Development of a Wearable Biosensor (Smart Ring & Cloth)

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Abstract. Biosensors are analytical tools for the analysis of bio-material samples to gain an understanding of their bio-composition, structure and function by converting a biological response into an electrical signal. Wearable Biosensors (WBS) are the biosensors which can be worn on the body. Recent advancements in miniature devices have fostered a dramatic growth of interest of wearable technology. Wearable Biosensors such as Ring Sensor will permit continuous cardiovascular (CV) monitoring in a number of novel settings.Thus Real-time, continuous monitoring would allow not only for emergency detection but also for long-term assessment to establish the right dose and timing of medication. One type of WBS called the Smart Shirt typically relies on the information provided by the wireless, miniature sensors enclosed in shirt. The vital signals and information gathered by the various sensors on the body travels through the smart shirt controller for processing, from these, the computed vital signals are wirelessly transmitted to the monitoring station. WBS could play an important role in the wireless surveillance of people during hazardous operations such as military, firefighting, etc or such sensors could be dispensed during a mass civilian casualty occurrence. WBS's take advantage of handheld units to temporarily store physiological data and then periodically upload that data to a database server via wireless LAN that allow internet connection and used for clinical diagnosis.

Keywords: wearable biosensors, cardiovascular, smart shirt, monitoring station.

1 INTRODUCTION

The research in this paper concentrates in the development of a wearable biosensor (Smart Ring & Cloth). Wearable biosensor are the non-obstructive devices that are the overcome of the limitations of ambulatory technology and provide the fast and furious response to the need of monitoring patients over a long time.

Wearable monitoring devices allows continuous or intermittent monitoring of physiological signals, is critical for the advancement of both the diagnosis as well as treatment of diseases.

Wearable biosensors could play an important role in the wireless surveillance of people during hazardous operations (military, firefighting, etc.).

With this in mind one could define a biosensor as a self-contained integrated device consisting of a biological recognition element (enzyme, antibody, DNA or microorganism) which is interfaced to an analytical device and together respond in a concentration-dependent manner to a given analyte (A substance of interest, to be measured or evaluated).

An electrochemical biosensor is a self-contained integrated device, which is capable of providing specific quantitative or semi-quantitative analytical information using a biological recognition element (biochemical receptor) which is retained in direct spatial contact with an electrochemical transduction element." Simply put, a biosensor is a device which can quantitatively detect an analyte and generate a measurable signal. These devices consist of basically two components: a transducer, and a biological element (Bio-Receptor) able to produce a specific reaction with the substance that it is required to be measured. The biosensor that has attracted the attention of many scientists and researchers is the wearable biosensors.

Wearable biosensors have the potential to become the center piece in healthcare technology by offering their capabilities for low-cost, pervasive and long term bio-signal monitoring. The use of wearable monitoring devices that allow continuous or intermittent monitoring of physiological signal is critical for the advancement of both diagnosis and as well as treatment of diseases. Wearable systems are totally non obtrusive devices that allow physicians to overcome the limitations of ambulatory technology and provide a response to the need for monitoring individuals over weeks or months. They typically depend on wireless, miniature sensors enclosed in a ring or shirt. They take advantage of handheld units to temporary store physiological data. The data stored using these systems are then processed to detect events predictive of possible worsening of the patient's clinical situations or they are explored to access the impact of clinical interventions.

Wearable Biomedical Sensors and Systems (WBSS) are gaining momentum in both academia and industry. IEEE EMBS founded a technical committee on this topic in 2004. Extensive research on the topic has so far shown that signal quality is one of the most important challenges in technical design of a wearable sensor system. Photoplethysmography (PPG) biosensor is one of the main sensors with many applications in monitoring, diagnosis and assessment. The signal quality is specifically critical for wearable PPG-based systems. PPG is a signal obtained by an optical sensor consisting of an emitting LED and a receiving photodiode. Briefly, a light is emitted towards blood vessels and the optical density received by photodiode reflects change of blood flow.

PPG signal is highly susceptible to motion. Overcoming motion artifacts presents one of the most challenging problems. One of the commonly used methods is adaptive noise cancellation using accelerometers as a noise reference signal. A two-dimensional adaptive noise cancellation has been tried using the directional accelerometer data for finger PPG sensor.

The main drawback is addition of another extra hardware for the noise reference. Additionally, using 3-axis accelerometer data is computationally intensive [4] and they reflect motion (as opposed to noise). There is no direct and high correlation between acceleration data from accelerometer and motion artifact in PPG signal.

