A Framework and Prototype of a Telehealth System via Fusion of Advanced Technologies and Open Source Applications

By

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Abstract

The aim of this research was to establish a framework for the development and design of a remote and safe monitoring system (telehealth system) for chronically diseased patients by using available wearable wireless sensors that are woven or knitted in smart textiles. When these sensors collect patient data, whether from a chronic diabetic or a chronic cardiac patient, it is sent via smart phones to the medical care system. This work benefits from the new applications available in smart phones by saving data and sending it to nearby caregiver centers, emergency centers, or any family member if the case is urgent. This system consists of a safety monitoring system which involves detecting falls and sending alarm messages to a medical provider or an emergency response team by using an open source smart phone application. The resulting signal is then relayed to the hospital or clinic server. In addition, the use of “air bag” technology protects patients if they fall. Since the number of chronic patients is increasing, the goal of this system is to optimize the role of the doctor in following patients remotely without any need for appointments and long waits, thus improving the patient experience and leading to a decrease in mortality cases among chronic patients. The development of a framework for synthesis and implementation of a long-term, safe and remote monitoring system is offered in this research as a conceptualization strategy for designers. The framework is illuminated via a prototype e-system for demonstration of design, fabrication, and use.

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Abbreviations

1. ADC……….. …………………………………Analog-to-Digital Converter
2. ADL .... .Activities of Daily Living
3. AMON……….....Advanced Care and Alert Portable Tele-Medical Monitor
4. ATA …………………… .. ...………….American Telemedicine Association
5. Bit……………………… ... ……………………………………...Binary Digit
6. BMI……………………………………………..……...Body Mass Index
7. BOK…… .. ……………………………………………..Body of Knowledge
8. BP…………………………… ....…………Blood Pressure Measurement
9. COPD……... ……………………..Chronic Obstructive Pulmonary Disease
10. CPU………… ..……………………………………. Central Processing Unit
11. DAC ……………………………. ……......Digital to Analogue Converter
12. ECG ……………………….. ………………………...Electrocardiography
13. EMG……………………………………... …………Electromyography
14. FVC… ...Ratio used diagnosis of obstructive and restrictive lung disease
15. GPS………..…………………………………… Global Positioning System

16. GSM… . ………………………..Global System for Mobile Communication

17. HRSA…………… . ……...Health Resources and Services Administration

18. I^2C™………………… . …………………………….Inter-Integrated Circuit

19. ICD…………………. …International Statistical Classification of Diseases

20. ICU…………………. ... ………………………........Intensive Care Unit

21. IrDA………………………….. …………………Infrared Data Association

22. IT……………………………….……... ……….Information Technology

23. ITV………………………... …………………......Independent Television

24. Life Shirt ……… ….Multi-Function Ambulatory System Monitoring Health

25. MCU……………………… ..... ………………………Micro-controller Unit

26. mHealth……… .. ………………………………………………Mobile Health

27. HIMSS… ...... Healthcare Information and Management Systems Society

28. MIThril………………... ……….…………………………..MIT Media Lab

29. PDA …………….... ………….……………………Personal Digital Assistant

30. RAM………………. ..………………………….Random Access Memory

31. REMOTE-HF™…… ..... ……Remote Control Your HF Rig via the Internet

32. RFID………………………...………….………Radio-frequency identification

33. RMS…………………….. .... .Remote Monitoring System

34. RMS-aiR1……………… .. ………………….…Prototype RMS of This Work

35. ROM……………..……………………………………… Read-Only Memory

36. RSSI… ....……………………………...Received Signal Strength Index

37. SPI…………………….. ………………......Serial Peripheral Interface Bus

38. SPO .....…………………………………………………Oxygen saturation

39. VDC………………..…………………………………Volts of Direct Current

40. VR…………. ……………………………………………..Virtual Reality

41. WSN……………. ………………………………..Wireless Sensor Network

Chapter 1

1.0 Introduction

1.1 History of Treatment of Chronic Diseases

The advancement of technology in protecting and promoting the health of seniors in the twentieth century has offered many opportunities for defeating the challenges of an aging society. Many developments have taken place in the health care system in the past few years. However, the health care system still suffers from many difficulties. As life expectancy increases in industrialized countries it brings with it many chronic diseases [1]. In addition, the size of the population continues to increase everywhere in the world. For example, the population was 1.6 billion people at the beginning of the twentieth century and grew to 6.1 billion at the beginning of the twenty-first century [2]. Presently, the population of the world is approximately 7 billion. The number of elderly people has also increased. In year 2000, 125 million Americans were suffering from one or more chronic conditions. This number is expected to increase by more than one percent each year until 2030. Between 2000 and 2030, the number of Americans with chronic conditions will increase by 46 million people [6] as shown in Figure 1.1 In the United States, approximately 20% of its population will be over 65 years old by 2030 [3] as shown in Figure 1.1 The increase in the population size will be accompanied by an increase in chronic conditions among elderly people such as diabetes, cancer, heart failure, and congestive heart failure [4].

Certainly, the elderly who face chronic diseases need continuous and effective monitoring to care for their health. One of the main problems that elderly

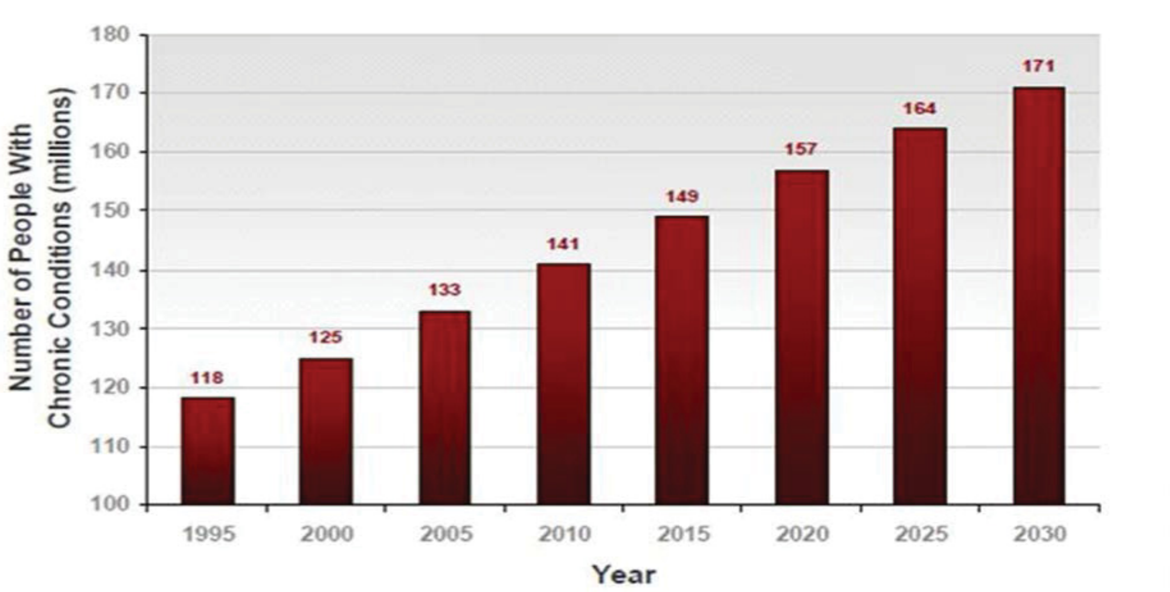

Figure1.1: The Projection of Incidence of Chronic Conditions in the United States [7]

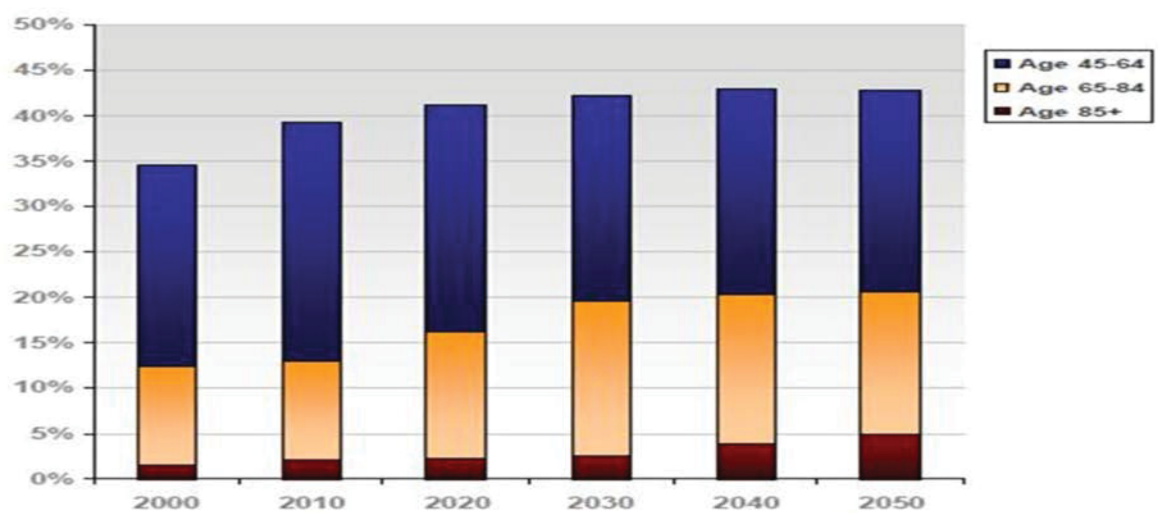

Figure 1.2: The Projection of Population Stratification by Age in U.S from Year 2000 to 2050 [8]

people face is the lack of doctors and nurses. There is a need for a new augmented health care system [5] because patients with multiple chronic diseases need to see 5 or more doctors and use more than 50 prescriptions a year. People with chronic conditions, especially those with several chronic conditions, are the greatest users of medical services. More access to all types of services is expected to be required: hospitalizations, office visits, home health care services, and prescription services. For example, people with several frequent conditions account for two-thirds of all prescriptions filled. The more chronic conditions an individual has, the more he or she utilizes these services [6].

In order to strike a balance between supply and demand of medical services, it will be necessary to make changes in health care technologies, particularly to new technologies that help in monitoring chronic patients and that facilitate the many medical tasks that will ensure the provision of appropriate health care for chronic patients [3].

1.2 Long-Term Care:

Long-term care services involve a wide scope of services that satisfy the needs of frail older people and other seniors whose abilities for self-care are restricted due to chronic sickness, injuries, physical, cognitive, mental disability, or other health related conditions. Long-term care services involve help with activities of daily living (ADL).

For example, the tactical activities of dressing, bathing, toileting, medication management, housework and general quality of life maintenance tasks. Long-term care services help older people in preserving or developing acceptance levels of physical activity and thus quality of life, and can include help from other people and special tools and assistive devices. Individuals may obtain long-term care services in an assortment of settings: in the home from a home health agency or from family and friends, in the community from a senior day services center, in residential settings from assisted living societies, or institutionally from nursing homes. Long-term care services from regulated providers are a considerable part of personal health care spending in the United States [9].

1.3 Rural Health Care

Any shortage of health care specialists can block access to health care administration and be an obstruction to widespread coverage. Such shortages in combination with unequal distribution of health care create a significant emotional effect. The misdistribution of health laborers between urban and rural or remote regions is a worry in practically all nations. In Senegal, for instance, the Dakar area, which is for the most part urban, has more than 60% of the nation's doctors though just 23% of the aggregate population. In Canada, 99.8% of the territory is rural with 24% of the population living in this area. However, only 9.3% of the doctors were located in rural areas in 2006 [10].

About 50% of the world's populace exists in rural and remote zones, yet this half is served by 25% of the world's specialists and by less than one third of the world's medical personnel. Approximately 20% of chronic patients in the US are located in rural areas. However, 9% of medical workers are in rural areas [11]. Lack of access to health specialists in rural and remote zones regularly leads to generally high death rates in such regions. It additionally leads to rural occupants looking for treatment and services at urban health offices and hence to congestion and expanded expenses at urban health facilities. The generally larger amounts of staff in urban zones and offices may prompt the underutilization of the talented health care workforce, who might then consider emigration [10].

1.4 Remote Monitoring System (Telehealth)

A Remote Monitoring System (RMS) or Telehealth system is a significant alternative for traditional styles of health care for treating chronic disease such as coronary disease, diabetes, or asthma. Any health care systems can be affected by factors such as sudden increases in cases attributed to chronic diseases and increased lengths of stay in care facilities. Therefore, it is necessary to strike a balance between medical services and the need for them [149]. A telehealth (RMS) strategy, also called self-observing-testing, empowers medical experts to observe a patient remotely utilizing different innovative devices. These services can give practically identical health care to conventional individual patient encounters, supply more contentment to patients, and may do so cost-effectively. In an RMS, sensors are utilized to capture and transmit biometric information. For instance, heart rate and temperature data can be transmitted to a specialist. This might be possible either in real time or the information could be saved and sent afterwards [12]. Telehealth can be used to provide a range of medical services depending on information captured from patients as from “video-visit” calls permitting users to see and hear each other benefiting both clients and nurses [149].

Examples of remote monitoring include:

- Home-based nocturnal dialysis
- Cardiac and multi-parameter monitoring of remote ICUs
- Home tele-health
- Disease management

Thus, a long-term, remote, and safe patient monitoring system (telehealth) can assist to constantly observe vital parameters of a patient such as heart rate, temperature etc., with the assistance of a sensor-based system which monitors these vital parameters and alerts an appropriate health care professional in the case of some abnormality in these vital parameters [12].

1.5 Wearable Technology

The connection between computers and daily items increases the use of information technology (IT) as advances provide access to things that were originally designed for other objectives: cars, buildings, appliances, and, increasingly, things we wear. For the purposes of this discussion, an internet connected smart watch or a pair of running shoes with sensors in them are “wearable technology,” while a cell phone or a tablet is essentially "portable" technology. Wearables might be networked or may store information that could be exchanged later to different devices. In many situations, the technology need not to be enacted; it essentially works as a feature of the thing. Wearables can input information from the body of the wearer or from the environment or output information, or both. Wearable technology could, for instance, find a lost child, deal with the wearer's telephone messages, provide therapeutic advice or provide a health care provider with a client's location [13].

One example of wearable technology is Google Glass®, an intricate, multifunction device. However, most wearable devices concentrate on a narrower scope of goals with a restricted set of specifications. These tasks may be as plain as informing the wearer of messages received via phone or social networking, or they may perform complex administrations, for example, a device for diabetics that monitors glucose levels and administers insulin as required. Some wristbands track fitness information, for example, steps taken, calories burned, and sleep patterns and send that information to the wearer's cell phone. In some cases heart rate sensors are woven into tank tops or tees and can be imported to exercise equipment. These devices offer a kind of computer supported mindfulness for the wearer, becoming a “measured self” who can utilize data from sensor based systems to optimize fitness or mental performance [13].

1.6 Benefit of Textiles

Artificial Intelligence has been recently embedded in several objects such as watches, necklaces, and bracelets. However smart textiles, as new potential components of smart devices or system show promise to allow several kinds of “flexible products.” Basic building units of the smart textile materials are fibers and filaments. Fibers are available in a wide range of materials, combined or single, natural or artificial, strong or flexible, solid or porous, biodegradable or biocompatible, and optical or electro-conductive. The fibers which form a smart textile have various lengths, fineness, cross-section, shape, surface coarseness, etc. Electronic garments show promise to combine these various properties in the development of multi-functional wearables [14].

Clothes can be considered as one’s own personal domain. Clothes which we wear daily can be made to measure. Also, users can get a perfect and comfortable fit. Clothes make contact with a large part of the human body. They make us comfortable and attractive. Textiles can be manufactured with efficient and productive machinery at an appropriate cost. These properties lead to various applications that were not possible before, especially in the monitoring and treatment of patients with chronic disease. It is very important to mention that intelligent electronics within clothes can be embedded at different level. It can happen either at the fiber level, a coating can be used, or different yarns can be added to the smart clothing. Also, the garment maker can connect independent devices within textiles to achieve the desired result. Ultimate success requires a full understanding of the applicable sensors and all the related components of textile materials [14].

1.7 Types of E-textile

The four types of E- textile with their various levels of complexity and integration of electronics are (1) embedded electronics (2) textronics (3) textrodes and (4) fibertronics, as is shown in Figure 1.3 and discussed below. [14].

1.7.1 Embedded electronics

Embedded electronics are “structure-in” materials that are constructed with the use of existing electronic parts in a textile. Instances are the ICD+ suit, created by Philips and Levi’s and the Lifeshirt from Vivo metrics. In the ICD+ suit, a mobile phone and an MP3 player are combined in a jacket.

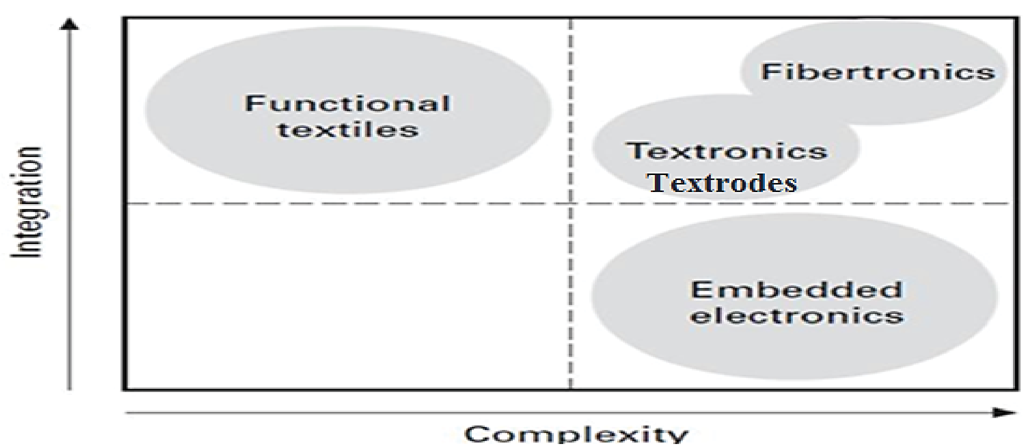

Figure 1.3: Combination Degree of Several Textile Electronics [14]

The degree of integration of the electronics of this suit is low, as an available mobile phone and an available MP3 player are used and the communication between the different parts (player, headphone) is made by standard electrical wiring. Moreover, the entire system can easily be disconnected from the suit, as the electronics and the interconnections cannot withstand a washing machine. The Lifeshirt is prepared for sports and health care purpose. Respiratory rate, ECG, blood pressure, position and movement can be observed by connection of existing portable sensors to a shirt. The information is saved on a PDA and is also sent via the shirt to a doctor for reading. As delineated by these instances, the most important aspect of the use of existing sensors in materials is the simplicity of joining the sensors and the garment. The drawbacks of these types of system are the lack of elasticity, lack of robustness, and the large size of the circuitry which may make the wearer uncomfortable. [14, 15, 16]

1.7.2 Textronics

"Textronics" refers to the production of electronic components by textile manufacturing techniques using textile materials. Examples are the developments at the University of Pisa where fabric based sensors are embedded in suits to achieve results in efforts to monitor rehabilitation, to perform ergonomic studies, to develop studies within virtual reality environments, and to perform ambulatory monitoring [17, 18]. Technologies used for the fabrication of sensors can be diverse. For example, to achieve electrodes for the measurement of ECG, or a sensor to measure blood glucose levels, or gauges for the measurement of posture and movement, or a sensor to detect respiration rate, many different strategies with a number of construction techniques can be employed. In one strategy polypyrrole is coated over lycra. In another strategy electrodes and strain gages are embedded in carbon filled rubber. The carbon-rubber mixture might be either specifically printed on the fabric or carbon filled rubber coated fibers can be woven. The most important advantage of textronics technology is the ease of the combination of the electronics in the clothes. The disadvantage is the restricted amount of elements that can be created by this method [14].

1.7.3 Textrodes

There has been a significant amount of research in the field of smart clothing for medical applications that mentions that textrodes which is similar to textronics. The measurement of physiological signals such as respiration rate, diabetes, heart rate, and ECG signals by different kinds of sensors integrated into smart garments has been studied by many research groups for several reasons. As an alternative to traditional gel electrodes, woven stainless steel electrodes, called ‘textrodes’, as shown in Figure 1.4 were created for the measurement of ECG .The benefit of the textrodes is their non-bothersome character versus the traditional gel electrodes, which may lead to skin irritations or sensitivity reactions, or both, in a shirt or a suit. The major obstacle of the textrodes is their inherent high skin–electrode resistance [14].

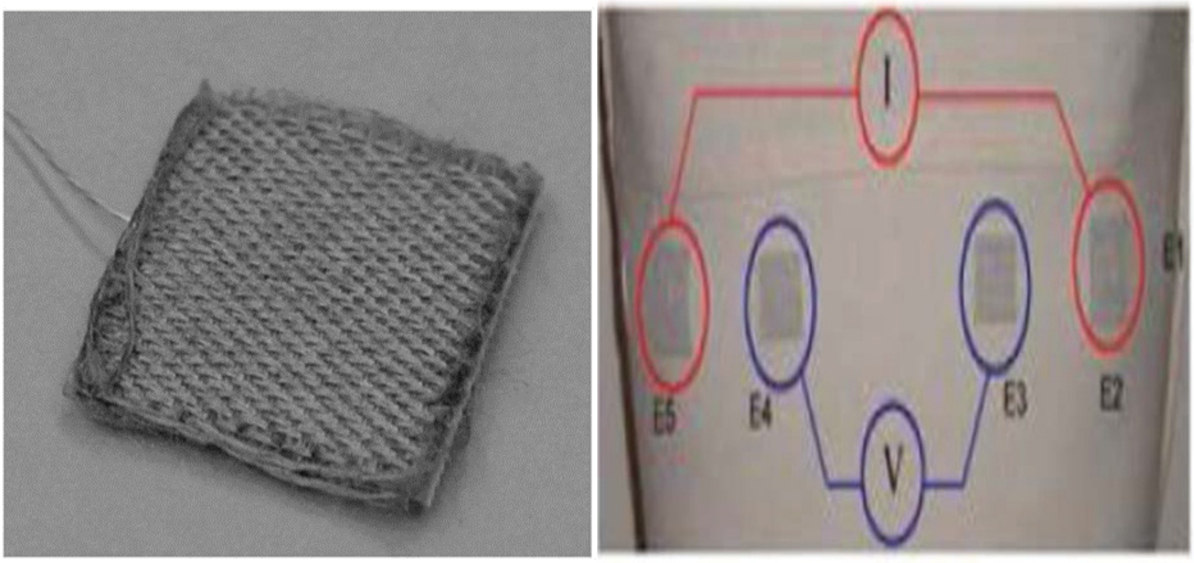

Figure 1.4: Knitted ECG Electrode [14]

1.7.4 Fibertronics (Future trends)

"Fibertronics" are referred to as the "building-in" materials constructed of electronic building blocks such as transistors, diodes and solar cells into yarns. Seamless combination of electronics into garments will be carried out only through fibertronics technology. Fibertronics technology has the potential of combining some particular elements such as sensors and antennas in a garment, but other more complicated electronic elements, such as microprocessors, cannot be fabricated in this style and must still be implanted in a garment [14].

1.8 Technological Benefits and Challenges

Textronics and textrodes, emerging technologies, create new opportunities, and with them new challenges. In Table 1.1 various properties that textile components can incorporate for sensing are listed with example functional structures that are commercially available. The term "sensors" ought to here be comprehended to refer to appliances or devices which change measured physical amounts into an electrical indicator [20].

Abbreviation	Smart Textile Sensing Models							
Property of E-Textile	Chemical	Optical	Mechanical	Electrical	Thermal	Magnetic	Acoustic	Nuclear
Functional Structure	Chameleon Fibers	Optical Fibers	Soft Switch	Conductive Fibers	Gonix	Lacking	Lacking	Lacking

Table1.1: Examples of Contemporary Fibrous Sensors' Structures [19]

Opportunities still exist to develop e-textiles with magnetic, acoustic and nuclear functional structures. Those that are known at present can perform in mechanical, electrical, chemical, optical and thermal modes. Among the known contemporary textile sensors, for example, are optical fiber sensors and conductive fibers which don't complete the entire scope of measurable properties. This gives rise to the continued need to utilize traditional devices, for example, thermistor components, in textronics or textrodes frameworks. At the same time, it drives the evolution of components that will operate in these elusive modes and convert their outputs to electronic signals. For example, certain sorts of optical waveguides, or conductive threads that require a particular physical structure. A need likewise emerges to evolve totally new devices which could, for example, react to changes in bio-potential due to the level of microorganisms of an infection [19].

All these existing or proposed sensors must have a fibrous structure and an electrical yield to be useful within the advancement of textronics. It appears polymer science has the most potential to respond to this challenge. Nonetheless, additional challenges arise, considering that proper flexibility, launder-ability, and resistance to cyclic mechanical stresses must be accomplished for the devices under discussion. [19].

The application of sinewy structures with shape memory has unique importance in the thermo- and hydro-controllability of textile products. The accessibility of a full range of fibrous sensors would permit the design, development and construction of fibrous automatic control systems which would allow dynamic monitoring and control of people and their health conditions in numerous uncommon circumstances and distinctive situations. The most troublesome issue facing the full implementation of textronics and textrodes is the electrical supply to the functional structures utilized. As of right now, conventional batteries and sensors are excessively vast and excessively substantial, and yet they most likely can't be utilized as a part of future textronics or textrodes applications [19].

1.9 Synthesis of Original Components

The most prominent disadvantage of textronics or textrodes technology is that only a few elements have been created and are available. For example, sensors, antennae, and wiring technology are available. While fibertronics promises to give garment producers the ability to add value to mass marketable products, embedded electronics makes it possible now to incorporate any available electronic elements into a special purpose garment material. The following are some of the many different methods to construct electronic structures into textiles [14].

- Weaving conductive yarns in weft and/or in warp direction, combined with a specific weaving pattern and specific weaving techniques (jacquard, loop weaving) for the realization of contacts [14].
- Knitting conductive yarns using either plain knitting, circular knitting, warp knitting or crocheting [14].
- During the textile finishing process, for example, coating or screen-printing. Recently, some first experiments of screen-printing with conductive inks were successfully carried out [14].
- During the textile production process, for example, by the embroidering of conductive thread onto the garment [14].

1.10 Conductive Fibers and Fibrous Materials

Sensors can be categorized into active and passive sensors. Passive sensors produce a change in some passive electrical quantity such as capacitance, resistance, or inductance and they require an external power source whereas active sensors have an ability to convert the input energy such as elastic or thermal into a significant change in voltage and they do not require an external power source. Passive sensors are constructed with the conductive fibers and other structures. Active sensors depend on piezo-electric effects. Electro-conductive fibers are used on a large scale for a variety of functions [14].

1.11 Concepts for Sensor Design

The essence of a sensor is that it converts one kind of input signal into a different kind of output signal. There are various materials and structures that have the capability of transforming signals. A thermal sensor, for instance, detects thermal change. Other instances are stimuli-responsive hydrogels that expand in reaction to a thermal variation or moisture sensors that measure relative moisture. Pressure sensors transform pressure to an electrical output and fatigue sensors convert strain into an electrical output. Chemical sensors are a system of sensors that detect the presence and concentration of chemicals. A biosensor is a sensing device that includes biological parts as the essential sensor. This element responds to a physiological measure, for example the sensing of blood glucose levels [21].

1.12 Overview of Available Types of Sensors

The sensor is a device that converts a physical variable of one form such as temperature, force, pressure, or displacement into a more convenient form such as an electrical output. The smart textile can include many physiological sensors depending upon the type of application. A wide set of physiological sensors may include the following [22, 23]:

- An ECG (electrocardiography) sensor for monitoring heart activity.
- An EMG (electromyography) sensor for monitoring muscle activity.
- PAS (Phenylboronic Acid Sensor) glucose monitoring sensor.
- An EEG (electroencephalography) sensor for monitoring brain electrical activity.
- A blood pressure sensor.
- A tilt sensor for monitoring trunk position.
- A breathing sensor for monitoring respiration.
- A movement sensor used to estimate the wearer's activity.
- A temperature sensor used to measure wearer's temperature.

Because of the new development in the manufacturing of electronics, the miniaturization of sensors and electrical circuit are available now and this has affected the development of the electronic garment. Two of the most prominent problems in sensing technology, particularly for wearable technology, has been the size of electrical circuits and sensors and that the hardware to collect physiological and movement data lack applications suitable to long-term monitoring systems. Currently there is development in microelectronics to enable manufacturers to minimize the size of circuitry and to increase capability in front-end amplification, microcontroller functions, and radio transmission [1].

1.13 Embroidered or Knitted Keyboards

A capacitive numerical keyboard, one of the first developments in the field of smart textiles, was acheived at MIT. It was created from silk brocaded with copper and incorporated in fabric, and was imagined as an interface for devices such as mobile phones or portable music players [94]. Figure 1.5 shows a knitted keyboard. As in several other examples mentioned here, conductive yarns created from stainless steel are used. By using the knitting technique, the resultant keyboard has a flexible structure, which can simply adjust to the body curves without a decrease in functionality. The main benefit of using this knitting technology for a keyboard is that the keyboard can be introduced in pieces of clothing during the knitting process; no additional production or creation step is needed [14].

