure 3.3 shows The Pulse sensor board from Proto-Central is an innovative addition to open medical hardware lineup. "Maxim's MAX30100" is a significant new product combining all things that are needed for a pulse oxi-meter (such as LEDs and Photo-diode) on one little chip. With a size of 14 millimeters in width and 40 millimeters in length, this board can be easily worn on the finger for the purpose of measuring the pulse. pulse of blood. it even provides a Velcro strap to hold it.

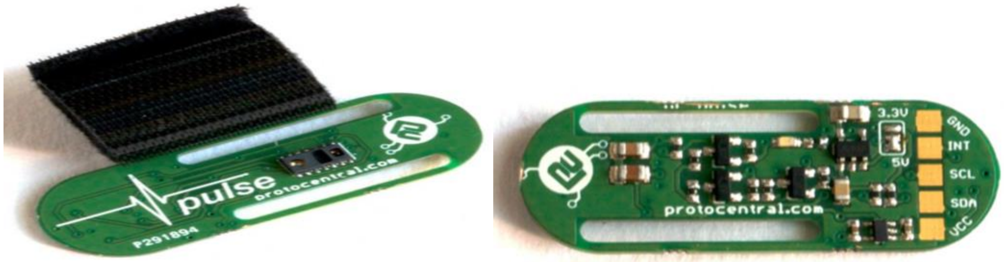


Figure 3.3: ProtoCentral Pulse Oximeter & Heart Rate Sensor based on MAX30100 (PC-6565)

Oxi-metry of pulse works on the red and infrared light absorption features of oxygenated and deoxygenated hemoglobin. The concentricity of blood oxygen can be **computed from the ratio** between the **absorption of red and infrared light by the hemoglobin**. Heart rate is detected by the variation in blood volume throughout the finger which is afterward quantified with the amount of light passing through the finger.

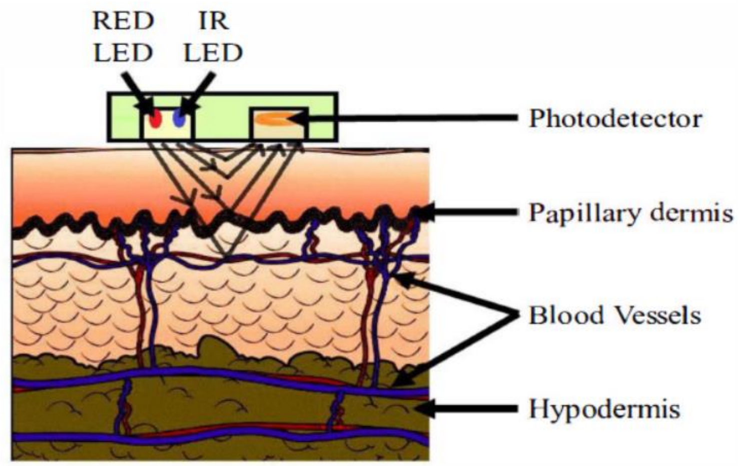


Figure 3.4: Principle of reflectance pulse oximetry in the finger.

From the LEDs, red light and infrared light are transmitted via the finger and the photo-detector integrated in the chip senses the light absorption of the two distinct wave-lengths as shown in Figure 3.4. In this thesis, each of the oxi-metry and heart rate detection procedures has been utilized with the “MAX30100”; therefore, it is possible to simultaneously capture each of heart rate and oxygen saturation.

3.4.3 Acceleration: Figure 3.5 shows the **“**GY-61 DXL335 3-Axis” Accelerometer Module is a three axis accelerometer sensor module based on ADXL335 integrated circuit. The ADXL335 is a triple axis accelerometer with extremely low noise and power consumption. The sensor has a full sensing range of +/-3g. It can measure **the static acceleration of gravity** in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

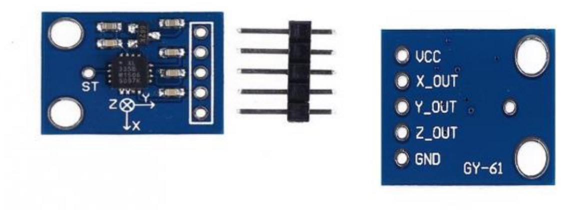


Figure 3.5: GY-61 DXL335 3-Axis Accelerometer Module

3.4.4 Bluetooth: this technology is a low power, inexpensive, short range, radio technology open standard for development of personal area networks (PANs). Bluetooth used to create a small network of devices that are close to one another, very short range, typically about 10m[60]. Figure 3.6 shows the Bluetooth Hc-6 slave this type allows your device to both send and receive the TTL data via Bluetooth technology without connecting a serial cable to your computer Signal coverage: 30ft.

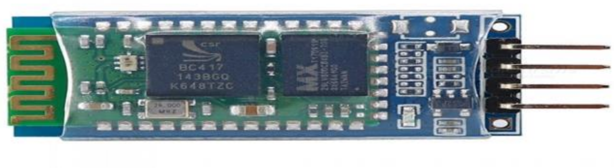


Figure 3.6: Bluetooth Hc-6 slave

3.4.5 Microcontroller: Figure 3.7 shows an Arduino Nano that is used as the micro-controlling unit in the designed system. Arduino is an instrument used to construct computers that can control and sense a greater amount of the physical world than typical

PC. It is an open-source physical computing platform based on a simple microcontroller board and a development environment for writing software for the board. Arduino can be utilized to create intelligent objects, taking inputs from a mixture of switches or sensors, and controlling an assortment of motors, lights, and other physical outputs. The main advantages that make Arduino preferred over other known techniques like FPGA are; its low cost, cross-platform (supports different operating systems), simple & clear programming environment, open source and extensible software and Hardwar.

Figure 3.7: Arduino Nano

3.4.6 Power supply: is an electrical tool supplying electricity for an electrical load. Its main task is converting electrical current from source to proper voltage, current, and frequency for powering the load. The power load that has been used is 3.7v.

3.5 HARDWARE IMPLEMENTATION OF THE PROPOSEDSYSTEM

The system implementation procedure can be summarized into four steps as follows:

1. Interfacing Myoware sensor with Arduino Board.
2. Interfacing Accelerometer and Pulse Oximeter and Heart Rate Sensor with Arduino Board.
3. Interfacing Bluetooth with Arduino.

3.5.1 Soldering the Sensors Breakout Board

- MAX30100: On the underside of the sensor there are five contacts; at least one wire should be soldered to the Power supply (+Vcc), Serial Clock Line (SCL), Serial Data Line (SDL) and Ground (GND).

- MyoWare AT-04-001: On the Right-side of the sensor there are three contacts; at least one wire should be soldered to the power supply (+Vcc), output Signal (SIG) and Ground (GND).
- GY-61 DXL335: On the Right-side also of the sensor there are five contacts; at least one wire should be soldered to the power supply (+Vcc), X-output, Y-output, Z-output and Ground (GND).
- Bluetooth HC-06 Slave: the power supply (+Vcc), Ground (GND). Receiver (Rx) and Transmitter (Tx).