2 BASIC ELEMENTS OF BIOSENSOR

There are two basic elements required for biosensor operations namely: transducerand biological elements.

2.1TRANSDUCER

A transducer is used to convert (bio) chemical signal resulting from the interaction of the analyte with the bioreceptor into an electronic one. The intensity of generated signal is directly or inversely proportional to the analyte concentration. Electrochemical transducers are often used to develop biosensors. These systems offer some advantages such as low cost, simple design or small dimensions. Biosensors can also be based on gravimetric, calorimetric or optical detection [1]. Four basic types of transducer are used for the construction of biosensors. These types of transducers are electrochemical, optical, thermal and piezoelectric transducers.

2.1.1 Electrochemical

According to its type of operation, electrochemical sensors can be divided in two groups: amperometric and potentiometric. In the case of the former, the response (a current) is a linear function of the concentration of the compound of interest (Analyte). In the later, the response (voltage) is an algorithmic function of the concentration of the analyte.

2.1.2 Optical

Conventional optical transducers were originally used for measurement of dissolved oxygen, carbon dioxide and pH. Several types of photometric behavior are useful for the construction of biosensors namely:
1. Visible/ultraviolet absorption
2. Fluorescence
3. Chemi or bioluminescence
4. Reflection spectroscopy and
5. Laser light scattering

Overall, the principle of measurement is as follows: an immobilized reagent, able to interact with analyte, forms a complex with distinctive optical properties which can hence be monitored by the sensor. Usually, the biological element is immobilized at one end of an optical fibre, with both the excitation and detection components located at the other end. The main principle involves the labeling of an antigen with a substance (like luminal or its derivatives) which, when oxidized, produces visible light, and the labeling of the antibody with a fluorescence compound such that emission from the luminal will excite fluorescence. A similar approach can be used with firefly luciferins.

2.1.3 Thermal

As most biologically-catalized reactions generate heat, the accurate measurement of this heat generation, together with the specificity of the biological element, can be used to construct a biosensor. Basically, this device is a small calorimeter, instrument with highly sensitive thermometer, usually able to detect temperature changes in the range of 0.0001-0.05°C are. This technique can detect analyte concentration as low as 10^5M,

2.1.4 Piezoelectric

Piezoelectric transducers are the smallest of balances. Crystals, such of those of quattz, have no centre of symmetry and produce an electrical signal when stressed mechanically (ie. By applying some pressure on them). A crystal oscillates at a certain frequency, which can be modulated by its environment. When the crystal is coated with some material, the actual frequency depends on the mass of the crystal and coating. The resonant frequency can be measured with great accuracy hence making it possible to calculate the mass of the analyte adsorbed onto the crystal surface. This means, that with these devices, detection limits are down to the pictogram level. Antibodies, enzymes and antigens have been used as biological elements in these devices.

2.2 BIOLOGICAL ELEMENTS

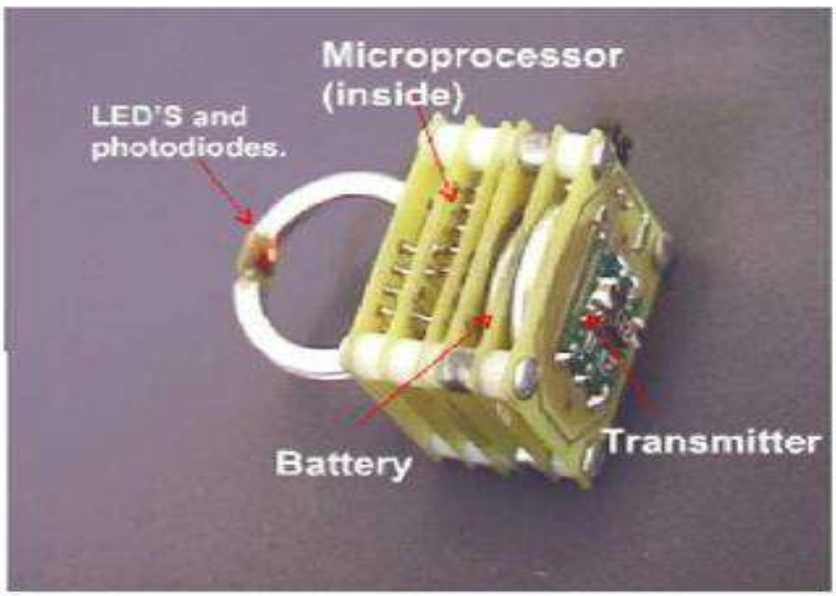
In the case of a biosensor, a biological element is, on the one hand, any biological entity capable of causing a specific reaction or a building with the compound or parameter that one wishes to analyte, and the other hand, is able to generate a signal detectable by a conventional sensor. The most common biological sensors are enzymes, antibodies, tissues, and microorganism, but nucleic acids and receptors have also been used.