1.14 Power Management

There are many ways to provide power to an electronic system incorporated in smart clothing. It is clear that using 220V or 110V is not suitable because in this situation the mobility of the wearer will be restricted.

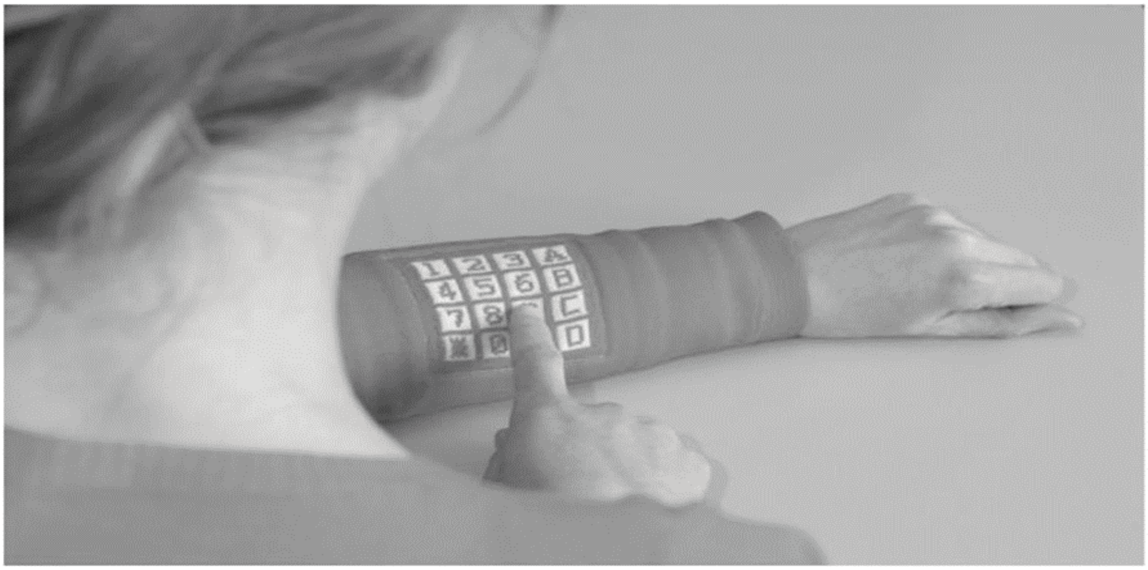

Figure 1.5: Knitted Textile Keyboard [14]

It is possible to use either non rechargeable batteries or rechargeable batteries. This method represents a straightforward method [14]. Moreover, power can be harvested between the wearer and the environment or it can be harvested from the movement of the wearer. The power harvesting adds an additional load on the source from which the energy is used. Power harvesting from the wearer's movement can lead to inhibiting the movement. Table 1.2 gives an overview of the different possibilities for the powering of electronics embedded in clothes [14].

Energy source	Available amount of energy	Remarks
Primary batteries (Li)	400 Wh/kg, 800 Wh/l	–
Secondary batteries (Li-Ion)	75 Wh/kg, 200 Wh/l	Lifetime: 2000 cycles
Si solar cells	20 W/m^2	Illumination or sunlight needed
Recovery of body heat	0.01 W/m^2	@ DT = 5 °C
Power harvesting from breathing	0.4 W	Uncomfortable for wearer
Power harvesting from walking	0.25 W	Continuous walking necessary
Microcombustion	10–50 W/cm^3	Fuel needed

Table 1.2: Possibilities for the Powering of Electronics Embedded in Clothes [14]

1.15 Lithium-ion Battery

Tak said in [14] "It is clear that during the last 15 years, battery power has not evolved in the same way as, e.g., disk capacity or CPU speed. Technological revolutions like the increase in CPU speed or disk capacity, however, result in an increase of the overall power consumption. New types of batteries such as Li-ion have an increased power capacity [14]. Lithium is an unstable metal, so Lithium-Ion batteries are made from ions of the Lithium element by using specific chemical processes. Because of their lightness and high energy density, Lithium-Ion batteries are ideal for portable devices, such as notebook computers. In addition, Lithium-Ion batteries have no memory effect and do not use poisonous metals, such as lead, mercury or cadmium. The only disadvantage to Lithium-Ion batteries is that they are currently more expensive than NiCd and NiMH battery packs [136].

1.16 Solar Cells

Using solar energy is the primary possibility for power harvesting. The solar radiation which provides photonic energy is converted into an electronic current. Currently, the consumer can get flexible solar cells from the marketplace. The largest amount of power output is currently 20 W/m^2. Currently, scientists have also developed organic semiconductors. This method permits fabrication of the polymer electronic product into an E-textile. These electronics have many good properties such as being lightweight, flexible, and low cost [14].

Moreover, one of the electronic products which has successfully been used is polymer solar cells. These kinds of power cells are a good candidate because they are lightweight, very flat and flexible. They can thus supply an independent electrical power source which can be incorporated into a garment to provide power to wearable electronics either directly or by rechargeable batteries [14].

1.17 Body Heat as an Energy Source

To recover heat of the body to power implant electronics is achieved by using thermopiles or thermocouples. Thermopiles or thermocouples have two basic elements which are two different conductive materials, generally metals, which compose a junction at one side. When the difference of temperature occurs between both metal layers and the junction, an electric voltage will be generate between the two sides of the materials which do not form a junction.

When the resistance is set between these two sides, a current will flow through into this resistance [14].

1.18 Power Harvesting from Natural Body Movement

It has become possible to convert the energy of movement into electric energy by using an electromechanical system or piezoelectric materials. Several parts of the body can provide energy by movement such as the thorax (respiration), arms, legs, and feet (walking). Since electromechanical systems use pistons and flywheels, it can have a higher efficiency up to (0.25 W). However, piezoelectric materials generated in flexible films are favored due to a more straightforward incorporation into smart garments and less inconvenience caused to the wearer [14].

1.19 Micro Fuel Cells

One of the most important types of cells used to provide energy to smart textiles are micro fuel cells since these cells have an ability to provide a higher power density. However, using these kinds of sources is still undergoing development since it lacks adequate sophistication to be used in powering smart clothes [14].

1.20 Embedded Airbag System

In developed countries the percentage of seniors over 65 years of age is increasing quickly. Current statistics reveal that in the United States 21,600 older adults died from falling in 2007 alone, and about 1.7 million older adults fall at least once a year around the world. Injuries occurring because of falls are the main problem for this population either in residential homes or hospitals, affecting the overall quality of life. As a result, seniors tend to live at home. Therefore, new technologies, such as automated fall detectors, are required to assist independence and safety [24]

Two major fall detection methods have been developed. The first method uses motion sensors, such as accelerometers and gyroscope sensors, and the other uses image processing with a camera placed in the room. The first technique is used to determine the direction and strength of a fall by using a particular algorithm. The second study placed a small digital video camera in the ceiling and classified falling patterns. The first method aims to develop a means to reduce or prevent injuries associated with falls. The first method measures the acceleration before and during falls, and then inflates an airbag. Thus, the first method has promise as a component of an e-garment. [25, 26, 27]. Figure 1.6 show the air bag device.

Figure1.6: Photograph of the Airbag System [25]

1.21 Bluetooth™

Bluetooth™ is one of several low-power short-range radio technology designed to make wireless connection to devices such as printers, keyboards, and mice. Its perceived potential has evolved into far more sophisticated usage models. Bluetooth™ devices can form a piconet (a network that is created using a wireless Bluetooth connection) of up to seven slaves and one master, enable access to web services and subsequent implementation of varied usage models including wireless headsets, Internet bridges, and wireless operations such as file exchange, data synchronization, and printing.

[28]. Bluetooth can be is used with microcontrollers as an interface to smart phones. Further, it can be integrated with smart textiles to transfer information from a user's body to another device such as a microcontroller or a smart phone.

1.21.1 Current Uses of Bluetooth™ [29]

- Mobile phones, including 'smart phones'
- Wireless controllers for video games
- Voice headsets and "Car kits"
- PCs
- M2M applications – credit card readers, industrial automation
- Stereo headsets and speakers

1.21.2 Energy Requirements of Bluetooth

Traditional Bluetooth is connection oriented. When a device is connected, a link is maintained, even if there is no data flowing. Sniff modes allow devices to sleep, reducing power consumption to give months of battery life. Peak transmit current is typically around 25mA [29].

1.22 Ambient Sensors

When objects are monitored in the home environment as shown in Figure 1.7, the sensors embedded in smart clothing are usually combined with ambient sensors. This combination provides great benefits in several areas of rehabilitation. For example, while monitoring seniors, interventions can be deployed to improve balance control and minimize falls by tracking movement and vital activities through the wearable sensors. Specially designed information analysis techniques would then be used to detect falls via analysis of motion and vital sign data [1].

Using ambient sensors in conjunction with embedded sensors can improve the precision of fall detection and more importantly, create the ability to detect a fall even at a time when the subject is not wearing a smart textile. When the patient is not wearing the smart clothing, the ambient sensors in a smart home still collect the vital signs and send them to a PC, phone, tablet, or laptop and then transmit this data to health service providers and send an emergency message in urgent situations. In addition to what was mention previously, ambient sensors facilitate the activities of daily life for patient by helping the patient with chronic disease in performing several household tasks. [30]. Figure 1.8 show some smart devices that help a patient in activity of daily life.

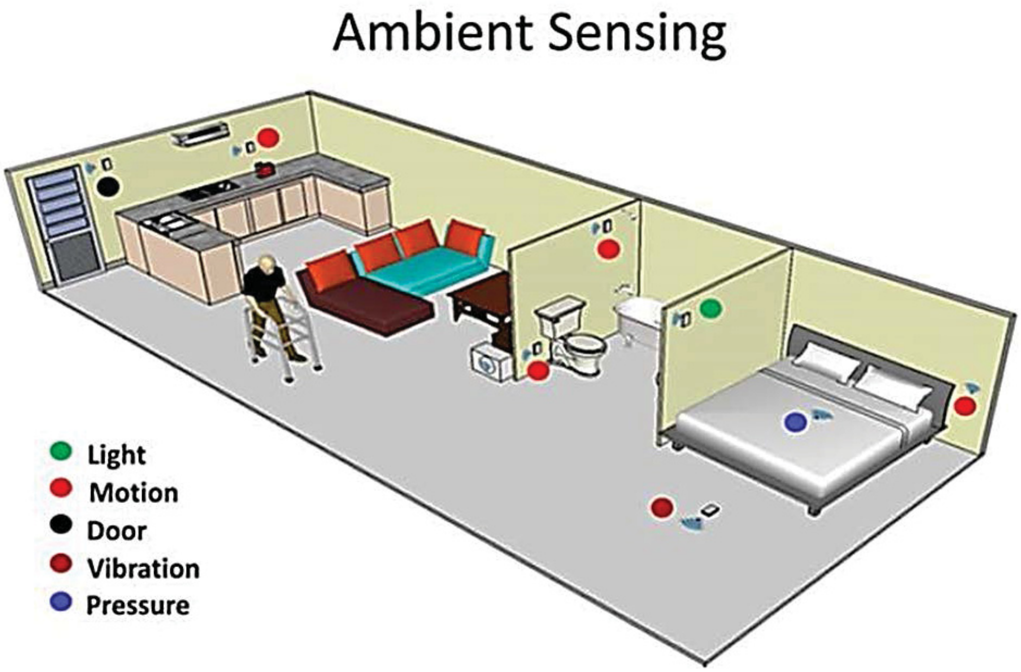

Figure 1.7: Ambient Sensors [1]

Figure 1.8: Smart Home Devices [30]

1.23 System Wiring

Textronic and textrodes textile technologies allow the electronic elements to be built on a macro level such as wired connections [14]. Figure 1.9 depicts the nature of copper wires embedded in smart textiles and isolated from other smart textile components.

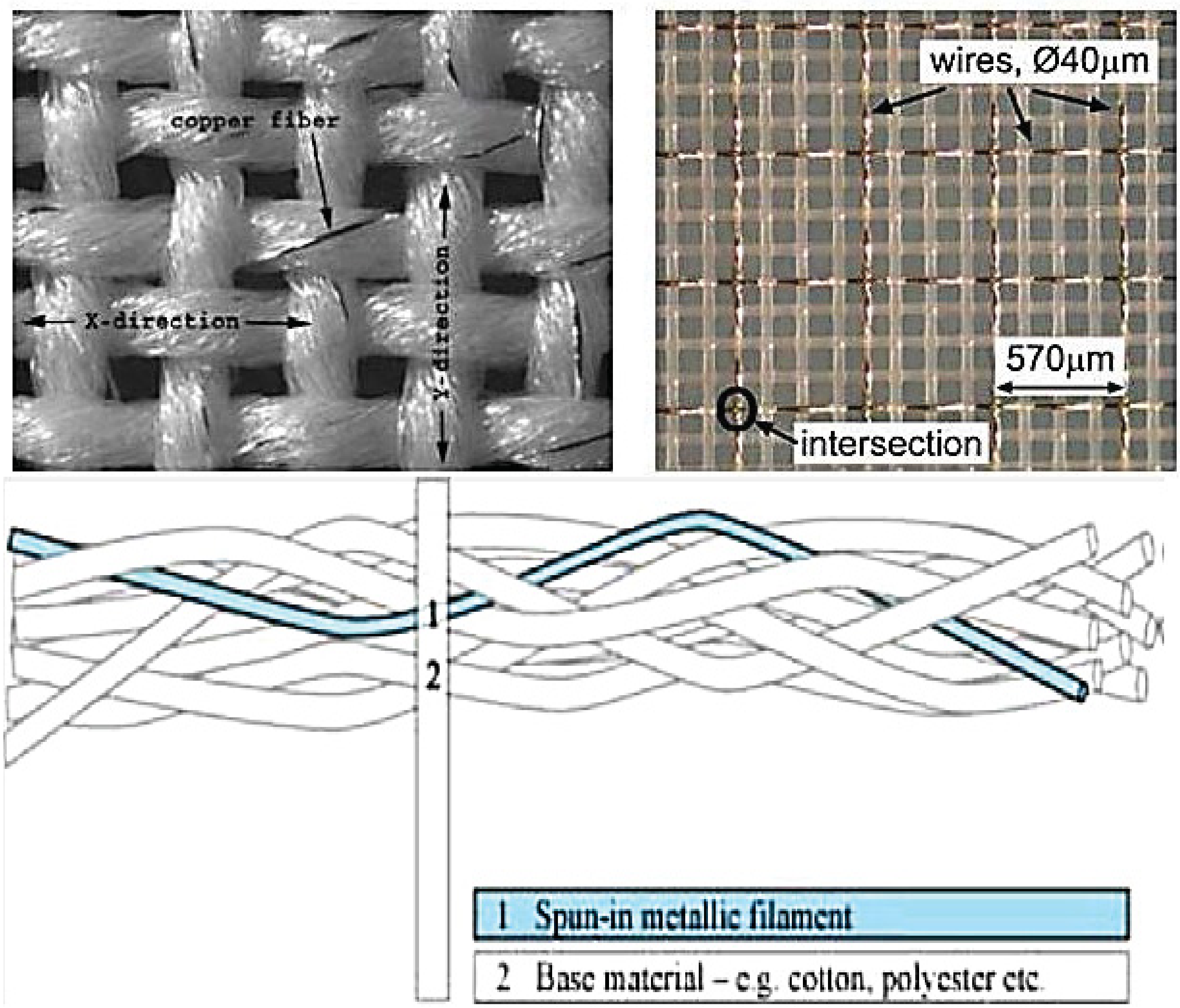

Figure 1.9: Standard Design of Copper Yarn Twisted with Polyester Fibers [111]

1.24 Integrating Wires and Plated Yarns into Fabrics of the System

The best approach is based on integrating wires and plated yarns into fabrics, but this approach has significant deficiencies related to the durability of the wires or conductive plating. For example, wires that are fine enough to significantly impair the textile's aesthetics are not durable enough to withstand elongation stresses normally encountered during textile manufacturing or use. The same is true for metal plated yarns, where the cladding develops stress cracks leading to failure when the yarns are strained. [109].

1.25 Microcontroller

This is the main circuit board of the system, also known as the mainboard. It is very similar to the motherboard of computers. A microcontroller, (see Figure 1.10) is a relatively small, low-cost computer-on-a-chip which usually involves an 8 to 32 bit microprocessor (CPU), a small amount of ram (RAM), programmable rom (ROM) and/or flash memory, parallel and/or serial I/O ports, timers and signal generators, an analog to digital converter (ADC) and a digital to analog converter (DAC) conversion. The microcontroller makes everything in a smart textile work together [100, 99].

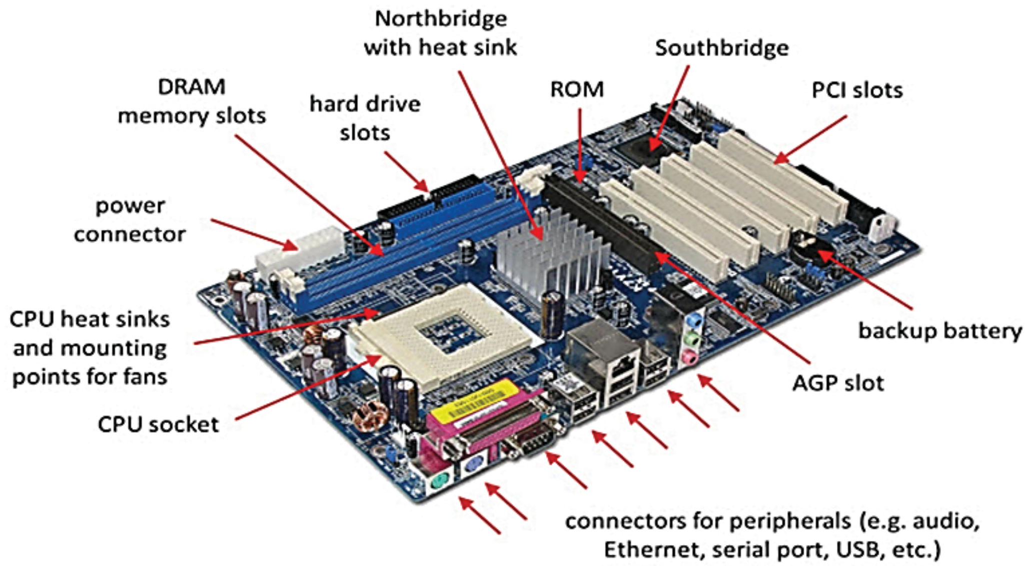

Figure 1.10: Microcontroller [100]

1.26 (4G) Android Smart Phone

The potential role of the 4G smart phone in wearable technology is to collect, save, and display information received from the smart textile by using specific applications combined with a web service. The smart phone and its applications enable patients to update the information and receive instructions from caregivers about taking medicine or any other feedback. Also, the smart phone could secure the connection between the patients and doctor anywhere in the world depending on new or existing available communication technologies. Many free and low cost applications are available in google play™. Android smart phones enable the patient to install several applications to help him or her to monitor different diseases [101].

1.27 Android Applications

1.27.1 Vitalbeat™ Application

• Definition of the Vitalbeat™ Application

Vitalbeat™ is a platform of mHealth which delivers healthcare services via mobile communication thus providing medical self-care to patients with chronic conditions or for real-time intervention to people going about their daily lives [103]. Vitalbeat™ is a straightforward integrated chronic illness management system for at-risk patients. It is a mobile application tailored to assist in maintaining a healthy body. Vitalbeat™ is currently available for clinicians to remotely monitor patients using smartphones, tablet, and computers. It provides an illness management program for improved care quality at a lower price. Patients, doctors and medical technicians' record, share and manage health information and users manage diet and medicine compliance by configuring alerts and reminders based on thresholds, goals and clinical necessities [102].

In addition, Vitalbeat™ is a simple, cost effective remote patient monitoring and integrated chronic disease management system for long-term conditions. The system connects patient application with a web-based doctor portal over a safe two-way web bridge. The smartphone, in turn, reminds patients to perform routine self-care tasks while it gathers information relating to patient complications and progress. Tow-way information transmission between portal and smartphone provides continuous correspondence between patient and practitioner [103]. Vitalbeat™ is an innovative supplier of remote patient observation and chronic disease management applications, as outlined in the Remote-HF clinical study highlighted at the 2011 mHealth Summit. This summit is organized annually by the National Institutes of Health in partnership with mHIMSS, the mHealth Alliance and the National Institutes of Health. Also, Aventyn is a reward winning health technology company delivering innovative, standards-based, mostly secure, core-to-cloud connected clinical science solutions [104].

• Role of Vitalbeat™ Application

Constant vigilance is required for monitoring and maintaining patients with chronic disease. Remarkably improved outcomes for chronic patients can be produced by guided self-care. Typical one-on-one strategies for delivering guided self-care face a variety of limitations [103].

The location of a selected practitioner is restricted to a range that is convenient for patients to travel. Patients with chronic sickness might find traveling any distance burdensome. Overseeing the personal care plans of multiple patients may be an overwhelming endeavor without the right tools. Vitalbeat™ seeks to remove these limitations by providing clinicians with a system to remotely deliver and efficiently monitor customized self-care plans to patients and by providing patients with reminders to follow those plans [103].

Vitalbeat™ Remote observance for Heart Failure (REMOTE-HF™) is an easy to use mobile observance tool for cardiac patients to remotely track vitals, manage diet and follow medicine guidelines at the patient’s location. The patient solution is personalized to support various cultural, ethnic, gender specific, and clinical conditions. It can be tailored thusly to assist in maintaining a healthy heart and reduce emergency room visits and hospitalizations. Wireless voice and information services have become an important part of the mobile health system for transferring information between patient and medical practitioner in a reliable manner. Vitalbeat™’s use of wireless service allows configuration of alerts for patient and medical consultation remotely. Using various mobile devices leads to lower cost health care across the U. S. The Vitalbeat ™ application provides goal oriented diet and medical compliance tools with secure, device encrypted report generation and trends analysis. The application works with Android 2.2 smartphone and Android 2.2 mini-tablet, among others [105].

• Use of Vitalbeat™ Application

A user can use Vitalbeat ™ after downloading it for free from Google play™ and registering in it. Since this application works on the Android platform, it is suitable for many smartphones, tablets and laptops such as Motorola, HTC, Samsung, LG, Sony Ericsson and many more. Between Google play™, Apple apps™, and Microsoft store™ there exists between 40000 to 60000 medical service applications. Vitalbeat™ is the best choice for several reasons.

- It is free and easy.

- It consists of services such as daily vitals and pain summaries for many diseases such as diabetes, asthma, COPD, and sleep disturbances.
- It receives information manually and by Bluetooth

The design of Vitalbeat™ includes smartphone app on one side, a doctor portal on the opposite side, and a two-way communication connecting the doctor and patients. The Vitalbeat™ architecture consists of the app on the smartphone, the portal application on the server and additional hardware and software that complete this implementation [102].

• Purpose of Smartphone Application.

The purpose of the smartphone application is to support patients' self-care tasks; to send compliance information to the doctor portal and to receive customized regimens and education from the doctor portal.[103].

1.27.2 Smart Help™ Application

This application may save a patient's life. This application can observe the phone's patient sensing elements in personal device to calculate the force generated by the phone, tablet, or pc. Through certain algorithms, the software can then verify automatically if you would like any assistance or not. As a result, the application can automatically send SMS along with your location (a patient may disable this setting) and can call the phone number that the patient has selected. It will place the call on loud speaker. The application recognizes if someone carrying the phone has an accident or another emergency situation (like falling down) and becomes unconscious with no one available for assistance [108].

This application will automatically sense if the user is running and the algorithm can adjust itself. If the user does not want to employ this automatic feature, he can disable it in the settings menu and simply use it manually. The user can click the chosen contact from the main screen and the application will automatically make the decision for you. If the user chooses “Auto Distress SMS” in settings, the application will send your location through SMS with a single click. It has a straightforward and clean user platform and is designed to be low maintenance on your electronic equipment and battery. Press and hold “Text” in Emergency Contact / Settings Menu for assistance. It should show a warning message for a fall detection. By hitting “I’m fine” it is possible to cancel the Auto update settings. The application will use GPS/Wireless Network/Internet to determine user location and to collect anonymous application settings and usage [108].

• Home Screen of Smart Help™ Application

The Main / Home Screen is the one that appears when you open the app [145].

- This screen is built to keep it clean and easy to access in case of emergency

- Keep the icon for this app in home screen and in case of emergency it can be opened to access to all emergency needs
- With one touch a call can be placed and the patient's location can be sent to a contact.
- Medical Notes will show health and medication detail.

• Menu of Smart Help™ Application

From the main screen, the user must click on the arrow on the top right to get to the menu. A user must Click on the arrow on the top right to get back [145].

- Emergency Contacts

  Select / assign the emergency contact using this option & selected contact will appear on the home screen.
- Medical Notes

  Here a patient's health and medication details can be specified for medical professional in case of a medical emergency.
- Settings

  Settings are the option to control the app's functionality.

1.28 Statement of Problem

This research proposes a framework for design and development of a long-term, safe, and remote patient monitoring system (telehealth) that combines smart textiles, ambient sensors in smart homes, and a smart phone with it's a prototype of Android applications together in one system. This system monitors and captures vital signs of a patient such as temperature, respiratory rate, blood sugar level, and blood pressure. When chronic diseases produce episodes such as seizures, hypertension, dysthymias and asthma, this system can facilitate diagnosis and provide information for ensuring treatment. [1, 31, 32, 33, 34, 35, 36]. Moreover, research suggests air-bag technology that can prevent injury due to falls.

1.29 Purpose of Research

From what has been said thus far, it is necessary to ask some essential questions [1].

- Is it possible to augment care for the overwhelming number of patients with chronic health problems?
- Is it possible to arrange good care for people who live in remote, rural areas?
- Is it possible to increase independence and participation for the mounting number of people with chronic health problems?

The answer to these questions may lie in the benefits found in new technologies, particularly the development of a Remote Patients Monitoring System as a component of a telehealth system for long-term care

The design of a long-term, remote, and safe patient monitoring system (telehealth) is one of the most important systems which has present solutions for many problems. For example, it is asserted that the healthcare system has long suffered from some issues, such as results of examining patients being written obscurely on paper, specialists not having the capacity to effectively access patient data, and also limits on time, space, and means for observing patients [37, 38, 39]. Also, it is expected to considerably improve the quality of healthcare while minimizing the costs, particularly for patients with inveterate disease, such as neurological, metabolic, and cardiovascular disorders which need steady long-term remote and safe monitoring, and patients discharged after an operation or intensive therapeutic regimen. It removes the obstructions to medical treatment. Pivotal data about a patient who lives far away from medical support can be obtained by the medical staff. More importantly it saves lives in critical care and emergency situations by alerting medical staff if there is a dangerous change in patient status [40, 36, 41].

Remote monitoring systems could solve all these problems. In addition, this system includes a safety monitoring capability which would detect falls and send alarm messages to medical professional or an emergency response team by using an Emergency Assistance application [108,145]. A safety monitoring system which is an air-bag system would use accelerometer and gyroscope sensors imbedded in smart textiles as a surrogate measure of a patient's posture to distinguish a real fall event from natural activities of patient life [42].

Simultaneously, after the Emergency Assistance application [108,145] receives the signals from accelerometer and gyroscope sensors, it would send an emergency signal to a hospital server. In addition to the use of an air bag to protect a patient when a fall happens [43], early detection of decline of patients can improve recovery and reduce mortality rates [44, 45, 46]. The system would provide mobile healthcare in that it allows a patient, or user, to be away from a hospital setting. They can be in another building, city, state, or even country.

Comfort is offered to the patient since they do not need to visit doctors, which involves traveling and waiting for a period of time. Return visits to get results are not required. Also, one of the most important principles supported by the system is making patient care about feeling healthy under the care of a health professional.

1.30 Methods of Research

This work aims to identify the necessary elements of a framework for achieving a long-term, safe, and remote monitoring system (telehealth) as shown in Figure 1.11 This research includes the study of all hardware components of the system. First, a smart textile (Figure 1.12) with its wireless woven or knitted sensors is proposed.

Assuming the viability of a smart textile with its wireless woven sensors collecting physiological and movement data from a patient's body such as electrocardiography data (ECG) and electromyography data (EMG), it is then proposed to send these kinds of information to a smart phone wirelessly by using Bluetooth technology [50].