3.5.2 Pin Mapping:

1. **MAX30100 (HR & SpO2)**

   MAX30100 VCC to +5V Arduino.
   MAX30100 GND to GND Arduino.
   MAX30100 SDL to SDL(pin) Arduino.
   MAX30100 SCL to SCL (pin) Arduino.

2. **MyoWare AT-04-001 (EMG)**

   MyoWare Vcc to +5V Arduino.
   MyoWare GND to GND Arduino.
   MyoWare SIG to pin() Arduino.

3. **GY-61 DXL335 (ACM)**

   GY-61 DXL335 VCC to +5V Arduino.
   GY-61 DXL335 GND to GND Arduino .
   GY-61 DXL335 X to pin(A0) Arduino.
   GY-61 DXL335 Y to pin(A1) Arduino.
   GY-61 DXL335 Y to pin(A2) Arduino.

4. **HC-06 (Bluetooth)**

   HC-06 VCC to +3.7V Arduino .
   HC-06 GND to GND Arduino.
   HC-06 Tx to Rx Arduino.
   HC-06 Rx to Tx Arduino .

After gathering the sensors and other component, we finish the hardware part. Figure 3.8 shows the Block Diagram of Hardware.

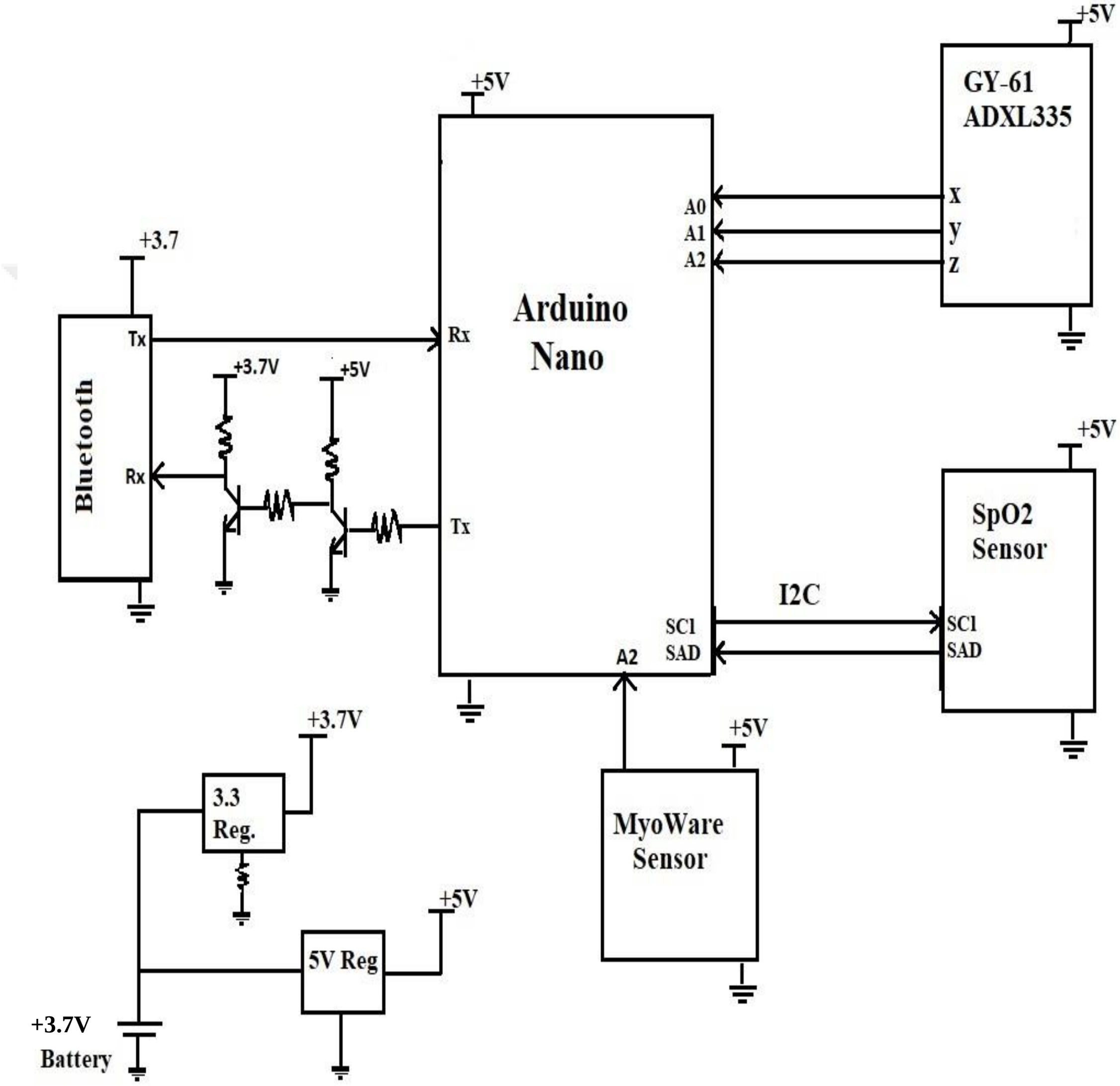


Figure 3.8: Block Diagram of Hardware' wrist-band'

As mentioned previously, the proposed system consists of three sensors and Bluetooth. Each sensor has a specific function.

3.5.3 Interfacing the Modules with Arduino Board

We are ready to program Arduino in order to send/receive data wirelessly following these steps:

a) First, the latest version of Arduino IDE is installed.

b) Arduino is connected to the PC.

c) Open the Arduino IDE software as shown in Figure 3.9 and select the type and serial port number of the Arduino board connected to the PC.

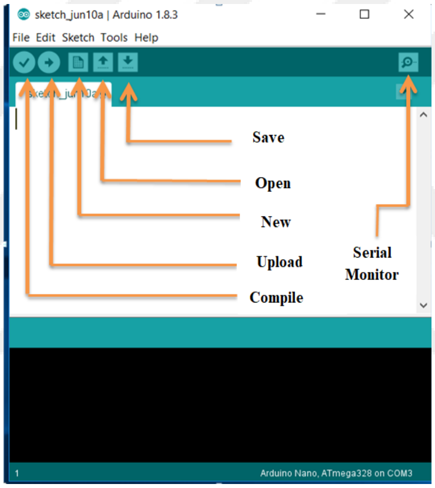
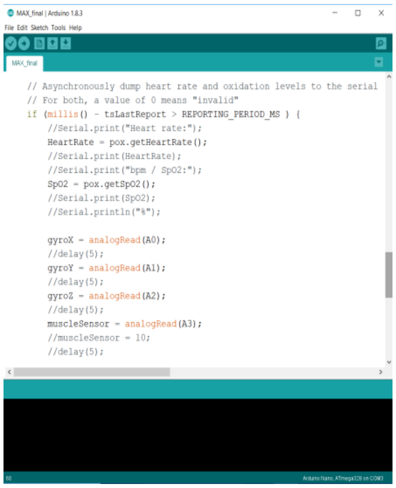