3 DEVELOPMENT OF WEARABLE BIOSENSOR

The development of wearable comes with the invention of ring sensor and smart shirt. These were designed to monitor patient without causing any discomfort to the patient.

3.1 Ring Sensor

A finger ring is a unique form of wearable sensors, and probably, the only thing that the majority of people will accept to wear at all times. To monitor a patient 24 hours a day continually, a miniaturized sensor in a ring is a rational design choice. Other personal ornaments and portable instruments, such as ear rings and wrist watches, are not continually worn in daily living. When taking a shower, for example, people remove wrist watches. Bathrooms, however, are one of the most dangerous places in the home. More than 10,000 people, mostly hypertensive andthe elderly, die in bathrooms every year. Miniature ring sensors provide a promising approach to guarantee the monitoring of a patient at all times. Also, a ring configuration provides the anatomical advantage of having transparent skin and tissue at the finger compared with other part of the body so that it is feasible to monitor arterial blood flow at the finger base using an opto electric sensor, Subsequently, a variety of simple cardiac and circulatory disorders may be detected by monitoring arterial blood flow at the finger base.



Figurel. A Ring Sensor

3.2 BASIC PRINCIPLE OF RING SENSOR

Each time the heart muscle contracts, blood is pushed out from the ventricles and a pulse of pressure is transmitted through the circulatory system. This pressure pulse when traveling through the vessels causes vessel wall displacement which is measurable at various points to detect the changes in the blood volume. Generally photo resistors are used for amplification purpose, photo transistors are also used. LED emits light and transmitted through the artery and the resistance of photo resistor is determined by the amount of light reaching it. With each contraction of heart, blood is forced to the extremities and the amount of blood inthe finger increases. It alters the optical density with the result that the light transmission through the finger reduces and the resistance of the photo resistor increases accordingly. The voltage produced by connecting the photo resistor as part of voltage divider circuit varies according to the increase of blood in the finger.

3.3 WORKING PRINCIPLE OF RING SENSOR

The LEDs and PD are placed on the flanks of the finger either reflective or transmittal type can be used. For avoiding motion disturbances quite stable transmittal method is used. Transmittal type has a powerful LED for transmitting light across the finger. This power consumption problem can be solved with a light modulation technique using high-speed devices. Instead of lighting the skiing continuously, the LED is turned ON only for a short time, say 10-100 ns, and the signal is sampled within this period, high frequency, low duty rate modulation is used for preventing skin-burning problem. The motion of the finger can be measured with an optical sensor. This motion detector can be used not only for monitoring the presence of motion but also for cancelling the noise. By using PD-B as a noise reference, a noise cancellation filter can be built to eliminate the noise of PD-A which completes with the noise references used.
The experimental results show that the invalid noise can be discriminated from the valid signal effectively by detecting the high frequency component and the saturation of the signal. Here an adaptive noise cancellation method is used.

3.4 NOISE CANCELATION METHOD

The noise cancelling filter combines two sensor signals; one is the main signal captured by the PD-A and other is the noise reference obtained by the PD-B. The main signal mostly consists of the truce pulsate signal, but it does not contain some noise. If we know the proportion of noise contained in the main signal, we can generate the noise of the same magnitude by attending the noise reference signal and then subtract the noise from the main signal to recover the true pulsate signal.