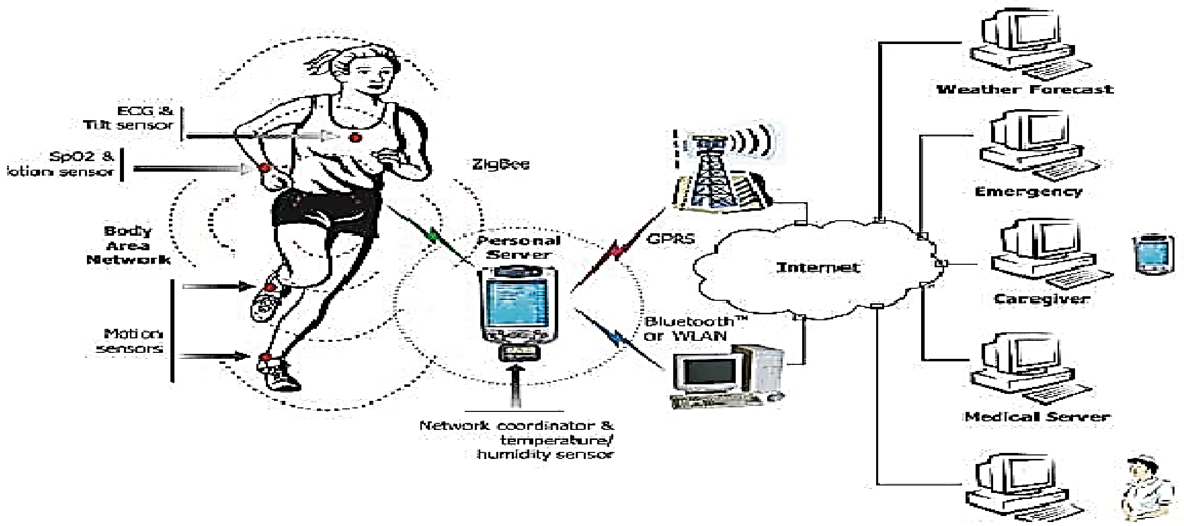

Figure 1.11: Long-Term, Safe, and Remote Monitoring System [47]

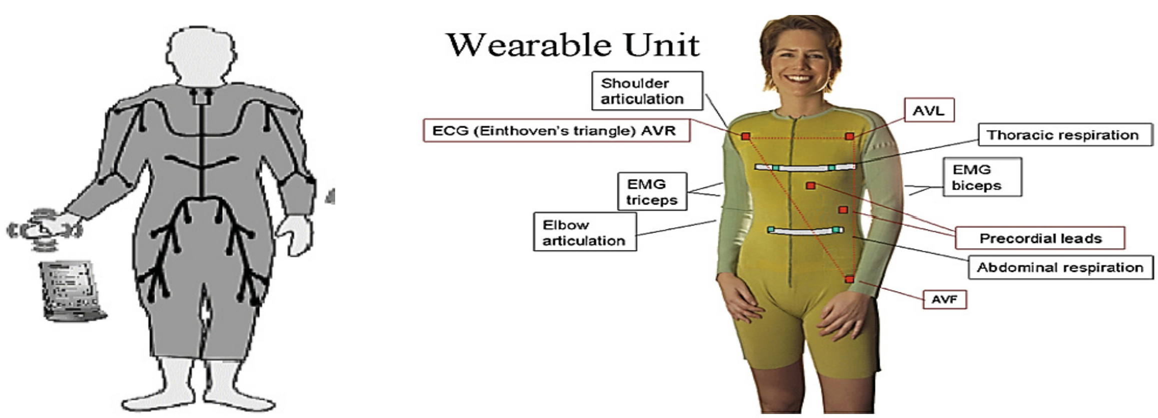

Figure 1.12: Example of E-textile System for Long-Term, Safe, Monitoring of Physiological and Movement Data [48, 49]

Then it is proposed that the textile sensors are integrated with ambient sensors in a “smart home” to accomplish the monitoring of patients at home to avoid the falls and support independence and community participation. Thus, to monitor patients in the home, ambient sensors can connect wirelessly with personal computers, tablets or smart phones of the patient.

A critical component of this system design effort is to interface with that of Android® based phones applications. The Android® based phones applications work as personal servers and connect wirelessly with processer in the hardware case. Phone applications transmit collected data to medical servers in remote service centers such as the hospital server to analyze these information sets and make decisions. Since the smart phones and its applications continue to evolve, the capability of the phone to store information most likely will increase.

In addition, smart phones are now available in most of the countries and the global smart phone market expands annually at a considerable rate. For example, there were more 400 million units shipped in 2013 [51]. Smart phones are preferable to traditional data recorders because they provide a practical, ready to use platform to log data as well as to transfer data to remote site. Moreover, it is proposed to use air bag technology to lessen injury due to fall of patients [43].

1.31 Expected results of Research

The aim of this research is to integrate wearable and communication technologies to demonstrate a framework for the development and implementation of a remote and safe monitoring system for long-term monitoring. Also, the aim is to achieve the specifications and design parameters and solve all the problems related to the system, such as the problem of energy. Therefore, the goals of remote monitoring of individuals in the home and community setting can be accomplished through linking together all components of the system's hardware and software effectively. It is also hoped to reduce mortality by preserving the lives of chronic patients by informing health centers or patients' families about the situation of patients so that action can be taken [1]. Also, the proposed framework for evaluating a long-term, remote, and safe patient monitoring system provides a platform for system collaborators to introduce, compare and select design features and promote a common interpretation of the design process itself.

1.32 Thesis Structure

This first chapter is an introductory chapter explaining the research motivation, the contribution of this thesis, scope of the work, and structure. Chapter 2 is a literature review demonstrating the historical background through relevant works. Previous relevant work and existing technology are discussed together. The literature review was conducted with the intent of demonstrating that remote monitoring and several other areas of research provide opportunities for the design methodology that follows in Chapter 3. The framework for analyzing and selecting features results in a prototype system of both hardware and software aspects. Chapter 3 provides the nature of system elements, specifications and features, for example, delineation of electronic textiles, smart phones, smart home sensors, and air-bag technology. In Chapter 4, the integration of disparate application features will be discussed and framed for system implementation. The framework for evaluating both the variables and the usefulness of the resulting design is possible. Thus, a hybrid framework of simulating the design and subjecting it to a usability study will be demonstrated. Chapter 5 provides conclusions, results and future work. Based upon a review of the proposed design, future directions for exploring remote monitoring with wearable technology follows naturally.

Chapter 2

2.0 Literature Review

2.1 Introduction

The expression ‘smart textiles’ is derived from smart materials. The term “smart material” was coined in Japan in 1989 [14]. Currently, garment producers and researcher are working on several new major projects to provide highly distinguished textiles for twenty-first century customers. One of the effective efforts in this field is the evolution of E-textiles or smart textile by integrating the textile with electronics [14]. E-textiles are fabrics that enable computing, sensing, digital components to be embedded in them. An electronic textile allows for garment structures that combine abilities for sensing (physiological and movement data), telecommunication (usually wireless), power transference, and interconnection technology to allow sensors or things such as data processing devices to be networked together within a fabric [14].

Smart textiles with woven or knitted wireless sensors, and some integrated with smartphone technology, have opened new opportunities in health monitoring systems. The incorporation of the present specialized medical technologies with smart phones and wireless sensors is a very hopeful application in safety, remote monitoring, emergency care and disaster response. Previously, remote monitoring systems used multiple biomedical sensors embedded into smart textiles. In early attempts, the network of embedded sensors used wires to connect each other. For example, the MIThril project was launched as a primitive trial of remote monitoring but the system suffered from many problems like lack of elasticity, lack of robustness, and excessive weight. Since the end of the 1990s, MIThril moved towards a workable, modular system of hardware and software for research in wearable sensing and context-aware interaction [52,53].

Numerous researchers tried to develop wearable systems. Dr. Sandy Pentland at Massachusetts Institute of Technology developed MIThril [54, 55, 56, 57], a system that combines hardware and software platforms as shown in Figure 2.1. The hardware consists of body worn sensors which are connected by wires in pockets in the garment. The software is an integration of user attended components and machine-learning tools that run on the Linux operating system. However, the MIThril system, like others, was not able to provide for continuous monitoring because of previous technological barriers. Therefore, the need and motivation to develop missing systems elements was an important product of these early systems. Recently, availability of very small electronic wireless sensors was provided the ability to propose and build remote monitoring systems with a variety of features to address former shortcomings.

Recently many systems which are similar to our proposed system were developed to monitor the health of patients and they can be summarized in five fields [48].

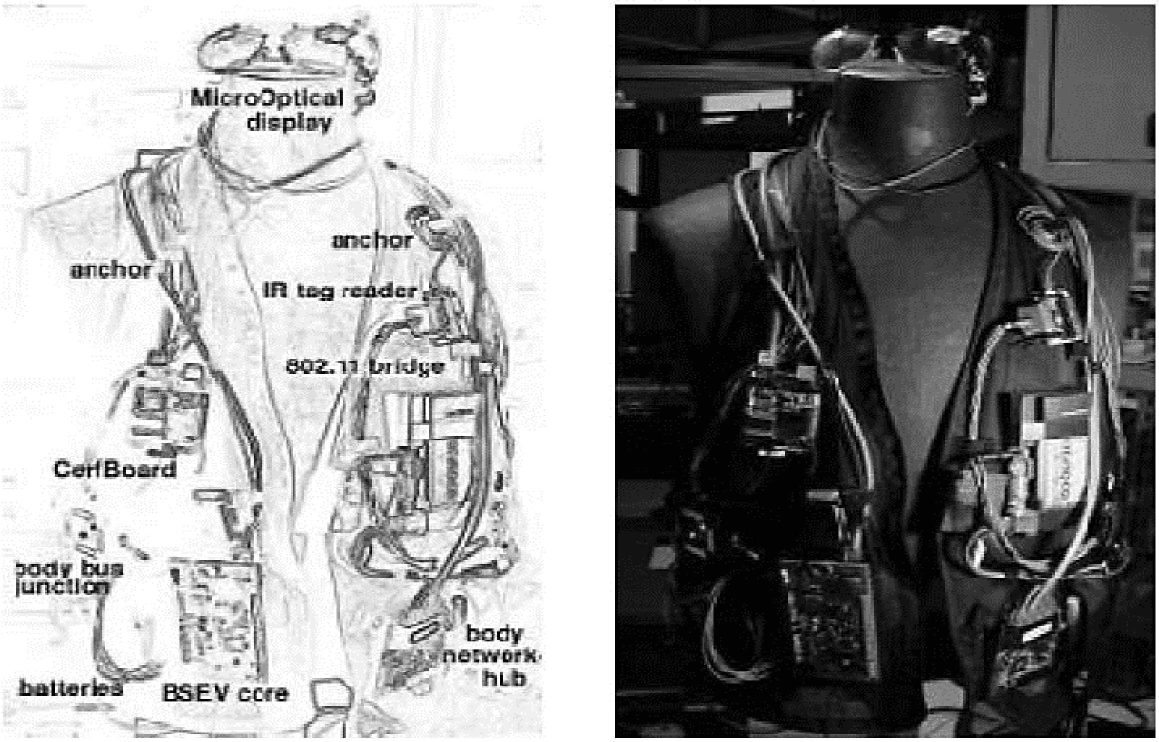

Figure 2.1: The MIThril System [48]

2.2 Long-Term Health monitoring:

As the number of elderly people and cost of health care are increasing, several countries are supporting the elderly with chronic conditions by aging-in-place programs which allows the individual with chronic conditions to remain in the home and community environment while they are remotely monitored in order to ensure their safety and to facilitate the application of clinical intervention. Monitoring the daily activity of those participating in aging-in-place has become a high priority. Accordingly, extensive research efforts have been made to assess the accuracy of wearable sensors in classifying activities of daily living. Several systems developed previously in this field are described.

2.2.1 Life Shirt System

The LifeShirt (Figure 2.2) system by VivoMetrics [58] is a comfortable, washable “shirt” that contains several established sensors that provide real-time monitoring of electrocardiography (ECG), respiration rate, blood pressure, and posture. Information from the sensors is registered in a tiny belt-worn register where it is encoded and sent to VivoMetrics Data Center by cellular telecommunication [59].

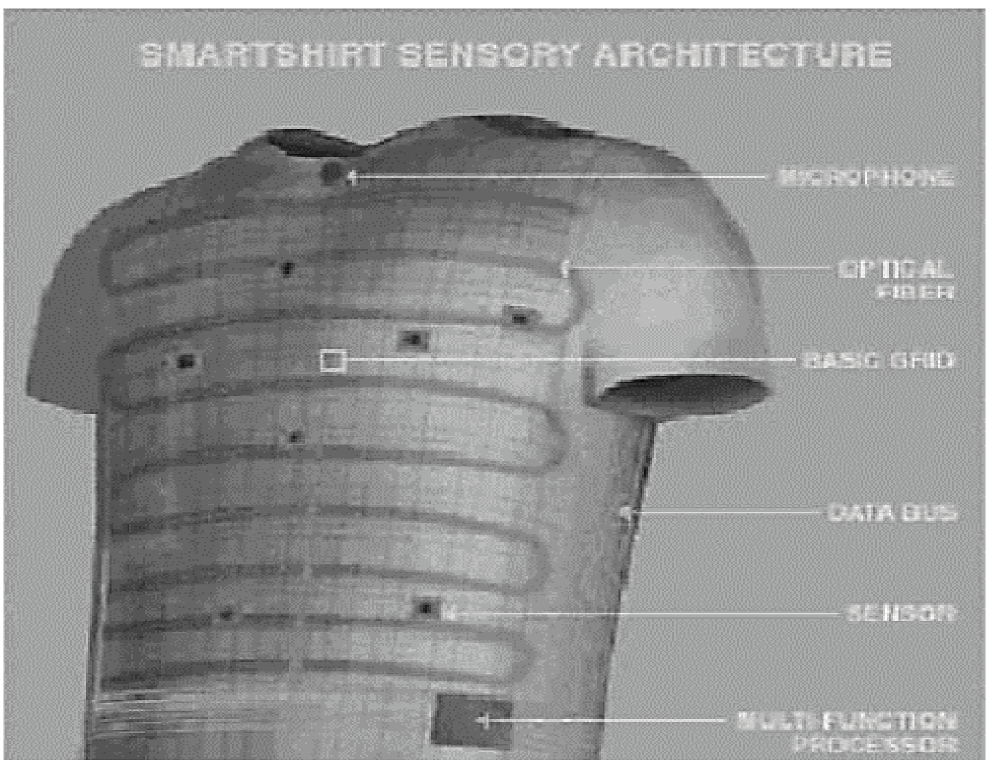

Figure 2.2: The Life Shirt [48]

2.2.2 DeRossi and Asada

An example of a textile designed to observe physiological signs are that evolved by Dr. Danilo De Rossi group at University of Pisa [60, 61] and Dr. Harry Asada at Massachusetts Institute of Technology [62, 63]. Their textile serves the need for observing patients' motion but as with all textile-based solutions, they require patients to wear a particular textile material. Whereas this innovation is practical for short-term observing, the use of miniature wireless sensors embedded in a traditional textile is more practical for long-term observation and progressive monitoring. [32].

2.2.3 LiveNet System

A flexible distributed mobile platform system that deployed for a variety of proactive healthcare applications. It is evolved in the MIT Media Laboratory, it can monitor 3-axis whole body acceleration, ECG, EMG, and galvanic skin behavior. This system was designed to observe Parkinsonian symptom and detect epileptic seizures [1, 64].

2.2.4 Amon System

An advanced care and alert portable tele-medical monitor (AMON) system. Figure 2.3 is a wearable monitoring and warning system for high-risk cardiac/respiratory patients. The system consists of real-time monitoring and appraisal of various vital signs, performs a multi-parameter assessment, and transmits patient status via connection to a medical center to obtain therapeutic recommendations.

The AMON system combines all sensors, processing devices and telecommunication in a single, comfortable and ergonomic wrist-worn device. Continuous long-term monitoring can be performed without interfering with the patients' everyday activities and without interfering with their movement [65].

Figure 2.3: AMON Device [66].

2.2.5 Activities of Daily Living (ADL)

This system monitors and analyzes activities of daily living by utilizing accelerometer to recognize the performance of activities of seniors in their home and community [67]. The accelerometer unit, a push button and a wireless transmitter were contained in a small plastic case.

2.2.6 Other Basic Activity Systems

Systems that monitor shoe pressure and acceleration are utilized to analyze and evaluate activities such as sitting, walking, and upper and lower arm movement [68].

2.3 Safety monitoring

Among the significant concerns in the care of elderly people is the early detection of a fall. An undetected fall can frequently turn into an issue of life or death for individuals living alone, particularly the elderly. It has been accounted that in the US, among individuals 65 years old and above, one in every three encounters a fall, annually. Every year there are instances of 300,000 hip fractures due to falls. All the more alarmingly, one in every five individuals with hip fracture dies within a year of the incident. In the majority of these cases, complications were the result of the inability to call immediate assistance to the fall victim's side. Several systems developed previously in this field include [1].

2.3.1 My Halo Clip

Worn as a chest strip, (see Figure 2.4), it was developed to correctly recognize a senior's fall and immediately transmit an alarm message to a family member or to emergency medical services. The My Halo system fall identification framework is extraordinary in that it is not focused around tilt-sensors of any sort. The framework utilizes accelerometer information and a robust motion analysis algorithm that permits My Halo to identify falls in circumstances not formerly conceivable [69].

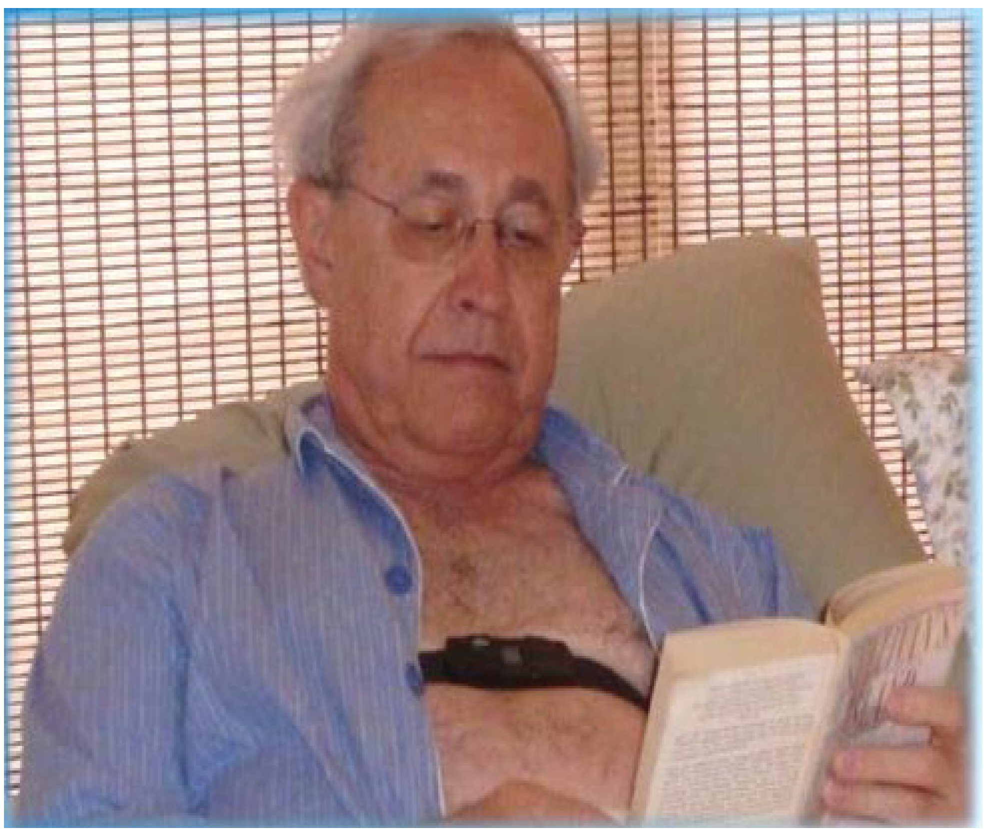

Figure 2.4: My Halo Clip [128].

2.3.2 Lying Pose Recognition for Elderly Fall Detection System

Fall recognition systems depending on embedded sensors [70, 71, 72, 73] or with fixed cameras [74, 75] have been connected to smart house systems. However, they are not precise in recognition nor provide any safeguard against an incident occurring. Smart robots, usually perceived to be equipped with a camera (see Figure 2.5). This system can ameliorate these issues due to the relative flexibility that they can offer in terms of positioning and interaction. In addition, they are more acceptable to the user, since the humanoid features integrated in robots permit a more naturally pleasing interaction with humans.

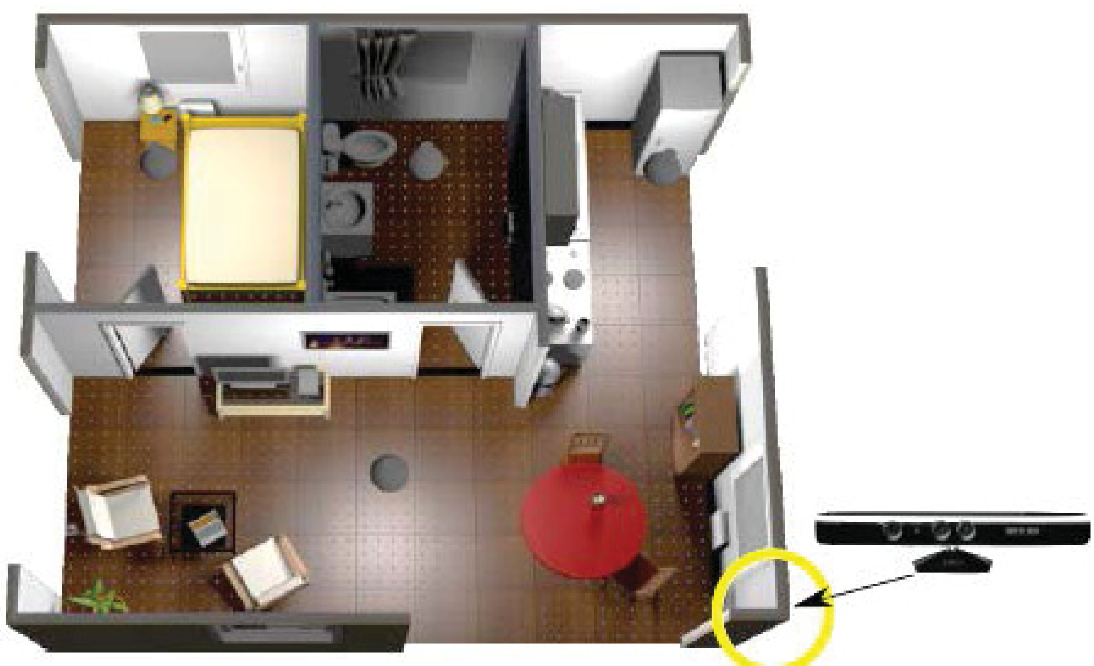

Figure 2.5: Lying Pose Recognition [110]

This system was developed to monitor and specify the orientation of the patient. The system has the ability to differentiate a fall from normal motion of the patient. Also, this system sends an alert massage to the caregiver center or nurse call station [76].

2.3.3 BrickHouse system

When a fall is recognized, the system can send an alert signal to the call system. It is very beneficial for monitoring the elderly. Regrettably, the present solutions for fall detection only detects falls in limited environments, for example at home. Such systems are too costly because they use specialized devices such as a sensing pendant. To eliminate this issue, mobile phone based solutions for fall detection can be used [77, 78].

2.3.4 A Fall Detection System by Wearable Vest

This vest uses 3-axis whole body acceleration data to determine the disposition of the patient and send an emergency message to a nearby caregiver center [79].

2.3.5 A Detection of Fall and Specification of Position of Patient System

This system relies on using the built-in accelerometers of some smart phones, using the GPS system now in smart phones, and using Google® map over the internet. Specifically, it is based on the Android brand system. When it detects the fall of the patient, it knows the location of the incident and can send an alert message to a family member or to a nearby health center [80, 81,82].

2.4 Home rehabilitation

A new area of wearable technology is the use of wearable sensors together with virtual reality (VR) software to be used in home-based rehabilitation. These systems attempt to combine rehabilitation exercise programs within an entertaining environment. For instance, the Rehabilitation Engineering Research Center at the University of Southern California is applying “virtual reality environment gaming” to improve patient acceptance and compliance with prescribed exercise regimens. Using a special interface device with VR simulation technology, the development of improved motor skills is proposed, specifically in the functional areas of reaching, hand function and walking [1].

Beyond the laboratory, there is hope to deliver VR-based rehabilitation in the home. This would be achieved through a tele-rehabilitation approach. The benefits sought would include decreased time and a continued preventive exercise program. When this situation is put into an interactive game-based context, the exercise regimen is more likely to be of lengths that can have an impact on motor function. Home-based systems need to be affordable and easy to deploy and maintain as well as facilitating the commitment required to produce improvements that translate to success in real world activities [1].

2.4.1 Valoedo Motion System

This is a therapeutic back ache remedy system. The system moves the patient through functional, recreational and strength building exercises for an improved remedy result. The Valoedo Motion System (Figure 2.6) promotes compliance, motivation and motion consciousness as it guides exercise for low back pain remediation. It promotes the patient's compliance and motivation through real time feedback and aids the attending physician by offering a status of the patient's trunk movement quality. It translates body motion detected by two wireless sensors into an interesting game-like environment and guides the patient through exercises specifically designed for low back ache remedy. To facilitate both challenging and efficient training, the exercises can be adjusted according to the patient's specific needs [83].

Figure 2.6: Valoedo System [84]

2.4.2 Stroke Rehabilitation Exerciser

The most common paralyses resulting from stroke involve hemiparesis and hemiplegia, which wrench the face, soften or paralyze a limb or an entire side of the body, making it difficult to walk or understanding objects. Although tissue harm in the brain as a result of a stroke is irreversible, survivors can optimize quality of life by relearning skills and learning to compensate for their weakness [85].

Moreover, the use of weakened limbs promotes the brain's capability to relearn and helps reduce the effect of disabilities. Some cases of stroke take some months or even years to complete rehabilitation. In this period the survivors need repetitive practice and a high degree of self-discipline. The doctor will try to begin rehabilitative therapy with 48 hours of the stroke. Doctors include passive and active range of movement exercises. Many extensive exercise programs have been established by physical therapists. The difficulties of daily life of many stroke patients cause them not to receive the rehabilitation they require so that recovery to maximum ability is not achieved. Since they need more exposure to rehabilitation, they need more careful instruction and the inspiration toward ongoing exercising at home once the therapy has ended [85].

The Philips Corporation is recently seeking modern means to improve the validation of therapy. The Stroke Rehabilitation Exerciser prototype (Figure 2.7) assists patients and therapists to plan and implement personalized neurological motor training that can be carried out at home. A wireless sensor-based system registers the motion and vital signs of a patient and then analyzes the information in contrast to the personalized plan and gives feedback to both the patient and therapist [85].

The Philips Stroke Rehabilitation Exerciser prototype connects a physician station with a patient unit, which is outfitted with a movement recording system. At the beginning of the practice program, the physician assembles an exercise program by picking activity components from a database. The laptop sized patient unit is linked with a screen as well as a number of sensors which the patient can easily wear on his upper limbs. The patient is first shown an instruction video and the Stroke Rehabilitation Exerciser coaches the patient through a series of neurological motor exercises. Whereas past technology-based exercises carried out at home have focused on gaining limb movements such as lifting one arm, the new exerciser focuses on functionality in daily living. For example, a daily living function would be lifting a cup to one's mouth [85].

A wireless inertial sensor system registers the patient's motions, analyses the information for deviations from a personal motion object and provides instant feedback to the patient. Commercially available sensor systems are either wired or lack the required accuracy. To make things simpler, Philips Research has created lightweight, match box sized sensors which broadcast data specifically to a receiver. These sensors can now be put on by the patients themselves without additional help [85].

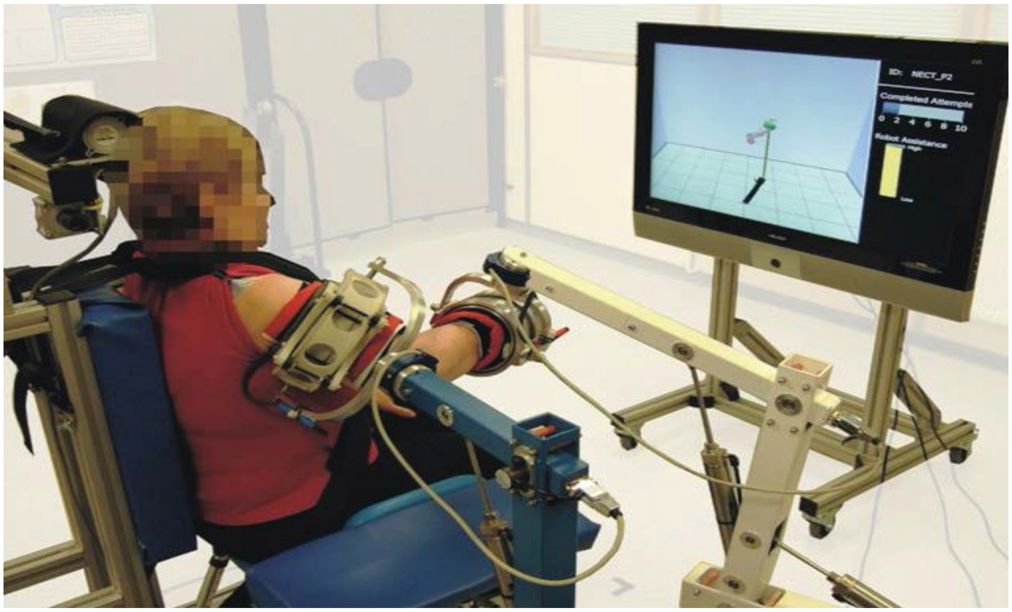

Figure 2.7: Stroke Rehabilitation Exerciser [86]

2.5 Estimate of Therapy Effectiveness

Alternatives to L-Dopa are currently becoming available to overcome levodopa induced dyskinesia in Parkinson’s disease. Then again, evaluation of their adequacy is restricted by the deficiencies of current schemes for dyskinesia estimation. With this goal in mind, at least one attempt has been taken to create a smart device to measure dyskinesia amid typical everyday exercises [1].