Figure 3.9: Arduino IDE GUI

d) Configure Arduino to sensors (HR, SpO_2, EMG, and Gry) as shown in Figure 3.10.



```
// Asynchronously dump heart rate and oxidation levels to the serial
// For both, a value of 0 means "invalid"
if (millis() - tsLastReport > REPORTING_PERIOD_MS ) {
    //Serial.print("Heart rate:");
    HeartRate = pox.getHeartRate();
    //Serial.print(HeartRate);
    //Serial.print("bpm / SpO2:");
    SpO2 = pox.getSpO2();
    //Serial.print(SpO2);
    //Serial.println("%");

    gyroX = analogRead(A0);
    //delay(5);
    gyroY = analogRead(A1);
    //delay(5);
    gyroZ = analogRead(A2);
    //delay(5);
    muscleSensor = analogRead(A3);
    //muscleSensor = 10;
    //delay(5);
```

Figure 3.10: Arduino configuration of sensors

e) Connect the hardware ‘wrist-band’ to PC as shown in Figure 3.11.

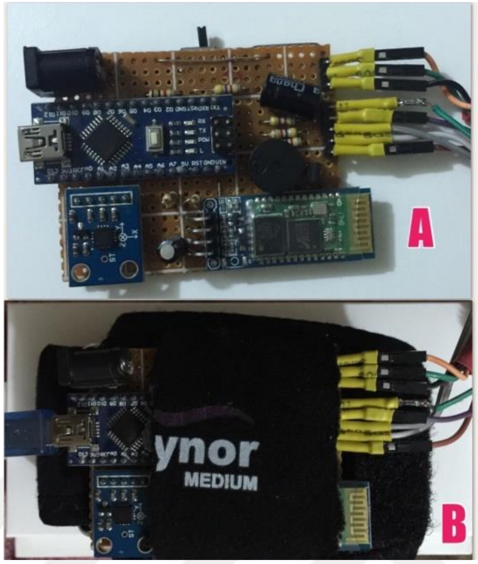
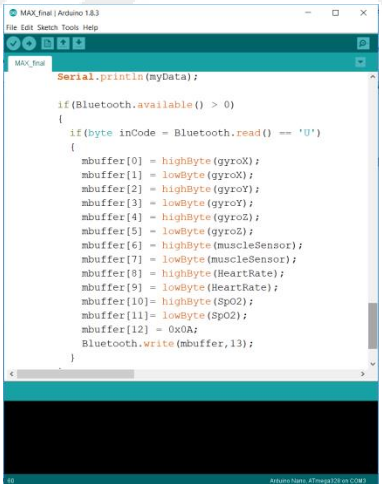


Figure 3.11: a) Hardware overview**. b)** Connecting hardware to PC

f) Show the data from sensors by serial monitors.

g) Configure Arduino to send data to mobile via Bluetooth as shows in Figure3.12.



```
    Serial.println(myData);

    if(Bluetooth.available() > 0)
    {
      if(byte inCode = Bluetooth.read() == 'U')
      {
        mbuffer[0] = highByte(gyroX);
        mbuffer[1] = lowByte(gyroX);
        mbuffer[2] = highByte(gyroY);
        mbuffer[3] = lowByte(gyroY);
        mbuffer[4] = highByte(gyroZ);
        mbuffer[5] = lowByte(gyroZ);
        mbuffer[6] = highByte(muscleSensor);
        mbuffer[7] = lowByte(muscleSensor);
        mbuffer[8] = highByte(HeartRate);
        mbuffer[9] = lowByte(HeartRate);
        mbuffer[10]= highByte(Sp02);
        mbuffer[11]= lowByte(Sp02);
        mbuffer[12] = 0x0A;
        Bluetooth.write(mbuffer,13);
      }
```

Figure 3.12: Arduino configuration to send data via Bluetooth

3.6 WEBSERVER AND DATA-BASE CENTER

The webserver is utilized for communicating with user smart-phone for continuously obtaining information connected to the activity type and status that the user is practicing. The fundamental tasks that are achieved by the webserver are as follows:

1- The webserver is responsible for storing the obtained data in a data-base for historical analysis and real time monitoring.
2- The webserver gives the authorized party ability to see received data for real time monitoring of the user status.
3- The webserver is responsible for the inspection of the obtained data and notifying the emergency-center for rapid response if the emergency station is needed.

3.7 GSM CLIENT AND WEB-BROWSER

In order to make the system available for people that are actually interested in user status, therefore, the proposed system gives any authorized party the access to the webserver from pc, smart-phone, tablet, or other device. For historical review and real time monitoring including:

1- Physiological activity.
2- User emergency notification.
3- User tracking location.

Moreover, the presented system is designed for sending emergency notifications to the contact phone number configured and set up in the system for emergencies and notifications.

3.8 ALARM PROCEDURE

In addition, the system is designed for providing additional data that is related to any event that occurs during the activity, like emergency notifications that are accomplished by the process of the alarm. When detecting an emergency event throughout the day, the alarm process is activated for making the following action:

1- Switching on an alarm and displaying a confirmation message, on the smart-phone of the user, asking them for a confirmation to the message whether or not they are well.
2- The system has a waiting period of 1 min. for receiving a message of confirmation from the user and, if he or she don't confirm it or respond negatively, the alarm process will send a notification of an emergency to the emergency center with a report of data (HR, SpO_2, and EMG).

3- Sending GSM notification message.

3.9 PROPOESD SYSTEM IMPLEMENTATION

Implementing the suggested system is classified to 5 main categories: Wrist-Band side, smart-phone side, server side, data-base center as depicted in Figure 3.13 and algorithm depicted in Figure 3.14, also the explained in the sub-section below.