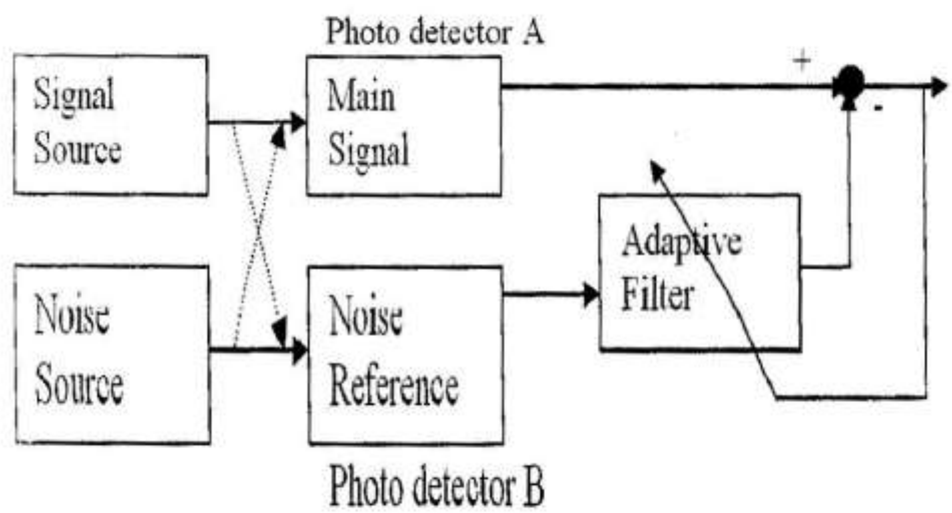


Figure2. Noise Cancellation Mechanism

3.5 DESCRIPTION OF THE COMPONENT OF RING SENSOR

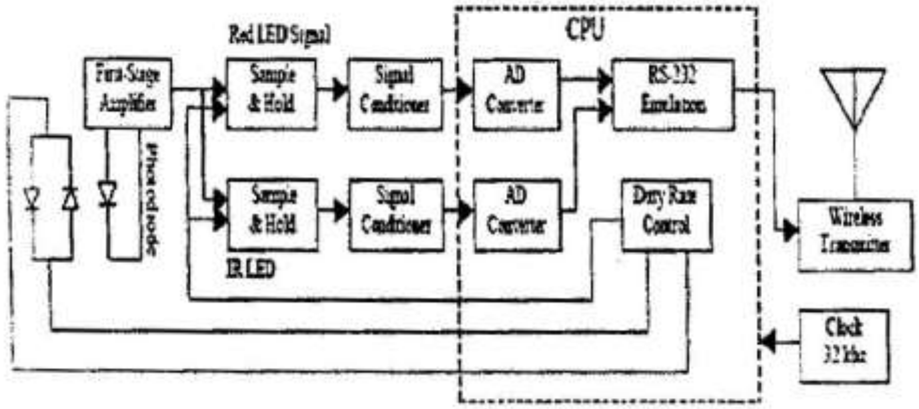


Figure 3 Block Diagram of the Ring Sensor

- ***Package***

The ring sensor consists of a ring with LEDs and a photodiode; a four-layer printed circuit board (PCB) for signal processing, another four-layer PCB for wireless transmission, and two batteries. The signal processing and the wireless transmission were separated to reduce severe interference between the two functions.

Two batteries are sandwiched between the two PCBs to supply the power to the two circuits. It has been found that the two circuits have to be powered separately to eliminate signal interference. I/O connections are distributed on the edge of theboards, providing the connections for power supplies, LEDs and programming. Four screws are used in the four ears on the boards to provide mechanical fixtures for the boards. All the circuitry on the boards is protected by optical epoxy after fabrication and debugging.

- ***LEDsandphotodiode***

One red LED and two infrared LEDs are used as the light sources. The peak wavelength of the red LED is 660 nm, and that of the infrared LEDs is 940 nm. The photodiode has the peak wavelength of 940 nm and the spectral sensitivity ranges from 500 to 1000. The voltage drop of the red LED is 1.6V and that of the infrared LEDs is 1.2V, and two infrared LEDs are connected in serial. We used LEDs in a die form and the diameter is less than 0.1 mm.

- ***First-stage amplifier***

The first stage amplifier must be fast enough to keep in pace with the flickering speed of the LEDs, which means that it must have a high slew rate. On the other hand, it is not desirable if this amplifier consumes a lot of power. We chose an OPA336 surface mount style amplifier from Burr-Brown. This amplifier has 0.03 V/ms of slew rate which is quite high for a 20 mA low power amplifier. Furthermore, this amplifier is designed to be used as a pre-amp for photodiode, which is very essential.