2.5.1 Dyskinesia Estimation

A convenient device was created for remote monitoring based on a tri-axial accelerometer worn on the shoulder and an information recorder that can record levodopa prompted dyskinesia. A computer system plots both unfiltered and acceleration components in excess of 0.5 Hz against time. This system calibrates accelerometer output to a severity scale for dyskinesia in a patient with Parkinson's disease. The capability to determine the severity of dyskinesia based on activities of daily life is key to obtaining the large amount of data that will be required to develop better dyskinesia estimation schemes. [1, 87].

2.5.2 Stroke Rehabilitation Estimation

Rehabilitation helps stroke survivors relearn skills that are lost when part of the brain is damaged. For example, these skills can include coordinating leg movements in order to walk or perform the steps involved in any complex activity. Rehabilitation also teaches survivors new ways of performing tasks to circumvent or compensate for any residual disabilities. Individuals may need to learn how to bathe and dress using only one hand, or even how to communicate again [88].

A system using accelerometer information can provide objective data about true arm function in stroke survivors. A test of the system involving 169 stroke victims undergoing constraint-induced movement therapy was conducted over a period of 3 days. These patients wore an accelerometer on both wrists providing a comprehensive data set. The results demonstrated by the system were in agreement with patient self-assessment of improvement. By measuring and comparing the degree of movement recorded by the system on disabled and healthy arms, the system can give a real-time limb status to the clinician [89, 90, 1].

2.6 Early Detection of Disorders

A very important area of application of wearable sensors is the early detection of patient behavior requiring special clinical intervention. An example of this type of application of wearable technology is the management of patients with chronic obstructive pulmonary disease and dementia. A major goal in the clinical management of patients with chronic disease is to achieve early detection of exacerbation episodes early detection and treatment of worsening symptoms are important to check the decline of clinical status and to identify the need for emergency room care or hospital admission. Remote monitoring systems can play an important role in early detection of trends in patients' health status that point towards an exacerbation event [1].

2.6.1 Remote Monitoring System for Dementia

Dementia is very common among the elderly population. Most patients with severe dementia are admitted to a health center because of their behavior can result in dangerous scenarios such as straying far from home and being seriously harmed. Due to the decreasing availability of caregivers in aged care, there is a need to prioritize the monitoring of such patients [91].

First, Haiying et al. said in [92] "developed a remote monitoring system for analysis of sleep patterns in patients with early dementia. By performing objective monitoring of quality, quantity and rhythm of sleep the authors aimed to identify the level of cognitive impairment of individuals undergoing monitoring.

The monitoring system included passive infrared (PIR) and bed pressure sensors. Preliminary results suggested that the sleep patterns of patients suffering from dementia are of lower quality when compared to control subjects. Other efforts to achieve the goal of assessing the progression of dementia have been made by another research groups" [1].

Second, Klingbeil et al., [95] created a remote sensor system for observing human movement and position in an indoor environment (Figures 2.8, Figure 2.9). Mobile nodes with inertial and heading sensors were worn by an individual inside a building. The system benefits from indoor guide data and static node positions. However, indoor location tracking system depends on providing for optimal separation distances between static power meter nodes and mobile nodes such as a wrist-mounted inertial sensor [91].

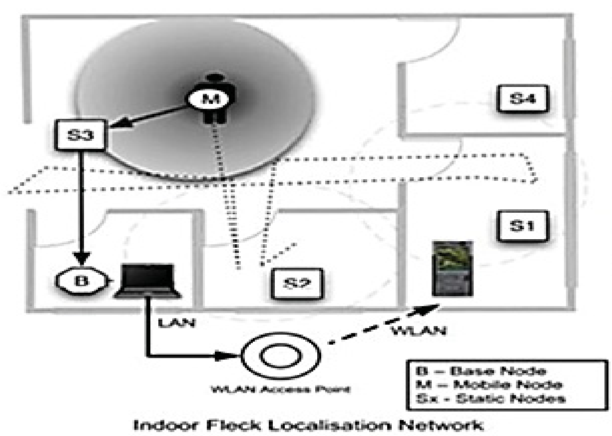

Figure 2.9 : locatisation network overview

Figure 2.8 : static node mountted on wall

Figure 2.8: Static Node Mounted on Wall [91]

Figure 2.9: Localization Network Overview [91]

2.6.2 Remote Monitoring System for Pulmonary Disease

This system is an ear worn sensor system developed to monitor activities and levels of exertion in patients with chronic obstructive pulmonary disease (COPD). Utilizing a developed technique of awareness algorithms, the system has the ability to recognize various types of physical activities and the severity of those activities from a single ear-worn sensor. The system can register and measure the status of patients during a specific period of time. The system is able to determine if the subject is wearing the device thus providing the level of compliance. Another interesting benefit from using this system was that subjects tended to increase their activity level during the first few days of monitoring [1, 96].

Chapter 3

3.0 Methodologies, Boundary Conditions, and Research Objective

3.1 Introduction

Chapter 1 introduced the concept of E- textile-based data generation for telehealth implementation, and gave a brief overview of present expectations for certain technologies Also Chapter 1 introduce the notion of wearable airbag technology. Chapter 2 reviewed the literature review for Telehealth operating systems, E-textiles, smart devices, applications, and wireless devices. Chapter 3 presents the research objectives with boundary condition of research with assumption. Also, this section outlines the proposed system's construction methodology, including details of the components and subcomponents of Hardware and software both to design and to build the system. This chapter also explains the role of all hardware and software components and subcomponents. Last, it explains how these components interface to each other.

3.2 Research Objective

As stated In chapter 1 and out lined in chapter 2, there have been numerous approaches to the remote monitoring systems (RMS) component of telehealth problem domain [1,14, 22, 23, 24, 28, 29, 99,100, 25, 26,30, 17, 19, 20]. The goal of this research was to develop RMS system architecture to improve upon current approaches. A real-time, flexible, transparent architecture was developed which supports past and present objectives within the telehealth area. This system architecture is depicted in Figure 3.1 [97].

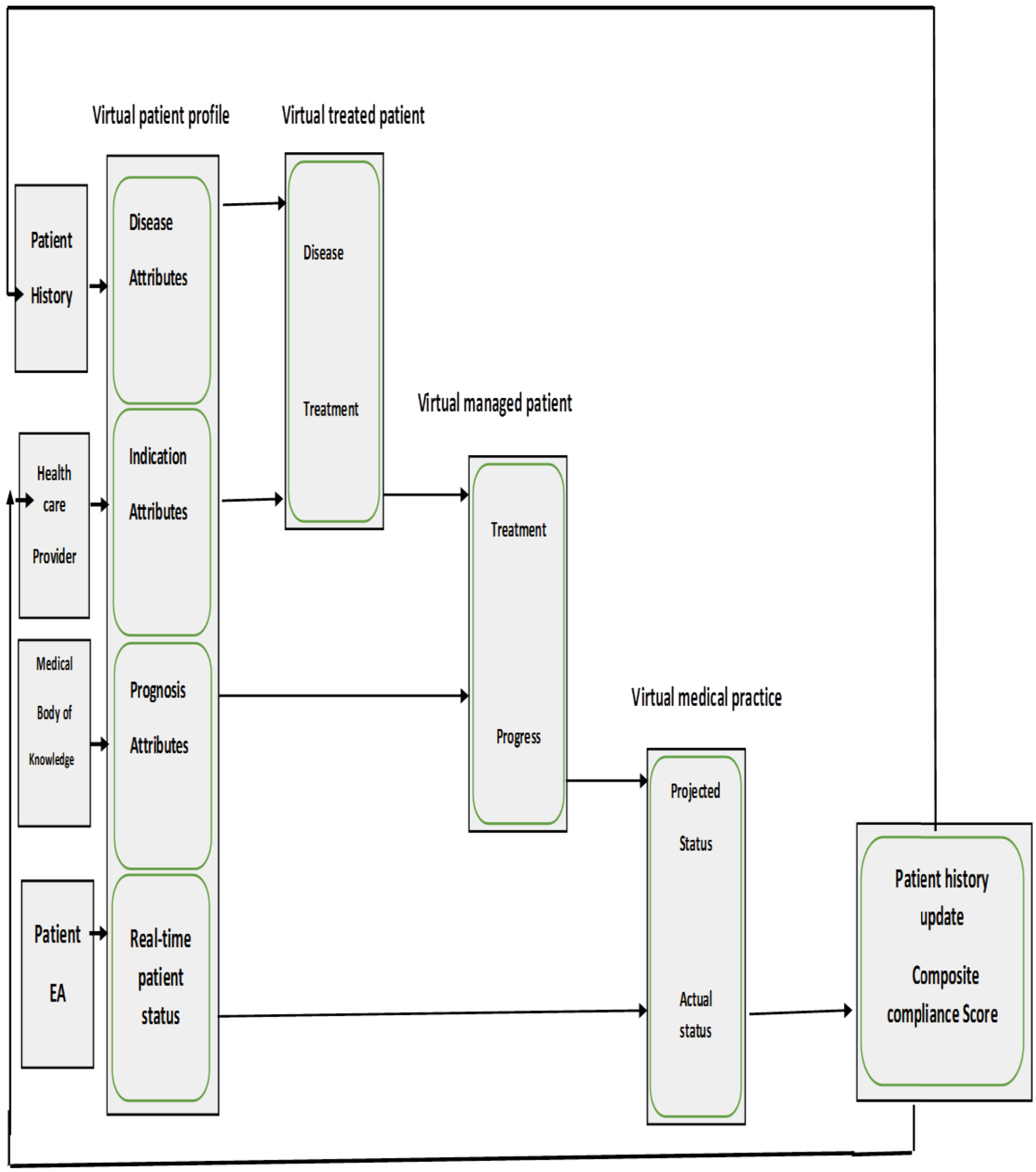

Figure 3.1: Model- Based Patient Management System Architecture

The research goals within the synthesis of the RMS-aiR1 prototype to demonstrate architecture are:

1. Development of a cloud-based virtual environment representing the domain as patient history node, a health care delivery node, a medical disease body of knowledge node (BOK). And a real-time node. The attributes at this node are illustration in table 3.1 through 3.4. In addition, an Emergency Assistance application provides real time facilitation to the patient interface environment.

Patient 1 with Disease A	Patient 2 with Disease B	Patient 3 with Disease c
• Diabetes, Glucose, stat • Diabetes, Mobility, low • Diabetes, BP, stat • • •	• COPD, HR, stat • COPD, BP, high • COPD, RR, low • • •	• Disease C, attribute 1, Value • Disease C, attribute 2, Value • Disease C, attribute 3, Value • • •

Table 3.1: Cloud Instance of Patients History Object-Attribute-Value Sets

Patient 1 Indications	Patient 2 Indications	Patient 3 Indications
• Patient 1 Disease • Patient 1 Projection score • Patient 1 Compliance Score • Patient 1 Critical incident History	• Patient 2 Disease • Patient 2 Projection score • Patient 2 Compliance Score • Patient 2 Critical incident History.	• Patient 3 Disease • Patient 3 Projection score • Patient 3 Compliance Score • Patient 3 Critical incident History.

Table 3.2: Health Care Provider Indication and Evaluation

Patient 1	Patient 2	Patient 3
• Stage of disease • Level of compliance • Direction of progress	• Stage of disease • Level of compliance • Direction of progress	• Stage of disease • Level of compliance • Direction of progress

Table 3.3: Disease Body of Knowledge of Node

Patient 1 with disease A	Patient 2 with Disease B	Patient 3 with Disease c
• Glucose • HR • Mobility	• BP sitting • Stroke volume • EKG	• Fatigue level • Chest pain • Sleep

Table3.4: Real-Time Patient Status Node

2. Development of the patient interface environment consisting of wearable sensing and communications technology through the fusion of e-textiles, wireless technologies and smart device open source application. Figure 3.2 depict RMS diagram.

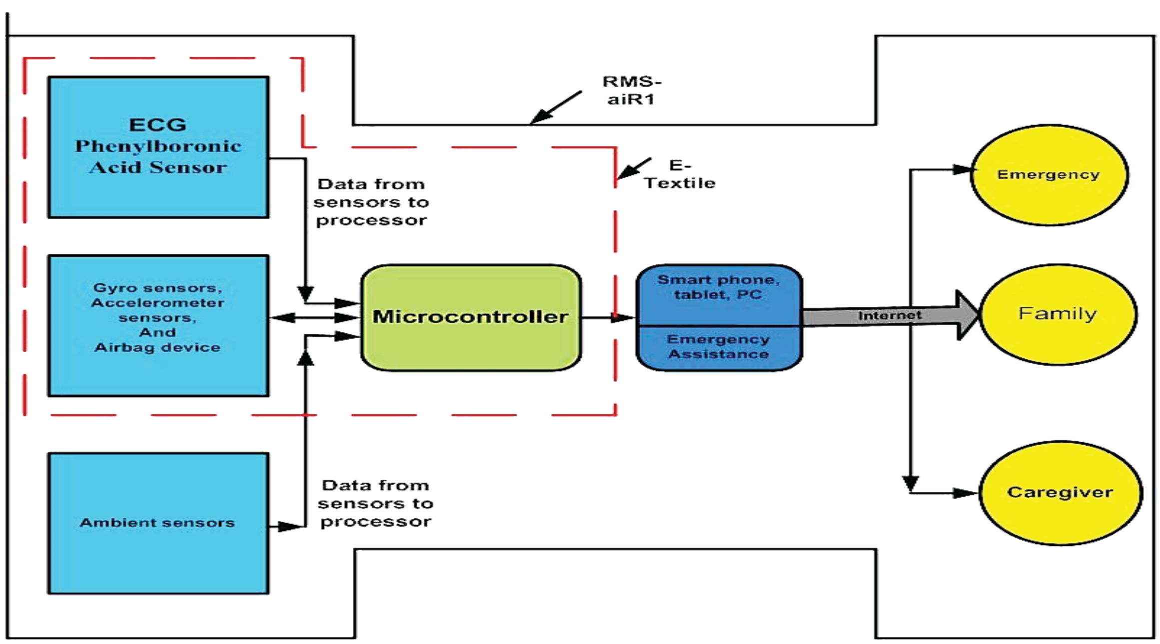

Figure 3.2: RMS Diagram

3. The development of an air bag system that protects the head and hips, the proposed air bag system will be incorporated in the same E- textile for sensing "bio information" and communication. The proposed system is intended to surpass the form and fit of existing passive devices (inflatable Helmut and inflatable belts) through its integration and it's active detonation method (see Figure 3.3).

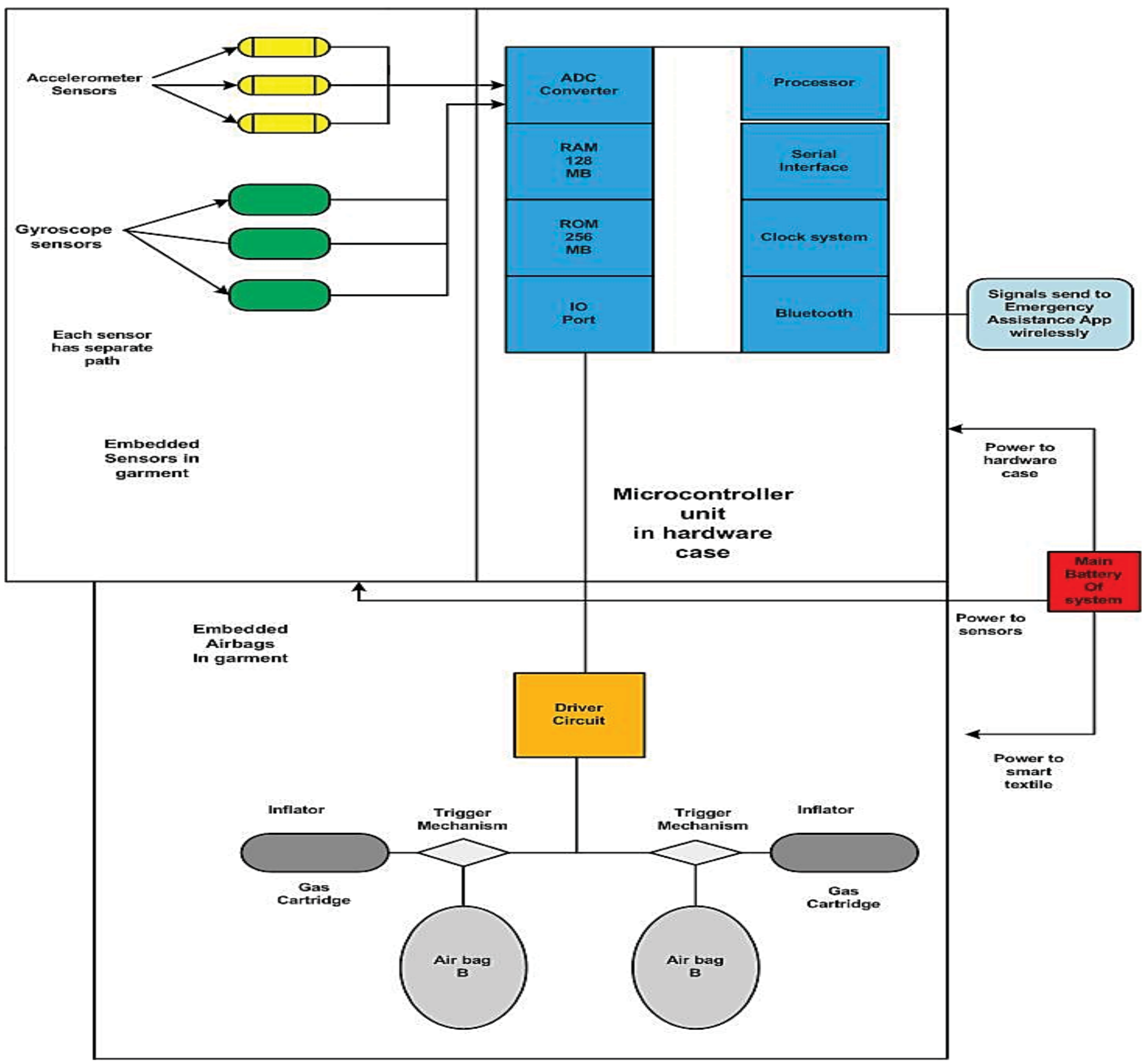

Figure 3.3: Block Diagram of the Air Bag.

4. The development of a universal graphical user interface (GUI) for patient, practitioner, and administrator with customizable dashboard based upon attributes of the user-user, use-module interface, (see Figure 3.4).

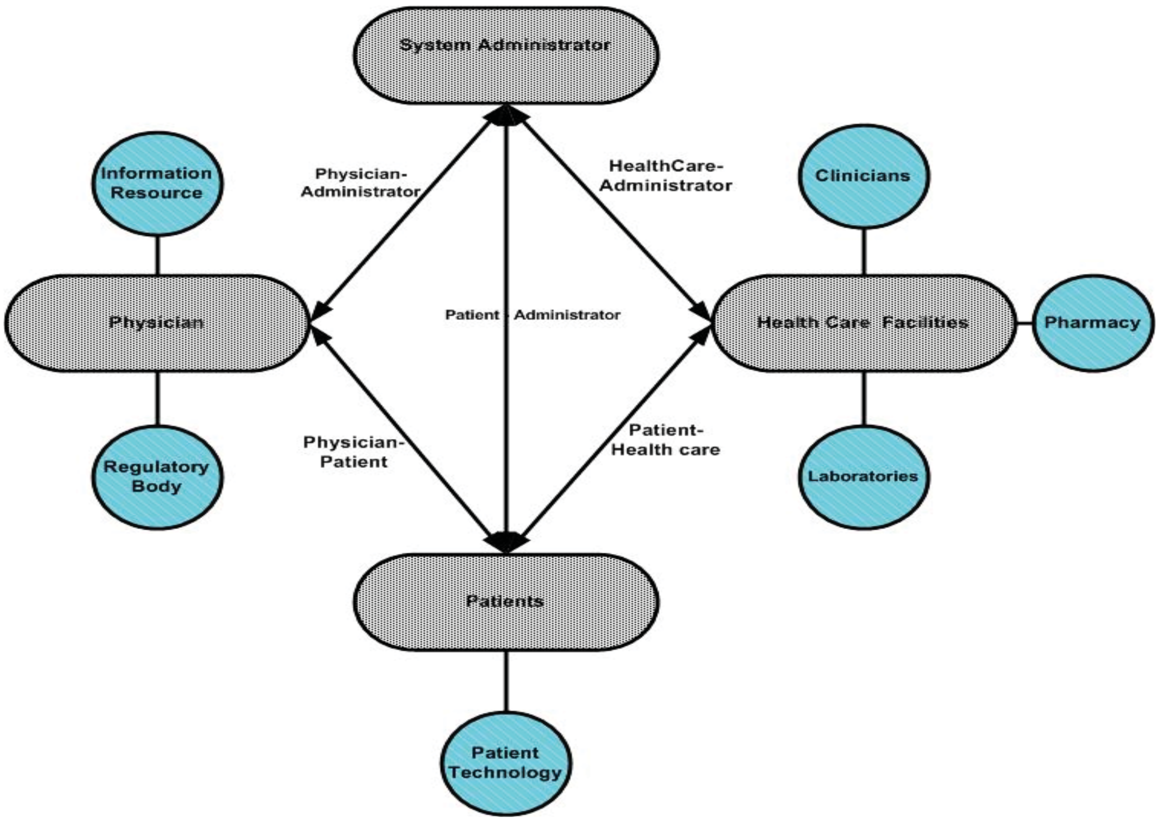

Figure 3.4: Graphical User Interface.

5. The development of a "logic module" for transaction of patient histories and immediate medical treatment into a virtual patient stream with symptoms, treatments and prognoses for each patient. Table 3.5 show treated patients cloud cluster.

Progress Direction Patient 1/ Diabetes	Progress Direction Patient 2/ Coronary Disease
• Compliance level (high, medium, low) • Prognoses (insulin ambulant, insulin bed rest, bed rest and Diet) • Symptoms (mobility, glucose level, numbness and pain in body)	• Compliance level (high, medium, low) • Prognoses (bed rest and diet, exercises, surgery and medication) • Symptoms (EKG waves, BP diastolic and systolic, respiration rate)

Table 3.5: Virtual Treated Patient Statuses

6. The development of a managed health care node patients which have been "indexed" to the body of knowledge for diseases of each patient. Table 3.6 show managed patient cloud cluster.

Diabetic Cohort	Coronary Stress Cohort
• Pharmaceuticals • Clinical capabilities • Consumables • Physical therapy	• Pharmaceutical • Surgical units • Consumables • Physical therapy

Table 3.6: Virtual Cohort/ Medical Resource Modeling

7. Development of a virtual telehealth medical node where all patient in the system are evaluated in real-time by comparison of projected status to actual status (see Table 3.7). Among other things, and as example of the many, a patient compliance score is rendered for feed back to the telehealth provider node with general updating of patient history to the respective node (see Figure3.5).

Patient 1	Patient 2	Patient 3	Patient 4
• Real-time status (return to history update) • Compliance evaluation and report items (provide feedback to provider)	• Real-time status (return to history update) • Compliance evaluation and report items (provide feedback to provider)	• Real-time status (return to history update) • Compliance evaluation and report items (provide feedback to provider)	• Real-time status (return to history update) • Compliance evaluation and report items (provide feedback to provider)

Table 3.7: Virtual/ Real-time Modeling of Patient Outcome

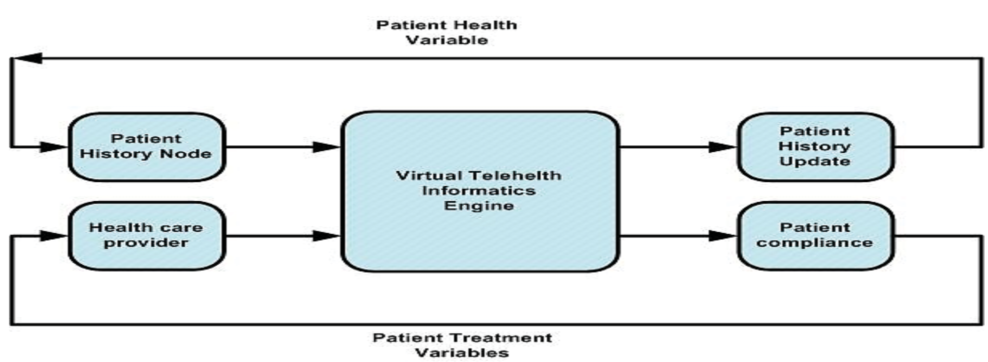

Figure 3.5: Simulation and Usability Study Environment

8. Research goals are completed with a demonstration of the ease of implementation, user-user adaptation, and the scalability of the RMS-aiR1 system. Examples of enhancing telehealth performance through the chosen advanced technologies are further demonstration in this chapter and in Chapter 4 through a virtual usability study protocol. Guidelines for improving the framework and protocol of an RMS will be offered in Chapter 5.

3.3 Research / Design Boundaries Conditions

A long-term, remote, and safe patient monitoring system (telehealth) increases the quality of patient health by allowing real time communication between the patient and the doctor or practitioner at the remote site. A long-term, remote, and safe patient monitoring system is considered a cost-effective alternative to the more traditional ways of providing medical care, for example, face-to-face consultations or examinations between provider and patient [137].

The distance that the proposed remote monitoring system can operate over ranges from a few hundred miles among several cities in the same country to thousands of miles across continents, depending on the kinds of communication technologies used, the smart phones, and the Internet networks between patient and caregiver. A long-term, remote, and safe patient monitoring system (telehealth) presents a unique opportunity to increase medical services to millions of new patients. Each caregiver center in this system can serve from just a few patients to hundreds of patients depending on the number of specialists and nurses in the center. Also, the capacity of software and devices used in the remote monitoring system impacts the number of patients served in the system [139]. A long-term, remote, and safe patient monitoring system has many of the following benefits [138].

- Improved Access: For over 40 years, remote monitoring systems have been used to provide healthcare services to patients in distant locations. Not only does remote monitoring improve access to patients but it also allows physicians and health facilities to extend their reach beyond their own offices, giving the provider the ability to provide the health care throughout the world, in both rural and urban areas [138].
- Cost Efficiencies: One of the most important reasons for a remote monitoring system is the increasing cost of health care. A long-term, remote, and safe patient monitoring system offers the opportunity to reduce the cost of health care and increase the level of efficiency through the best management of chronic conditions, health professional staffing, minimized travel times, and shorter hospital stays [138].
- Improved Quality: Studies have shown that the quality of health care offered by long-term, remote, and safe patient monitoring system is as good as that provided in typical in-person consultations. In some areas, especially in mental health and ICU care, the system provides an excellent product with greater results and patient satisfaction [138].

- Patient Demand: The most important impact that long-term, remote, and safe patient monitoring system makes is on the patient, their family, and their community. Time, travel and related stresses of the patient can be minimized by this technology. Through the past 15 years, study after study has registered high patient satisfaction for remote monitoring services. These services offer patients access to providers that might not be available otherwise and without the need to travel long distances [138].

It is clear that using the long-term, remote, and safe patient monitoring system is very useful even if the distance between the patients and doctors is not great. For example, even if both are located in the same state or city, this system reduces the cost and the time for patients and specialists while increasing the quality of care. Currently the United States government is the most active political arena for telehealth (long-term, remote, and safe patient monitoring system) services. There is a wide range of policies adopted by the US for telehealth. American Telemedicine Association (ATA) is using Health Resources and Services Administration (HRSA) funding to provide HRSA grantees, public officials, ATA members and the public with information and technical assistance regarding state policies affecting telehealth services. The information builds on extensive information resources available from ATA, ATA members and allied organizations [139].

There are some factors that affect the licensure and range of practice. Requirements for healthcare professionals to obtain a separate permit in each state where they provide a service has become an important obstacle to both patients and providers. [139].

- <u>For patients</u>: it limits access to the best possible medical care. It prohibits people from receiving critical, often life-saving, medical services, such as treatment for a rare disease that may be available to their neighbors living just across a state line. In short, the fragmented licensing system restricts patient choice [139]
- <u>For patients</u>: It prevents continuation of access to their instituted providers because of seasonal travel, such as “snowbirds” or recent relocation to a new state for employment [139].
- <u>For providers</u>: Specialists should have the ability to confer with out-of-state specialists or other colleagues without needing to also be licensed in that state. In order to entertain several service models featuring a team approach to providing and coordinating a patient's care, such as a “medical home” that serves a multi-state area, a change is needed [139].
- <u>For providers</u>: The requirements for remote monitoring systems are expensive and they represent a barrier to fair competition. The costs of licensing health professionals cost taxpayers hundreds of millions of dollars each year. Therefore, it is irrational for specialists to need separate licensing for clinical services that do not require face-to-face interaction such as the interpretation of images or provider to provider consultations [139].