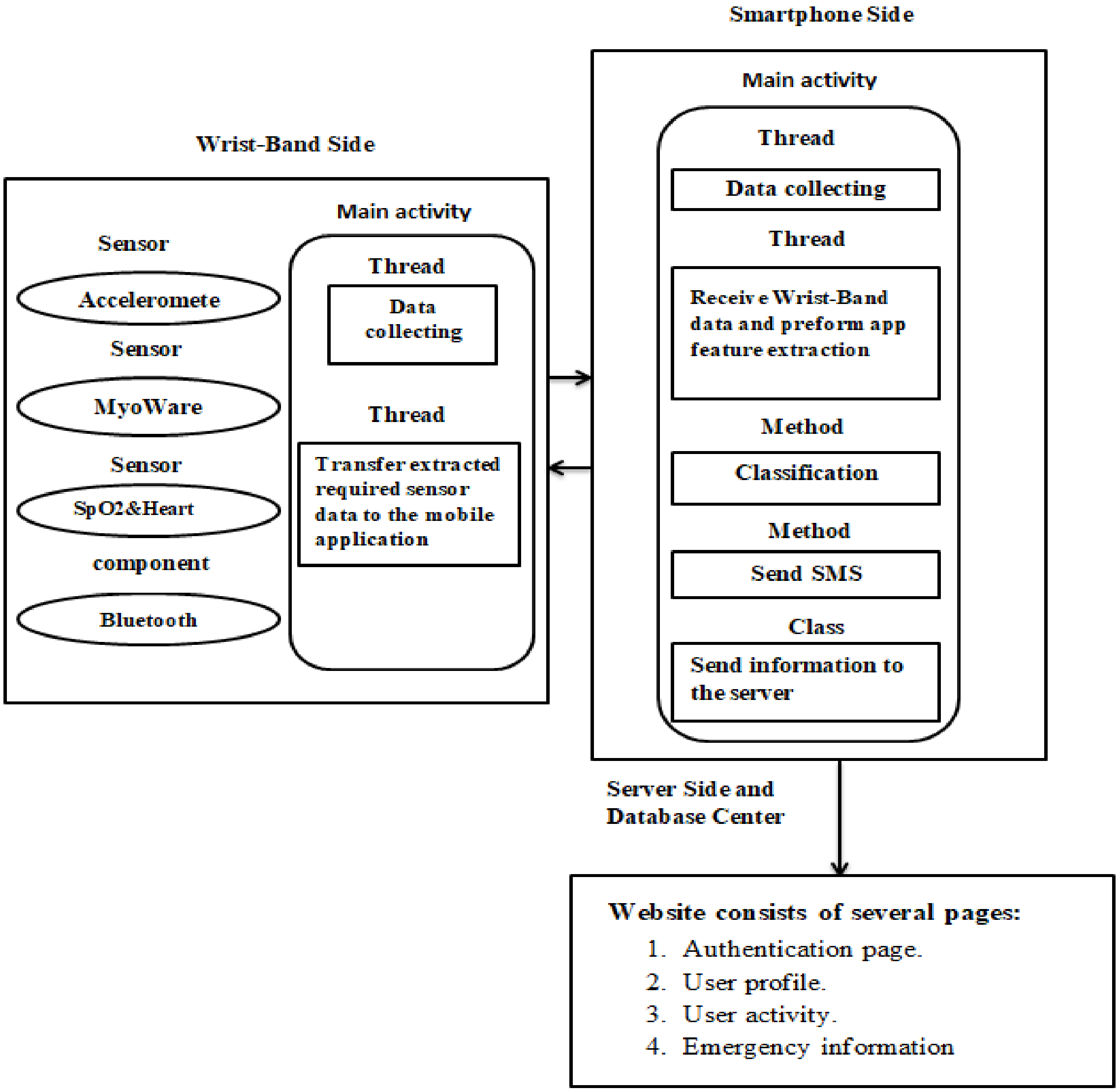


Figure 3.13: The main parts, class, thread, and methods used in implementing the proposed system