- ***Sample-and-hold circuit***

Since one photodiode is shared by two channels of signal conditioner, the sample-and-hold circuit is necessary to hold the right signal for a brief moment. The two LEDs are alternatively lit and the two bilateral switches are also in synchronization with the LEDs. When the red LED is on, the bilateral switch of the first channel is turned on to make the signal flow into the first channel. When the infrared LED is on, the switch on the second channel is turned on and the signal is held by the sample-and-hold circuit. With these sampling-and-hold channels, the single photodiode can generate two wave forms from the different LEDs at the same time. The sample-and-hold circuit comes with a 1000 pF capacitor which is enough to hold the signal for a while. To reduce the circuit size to that of a real ring, die-form chips are used and the connections were done by wire bonding machine that uses extremely thin gold wire.

- ***Signal conditioner***

The signal conditioning part is composed of filters and amplifiers. Since the signal from the first stage amplifier is weak in a millivolt range, it must be amplified 1000 times. We used a MAX407 operational amplifier from Maxim for the signal conditioner stage.

One of the major reasons for choosing this amplifier is that it consumes extremely low power which is around 1.2 mA per amplifier. In this stage, the slew rate is not an important factor since the frequency of interest at this stage is less than 10 Hz.

This amplifier is also used in a low pass filter circuit. The low pass filter cuts off most of the frequency components higher than 20 Hz. Also there is a simple high pass filter circuit composed of a resistor and a capacitor that removes DC components. We used die-form integrated chips and wire-bonding-style resistors whose size is on the order of 20 by 40 mm.

- ***CPU***

The CPU on the board controls all the operations of the ring from scheduling LEDs to digitally converting acquired analog signals to formatting the signals in an RS-232 form for transmission. Since the CPU is one of the major components of power consumption, it has to be chosen carefully. This CPU has two channels of embedded A/D converter, and 8 channels of digital I/O line. It has 1KB of EPROM which is enough for the code that satisfies task of operation. An advantage of this chip is that it consumes extremely low power (usually less than 40 mA with 32 kHz clock speed) in the normal operation mode and almost no power in the sleep mode. This chip even comes with built-in RS-232 signal generation function. However, we do not use this function since a much higher clock speed is necessary to obtain a satisfactory baud rate for the RS-232 generator, which will result in more power consumption.

- ***RF transmitter***

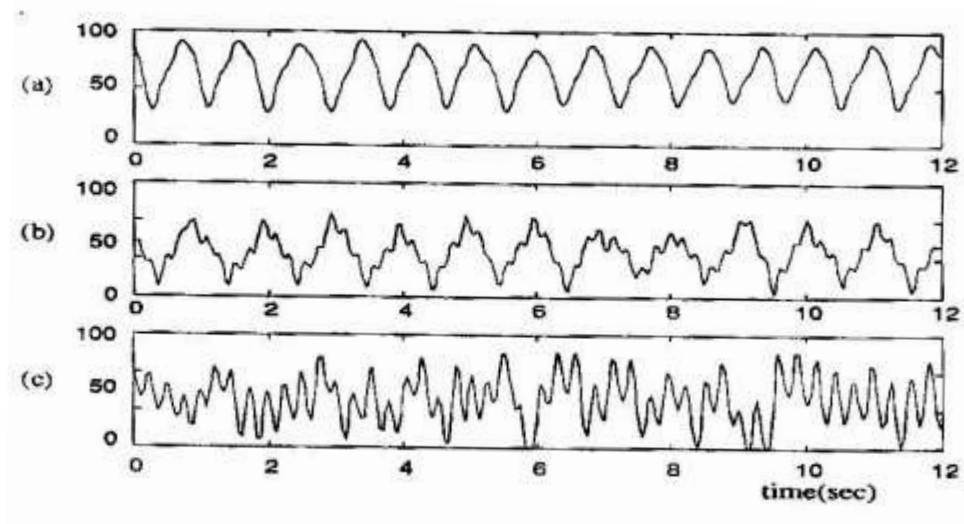
The piecewise constant waves generated at the LED circuit are converted to digital signals by an 8-bit A/D converter and transmitted through an RF wave by the microprocessor. The transmitter is simply an ON/OFF transmitter. In other words, it transmits signal when the input is high, and does not transmit anything when the input is low, hence, the power is consumed only when the input is high. We can save the power by reducing the width of the T bit, which will happen when we use a higher baud rate. Currently we are using 600 and 1200 bps.