A long-term, remote, and safe patient monitoring system (telehealth) is used to provide health care to patients. It is not a separate clinical specialty nor does it require a unique license. ATA adheres to a “one state license” model and insists consideration of its application for all federal health care (covering all agencies, health programs, and federally-funded health care sites) and interstate health care commerce [139]. ATA also opposes the establishment of any separate state licenses for providers using telehealth. ATA supports states eliminating barriers to provider consultation and coordination.

3.3.1 Scope of Practice

Other emerging problems for telehealth involve unequal and inappropriate scope of practice standards for telehealth by state medical boards. Many states medical boards have considered imposing practice rules with higher criterion for telehealth than in-person care. These involve specific requirements for telehealth, and that a patient should be a confirmed patient of the doctor having received a prior in-person physical from that provider. Other proposed rules include the requirement for maintaining and sharing extensive medical histories and an outright ban on issuing any prescription by telemedicine [139].

There are many encumbrances put on suppliers using long-term, remote, and safe patient monitoring system intended to inhibit competition rather than to promote patient safety. No ranking of suppliers is required, for example, those located in emergency departments, urgent care centers or even private practices.

State medical boards should not assess telemedicine differently than the traditional practice of healthcare. There should be no difference for non-clinical requirements, such as notices to patients, informed consent from patients, and use of electronic health records. Not should there be synthetic boundaries for the farthest point to obtain, unencumbered by regulation, solutions from an appropriately qualified supplier [139].

The ATA forces misleadingly higher guidelines for telemedicine (long-term, remote, and safe patient monitoring system) services. Patients regularly get ministrations from suppliers over state lines. Just about every substantial medical services framework spans over multiple states. Unrealistic and unfair practice regulations hurt the capacity of patients to get to medical services and can debilitate wellbeing. The United States needs to work to streamline practice regulations for all health providers and suppliers. This can be accomplished through cooperation among states or through federal coordination [139].

The prototype RMS-aiR1 system is a framework for communication and processing with a telehealth system. A unique feature is in the degree of integration and proximity of sensors and communication capabilities to the patient’s body particularly. The Bio-sensors, communications devices, fall protection devices and smart phone applications are gathered into a singularly definable E-garment. The research environment is depicted in Figure 3.6.

1. The RMS-aiR1 system.
2. Cloud based Telehealth.
3. Medical diseases databases.

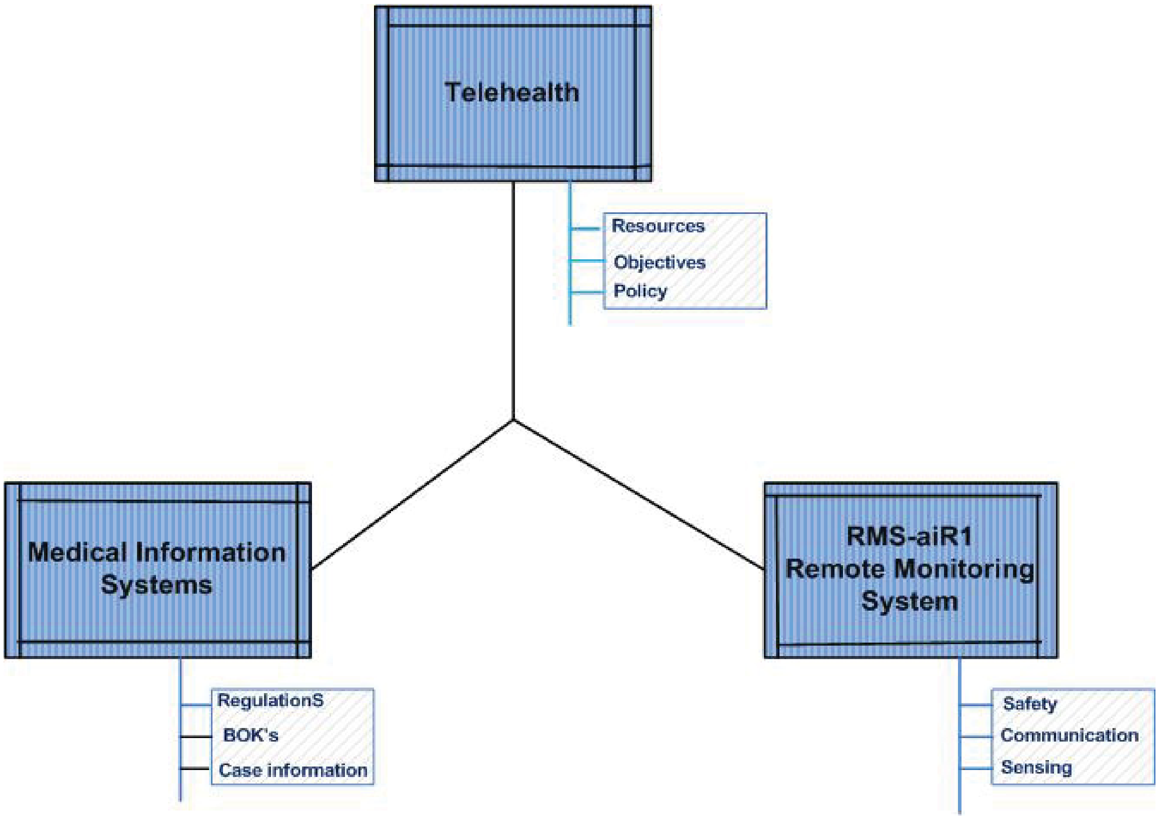

Figure 3.6: Constituent of the Research Environment

3.4 Domain Characteristics

Telehealth as discussed in previous chapters has been implicit to serving a variety of patients. From this has hopefully strengthened the introduction of relevant concept and relevant literature for application to the remote monitoring aspect of telehealth. In this research to effect, a framework for remote monitoring. A broad a scope has been considered while focusing on the patient experience.

The characteristics of the telehealth domain for these purpose are health care providers, medical information source, and the specialized patient environment if the RMS-aiR1 system. Any type of patient disease could be addressed by this system but the prototype will be confined to diabetes and heart health as two areas for demonstration.

3.5 Research/ Design Methodology

The hardware design consists of components either commercially available or fully described in the literature. The hardware components are identified as follows:

1. Smart textile in this research is Textronics or Textrodes textile which include all necessary components, for example, electrodes (sensors), and wires [14, 17, 18, 19, 20]. Also, a smart textile includes the hardware case which includes, power supply (battery) with its charger, AD/DA converter, amplifier and microcontroller unit, and Bluetooth technology, and data processing, etc. [1, 14, 21, 22, 23, 24, 28, 29, 99,100]. Moreover, e-textile involves air bag device [24, 25, 26, 27] which is a part of safe technology to protect the user.
2. Ambient sensor in smart home [1,30]
3. 4G Smart Phone as described in Chapter 1 [101].

The software components consist of the prototypes of two applications as follows:-

1. RMS-aiR1 application [102,103,104,105, 106, 107].
2. Emergency Assistance application [108].

3.6 Synthesis of E-Textile from Advanced Technologies

3.6.1 E-Textile

In the first chapter, just a few characteristics of textronics and textrodes were described. Therefore, in this chapter, additional specifications of textronics and textrodes are delineated [109].

- Durable, conductive wire yarns made with commercial materials on standard textile-processing equipment.
- An e-textile yarn with significant elastic properties.
- Customizable conductivity range from metal-like to resistive.
- Conductivity stays constant over elongation range.
- Textile “friendly” for easy knitting and weaving.

3.6.2 Wireless Sensors

For prototyping purpose, this research focuses on two kinds of medical monitoring situations, one concerning coronary performance and the other concerning glucose level. There are three electrodes (sensors) to monitor the heart rate function and two sensors to monitor glucose. These sensors send the vital data through a Bluetooth 2.4 GHz system. The electrocardiography (ECG) electrodes (Figure 3.7) are placed to measures electrical signals created throughout muscle contractions of the heart, and provide standard 3-lead ECG tracings. These tracings are representations of electrical impulses generated within the upper right auricle of the heart. As shown in Figure [120, 121].

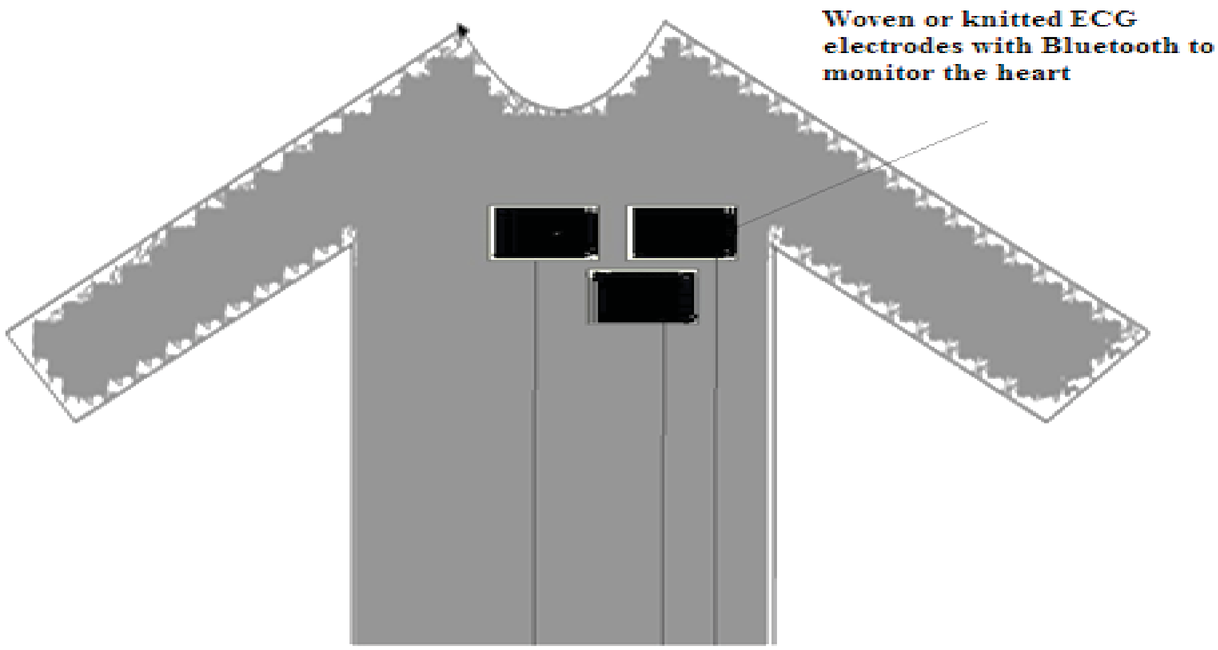

Figure 3.7: ECG in Smart Textile

Current methods of glucose monitoring rely predominantly on enzymes such as glucose oxidase for detection. A phenylboronic acid sensor and (Figure 3.8) which is also called a holographic glucose sensor has been proposed as an alternative glucose monitoring. The aim of the current research was to measure glucose in human blood plasma and blood as opposed to traditional methods such as track changes in concentration at a rate mimicking glucose changes in vivo [123, 124,125,126].

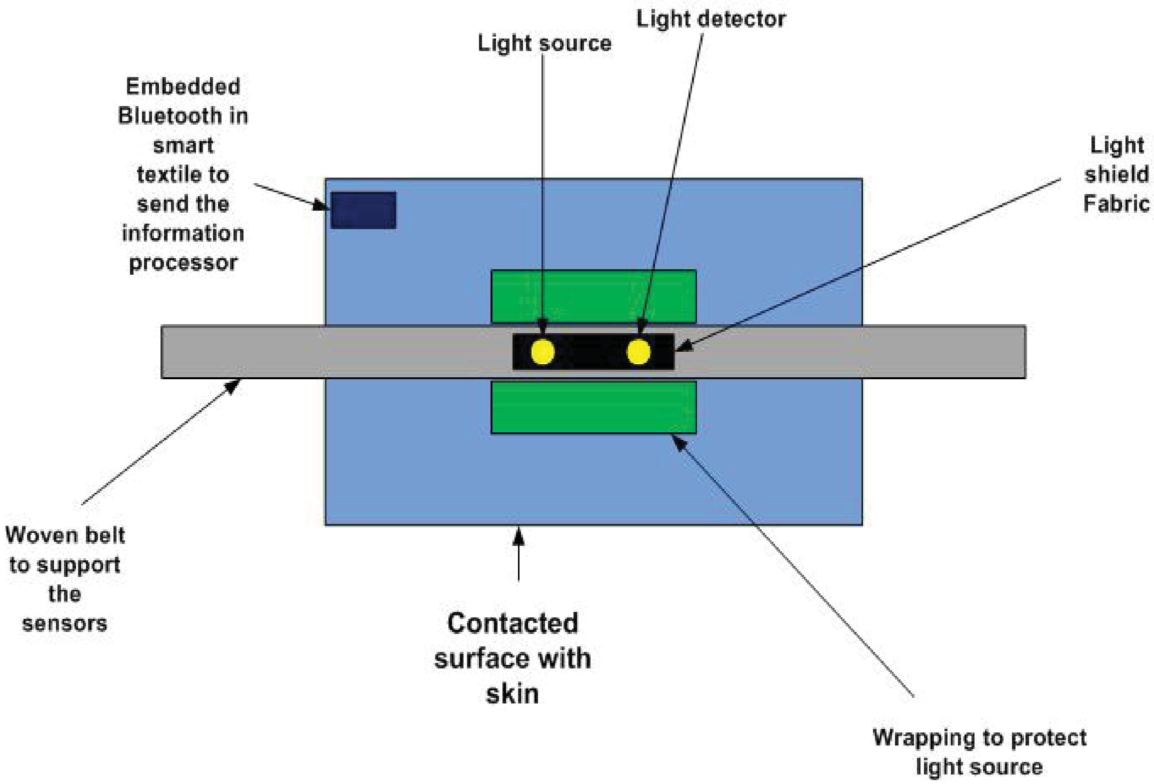

Figure 3.8: Woven 3D Graph for a Phenylboronic Acid Optical Sensor

3.6.3 Characteristics of Phenylboronic Acid Optical Sensor [126, 127, 147]

- Supply Voltage: 3.3 V
- UV excitation wavelength : 400 nm
- Single sample rate: 100 ms
- Sensor size: 320 μm × 790 μm or 320 μm x 1125 μm

3.6.4 Characteristics of ECG Sensor [129]

- Input Dynamic Range
  - DC: 300 mV DC
  - AC: 10 mV p-p AC
- ECG signal slew rate: 320 mV/s maximum
- Input impedance: >2.5 MΩ at 100 Hz
- DC to 40 Hz (0.0 ± 0.25 dB) and 40 to150 Hz (0.0 ± 1 dB).

3.6.5 Hardware Case

The case includes all hardware components. This case is produced from composite materials so that it is resistant to shocks and falls. The dimensions of the case are 5 inches length by 3 inches width by 1 inches thickness, (see Figure 3.9). A patient can hang the case on his belt and connect it with a smart textile by a special plug or port. This case has two ports, one for the battery charger and the other to connect the hardware with the smart textile, (See Figure 3.10).

3.6.6 Objective and Methods of Airbag system

As discussed in chapter1, the coupling with air bag system is a value added feature of a long-term, remote, and safe patient monitoring system. Therefore, to design and complete this system, it is necessary to explain the specifications of the airbag system [25].

Figure 3.9: Hardware Case

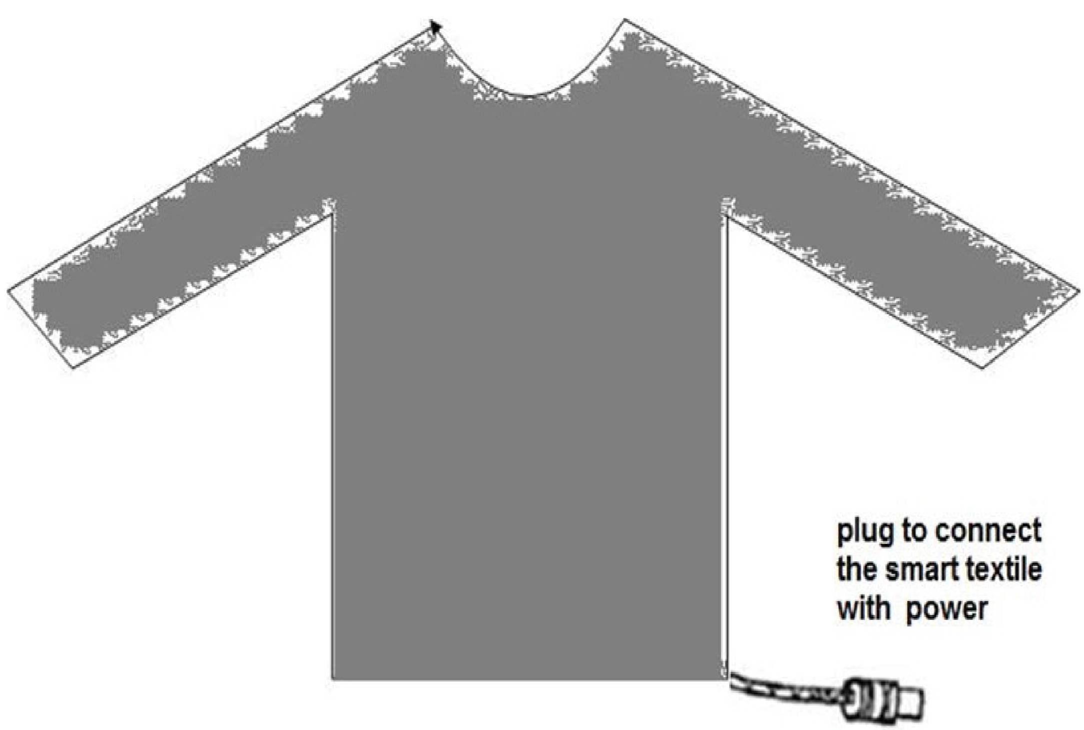

Figure 3.10: Connector of Smart Textile to Main Device

- It must be able to detect falls while the wearer is steady or moving [25].
- It must protect the head and thighs [25].
- It must be relatively small, lightweight, and simple to wear [25].
- It must be activated only during falls and not during daily activities [25].

3.6.7 Components of Airbag system

1. An inflatable airbag
2. Battery
3. A gas cartridge
4. Sensors to determine acceleration (tri-axial accelerometer sensors) and angular velocity (a tri-axial gyro-sensor).
5. Trigger mechanism to release the gas
6. Inflator to inflate the gas.

Previously, Figure 3.2.0 depicted the block diagram of the air bag system. There are two kinds of sensors embedded in this system [25].

3.6.8 Accelerometer Sensors

These sensors provides dynamics conditions such as titling and orientation of the body [93]

- 2.16 V to 3.6 V supply voltage
- <1W power consumption

3.6.9 Gyro Sensor

Angular rate sensors or angular velocity sensors are devices that sense angular velocity and sense change in orientation [98]

- supply voltage: 2.4 V to 3.6 V
- <1W power consumption

Central to this system is that the sensor detects falls. It must be able to detect falls while the wearer is standing or walking. Simultaneously, an Emergency Assistance application in the smart phone detects the fall when receiving the fall signals from accelerometer and gyroscope sensors then send an emergency message to the nearest emergency providers. The system must be relatively small, lightweight, and simple to wear. It must be activated only during falls and not during daily activities. Tri-axial acceleration sensors and gyro sensors are used to measure subject movement. Acceleration and angular velocity wave forms are converted into digital data transferred to the CPU and analyzed with the fall detection algorithms [25].

It is possible to protect the head and hips through using an airbag. Before inflation, One bag is folded on the back. This air bag only covers the head and neck after inflating. This airbag mseares 480 × 340 mm before inflation and has a volume of about 12 liters after inflation.The second airbag protecting the hips is folded inside a pouch. When it inflates, the airbag covers the hips and thighs. Its gauge is 230*400 mm before inflation and its volume is also 8 liters after inflation. Each airbag has a seperate inflator and cartridge [25].

The weight of two airbags is 2.314 Ib [25] and they are embedded in smart clothing. When the fall happens, the sensors detect the fall and send the signals to microcontroller then microcontroller send a trigger signal to automatomaticaly release gas from the cartridge to inflate the airbag and protect the user [25].

Simultaneously, an Emergency Assistance application sends an emergency message to a nearby health care provider. Gunpowder is used to release the gas when the 3V triggering signal is formed, and a 3V signal is moved to cause ignition. After that, gunpowder ignites, making a small hole in the gas cartridge. The inflator is made from an aluminum block big enough to avoid accidents when the gunpowder explodes. Each gas cartridge weighs about 0.33Ib and measures 20 × 120 mm. The gunpowder weighs 0.2425 Ib [25].

3.6.10 Wireless Technology

The proposed wireless technology in this research is a Bluetooth module since it is low energy Bluetooth™. Therefore, it is suitable for connection to microelectronics. In this research, three Bluetooth modules are used. First Bluetooth is embedded in smart textile, the second Bluetooth putting with microcontroller unit in hardware case; the third is integrate with smart phone [29].

- Range: ~ 10-100 meters
- Output Power: ~ 10mW
- Max Current: ~ 15mA
- Latency: 3 ms

- Connections: > 2 billion
- Modulation: 2.4 GHz
- Robustness: Adaptive frequency hopping, 24 bit CRC
- Security: 128bit
- Sleep current ~ 1μA

3.7 Non Design Components

Addition non design electronic components of e-textile which are commercially available are described below:

3.7.1 Microcontroller (MSP430)

The proposed system uses microcontroller type MSP430x22x2 or MSP430x22x4. Hornos said “The MSP430 is the family name of the ultra-low power 16-bit mixed-signal RISC processors from Texas Instruments. The 16-bit central processing unit (CPU), the peripherals and the flexible clock system are combined by using Neumann architecture with common memory address bus and memory data bus. Both the address and data buses are 16-bit wide, as well as the registers. They can be used interchangeably for either data or memory addresses. This makes the microcontroller unit (MCU) simpler than any 8-bit processor with 16-bit addresses. The MSP430 has 16 registers, and the ability to perform arithmetic operations directly on values in the memory [112].

3.7.2 Characteristics of Microcontroller (MSP430x22x2 or MSP430x22x4) [113]

- Low supply voltage range 1.8 V to 3.6 V
- Ultralow-power consumption
  1- Active mode: 270 μA at 1 MHz, 2.2 V
  2- Standby mode: 0.7 μA
  3- Off mode (RAM retention): 0.1 μA
- Ultrafast wake-up from standby mode in less than 1 μs
- 16-Bit RISC processor architecture, 62.5-ns instruction cycle time
- Basic clock module configurations:
  1- Internal frequencies up to 16 MHz with four calibrated frequencies to ±1%
  2- Internal very-low-power low-frequency oscillator
  3- 32-kHz crystal
  4- High-frequency crystal up to 16 MHz
  5- External digital clock source
- Timer A with three capture/compare registers
- Timer B with three capture/compare registers
- 10-Bit, 200-ksps A/D converter with internal reference, sample-and-hold, auto scan, and data transfer controller.

3.7.3 Amplifier

The function of the amplifier is to scale the incoming signal up or down to be compatible with the range of the analog to digital converter [23]. Frequency range is from 300 kHz to 6 GHz. [114].

3.7.4 Filtering

Filtering is the most common signal conditioning function, as usually not all the signal frequency spectrum contains valid information [23]. Frequency bandwidth is between 0.04Hz to 150 Hz [115].

3.7.5 Battery

Recently, new types of batteries appear such as Lithium-ion or polymer which maximizes power capacity. These kinds of batteries are rechargeable. It can provide the power for each sensor and the air bag system, and hardware components. The specification of these kinds of batteries is as follows. [116, 117,118].

- Current capability: 1500 mA
- Voltage: 3.7 VDC
- Weight: 25g
- Recharge time: 1 h
- Working time Max: 24 h

Therefore, the user can have enough time to recharge the batteries during the night.

3.7.6 Converter/Charger for Lithium- ion Battery [118,119]

- Input voltage: 100 to 240 V @ 0.3 A
- Frequency: 50 to 60 Hz
- Output voltage: 5.3 V@ 2 A
- Cable of adapter with micro USB

3.8 System Integration Effort.

Figure 3.11 depicts the fundamental parts of an electronic framework. It is comprised of a processor and memory, sensors and actuators, a power source, and hard wired or remotely connected internal or external devices by configuration choices. When incorporating this sort of electronic framework into a garment, two significant difficulties must be overcome [14].

1. Realization of the electronic elements.
    - Selection of existing devices with modification
    - Development of original devices
    - Combination of existing devices with original devices
2. Assure continuous power to the system.
    - Commercially available batteries

- Miniaturized power circuits with batteries
- Miniaturized power circuits with rechargeable batteries

3.9 Ambient Sensors Integration Opportunities

The proposed system is enhanced by coupling ambient sensors embedded in residential smart homes. Smart homes are realized with advanced electronics, sensors and automated devices specifically designed for care delivery, remote monitoring, and early detection of problems or emergency cases. They have the potential to promote residential safety and independent living [1, 30, 31, 130].

It typically utilizes Bluetooth technology in order to monitor physical or environmental conditions. Figure 3.12 describe the notion of the integration of smart textile, smart phones, and smart Home. The temperature, humidity, sound, vibration, pressure, motion, pollutants, and even biometrics parameters such as ECG, blood pressure, SpO2, etc.

This data is then locally processed before being transmitted to a remote location for further analysis and interpreted before any decision making takes place [30,130,131].

Smart home systems can include many types of ambient sensors which make the lives of the ageing population easier. Figure 3.13 shows several types of sensors and appliance that this research can use to monitor and help the patients with chronic conditions in different situation with in the home

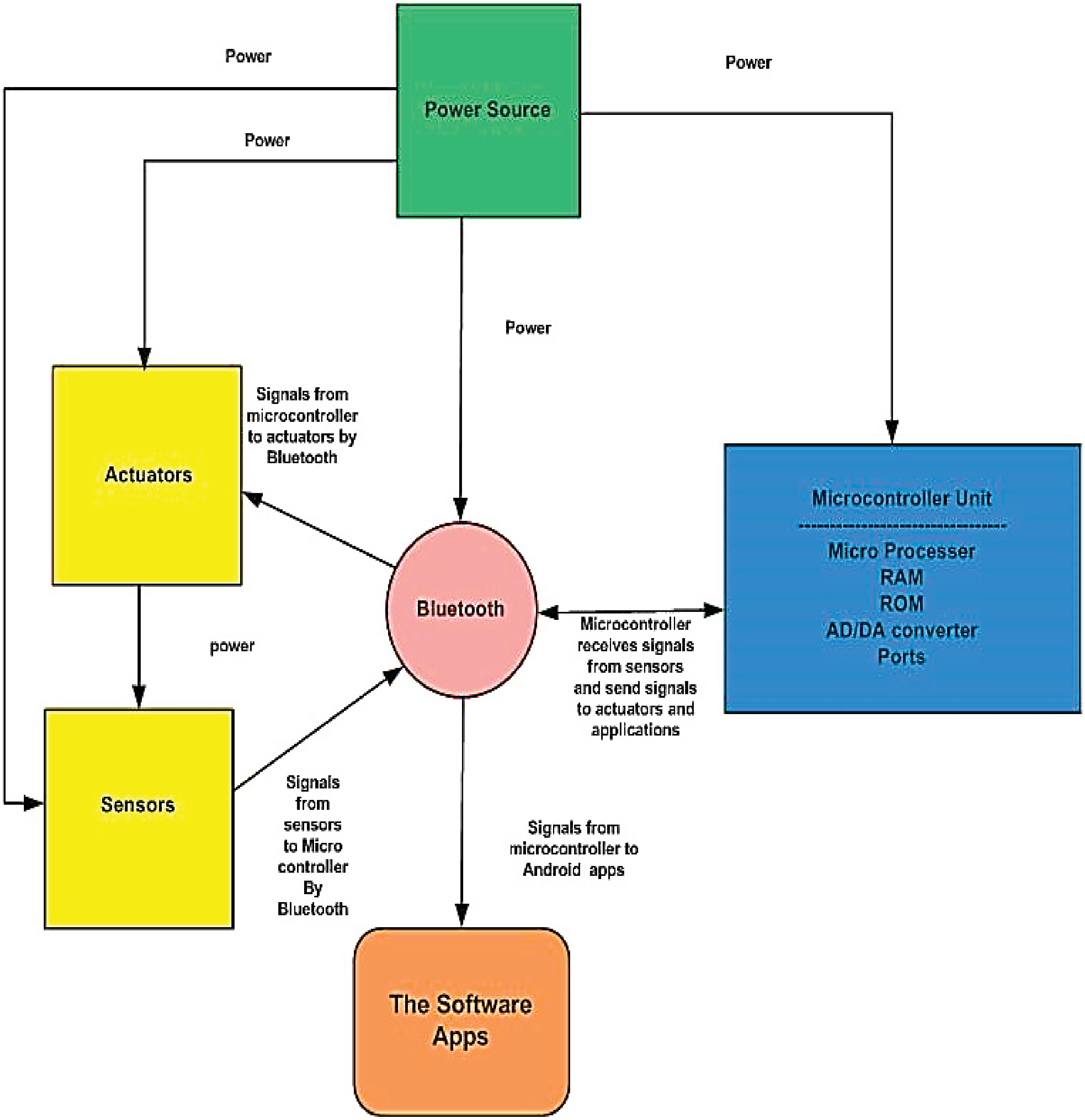

Figure 3.11: Schematic Overview of Typical Electronic System

environment and send the information to main controller [30]. Moreover, table 3.8 shows several types of smart devices.