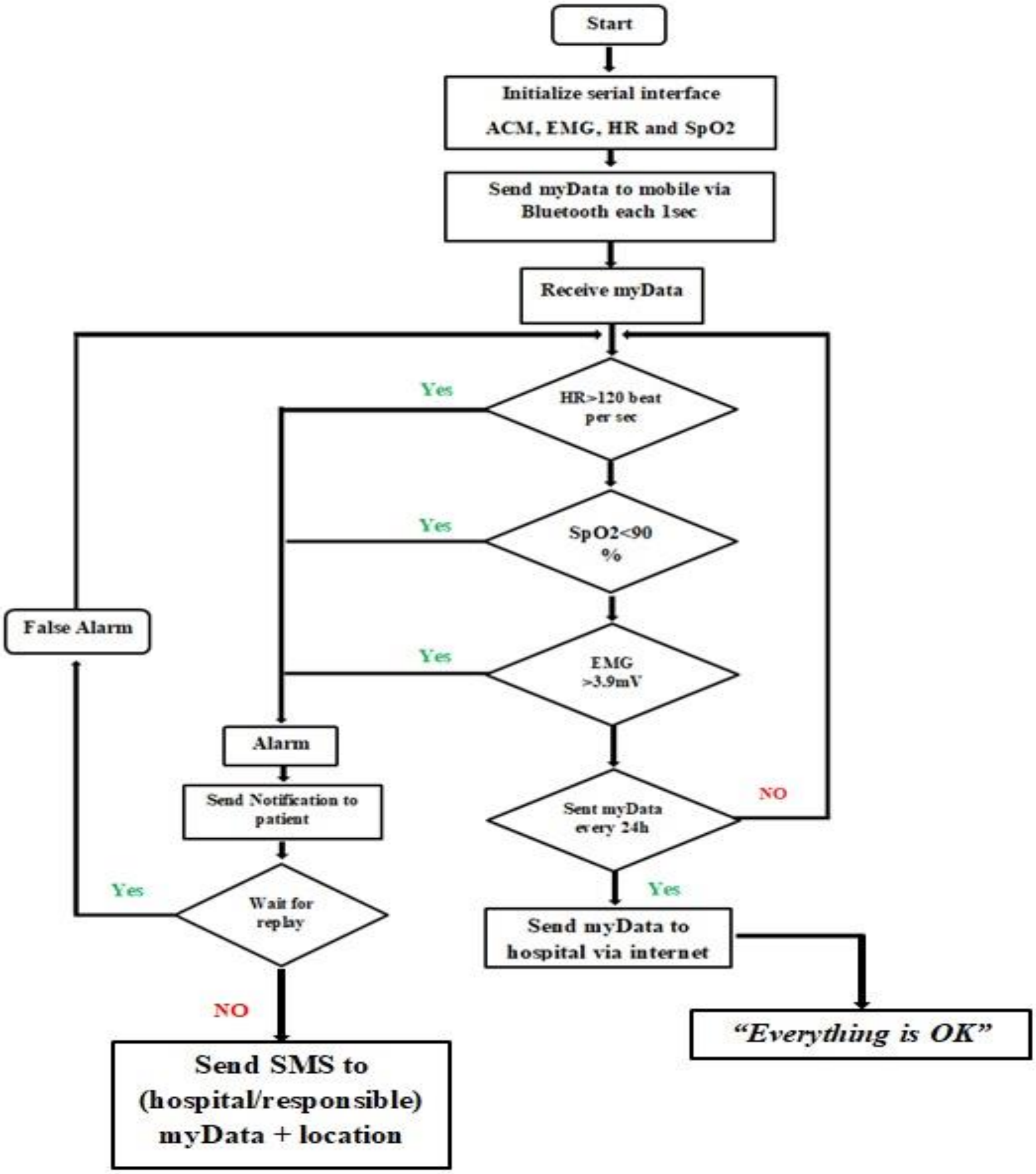


Figure 3.14: Flowchart of the implementation of proposed system

3.9.1 Wrist-Band Side

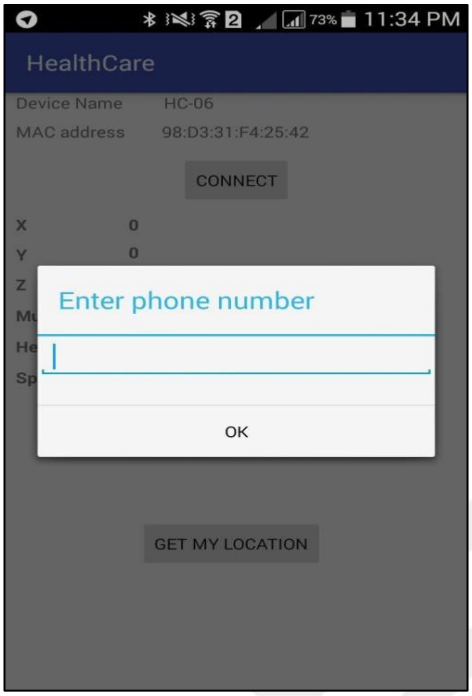
The Wrist-Band system software is written in Arduino programming language, the Wrist-Band memory is prepared for execution when activating the system. The Wrist-Band software has the responsibility of gathering information from the embedded sensors, windowing and property extracting. After that, the obtained properties are transmitted to the smart-phone by Bluetooth.

3.9.2 Smart-phone Side

The software of the smart-phone system is programmed using Java programming language, under the Android platform IDE that is loaded in smart-phone memory prepared for execution after activating the system. The software of the smart-phone has the responsibility of gathering information from the sensors and receiving properties that have been obtained from the data of the wrist-band sensor. Moreover, the processes of classification are achieved inside the smart-phone. In addition to that, the smart-phone has the responsibility of the generation of emergency notifications and sending them to the data-base center and the contact of emergency.

The application of the smart-phone needs to fully control the hardware of the smart-phone and required permission for accessing and using smart-phone software and hardware components, like sending GSM messages, Bluetooth, Internet access, SQLite data-base, running in the background.

The software of the smartphone is made up of 3 user interfaces, the first, which is depicted in Figure 3.16, is utilized for entering or changing the phone number of the person in charge.The second is the interface of the main user, which is depicted in Figure 3.17, and utilized for monitoring user activities and interacting with the system. The third, which is depicted in Figure 3.18, is utilized when an emergency case happens; it shows a message of confirmation with alarm sounds.


11:34 PM

HealthCare

Device Name HC-06

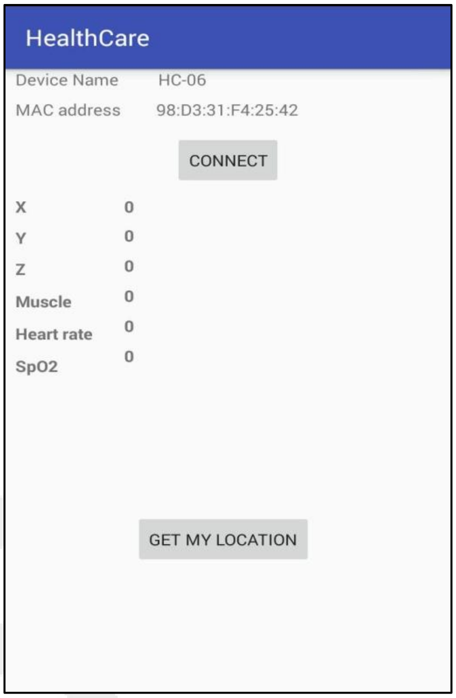
MAC address 98:D3:31:F4:25:42

X 0

Y 0

Enter phone number

Figure 3.15: Responsible information


HealthCare

Device Name HC-06

MAC address 98:D3:31:F4:25:42

X 0

Y 0

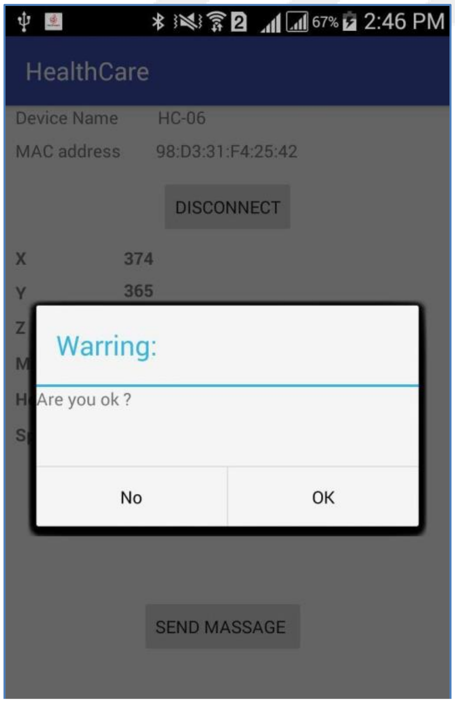
Z 0

Muscle 0

Heart rate 0

SpO2 0

Figure 3.16: Main user interface in smartphone application


2:46 PM

HealthCare

Device Name HC-06

MAC address 98:D3:31:F4:25:42

X 374

Y 365

Warring:

Are you ok ?

Figure 3.17: Emergence message interface for the smartphone application

3.9.3 Server Side

The software in the server side has the responsibility to receive and store the data in the center of the data-base and provide it to the browser.

- Web Server: The web-server is a system that delivers contents or services to the end users over the Internet. It consists of a physical server, server operating system, and software used to facilitate HTTP communication.
- Database center: The database center is responsible for storing user activities information and emergency notification messages.

3.10 CLINICAL TRIALS

The device was applied to patients with generalized seizure in under the supervision of the doctors of the EEG-Video recording in Department of Neurology at Baghdad Hospital. every day comes one patient to the department of EEG-Video recording for 5 hours it’s the protocol of the hospital , the patients most of them were Generalized seizure in the case of prediction of the used device the patients should be GTCS (Generalized tonic-clonic seizure) type ,almost all the patients had no-seizure during the EEG-Video recording which was one of the problems was faced during the trials of device, the device was applied on xx patients of epilepsy and as mentioned previously the seizure come with no Warning.

According the problem was faced the work change from online to offline simulation the result of the device showed in next chapter is offline and by depending on the other researcher works.

In the next chapter, first, the proposed detection system will be tested using prototype date and then it will be actual connect it on the patient body.

4.The RESULT OF THE PREFORMANCE OF THE PROPOSED SYSTEM

4.1 INTRODUCTION

This chapter has illustrated the efficiency of the proposed system performance and result; the obtained results are checked by testing the proposed system.