Components	Specifications
Appliances	Socket 3 pin (WiFi), voltage range100-240V AC, max current 10A
RFID Door	RFID reader, magnetic lock, 8-bit microcontroller with 22 I/O, operate with 5V
Alarm	Buzzer(speaker), (12-24 VDC), Amps 0.6
Camera	C328R CMOC Camera, small size 32 x 32mm ,adjustable resolution, Max VGA, 5V operation, low Power consumption 80mA
Smart Light	Bulk lump (presence sensor), switch/relay, 120-220V

Table 4: Specifications of Some Ambient Devices [30]

3.10 System Applications

This research utilizes two kinds of application. These applications help the patient in collecting data and sending it to caregivers. Using these applications lead to integrate the system in this research.

3.10.1 RMS-aiR1 Application

This research proposed a prototype of RMS-aiR1. RMS-aiR1 application work on Android based smart phones. RMS-aiR1 can receive information from patient body via wireless technologies and send it to doctors through web services.

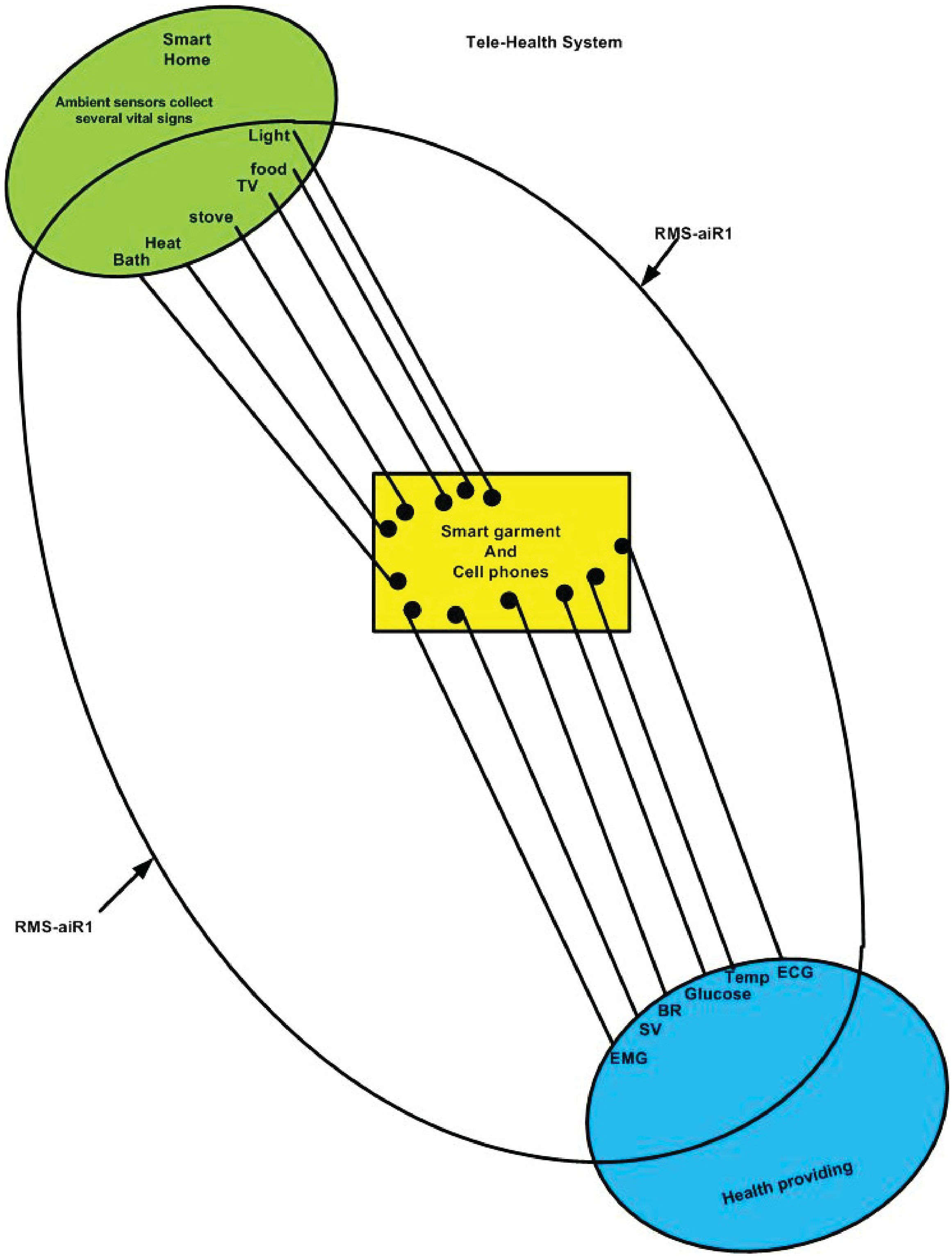

Figure 3.12: Tele-Health System

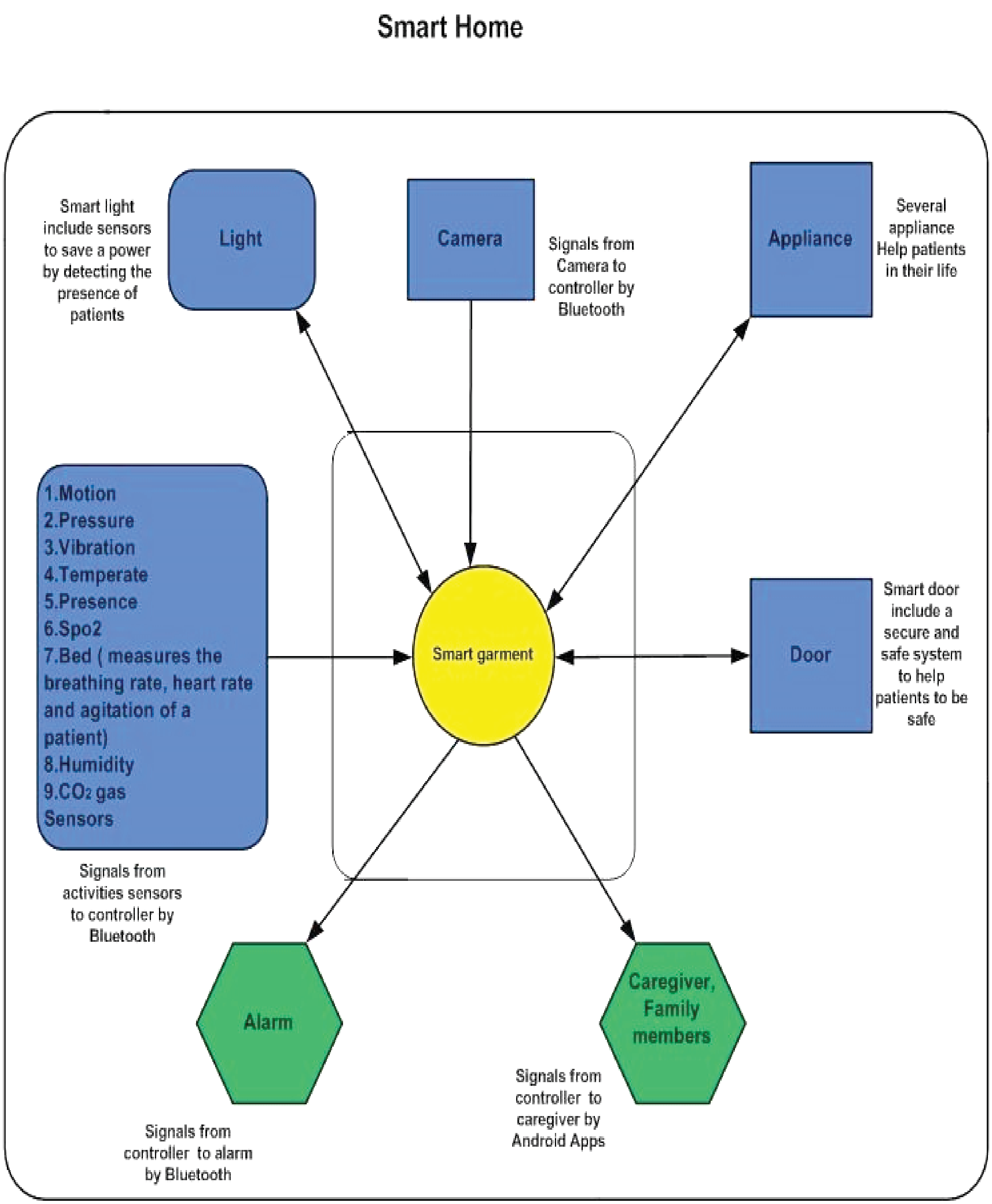

Figure 3.13: Integration of Smart Home Devices with the Wireless Garment

RMS-aiR1 connect caregiver server, smart textile, smart home, and smart phones together. To use RMS-aiR1 system, patients should register in this system (see Figure 3.14), and then use the home page to select the type of test from it (see Figure 3.15). RMS-aiR1 is a self-monitoring system can alert the patient to perform the test of different diseases.

This application includes many features. However, this research focus on glucose level and heart health features.

1. Heart Health (Figure 3.16): By using this feature the user and doctor can identify many characteristics. The information can be collected manually or by wireless technology. The wireless technology (Bluetooth) receives the vital signs from wireless sensors collected the data from the patient's body. By using this feature the patient can observe himself and make some simple decisions and send the information to a doctor. The characteristics of first feature are blood pressure, pulse rate, and medication intake as shown in Figure 3.17.

The patient can send the information to doctor directly by pressing the phone button or save it into the device to send it to a doctor later. This feature can alert a user about prescribed medication as well as inform a doctor about daily symptoms.

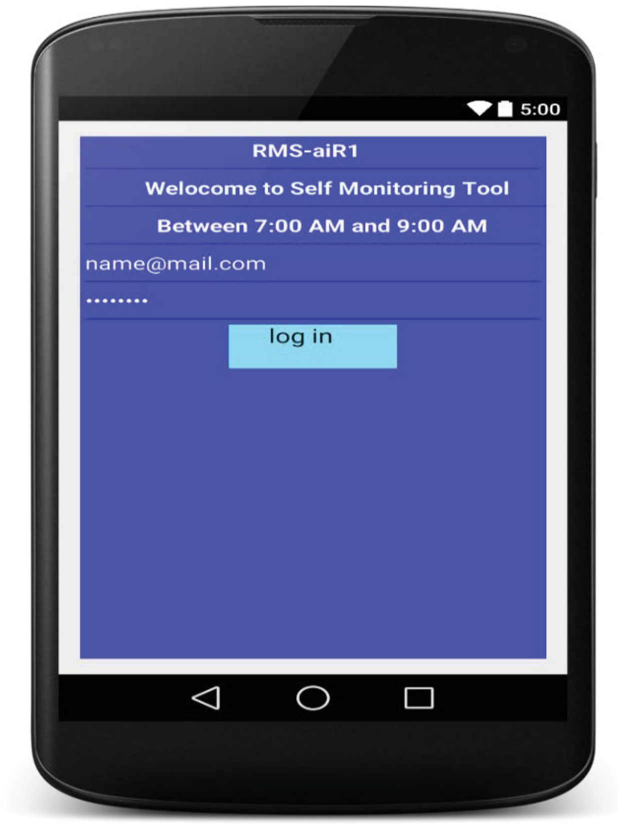

Figure 3.14: Registration Page of RMS-aiR1 Application

Figure 3.15: RMS-aiR1 Home Page

The daily symptoms of these features are:

- Excessive fatigue.
- Breathlessness at exertion
- Breathlessness at night time
- Dizziness
- Chest pain
- Sleep.

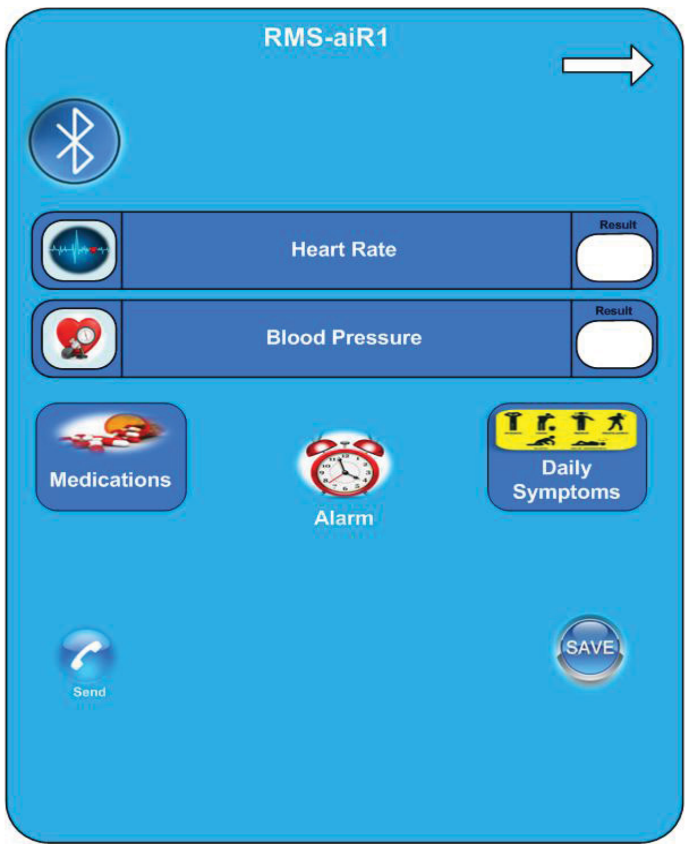

Figure 3.16: Heart Health Test

2. Blood Glucose (Diabetes): this feature includes three characteristics (see Figure 3.17).

- Breakfast
- Lunch
- Dinner

Also, the information can be collected manually or automatically. This feature enables the patient to make immediate decisions and send the information to doctors. This feature alerts the patient about medications, and the patient can described his or her daily symptoms to a doctor.

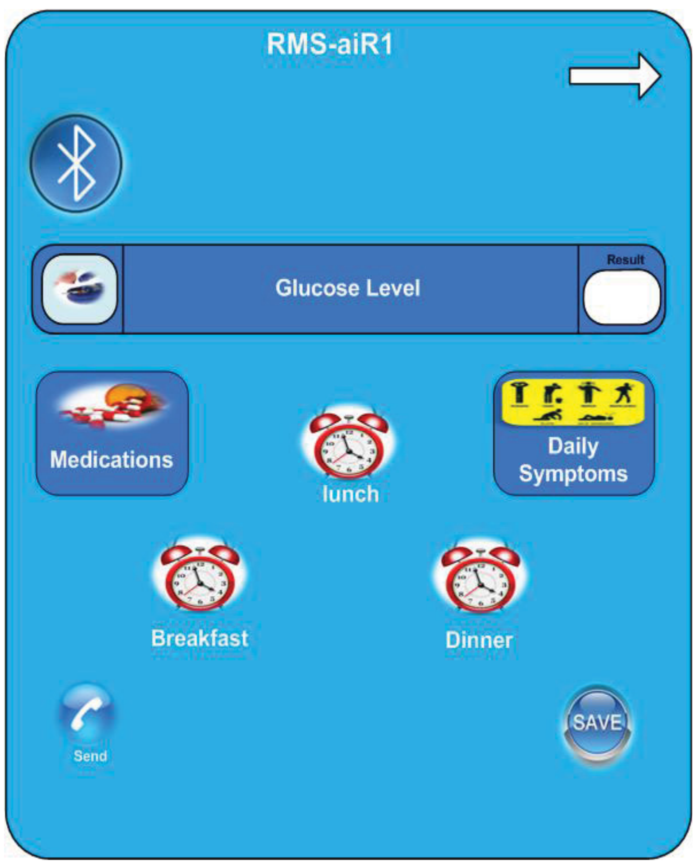

Figure 3.17: Glucose level Test

3.10.2 Emergency Assistance Application

An Emergency Assistance is able to detect the patient fall by receiving the fall signal from the accelerometer and gyro scope sensors which embedded in smart textile. The main microcontroller receive the signal of fall from accelerometer and gyroscope sensors then send two signals one for air bag device and the other to Emergency Assistance application wirelessly. The application can differentiate between the real fall and daily activity such as running or jumping by using some algorithms to calculate the fall's force.

In case the application receives signals from sensors, It start calculating a force equivalent to a fall, and it gives the user a twenty-five second warning asking the user if he wishes assistance. If the user does not answer, it will do nothing (see Figure 3.18) [145].

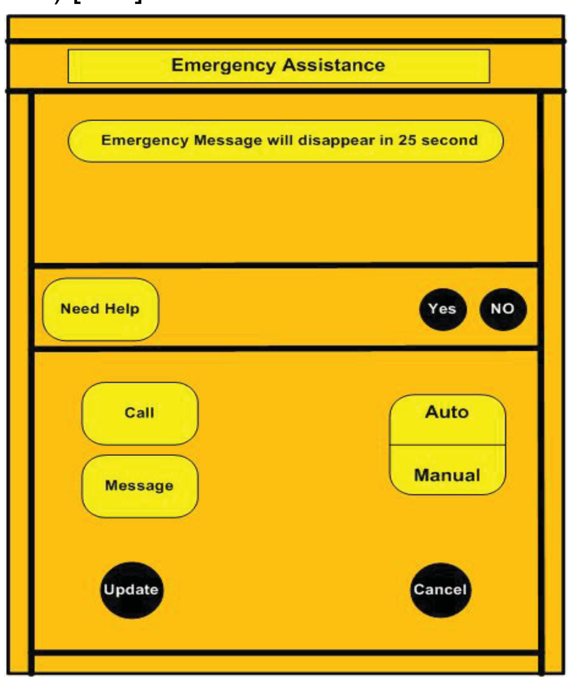

Figure 3.18: Strategy One of Emergency Assistance Application

Also, if the force is determined to be high, it will still show a warning for twenty five seconds as in stage one. However, if the user does not answer, the application can automatically send an urgent message and alert your primary emergency contact (see figure 3.19) [145].

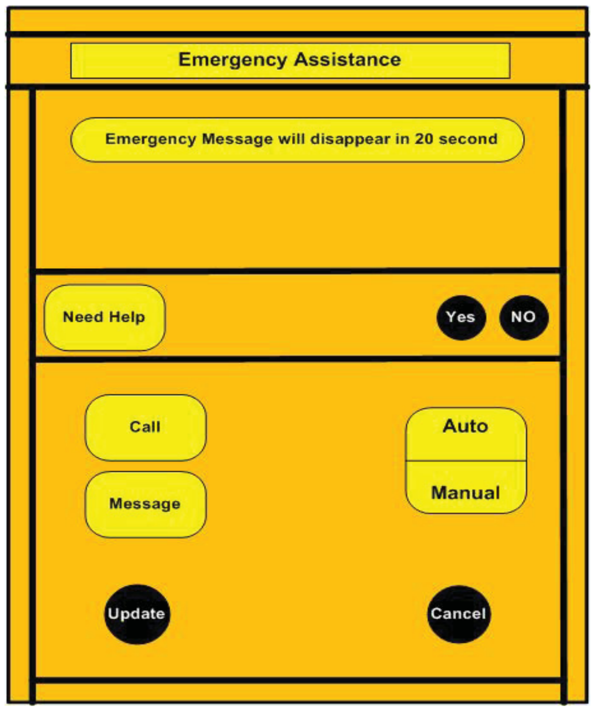

Figure 3.19: Strategy Two of Emergency Assistance

If the user feels that the warning has occurred due to a traditional activity like walking, the user can press the “No” button and the application will display the Auto Update Settings screen. The user would not update the system during activities such as jumping, running or doing something gymnastic [108].

3.11 Assembly of Smart Textile Components.

Smart textiles using textronics or textrodes were indicated as the foundation for system hardware development. The electrode is a woven sensor that uses textile materials developed of structurally to sense the human body's bioelectricity. Recently, various structures for textile electrodes have been developed, including ones that are woven, knitted, non-woven, and embroidered. [133]

Fabric conductors are related to the dry electrode class. As a result, the substrate fabric electrodes are a part of the textile product and the soft electrode surfaces bond with the surface of the body. This will reduce the human sensation and electronic noise generated by the movement between the electrode and the skin while maintaining contact with the body's surface [133,132].

The electrode is woven during the creation of the textile [132] by using the weft or warp method mentioned in Chapter 1. This research uses woven or knitted electrodes of the following construction methods.

1. weaving conductive yarns in weft and/or in warp direction, combined with a specific weaving pattern and specific weaving techniques (jacquard, loop weaving) for the realization of contacts
2. knitting conductive yarns using either plain knitting, circular knitting, warp knitting or crocheting.

For illustration a conceptual diagram, a smart textile is depicted in Figure 3.20 and Figure 3.21. The electrodes and wires are isolated for safety of the wearer and the devices. [132,133, 134,135].

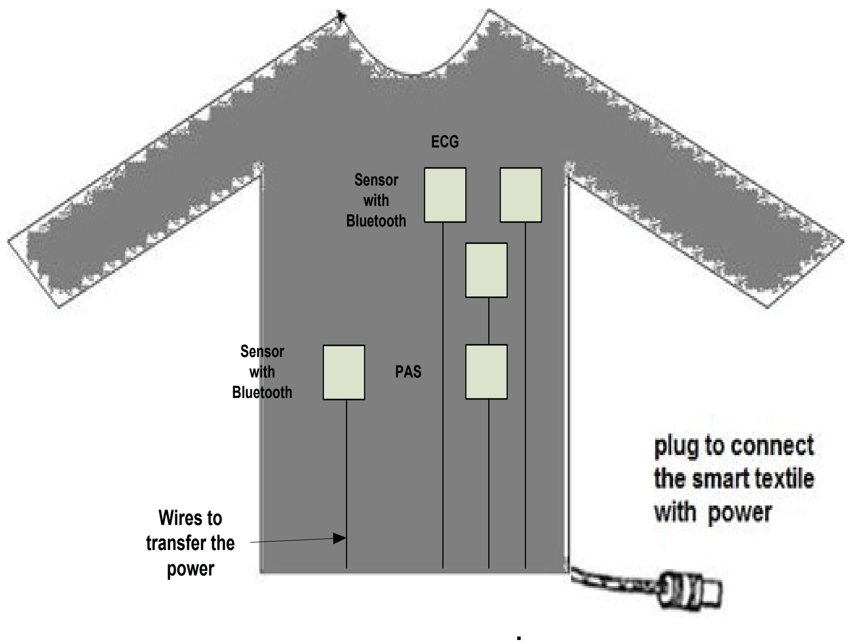

Figure 3.20: Architecture of the Smart Textile (as depicted in a garment)

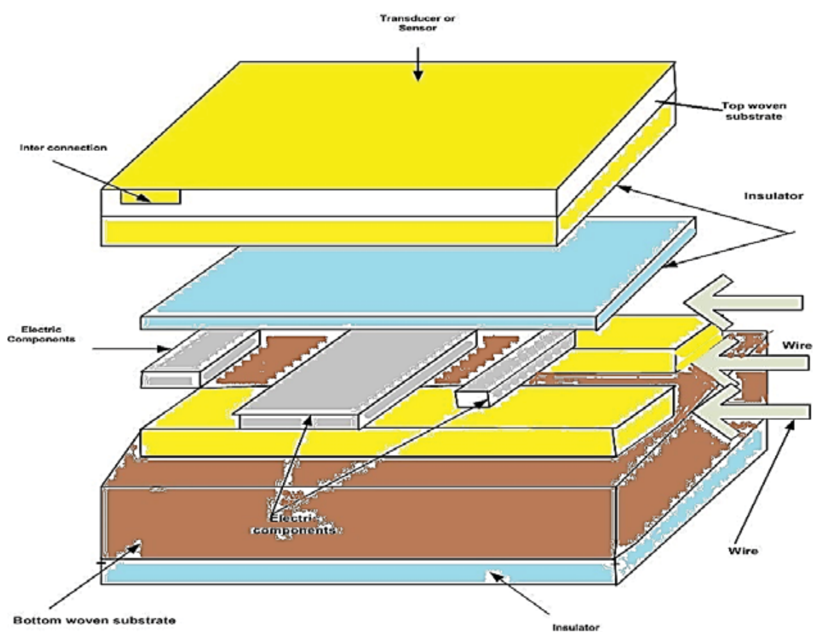

Figure 3.21: Conceptual of Typical Electrodes (ECG)

Different types of electrodes can be weaving into a smart textile to achieve different types of sensors in order to monitor patient vital signs and posture. These biometrics including heart activity, muscle activity, brain electrical activity, blood pressure, trunk position, respiration, movement activity, temperature, etc. However, this research focuses on two types of sensors which are the wireless ECG and the Phenylboronic Acid sensor woven into a smart textile.

3.12 Assembly of Hardware Case Components

After the sensors detect vital signs from the patient's body, the signals are transferred by embedded Bluetooth™ to the hardware case, which has a processor, ROM, RAM, slots, plugs, batteries, and the Bluetooth module, for example, Figure 3.22 shows the system diagram with the interconnection of all components in the hardware case. When the signal enters the microcontroller, it passes through several steps. First, through the signal conditioning the signal is converted to a more suitable signal. Then the multiplexer divides it into many signals in several channels. After that, the amplifier scales the incoming signal to be compatible with the range of the analog to digital converter. (See Figure 3.22).

Analogue to digital converter convert the signals from analogue signals to digital signals so that the processor can receive it. The processor addresses the signals collected by the sensors from the body of the patient to send them to the wireless technology and then to the smart phone application RMS-aiR1 application which then sends the information to caregivers. In case of a fall, the gyro and accelerometer sensors send a signal to the microcontroller to send a command to the inflator to open the air bag. Also, the microcontroller sends a signal to Emergency Assistance application in smart phone as shown in Figure 3.22.

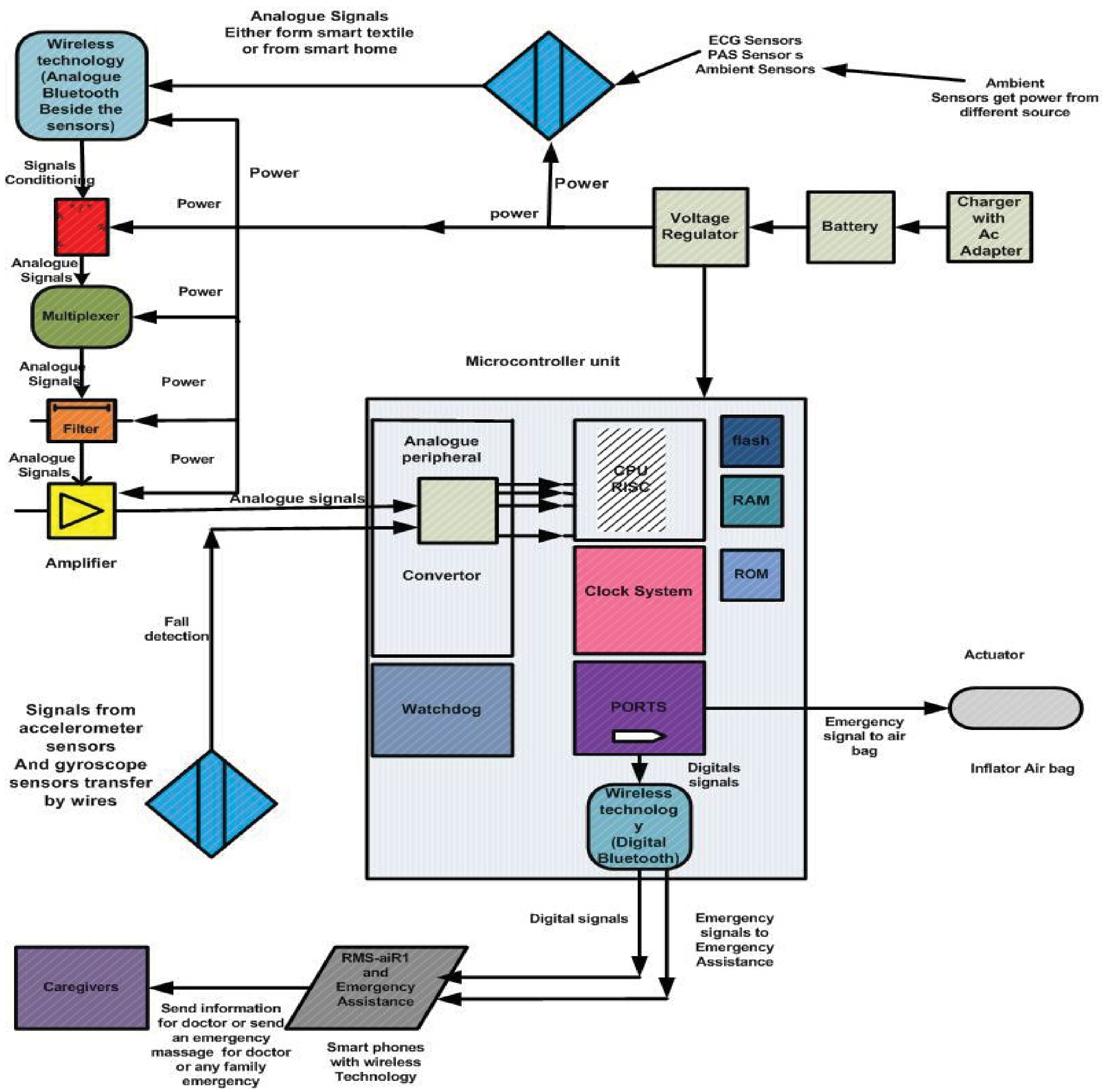

Figure 3.22: The System Diagram

The smart textile can be provided with the necessary power from a battery (1500mA). The voltage that is required is between 1.8 V and 3.6 V. Also, the power can be provided by several methods, as mentioned in Chapter 1, either by solar cells, body heat of the patient, the movement of the patient, or micro fuel cells, but this research focuses only on providing power from Lithium - Ion batteries leaving other option to be used in the future.