4.2 RESULTS AND PERFORMANCE

In the classification of the proposed system (previous chapter), the activities and specifications of the proposed system are categorized as listed below:

A- Heart rate tracking with oxygen level and EMG.

B- User tracking location.

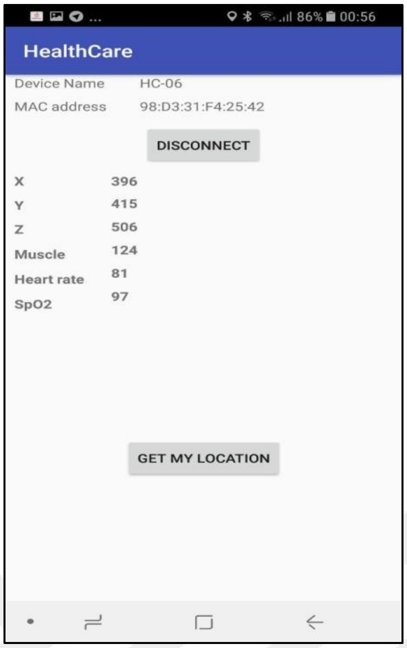
C- Emergency notification and report.

These categories are used to apply the system for the Epileptic patients and the results were stimulated of the seizures.

4.3 DATA ANALYSIS

The primary goal of the data analysis was to find specific aspects of the acquired measurement data based on which detect a tonic seizure. The multimodal approach of the device provides four modalities from which a combination of distinctive features could provide the base for a tonic seizure detection algorithm. Through using the proposal system obtained a good detection of specific signal features for the identification of tonic seizures.

The data which was collected from the wrist-band were sent to the smartphone to be displayed by the application as shown in Figure 4.1. After taking the patient information by the IT department of the hospital, the healthcare application was downloaded to the patient’s phone and the phone number of the responsible / hospital was also set at this application.



Device Name	HC-06
MAC address	98:D3:31:F4:25:42

X	396
Y	415
Z	506
Muscle	124
Heart rate	81
SpO2	97

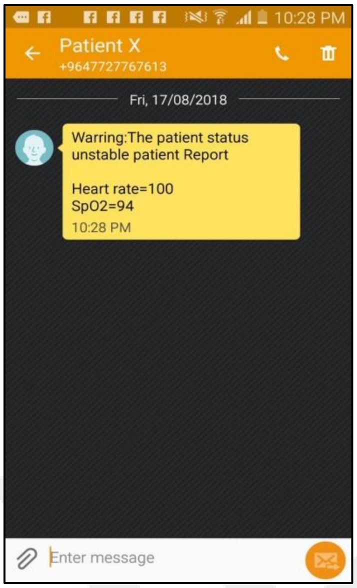
Figure 4.1: The data of muscle, HR, and SpO_2 for patients by using the application

4.5 HYPOTHESIS AND THE RESULT OF THE PROPOSED SYSTEM

4.5.1 Heart Rate tracking and oxygen level

The HR and SpO_2 measurements data have been extensively analyzed. The expectations that they showed distinctive features during tonic seizures change in HR↑ ⇒ SpO2 ↓. 15%, 20%, 25% and 30% increases for HR, based on Osorio are finding [23] and these levels are useful for detecting seizures. The levels 5%, 7.5%, 10% and 12.5% are considered as SpO_2 decreases, where these levels were chosen because apnea is defined as a 4% drop in SpO_2 for 8 sec or more. Normal SpO_2 levels are between 95% and 100% and readings below 90% are low [15]. In the next Figures the result shows when we set the threshold, $HR \geq 100$ and $SpO_2 \leq 94$. The heart rate in tonic seizure is reached 120 beats per sec in the seizure's condition, but because of the difficulties to reach this rate (120 beats per sec) in reality, so we got this rate 100 beats per sec by using the electrical walking machine.

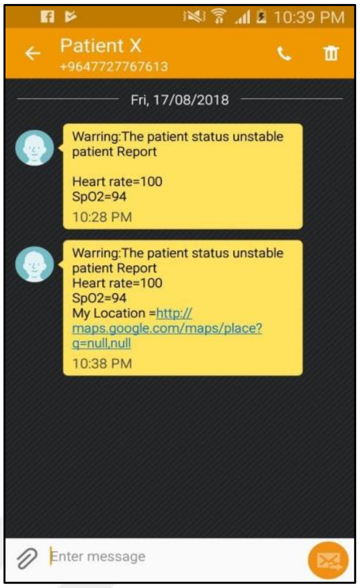
The patient status (HR: 100, SpO_2: 94) begins to alarm that the patient is undergoing a seizure and for that, the system has responded to the status of the patient and notified the responsible person/hospital to make the appropriate action (Figure 4.2).



Warring:The patient status unstable patient Report

Heart rate=100
SpO2=94
10:28 PM

Figure 4.2: Tracking the HR & SpO2 without GPS



Warring:The patient status unstable patient Report

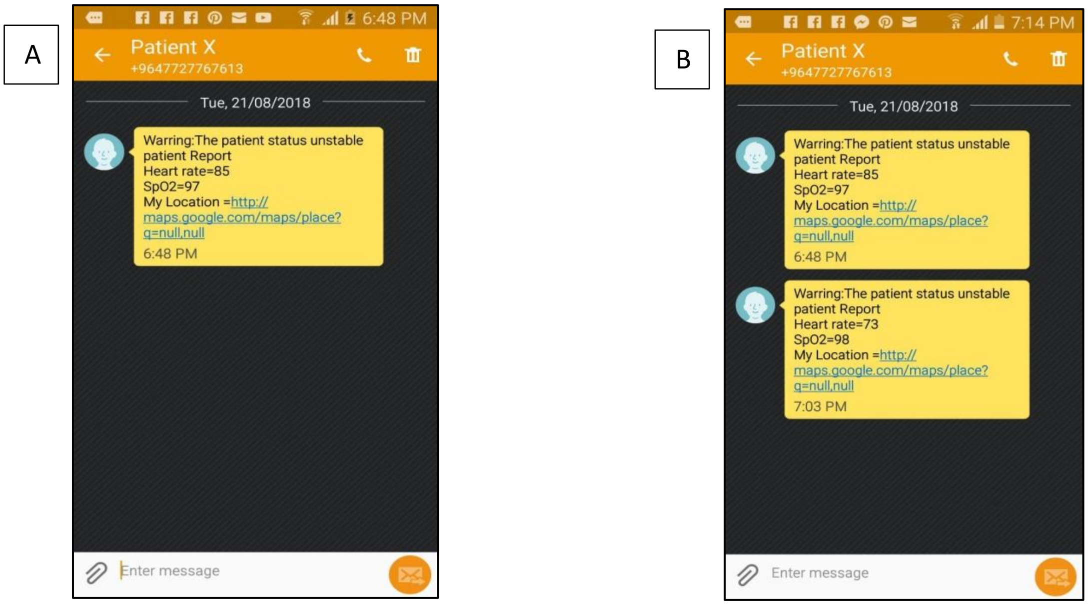
Heart rate=100
SpO2=94
10:28 PM

Warring:The patient status unstable patient Report
Heart rate=100
SpO2=94
My Location =http://maps.google.com/maps/place?q=null,null
10:38 PM

Figure 4.3: Tracking the HR & SpO2 with GPS

The Figure 4.3 illustrates the location of the patient's site by using GPS. In addition to, alarming that the patient is undergoing a seizure and the system responses to the status of the patient and notified the responsible person/hospital to make the appropriate action.