3.13 Integration E-Garment with RMS-aiR1 System

The Bluetooth module sends the biometric signals to the RMS-aiR1 application which is available on an Android phone. When the patient turns the power on, the Bluetooth Module in the hardware case works automatically. The patient has to turn the Bluetooth module on in the Android phone to enable the applications to receive the vital signs. The patient can save the information for transmission to a doctor at a later time. The system offers the ability for the patient to see his/her test result. The patient may make an immediate decision such as taking a medicine or doing exercises and he or she can answer the doctor's daily symptom questions, as shown in Figure 3.23.

After the patient collects the information and makes an immediate decision, the patient can send the information to a doctor who will receive the data through the RMS-aiR1 application portal either about patient heart health or glucose level. If the patient needs any treatment, the doctor can schedule an appointment for the patient, as shown in Figure 3.23.

In emergencies, Emergency Assistance application sends an emergency signal either automatically or manually depending on the setting mode that the patient chooses, to the caregiver or to a member family. Also, the application identifies the location of the patient on a GPS system so that the caregiver could find the patient easily (see Figure 3.23).

3.14 Integration of the system with role of Ambient Sensors

The ambient sensors available in a smart home work together with the smart textile to detect the activities of the patient in the home environment in case the patient does not wear the smart textile. These sensors are provided with Bluetooth capability to send the information to the patient's microcontroller to compile the information and send it to the patient's phone, PC, or tablet. As shown in Figure 3.23.

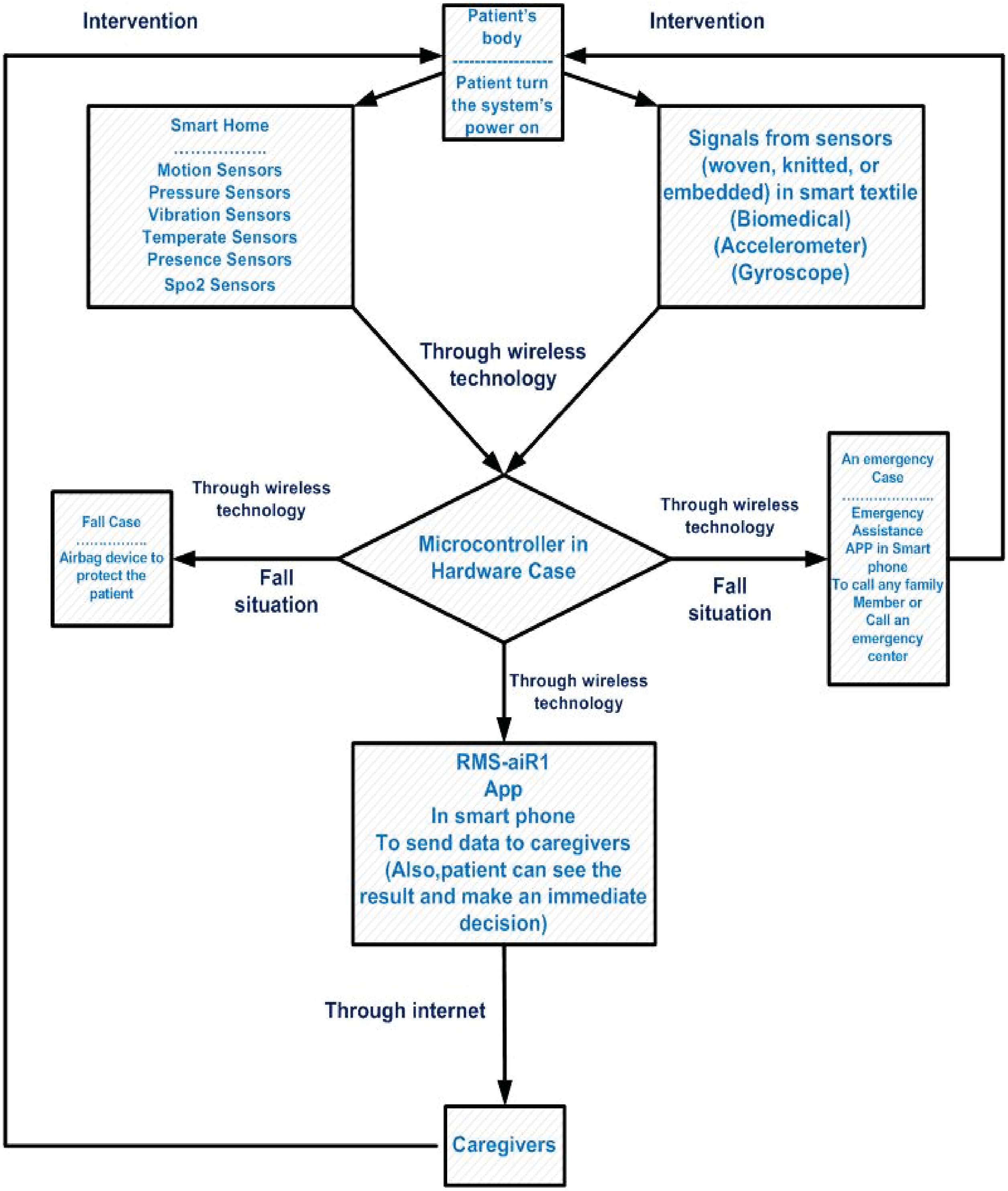

Figure 3.23: Flow Diagram of RMS

Chapter 4

4.0 Simulation of System Performance, System Features, and Usability Study

4.1 Introduction

Previously in Chapter 3, research objectives and methodology, were stated that RMS system could be carried out by using different kinds of technologies such as wearable sensing and communications technology through the fusion of e-textiles, wireless technologies and smart device open source application in order to develop a cloud-based virtual environment. In this chapter, the system validation is performed in detail through the simulation of system performance. Also, in this part of research the study of usability is carried out, and the features of system are explored.

4.2 Simulation of System performance

During this part of research, it is necessary to simulate the entire system. The system integrates the smart textile, smart home, and smart phone. The long-term, remote, and safe patient monitoring system (telehealth) traces the patient's activities such as diet, medication intake, and exercise and issues warnings and suggestions to avoid accidents and to improve the patient's behavior by following the daily symptoms. The process diagram for long-term, remote, and safe patient monitoring system services is illustrated in Figure 4.1. In this system, two applications are used between patients and doctors or between patients and any family member to connect each other in normal or emergency situations. Therefore, the patient and the doctor can work together to continuously improve the objectives of treatment.

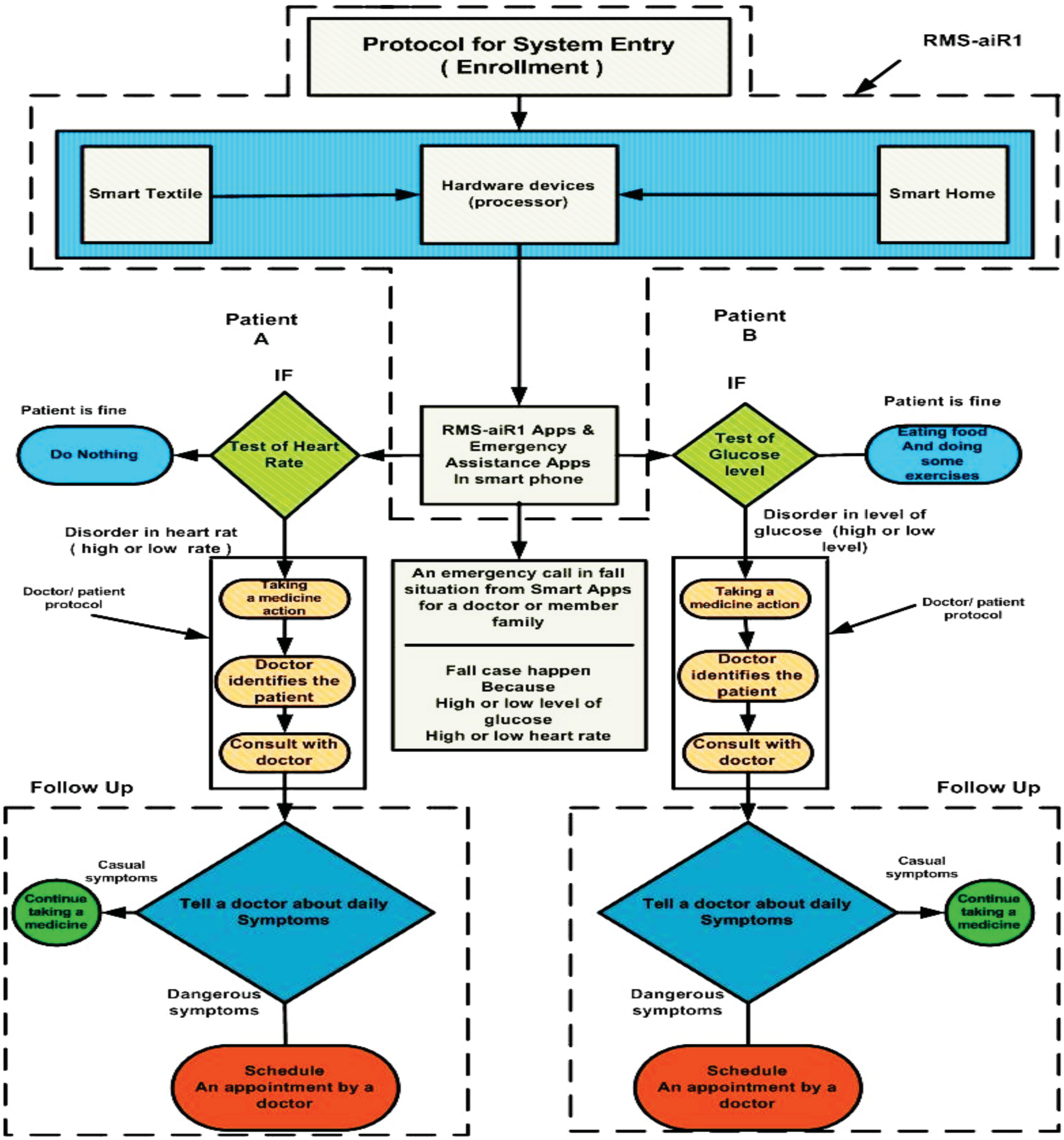

Figure 4.1: Architecture of Telehealth System Based on RMS-aiR1

4.3 Using Boolean's Propositional Calculus to simulate the system performance.

Let us represent all the statements with variable labels and operational symbols variables:

m: Fall situation is true.

n: Emergency call is true.

p: Test Diabetes is true, 1 disorder(High/low) in diabetes, 0 if unremarkable.

q: Test Heart Rate, 1 if disorder(high/low) in heart rate, 0 if unremarkable.

r: Taking medicine is true.

s: Doctor identifies patient is true.

t: Consultation with doctor is true.

u : Symptoms, 1 if dangerous , 0 if casual.

v: Schedule an appointment with a doctor.

w: Eating food and doing exercises.

x: Do nothing.

Operators:

$\neg$: not

V : or

$\land$: and

1. **If (p $\lor$ q) then m.**

Fall case happens in case of High/low diabetes or high/low heart rate

2. **If m then n**

   An emergency call happens in case of fall situation from Emergency Assistance application for a doctor or family member.

3. **If p $\lor$ q then { r, s, t, u, v }**

Disorder in heart rate or diabetes will lead to doctor patient protocol and Follow up protocol.

- Doctor /Patient Protocol: If r then {s, t }

Take a medicine action then doctor identifies patient resulting to consult with doctor followed by follow up protocol

- Follow up Protocol: If u then v

Tell a doctor about daily symptoms and Schedule an appointment by a doctor in case there is a dangerous symptom.

4. **If (p $\lor$ q) $\land$ ($\neg$ u) then r**

Disorder in heart rate or diabetes and casual symptoms during follow up required continuing taking medicines.

5. If ¬ p then w

If patient is fine (level of glucose is good), eat food and do some exercises.

6. If ¬ q then x

If patient is fine (heart rate is good), do nothing.

4.4 Exploration of System Design Features

Authors in [140] mentioned “features can be viewed as information sets that refer to aspects of form or other attributes of a part, such that these sets can be used in reasoning about the design, performance or manufacture of the parts or assemblies they constitute. Feature technology, therefore, is expected to be able to provide for a better approach to integrate design and applications following design such as engineering analysis, process planning, machining, and inspection.” RMS’s features are a set of logically related requirements that allows the user to satisfy the objectives. RMS Features are identified as objectives come from high level requirements [146]. Table 4.1 shows several requirements and features of a remote and safe patient monitoring system.

Requirements	System Features
1. Comfort	1. Lightweight and wireless design allows freedom of movement.
2. Validity of monitoring	2. The system was designed for continuous monitoring.
3. Reliability of communication	3. Long transmission range.
4. The quality of battery	4. Long battery Life.
5. The diversity of textile materials to supply more options for user to choose	5. The material of the smart textile can produced from either wool or polyester.
6. The diversity of textile designs to supply more options for patient to choose	6. The smart textile can be either a jacket or shirt.
7. Increasing the reliability of protection	7. There are two pieces of thick rubber behind the elbows of the patient's arms to protect them.
8. guarantee of connectivity	8. The case of the hardware includes two port to connect with the textile, one port to provide the power for the smart textile and the other for the battery charger.
9. The reliability of diversity for data insertion	9. The prototypes of RMS-aiR1 and Emergency Assistance are available on PC, tablet, or smart phone and the patient can input information into these applications either manually or by wireless technologies.
10. Reliability of endurance for shocks and falls	10. The hardware case are made from composite materials to withstand shocks and falls.
11. Hygiene	11. The system is washable.
12. The diversity of textile colors to supply more options for patient to choose	12. The smart textile is available in a variety of colors.
13. Efficient usability	13. The system is easy to prepare for use. The patient connects the smart textile to the case of the hardware and turns the wireless technology on in the RMS-aiR1 application to send the data to a doctor.
14. The diversity in diseases monitoring	14. The system can measure two types of vital signs, glucose level and heart rate.
15. Customizability or personalization	15. The system can be customizable

Table 4.1: Requirements and Features of RMS

4.5 Usability of Design

Usability means making products and systems effective and easy to use, and matching them more closely to user needs and requirements [141]. The usability of this system can be discussed from two sides, one for hardware and the other side for the software. As Nielson said in [142] “usability has multiple components and is traditionally associated with learnability, efficiency, memorability, low error rate, and satisfaction”. Usability studies eliminate design problems for the product which should improve the end user experience with the product. [143].

4.5.1 Features Targeted by Usability Study [142]

1. The system must be easy to learn either through the hardware components or software components so that users can quickly achieve results
2. The system must be efficient to use. For example, connecting the smart textile with the hardware case or using RMS-aiR1 application should be clear and easy for any user, so that a user becomes familiar with the system quickly.
3. The software installation must be easy for the casual user.
4. The system should be easy to remember either through the software or hardware so that a casual user can return to wearing the smart textile or use hardware case and using the RMS-aiR1 application or Emergency

Assistance application after a long period, without needing to re-learn the entire system.

5. The system should favor few errors by users. Through errors measuring with help instructions, when and if errors occur, users should be able to recover from them easily. For instance, entering the data in RMS-aiR1 application or Emergency Assistance application must be very easy to avoid making mistakes. Furthermore, catastrophic errors must not occur.
6. The smart textile should be comfortable, lightweight, modern, aesthetic, durable, socially acceptable, washable and anti-allergic. Also, using the RMS-aiR1 application and Emergency Assistance application must be very amenable so that the user will be comfortable with it’s use.

4.5.2 Framework for Usability Study

Because the number of patients available to test the telemedicine system has been limited until recently, there is potential to provide a general exploration of the usability issues that became evident during experimental activities. The initial design of this system at the first stage was based on clinicians’ predictions and developers’ understanding of what patients need to encourage self-care [144]. Extensive testing has been conducted with a research group to simulate real use by patients. Therefore, the test of the system depends on what the doctors and developer observe in the lab.

The intelligent garment (textronics) is more developed than the classic type, which is known as smart textile. To conduct the usability test for smart textiles, it is necessary for the specialist, developer or doctor to observe the patient for system problems. For example, if the user feels uncomfortable when wearing a smart textile, the problem must be identified to make the user more comfortable. Such problems might include the textile weight, an allergic reaction, unattractiveness, or safety. Then the developer can modify the design to avoid the problem. For example, weight can be minimizing by deleting unnecessary elements. If there is an allergy, the kind of textile itself can be changed, or if the user is uncomfortable with the design, that can also be changed.

A second problem that doctors and developers have to monitor is the preparation for use of the smart textile with the hardware case and whether or not the patient can remember how to prepare for use it again after a period of time. If so, the developers should make the perpetration for use easier by reducing the level of the complexity.

A third problem the developer should focus on is the error rate during system use. Types of errors that may occur in using the hardware case, might be how to connect the smart garment with the case, or how to recharge the batteries of the system. The developer can avoid these errors by creating errors message with help instruction so the user can correct, learn about, and avoid problems.

The usability study of the RMS-air1 prototype system should focus on the monitoring of a patient's heart health and diabetes status. This study could be divided into three parts. First, the application should remind the user to initiate diagnostic procedure and the transmission of information to the doctor and remind patients about medical instructions. There might be many types of alarms between 7 A.M and 9 A.M the day after, for example. When the reminder works, the patient responds to the alarm with logging to test for his/ her blood or heart rate to send the information to a doctor. If the patient does not respond to a reminder, the doctor will be altered. In the case of responding to the reminder questions or questions about symptoms, there will not be any warning. The patient does not need to answer questions about symptoms daily but on a weekly basis.

Second, there is the user-interface that is directly accessed by patients, such as button size, text size, and colors. In this case, a user should use the app while the developer and doctor observe the problems. When the developer notices problems in with application because of the small size of the text or unclear color, they can modify the design.

The third part of the usability study focuses on the communication between the patient and a doctor. The objective of this study is to identify any problem in delivery of services from doctor or communication from patient. The delivery of services depends on the strength of the 4G wireless signal since this signal is not always steady. The signal can be lost or work only intermittently in some areas. The patient can avoid this problem by saving the data until the signal works again then sending it, or the app can be modified to automate the logging of information when there is not a strong enough signal and to send it when the signal is available.

In a similar way, the usability study of Emergency Assistance app can be divided into three parts. To conduct a general study of the application's function, the user has to enable "Auto Fall Detect" Option in the setting and restart a smart phone. When the phone is ready, the user should shake the phone as hard as he or she can and then keep it at floor level for 30 seconds without dropping or throwing it. It should show an emergency message for fall detection and the user should hit the "I'm fine" button cancelling the emergency and auto updating setting. [145].

Also, usability study focuses on the communication technology of this application. Emergency Assistance application utilizes the GPS/Wireless Network/Internet to determine user location. The determining of location depends on the strength of the 4G wireless signal since this signal not always steady. The signal can be lost or work only intermittently in some areas. In this case, the patient can use call or text to tell a doctor or family members about his or her location. Another feature, the application can be modified to save the information of location when there is not a strong enough signal and send it when the signal is available.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

Increases in population lead to increases in the number of senior citizens with multiple chronic diseases. Therefore, the need for medical services increases as well. Also, the growing need often will be correlative with the lack of doctor and nurses since these chronic patients, on average, need to see 5 or more doctors and use more than 50 prescriptions a year. Therefore, it is necessary to make changes in health care technologies, particularly toward new technologies that help in monitoring chronic patients remotely, especially in rural and remote areas because of the many health centers that cannot serve a great number of chronic patients.

This research result in the framework for the development design and possible implementation of long-term, remote, and safe patient monitoring system which integrates a smart textile system and smart home with Android smart phone applications to facilitate the management of chronic conditions such as diabetes and heart diseases. The system can monitor the patient 24 hours to allow the patient and doctor to collect important information about the patient's health. The design of framework of long-term, remote, and safe patient monitoring system in this research help designers by providing a set of design attributes and their characteristics in design process which are helpful in understanding the design process itself. It is very easy for the end user to use this system since it only requires the user to turn a switch on in order to connect the sensors, which are woven into the smart textile, with a processor in hardware case by wireless technology then sends the signals to Android smart phone applications. The use of smart phone application is very simple for the casual end user since it allows the user to enter the information by Bluetooth or manually. The long-term, remote, and safe patient monitoring system includes an air-bag system embedded at the back of the smart textile to protect the patient when he or she falls and then send an emergency message to a doctor or member family through the Emergency Assistance application.

The long-term, remote, and safe patient monitoring system improves access to doctors since it brings medical services to the patient in the home or any place in the community. A long-term, remote, and safe patient monitoring system allows doctors and health facilities to provide medical service to a large number of patients since it saves doctors' time by eliminating meeting and examining patients. This system gives doctors and health facilities the ability to extend their medical services by using communication technologies to provide health service overseas. A long-term, remote, and safe patient monitoring system reduces the cost of chronic disease treatment by dispensing with traditional delivery in hospitals, which is very expensive. It saves time and effort for the patients by eliminating the need to travel long distances to reach specialists.

Generally, a long-term, remote, and safe patient monitoring system improves health since it reduces mortality among the elderly. A unique benefit of this system is patient comfort while wearing the smart textile since the sensors and actuators are woven and embedded within the smart textile. Also, the smart textiles do not cause embarrassment to its wearer since it does not appear as a medical device.

5.2 Future work

Remote healthcare services and technology are quickly becoming commonplace for healthcare organizations in anywhere in the globe. How very quickly specific countries adopt these technologies varies, however, and the U.S. is among the slowest to realize the widespread benefits these methods can deliver [150].

More than 2,000 studies have been adopted researching telemonitoring, with the large majority showing just how valuable remote healthcare can be. Results have included reducing hospital readmissions by 83 percent, decreasing home nursing visits 66 percent, and lowering overall costs by more than 30 percent. Moreover, patients and caregivers using telehealth technologies have reported increased satisfaction with treatments. These findings have been enough to encourage many countries to integrate remote healthcare with their current healthcare practices [150]

Actually, the body of evidence supporting remote medicine and its findings continues to grow. Huge data continues to mount in favor of remote healthcare. The immense cost savings cannot be ignored and nothing else has worked to reduce these expenses. The improved communication between doctor and patient it facilitates will inevitably make remote medical services and telehealth technologies an integral part of many healthcare organizations [150].

Therefore, advancing ideas in this work some suggestions and recommendations for the future are:

1. Using more sensors woven or knitted into smart textiles to increase the ability to monitor more chronic diseases.
2. Using fibretonics in creating electronic components so that it can be possible to add new electronics to garment such as diodes, solar cells, and microprocessors since textronics cannot have this ability.
3. Incorporating all hardware in the fibretronics in the garment, so that hardware case can be eliminated.
4. Adding Embroidered or knitted keyboards into a smart textile to enable a user to inter some information to smart phones, tablet, or laptop through a Bluetooth module.
5. Reducing the weight of air bag system by using composite-based materials instead of aluminum based materials in creating inflator.
6. Using a spare battery in case of emergency.
7. Using other types of power resources such as solar cells, the body heat of patients, the movement of patients, or micro fuel cells rather than batteries to provide the primary system with necessary power.
8. Training staff to increase the skill of physicians who want to use this system to deliver services in new ways.

9. Furthering the development of the prototype RMS-aiR1 and Emergency Assistance applications beyond mere example inputs and outputs by acquiring the assistance of medical practitioners to provide truly essential medical practice features.

References

[1]. Patel, S. , Hyung P. , Bonato, P. , Chan L. , & Rodgers, M. "A Review of Wearable Sensors and Systems with Application in Rehabilitation." Journal of NeuroEngineering and Rehabilitation 9.1 (2012): 1-2. Print.

[2]. "Population Reference Bureau." Choice Reviews Online 45.03 (2007): 45-1233. Print.

[3]. Yang, L., & Webster, T. "Monitoring Tissue Healing Through Nanosensors." New York: Springer, (2011): 1-2. Print.

[4]. Fass, L. (2007) Patient centric healthcare. 3rd IET Int. Conf. on Medical Electrical Devices & Technology (London, 2–3 October 2007). 3-8. Print

[5]. Feied, C.Ordan, N. , Kanhouwa, M. & Kavanagh, J. (2006) The new world of healthcare work: a Microsoft white paper. UK Focus International Lecture, The Royal Academy of Engineering (7 November 2007):3-7. Print

[6]. Anderson, G. & Johns Hopkins. "Chronic Conditions: Making the Case for Ongoing Care." (November 2007): 5-25. Print.

[7]. Wu, S. and Green, Anthony. Projection of Chronic Illness Prevalence and Cost Inflation. RAND Corporation, (October 2000).4-8. Print

[8]. U.S. Bureau of the Census. Projections of the Total Resident Population by 5-Year Age Groups and Sex with Special Age Categories: Middle Series, 1999 to 2100. (NP-T3) Washington, D.C., (March 2004). 7-10. Print

[9]. Harris-Kojetin L, Sengupta M, Park-Lee E, Valverde R. Long-term care services in the United States: 2013 overview. Hyattsville, MD: National Center for Health Statistics. (2013). 14-20. Print

[10]. Buchan, J., DCouper, I., Tangcharoensathien, V., Thepannya, K., Jaskiewicz, W., Perfilieva, G., and Dolea, C."Early Implementation of whom Recommendations for the Retention of Health Workers in Remote and Rural Areas." Bulletin of the World Health Organization 91.11 (2013): 834-40. Print.

[11]. Health care disparities in rural areas: Selected findings from the 2004 National Healthcare Disparities Report. Agency for Healthcare Research and Quality; (2005), (Editor ed.^eds.). 5-10. print.

[12]. Verulkar, S.M. and Limkar, M. "Real Time Health Monitoring Using GPRS Technology." International Journal of Computer Science and Network (IJCSN) 2277-5420 1.3 (June 2012): 1-2. Print.

[13]. "Wearable Technology." A Creative Commons Attribution-NonCommercial-NoDerivs 3.0 License. (n.d.): n. pag. Web. (Nov. 2013). info@educause.edu..

[14]. Langenhove, L. Van. Smart Textiles for Medicine and Healthcare: Materials, Systems and Applications. Manchester: Textile Institute, (2007). 08-107. Print.

[15]. F.H. Wilhelm, E. Handke and W.T. Roth, ‘Measurement of respiratory and cardiac function by the Lifeshirt: initial assessment of usability and reliability during ambulatory sleep monitoring’, Biological Psychology, vol. 59, pp. 250–251, (2002). Print

[16]. E. Aarts and S. Marzano, the New Everyday – Visions on Ambient Intelligence, 101 Publishers, Rotterdam, the Netherlands, (2003). 115-120. Print

[17]. A. Mazzoldi, D. De Rossi, F. Lorussi, E. P. Scilingo and R. Paradiso, 'Smart Textiles for Wearable Motion Capture Systems', AUTEX Research Journal, vol. 2, no. 4, pp. 199–203, Dec. (2002). Print

[18]. D. De Rossi, F. Carpi, F. Lorussi, A. Mazzoldi, R. Paradiso, E. P. Scilingo, and A. Tognetti, 'Electroactive Fabrics and Wearable Biomonitoring Devices', AUTEX Research Journal, vol. 3, no. 4, pp. 180–185, Dec. (2003). Print

[19]. Krzyszto, G. "The Basic Problems of Textronics." 45th ser. Vol. 12.1 (2004): 1-4. Print.

[20]. McGhee J., Henderson I.A., Korczyński M.J., Kulesza W.: Scientific Metrology, LODART S.A., Łódź, (1998). 155-165. Print

[21]. Berglin, Lena. 2013. Smart Textiles and Wearable Technology - A study of smart textiles in fashion and clothing. A report within the Baltic Fashion Project, published by the Swedish School of Textiles, University of Borås.(2013). 44-55. Print.

[22]. Emil, J., Milenkovic, A., Otto1, C., and Piet C De Groen2. "A Wireless Body Area Network of Intelligent Motion Sensors for Computer Assisted Physical Rehabilitation." Journal of NeuroEngineering and Rehabilitation (2005): 4-6. Print.

[23]. Mikell, G., Automation, Production Systems and Computer-integrated Manufacturing. 3th ed. Upper Saddle River, NJ: Prentice Hall, (2001): 145-155. Print.

[24]. Maarit, K., Konttila, A., Lindgren, P., Winblad, I. and Jämsä.T., "Comparison of Low-complexity Fall Detection Algorithms for Body Attached Accelerometers." Gait & Posture 28.2 (2008): 285-91. Print.

[25]. Toshiyo, T., Yoshimura, T., Sekine, m., and Uchida, M., "Development of a Wearable Airbag for Preventing Fall Related Injuries." (2010): P55. Print.

[26]. Bourke, A.K., O'Brien, J.V., Lyons, G.M.: Evaluation of a threshold-based tri-axial accelerometer fall detection algorithm. Gait & Posture 26(2), 194–199 (2007).Print

[27]. Nait-Charif, H., McKenna, S.J.: Activity summarisation and fall detection in a supportive home environment. In: Proceedings of the 17th International Conference on Pattern

Recognition, ICPR 2004, vol. 4, pp. 323–326 (2004). Print

[28]. "Bluetooth® Breakthrough Awards Finalists Announced." Bluetooth Technology Website. N.p., n.d. Web. (07 Jan. 2015).

[29]. Joe, D., "Bluetooth 4.0: Low Energy." Changing the Way the World Connects (n.d.): 5-10.(210). Print.

[30]. Hamdan, S., Rashid, R., Latiff, M., Fisal, H., Mohd, A., Yusof, K., and Abd Rahim, R., "Lightweight Priority Scheduling Scheme for Smart Home and

Ambient Assisted Living System." International Journal of Digital Information and Wireless Communications 4th ser. (2014): 14-15. Print.

[31]. Soniyapriyadarshini, R. “Case Study on Smart Wearable Sensors and Systems with Application in Rehabilitation.” International Journal of Scientific & Engineering Research 2229-5518 4.5, (May-2013): 5-8. Print

[32]. Bonato, P. "Advances in Wearable TECHNOLOGY for Rehabilitation." 145 (2009): P15. Print.

[33]. Lymberis, A., & De Rossi, D. “Wearable Ehealth Systems for Personalised Health Management: State of the Art and Future Challenges.” Vol. 108. Amsterdam: IOS, (2004). 121-122. Print.

[34]. Van Langenhove, L. “Smart Textiles for Medicine and Healthcare: Materials, Systems and Applications.” Vol. 24. Manchester: Textile Institute, (2007). P (166). Print.

[35]. Pandian, P. Safeer, K., Pragati G., Shakunthala, D., Sundersheshu, B. & Padaki, V. "Wireless Sensor Network for Wearable Physiological Monitoring." Journal of Networks 3.5 (2008): n. P (1-5). Print.

[36]. Anliker, U., Ward, J., Lukowicz, P., Troster, G., Dolveck, F., Baer, M., Keita, F. …E. & Vuskovi, M. "AMON: A Wearable Multiparameter Medical Monitoring and ALERT SYSTEM." IEEE Transactions on Information TECHNOLOGY in Biomedicine 8.4 (2004): 415-27. Print.

[37]. Mora, F.A., Passariello, G., Carrault, G. & Le Pichon, J.P. "Intelligent Patient Monitoring and Management Systems: A Review." IEEE Engineering in Medicine and Biology Magazine 12.4 (1993): 23-33. Print.

[38]. Meingast, M., Roosta, T. & Sastry, S., (2006), Security and Privacy Issues with Health Care Information Technology, In: the 28th IEEE EMBS Annual. 41-74. Print.

[39]. Bonato, P. "Wearable TECHNOLOGY and Its Applications in Physical Medicine and Rehabilitation." (2008): 7-8. Print.

[40]. Varadan, K. Vijay, and Linfeng Chen. "Mobile Wearable Nano-Bio Health monitoring SYSTEMS with Smartphones as Base Stations Vijay K. Varadan and Linfeng." Journal of Nanotechnology in Engineering and Medicine 3.4 (2012): 2-3. Print.

[41]. "Metria™ Informed Health." Metria Informed Health. N.p., (2013). Web. 19 Mar. (2015). <http://www.averydennison.com/en/home/technologies/creative-showcase/metria-wearable-sensor.html>.

[42]. Bianchi F., Redmond S., Narayanan M., & Cerutti, S. Lovell. NH: Barometric pressure and triaxial accelerometry-based falls event detection. IEEE Trans Neural Syst Rehabil Eng (2010), 18:619-627. Print

[43]. Fukaya, K. & Uchida, M.: Protection against impact with the ground using wearable airbags. Ind Health (2008), 46:59-65 Print

[44]. M.D., Everett. "LIFE ALERT ® - Medical Alarm – 24/7 Emergency Response." LIFE ALERT ® - Medical Alarm – 24/7 Emergency Response. N.p., (2014). Web. 19 Mar.(2015). <http://www.lifealert.com/classic.aspx>.

[45]. Giuseppe, R., and GAGGIOL, A., "Rehabilitation as Empowerment: The Role of Advanced Technologies." Applied Technology for Neuro-Psychology Lab., (2010): 2-18. Web. 2015. <http://www.neurovr.org/emerging/book9/chapter_1.pdf>.

[46]. Prytherch, D., Smith, G. B & Schmidt, P., 2006, Calculating Early Warning Scores - a Classroom Comparison of Pen and Paper and Hand-held Computer Methods. Resuscitation, 70, 173-178. Print.

[47]. Jovanov, E. Aleksandar M. Chris O. and Piet C. De Groen. "A Wireless Body Area Network of Intelligent Motion Sensors for Computer Assisted Physical Rehabilitation." Journal of NeuroEngineering and Rehabilitation 2005 0003-2-6 10.1186.1743 (2005): 1-10. Web. 20 Mar. 2015. <http://www.jneuroengrehab.com/content/2/1/6>.

[48]. P., Ponato. "Wearable Sensors and Systems. From Enabling Technology to Clinical Applications." Engineering in Medicine and Biology Magazine, IEEE 29.3 (2010): 25-36. Web. 20 Mar. 2015. <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=5463017>.

[49]. Patel, S. Hyung P. Paolo B. Leighton C., and Mary R. A Review of Wearable Sensors and Systems with Application in Rehabilitation 21st ser. 9.1 (2012): 3-4. Print.

[50]. G., Chao,"An Introduction to IEEE 802.15.4 (zig Bee)." N.p., 2005. Web. 30 Mar. 2015. <http://docweb.khk.be/khk/embedded/ppt/gaochao.pdf>.

[51]. Want R, “iPhone: smarter than the average phone. Pervasive Computing IEEE” 2010, 9:6-9.

[52]. Brown, P., Bovey, J., & Chen, X. “Context-Aware Applications: From the Laboratory to the Marketplace”, IEEE Personal Communications, 4(5), (October 1997), pp. 58-64. Print

[53]. Pascoe, P. “Adding Generic Contextual Capabilities to Wearable Computers”, Digest of Papers. 2nd International Symposium on Wearable Computers, IEEE, October (1998), pp. 92–99. Print.

[54]. Pentland, A. Healthwear: medical technology becomes wearable, Studies in Health Technology and Informatics 118 (2005), 55-65. Print.

[55]. Sung, M., Marci, C. & Pentland, A. Wearable feedback systems for rehabilitation, Journal of Neuro Engineering and Rehabilitation 2 (2005), 17. Print.

[56]. Standaert, D.G. &Young, A.B. Treatment of CNS Neurodegenerative Diseases, in: J.G. Hardman, L.E. Limbird (Eds.), Goodman and Gilman's Pharmacological Basis of Therapeutics, McGraw-Hill, (2001), pp. 549-620. Print

[57]. DeVaul, R., Sung, M., Gips, J., & Pentland, A: MIThril 2003: applications and architecture. Seventh IEEE International Symposium on Wearable Computers 2003, 4-11. Print.

[58] "LifeShirt." Vivonoetics RSS. N.p., 2011. Web. 20 Mar. 2015. <http://vivonoetics.com/products/sensors/lifeshirt/>..

[59]. Toshiyo, T., Sekine, M., Miyoshi, H., Kuwae, Y., & Fujimoto, T. "Wearable Inertia Sensor Application in the Rehabilitation Field." Advances in Science and Technology 85 (2012): 28-32. Print

[60]. De Rossi, D., Lorussi, F., Scilingo, E., Carpi, F., Tognetti, A. & Tesconi, M. Artificial kinesthetic system for telerehabilitation, Studies in Health Technology and Informatics 108 (2004), 209-213.Print

[61]. Tognetti, A., Lorussi, F., Bartalesi, R., Quaglini, S., Tesconi, M., Zupone, G. & De Rossi, D. Wearable kinesthetic system for capturing and classifying upper limb gesture in post-stroke rehabilitation, Journal of Neuroengineering Rehabilitation 2 (1) (2005), P8. Print

[62]. Wade, E. & Asada, H. Cable-free body area network using conductive fabric sheets for advanced humanrobot interaction, Conference of the IEEE Engineering in Medicine and Biology Society 4 (2005), 3530-3533. Print.

[63]. Gibbs, P. & Asada, H. Wearable conductive fiber sensors for multi-axis human joint angle measurements, Journal of Neuroengineering Rehabilitation 2 (1) (2005), 7.

[64]. Sung, M. & Pentland, A: Wearable feedback systems for rehabilitation. J Neuroeng Rehabil 2005, 2:17. P66. Print.

[65]. "Result Filters." National Center for Biotechnology Information. U.S. National Library of Medicine, n.d. Web. 15 Aug. 2014.

[66]."Medical." Art of Technology. N.p., 2011. Web. 20 Mar. 2015. <http://art-of-technology.ch/projects/medical/>

[67]. Mathie M. & Coster, A. Lovell NH, Celler BG, Lord SR, Tiedemann A: A pilot study of long-term monitoring of human movements in the home using accelerometry. J Telemed Telecare 2004, 10:144-151. Print.

[68].Nagaraj, H. & Sazonov, E. "SmartStep: A Fully Integrated, Low-Power Insole Monitor." Electronics (18 June 2014): 2-11. Print.

[69]. "Halo Monitoring - Halo Monitoring and MyHalo Are Now Part of MobileHelp." Halo Monitoring - Halo Monitoring and MyHalo Are Now Part of MobileHelp. N.p., (2014). Web. 20 Mar. (20150. <http://www.halomonitoring.com/>.

[70]. Zhang, T., Wang, J. & Xu, L., et al. Using wearable sensor and NMF algorithm to realize ambulatory fall detection. Lecture Notes in Computer Science, Advances in Natural Computation, 4222:488–491, (2006). Print.

[71]. Tan, A., Nyan, M., Tay, F. & Seah, K. Distinguishing fall activities from normal activities by angular rate characteristics and high speed camera characterization. Medical Engineering and Physics, 28(8): 842–849, (2006). Print.

[72]. Lai, C., Chao, H., Huang, Y. & Park, J. Adaptive body posture analysis using collaborative multi-sensors for elderly falling detection. IEEE Intelligent Systems, (2010).

[73]. Leone, A. A multi-sensor approach for people fall detection in home environment. In ECCV'08, (2008). P3. Print.

[74]. Sung, P., Miaou, S. & Huang, C. A Customized Human Fall Detection System Using Omni-Camera Images and Personal Information. In Transdisciplinary Conference on Distributed Diagnosis and Home Healthcare, (2006). P 69. Print.

[75]. Williams, A., Ganesan, D. & Hanson, A. Aging in place: fall detection and localization in a distributed smart camera network. In MULTIMEDIA'07, (2007). Print.

[76]. António, De Jesus Manue. "Special Issue "Ambient Assisted Living (AAL): Sensors, Architectures and Applications"" Sensors. N.p., May (2014). Web. 21 Mar. (2015). <http://www.mdpi.com/journal/sensors/special_issues/aal>

[77]. "24/7 Medical Alert Monitoring For Seniors | Fall Detection Medical Alarm." 24/7 Medical Alert Monitoring For Seniors | Fall Detection Medical Alarm. N.p., Mar. 2012. Web. 21 Mar. 2015. <http://www.brickhousealert.com/>.

[78]. Stankevich, E., Paramonov, I. & Timofeev, I. "Mobile Phone Sensors in Health Applications." (n.d.): 5-8. Print.

[79]. Bourke, A., Van de Ven. P., Chaya, A., OLaighin G. & Nelson, J: Testing of a long-term fall detection system incorporated into a custom vest for the elderly. Conf Proc IEEE Eng Med Biol Soc (2008), 2008:2844-2847. Print

[80]. Sposaro, F. & Tyson, G: iFall: an Android application for fall monitoring and response. Conf Proc IEEE Eng Med Biol Soc (2009), 2009:6119-6122. Print.

[81]. Dai, J. Bai, X., Yang, Z. , Shen, Z. & Xuan, D. : PerFallD: A pervasive fall detection system using mobile phones. IEEE International Conference on Pervasive Computing and Communications Workshops; Mannheim (2010), 292-297. Print.

[82]. Yavuz, G., Kocak, M., Ergun, G., Alemdar, H., Yalcin, H., Incel, O. & Ersoy, C: A smart phone based fall detector with online location support. International Workshop on Sensing for App Phones; Zurich, Switzerland (2010), 31-35. Print.

[83]. "Low Back Pain Treatmeant with Motivating Functional Movement Therapy." Valedo™Motion (n.d.): n. pag. Print. International Headquarter Hocoma, Switzerland Tel. +41 43 444 22 00 E-mail info@hocoma.com.

[84]. "Valedo®Motion and Valedo®Shape Special Offer." - Hocoma. N.p., 2011. Web. 21 Mar. 2015. <http://www.hocoma.com/en/news-and-events/valedo-insights/valedo-insights-2014-01/valedormotion-and-valedorshape-special-offer/>.

[85]. "Stroke Rehabilitation Exerciser Helps Patients along the Road to Recovery." Reaching Higher (2012): 25-28. Web. <ncenter.medical.philips.com/doclib/enc/fetch>.

[86]. "HOPE: The Stroke Recovery Guide." Stroke.org. Stroke Association, 09 Sept. 2010. Web. 21 Mar. 2015. <http://www.stroke.org/stroke-resources/library/hope-stroke-recovery-guide>.

[87]. Manson, A., Brown, P., O'Sullivan, J., Asselman, P., Buckwell, D. & Lees, A: An ambulatory dyskinesia monitor. J Neurol Neurosurg Psychiatry (2000), 68:196-201.

[88]. "Symposium: Post Stroke Rehabilitation Guideline." The Japanese Journal of Rehabilitation Medicine 41.2 (2004): 81-99. Print.

[89]. Uswatte, G., Foo. W., Olmstead, H. & Lopez K, Holand A, Simms LB: Ambulatory monitoring of arm movement using accelerometry: an objective measure of upper-extremity rehabilitation in persons with chronic stroke. Arch Phys Med Rehabil (2005), 86:1498-1501. Print.

[90]. Van Remoortel, H., Giavedoni, S., Raste, Y., Burtin, C., Louvaris, Z., Gimeno-Santos, E., Langer, D. …& Troosters, T. "Validity of Activity Monitors in HEALTH and Chronic Disease: A Systematic Review." International Journal of BEHAVIORAL Nutrition and Physical Activity 9.1 (2012): 84-95. Print.

[91]. D'Souza, M., Montserrat, R., & Karunanithi, M. "An Indoor Localisation and Motion Monitoring System to Determine Behavioural Activity in Dementia Afflicted Patients in Aged Care." 7(2):e14 (2012): 1-8. Print.

[92]. Haiying W, Huiru Z, Augusto JC, Martin S, Mulvenna M, Carswell W, Wallace J, Jeffers P, Taylor B, McSorley K: Monitoring and analysis of sleep pattern for people with early dementia. Bioinformatics and Biomedicine Workshops (BIBMW), 2010 IEEE International Conference on; 18-18 Dec. 2010 2010, 405-410.

[93]. "A Beginner's Guide to Accelerometers." A Beginner's Guide to Accelerometers. N.p., n.d. Web. 02 Apr. 2015. <http://www.dimensionengineering.com/info/accelerometers>.

[94]. E. R. Post and M. Orth, ‘Smart Fabric, or Washable Computing’, in *Proceedings of the IEEE International Symposium on Wearable Computers*, Cambridge (MA), USA, Oct. 1997, pp. 167–168

[95]. Klingbeil, L. & Wark, T. A wireless sensor network for real-time indoor localisation and motion monitoring, in Proceedings of the 7th international conference on Information processing in sensor networks. (2008); IEEE Computer Society. 39-50. Print.

[96]. Yang, C., & Hsu, Y. "A Review of Accelerometry-Based Wearable Motion Detectors for Physical Activity Monitoring." Sensors 10.8 (2010): 7772-788. Print.

[97]. Cala, Martin. An Intelligent Model-based Process Planning Methodology for Surface Mount Technology. Thesis. Binghamton, 1991. New York: n.p., 1991. Print.

[98]. Gyro Sensors - How They Work and What's Ahead | Gyro Portal | Epson Quartz Crystal Devices." Gyro Sensors - How They Work and What's Ahead | Gyro Portal | Epson Quartz Crystal Devices. N.p., n.d. Web. 02 Apr. 2015. <http://www5.epsondevice.com/en/sensing_device/gyroportal/about.html

[99]. Chandy, John A. "Microcontroller Introduction." (2010)(n.d.): 16-20. Print. Adapted from Prof. Martin Fox’s ECE266 Notes.

[100]. Andy, L., What's a Microcontroller? Student Guide. 3th ed. S.l.: Parallax, (2009). Https://www.parallax.com/sites/default/files/downloads. Web. 21 Mar. 2015.

[101]. Ballagas, R., J. Borchers, M. Rohs, and J.g. Sheridan. "The Smart Phone: A Ubiquitous Input Device." IEEE Pervasive Computing 5.1 (2006): 70-77. Print.

[102]. "Aventyn." *- Android Apps on Google Play*. Aventyn, Dec. 2014. Web. 21 Mar. 2015. <https://play.google.com/store/apps/developer?id=Aventyn>.

[103]. Bambang, P., Pramana, G., Xie Yu, D., Fairman, A., Dicianno, B., and Mccue, M., "IMHere: A Novel MHealth System for Supporting Self-Care in Management of Complex and Chronic Conditions." JMIR Mhealth and Uhealth 1.2 (2013): E10. Print

[104]. Chandler, Puja. "Aventyn® Remote-HF-1 Mobile Heart Failure Clinical Study Sponsored at International Heart Centers." (n.d.): 1-3. Print.

[105]. "Aventyn." Aventyn. Aventyn Inc, Dec. 2013. Web. 21 Mar. 2015. <http://www.aventyn.com/>.

[106]. "SCBC Wireless Health Training Center Open House To Demonstrate Vitalbeat." PRWeb. N.p., Dec. 2013. Web. 21 Mar. 2015. <http://www.prweb.com/releases/2013/3/prweb10563408.htm>.

[107] "Android." Vitalbeat. Http://www.aventyn.com/, Dec. 2014. Web. 21 Mar. 2015. <https://play.google.com/store/apps/details?id=com.aventyn.vital_beat&hl=fr_BE.

[108]. "Android." Smart Help. N.p., Sept. 2012. Web. 21 Mar. 2015. <https://play.google.com/store/apps/details?id=com.dee.smart.help>

[109]. "Bio-Monitoring, Wearable Monitoring, Electronic Textiles & Wearables by Textronics." Textronics News. N.p., n.d. Web. 08 Jan. 2015.

[110]. Amandine, D., and Charpillet, F., To. "Automatic Fall Detection System with a RGB-D Camera Using a Hidden Markov Model." (2013): 1-9. Print.

[111]. Matteo, S., and Chiolerio, A., "Wearable Electronics and Smart Textiles: A Critical Review." Sensors 40711957 (2014): 11957-1992. Print.

[112]. Tamas, H., Wireless ECG/EEG with the MSP430 Microcontroller. Thesis. University of Glasgow, 2009. N.p.: n.p., P85. Print.

[113]. "MSP430x22x2, MSP430x22x4 MIXED SIGNAL MICROCONTROLLER." N.p., July 92007). Web. 21 Mar. 92015). <http://coecsl.ece.illinois.edu/ge423/datasheets/MSP430Ref_Guides/msp430f2272datasheet.>.

[114]. "Amplifiers - Amplifier Solutions." Amplifier Solutions. N.p., 2012. Web. 21 Mar. 2015. <http://www.amplifiersolutions.com/amplifiers/>.

[115]. "Agency Reviews Patent Application Approval Request for "Method and System for Detection and Rejection of Motion/Noise Artifacts in Physiological Measurements"" n.d.: n. pag. (2012) Print.

[116]. Sengupta, U., S. Megahed, A. Homa, and S. Ruth. N.p., (2007). Web. 21 Mar.2015.<http://www10.zetatalk.com/docs/Batteries/Alkaline/Reusable_Alkaline_Battery_From_Rayovac_2007>.

[117]. Goncalves, L.m., J.f. Ribeiro, M.f. Silva, M.m. Silva, and J.h. Correia. "Integrated Solid-state Film Lithium Battery." Procedia Engineering 5 (2010): 778-81. Web. <http://www.sciencedirect.com/science/article/pii/S187770581000771X>.

[118]. "Welcome To Battery University." Basic to Advanced Battery Information from Battery University. N.p., Feb. 2015. Web. 21 Mar. 2015. <http://batteryuniversity.com/>.

[119]. "Electrical Engineering Stack Exchange." Electrical Engineering Stack Exchange. N.p., n.d. Web. 21 Mar. 2015. <http://electronics.stackexchange.com/>.

[120]. "EKG Sensor." Vernier Software & Technology. N.p., (2013). Web. 21 Mar. (2015). <http://www.vernier.com/products/sensors/ekg-bta/>.

[121]. Non-Invasive Tests and Procedures." Non-Invasive Tests and Procedures. N.p., n.d. Web. 20 Mar. 2015. <http://www.heart.org/HEARTORG/Conditions/HeartAttack/SymptomsDiagnosisofHeartAttack/Non-Invasive-Tests-and-Procedures_UCM_303930_Article.jsp>.

[122]. Jo, Letwaitis. "MY Halo Clip Monitoring." N.p., n.d. Web. 22 Mar. 2015. <http://www.slideshare.net/jtlmecca/halo-monitoring>.

[123]. Worsley, G. J., G. A. Tourniaire, K. E. S. Medlock, F. K. Sartain, H. E. Harmer, M. Thatcher, A. M. Horgan, and J. Pritchard. "Continuous Blood Glucose Monitoring with a Thin-Film Optical Sensor." Clinical Chemistry 53.10 (2007): 1820-826. Print.

[124]. Worsley, G. J., G. A. Tourniaire, K. E. S. Medlock, F. K. Sartain, H. E. Harmer, M. Thatcher, A. M. Horgan, and J. Pritchard. "Measurement of Glucose in Blood with a Phenylboronic Acid Optical Sensor." Journal of Diabetes Science and Technology 2.2 (2008): 213-20. Print.

[125]. Shirley, C., Wu, Y., King-Tong Lau, K., Brady, S., Wallace, G., and Diamond, D., "Bio-sensing Textiles - Wearable Chemical Biosensors for Health Monitoring." (2008): 35-36. Print.

[126]. Mark, M., and DeHennis,A., "Performance Characterizationofanabioticand Fluorescent-based Continuous Glucosemonitoringsysteminpatientswithtype1diabetes." Biosensors AndBioelectronics (2014): 227-31. Print.

[127]. Worsley, G. J., G. A. Tourniaire, K. E. S. Medlock, F. K. Sartain, H. E. Harmer, M. Thatcher, A. M. Horgan, and J. Pritchard. "Measurement of Glucose in Blood with a Phenylboronic Acid Optical Sensor." Journal of Diabetes Science and Technology 2.2 (2008): 213-20. Print.

[128]. Jo, Letwaitis. "MY Halo Clip Monitoring." N.p., n.d. Web. 22 Mar. 2015. <http://www.slideshare.net/jtlmecca/halo-monitoring>.

[129]. "ST." Sense & Power and Automotive Products. N.p., 2011. Web. 21 Mar. 2015. <http://www.st.com/web/en/catalog/sense_power>.

[130]. Abhaya, C., "Smart Homes, Intelligent Kitchens, Sensate Floors - Ambient Intelligence." (2008): 11-16. Print.

[131]. Rubén, B., Marco, A., Casas, R., Cirujano, D., and Picking, R., "A Smart Kitchen for Ambient Assisted Living." Sensors 14.1 (2014): 1629-653.Print.

[132]. Yunqi, Z., Liu, X., Wang, Y., and Li, X., "Progress in Preparation and Application of Fabric Electrodes." Journal of Minerals and Materials Characterization and Engineering, 2014, 2, 598-604 (2014): 598-604. Print.

[133]. Tae-Ho, K., Merritt, C., Karaguzel, B., Wilson, J., Member IEEE, Paul Franzon, Senior Member IEEE, Behnam Pourdeyhimi, Edward Grant, Senior Member IEEE, Troy Nagle, and Fellow IEEE. "Sensors on Textile Substrates for Home-Based Healthcare Monitoring." (2006): 5-7. Print.

[134]. Sungmee, P., and Jayaraman, S., "Smart Textiles: Wearable Electronic Systems." MRS Bulletin 28.08 (2003): 585-91. Print.

[135]. Rita, P., Loriga, G., Taccini, N., Gemignani, A., and Ghelarducci, B.,"WEALTHY – a Wearable Healthcare System: New Frontier on E-textile." Journal of Telecommunication and Information Technology (n.d.): 106-13. Print.

[136]. Charging Lithium-Ion Batteries." – Battery University. N.p., n.d. Web. 22 Mar. 2015. <http://batteryuniversity.com/learn/article/charging_lithium_ion_batteries>.

[137]. ATA. "State Medicaid Best Practice Telerehabilitation." N.p., Jan. 2014. Web. 22 Mar. 2015. <http://www.americantelemed.org/docs/default-source/policy/state-medicaid-best-practice---telerehabilitation>.

[138]. "What Is Telemedicine?" What Is Telemedicine? ATA, (2012). Web. 22 Mar. (2015). <http://www.americantelemed.org/about-telemedicine/what-is-telemedicine>.

[139]. ATA. "American Telemedicine Association Current State Policy Projects." American Telemedicine Association Current State Policy Projects (2012): 1-20. Web. 22 Mar. 2015. <http://www.americantelemed.org/>.

[140]. Salomons, w.,Houten, F., and Kals. H., "Review of Research in Feature-based Design." Journal of Manufacturing Systems 12.2 (1993): 113-32. Print

[141]. "What Is Usability?" UsabilityNet: Definition of Usability. N.p., 2003. Web. 22 Mar. 2015. <http://www.usabilitynet.org/management/b_what.htm>.

[142]. Gilsoo, C., "Chapter 1." Smart Clothing: Technology and Applications. Boca Raton, FL: CRC, 2010. 13-14. Print.

[143]. Aruna, A., Usability Testing of Android Applications. Thesis. Us (San Diego State University), 2012. N.p.: n.p., 2013. Web. 22 Mar. 2015. <http://hdl.handle.net/10211.10/3556>.

[144]. Susanna, P., Antonicelli, R., Mazzanti, I., and Gambi, E., "Technological Approaches to RemoteMonitoring of Elderly People in Cardiology: A Usability

Perspective." International Journal of Telemedicine and Applications 104561st ser. 2012 (2012): 1-10. Print.

[145]. "The Smart Help." The Smart Help. N.p., Dec. 2012. Web. 22 Mar. 2015. <https://sites.google.com/site/thesmarthelp/>.

[146]. What Is the Difference between a "Requirement" and a "Feature"?" What Is the Difference between a "Requirement" and a "Feature"? N.p., n.d. Web. 18 Apr. 2015. <http://www.accompa.com/kb/answer.html?answer_id=170>.

[147]. Akashi, T., Takahashi, M., Uejima, K., Masuda, K., Kawamura, T., Ohta, Y., Motoyama, M., Noda, T., Sasagawa, K., Okitsu, T., Takeuchi, S., and Ohta, J., "CMOS Image Sensorbased Implantable Glucose Sensor Using Glucoseresponsive Fluorescent Hydrogel." Biomedical Optical (2014): 4-6. Print.

[148]. "Charging Lithium-Ion Batteries." – Battery University. N.p., n.d. Web. 22 Mar. 2015. <http://batteryuniversity.com/learn/article/charging_lithium_ion_batteries>.

[149]. Hebert, Marilynne A., Barbara Korabek, and Richard E. Scott. "Moving Research into Practice: A Decision Framework for Integrating Home Telehealth into Chronic Illness Care." International Journal of Medical Informatics 75.12 (2006): 786-94. Web. 6 Apr. 2015.

[150]. Global Media Group,. "The Future of Telehealth." The Future of Telehealth. N.p., 2002. Web. 13 Apr. 2015. <http://www.globalmed.com/additional-resources/the-future-of-telehealth.php>.