The results showed different thresholds of normal heart rate for checking the system response and reaction to the given status (Figures 4.4).



Warring:The patient status unstable patient Report
Heart rate=85
SpO2=97
My Location =http://maps.google.com/maps/place?q=null,null
6:48 PM

Warring:The patient status unstable patient Report
Heart rate=85
SpO2=97
My Location =http://maps.google.com/maps/place?q=null,null
6:48 PM

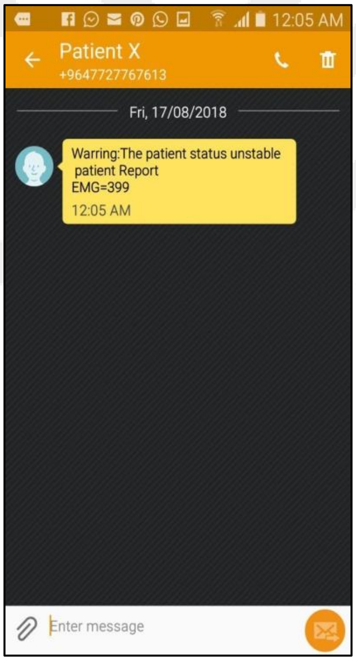
Warring:The patient status unstable patient Report
Heart rate=73
SpO2=98
My Location =http://maps.google.com/maps/place?q=null,null
7:03 PM

Figure 4.4: Different tracking of the patient status with HR, SpO_2 & his location (A and B).

4.5.2 EMG tracking

Van Sluis[101] revealed important features of detection for tonic seizures. The study results showed that 70% of a dataset of the tonic seizures showed the higher activity of EMG in contrast of EMG activity in regular movement.

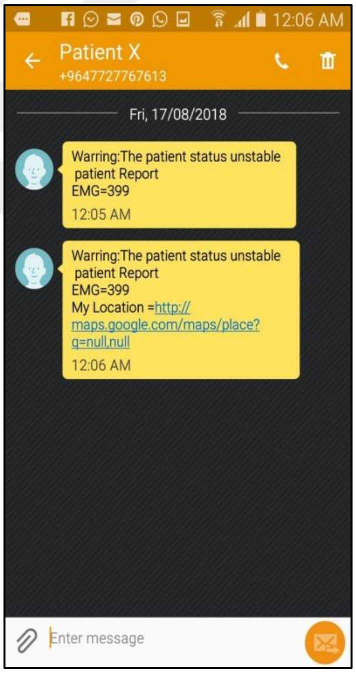
In the Figure 4.5 shows a message received from the application of patient's mobile phone which has been downloading from the IT of the hospital to the responsible / hospital reveals a report that the patient is in unstable status and there's a dysfunction in the nerve or muscle system which is revealed by the electromyography system (EMG). While Figure 4.6 illustrates the location of the patient by using the GPS system in order to facilitate the case management.



Fri, 17/08/2018

Warring:The patient status unstable
patient Report
EMG=399
12:05 AM

Fig 4.5: Tracking the EMG without GPS



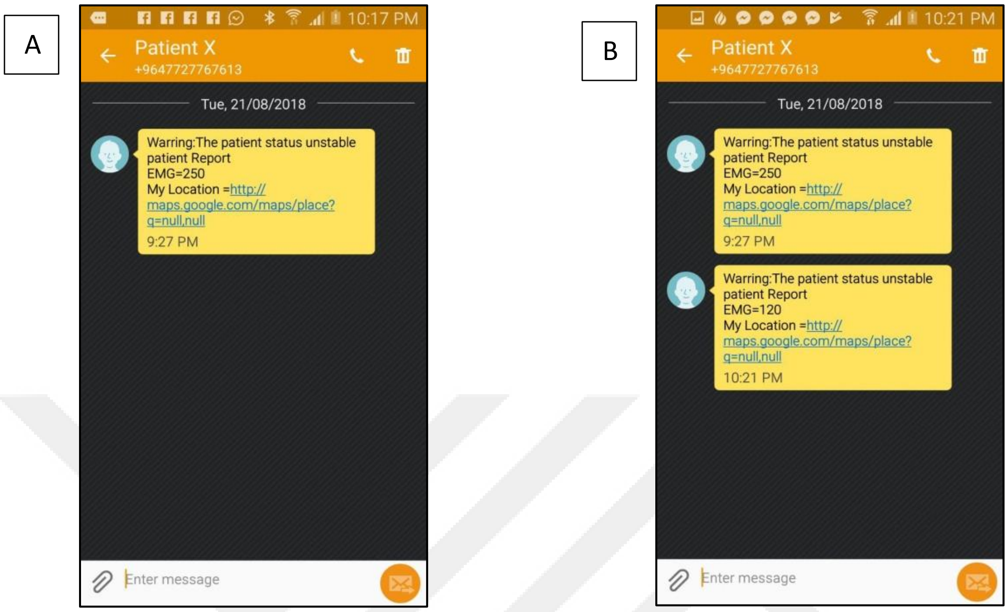
Fri, 17/08/2018

Warring:The patient status unstable
patient Report
EMG=399
12:05 AM

Warring:The patient status unstable
patient Report
EMG=399
My Location =http://maps.google.com/maps/place?q=null,null
12:06 AM

Fig 4.6: Tracking the EMG with GPS

In the Figure 4.7 showed the different thresholds of EMG for checking the system response and reaction to the given status. The 0-300 reading for muscles is considered relaxes, while 700-900 is regarded to be tensed.



A

Tue, 21/08/2018

Warring:The patient status unstable
patient Report
EMG=250
My Location =http://
maps.google.com/maps/place?
q=null,null
9:27 PM

B

Tue, 21/08/2018

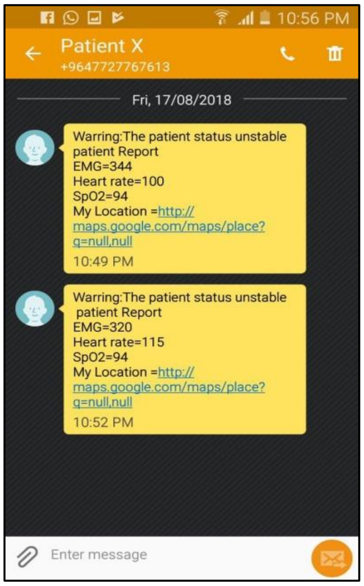
Warring:The patient status unstable
patient Report
EMG=250
My Location =http://
maps.google.com/maps/place?
q=null,null
9:27 PM

Warring:The patient status unstable
patient Report
EMG=120
My Location =http://
maps.google.com/maps/place?
q=null,null
10:21 PM

Figure 4.7: Different tracking of the patient status with EMG & location (A and B)

4.5.3 Full Report of a patient

In the Figures 4.8-4.9, illustrates the final full report of the patient with an alarming message with a different reading. The report is useful in recording the patient's data by time to know the time between seizures which help in monitoring the patient condition.

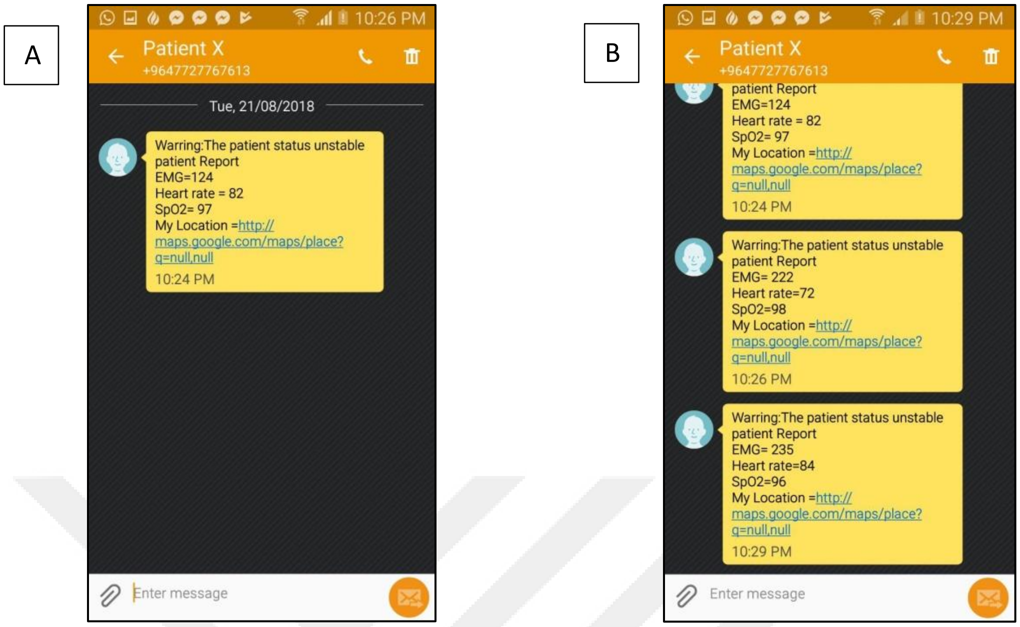


Fri, 17/08/2018

Warring:The patient status unstable
patient Report
EMG=344
Heart rate=100
SpO2=94
My Location =http://
maps.google.com/maps/place?
q=null,null
10:49 PM

Warring:The patient status unstable
patient Report
EMG=320
Heart rate=115
SpO2=94
My Location =http://
maps.google.com/maps/place?
q=null,null
10:52 PM

Figure 4.8: Final Full Report Critical condition



Tue, 21/08/2018

Warring:The patient status unstable
patient Report
EMG=124
Heart rate = 82
SpO2= 97
My Location =http://maps.google.com/maps/place?q=null,null
10:24 PM

patient Report
EMG=124
Heart rate = 82
SpO2= 97
My Location =http://maps.google.com/maps/place?q=null,null
10:24 PM

Warring:The patient status unstable
patient Report
EMG= 222
Heart rate=72
SpO2=98
My Location =http://maps.google.com/maps/place?q=null,null
10:26 PM

Warring:The patient status unstable
patient Report
EMG= 235
Heart rate=84
SpO2=96
My Location =http://maps.google.com/maps/place?q=null,null
10:29 PM

Figure 4.9: Different tracking of the patient status & location (A and B)

In this study was incorporated Arduino platform ‘wrist-band” as a component part of the system. From the applied test it showed that the fixed wrist-band is comfortable to use by the patient hand. Also, the used sensors were reflected good signals of the studied parameters. The proposed system provides different services such as heart rate tracking and oxygen level, user tracking location and emergency notification.

The Arduino-wear and android-smartphone side of the proposed system is implemented by the Android studio using java programming, while the portable written by Arduino programing language. The results of the proposed system response show a promising outcome that can depend on for predicting the seizure.

5. CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

This study applied the biosensors to predicate the Epileptic seizure throughout the measurements of some physiological signals such as HR, SpO_2 and EMG. The study started with Epilepsy patients and the study changed to virtual investigation. Several points observed and noticed as follows:

1. The study used the integration of the wrist-band with smartphone and achieved a good signal which reflected the status of the patients. The results realized these signal with standards features of normal and unstable of patient's status.
2. To strengthen such activity system, the proposed system supports important services used to protect user health like:
   - **a.** Physiological activities used to monitor any change in the patients user daily routine to reflect his/ her status.
   - **b.** The application was reduce the problem of the sudden unexpected death by emergency notification which has sent by the system.
   - **c.** The tracking of HR and SpO_2 were the fast signal responded to any change in the patient's status and, a notification send to emergency center in order to help the patients.
   - **d.** The user location tracing is important application to find the patient when the seizure begins. Also, it used to monitor his/her status of the patient during his daily activities.
3. Some features were used to maintain the false alarm, these features added to the application because all emergency notification systems exposed to error. These features as follow:
   - **a.** The application send notify a conformation message to patient to ask him on his/her smartphone, in order to confirm the status by answering YES or NO if she/he is well or not. The application has option to correct the notification is FALSE or CORRECT alarm.

    b. In case, the patient could not response the notification hence the application will be send automatically an emergency SMS from the user phone to emergency contact with his/her report.

4. The used device in this study characterized by the features as follows: can be used by patient during daily life, cheaper coast, let the monitoring of the patient status more easily and fast response and can detect the patient's location in emergency condition. While the disadvantage is the location of the device and prefer to find another suitable place to measure the heartbeat and oxygen levels without being affected by the movement of the fingers of the patients.

5.2 FUTURE WORK:

To increase the efficiency of the proposed system needs to add some recommendation:

1. It's preferred to connect the proposed system into Cloud in addition to use GSM-phone.
2. To use the Nano-technology to reduce the size and be more confortable to use by users.
3. Encourage the health institution to use these system on real patients to check their efficiency
4. Use extra sensors to detect the seizure such as EDA, breathing rate and temperature.
5. The use of wrist-band which has GPS and GSM will increase the efficiency of portable device and drop the smartphone from the proposed system.

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