3.6DESCRIPTION OF THE RECEIVER

Transmitted waveforms from the ring sensor are received by a home computer, the home computer analyzes the transmitted photoplethysmograms and sends a warning signal to a telenursing center through a telecommunication channel such as internet if any abnormality is detected. The technology of pulse oximetry is implemented on the computer to monitor the patient's pulses and blood oxygen saturation continuously. Although the signal is already filtered and refined by the analog signal conditioner in the ring sensor, it still contains high frequency noises due to ambient light sources and motion artifacts. For example, Fig. 4(a) shows a steady photoplethysmogram without having any artifact, whereas Fig. 4(b) and (c) show the signal contaminated with the influence of ambient light and motion artifact, respectively.

It is clearly seen that the contaminated signal carries high frequency noise even though it already passed through the hardware low pass filter.

In general, human pulse waves are periodic signals with relatively low frequencies and the noises from motion and ambient light are random or high-frequency signals. Considering the nature of these signals, an efficient algorithm has been developed for capturing the original pulse waves from a noisy photoplethysmograph by applying the autocorrelation method. The autocorrelation method is a very powerful tool in catching a periodic signal buried in random signals. Fig. 5 shows the flowchart of the signal processing software. Transmitted signal from the ring sensor first passes through the low pass filter. This filter mainly removes the relatively high frequency noises higher than 5Hz including 60 Hz frequency component of the room light. The filtered signal then goes through the autocorrelation function. With this process, most of the non-periodic components are removed from the original signal and only periodic components of relatively low frequency



will survive as the pulse waves. The autocorrelation function works as a kind of smoothing factor.

Figure 4 Various Signals Detected by the Ring Sensor

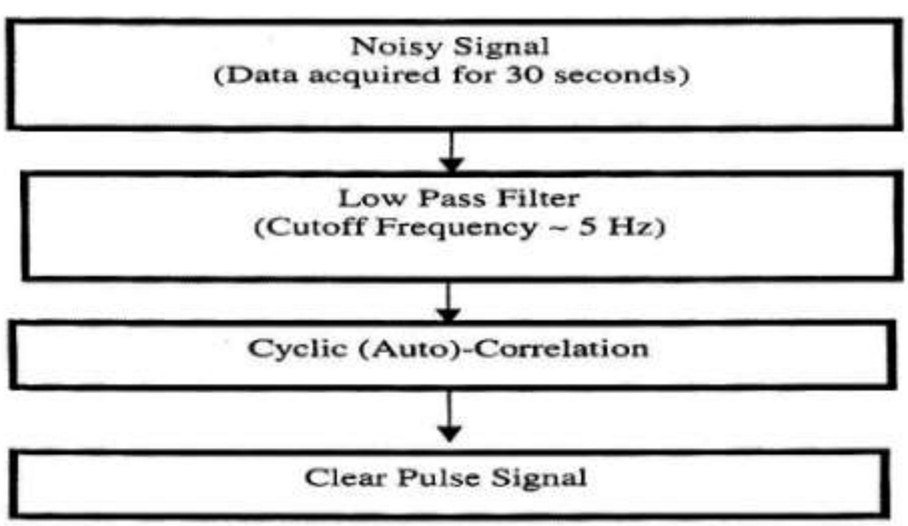


Figure 5 Flowchart of the Signal Processing on the Ring Sensor

3.7 DISTINCTIVE FEATURES OF RING SENSOR

The ring sensor and the 24 hour patient monitoring system have the following distinctive features:

- ***Photoplethysmograpy and pulse oximetryfor diagnosis***

The ring sensor measures and transmits photoplethysmographic signals to the home computer in real time. The photoplethysmograms provide a rich variety of diagnostic information, from which a class of cardiac and circulatory disorders can be detected. For example, a recent investigation has revealed that the likelihood of heart attack can be predicted by examining the rhythm of a plethysmogram over a long period of time. Also, peaks of the acceleration plethysmogram, i.e., the curve obtained by twice differentiating the original plethysmogram, provide important information for arteriosclerosis diagnosis.

Pulse oximetry was also implemented in the ring sensor using two wavelengths of light. A patient's saturated oxygen level is known to provide one of the most fundamental physiological variables needed for diagnosis of cardiovascular disorder such as congestive heart failure.

- ***Continuous monitoring***

Twenty-four hour continuous monitoring can be performed for an extended period of time, i.e., many months or years. This would provide unique physiological data and allow new types of healthcare services, which would be difficult to provide in traditional hospital facilities. Traditional medical exams conducted at hospitals areinevitably snap-shot data or short-term data taken under special conditions, while ring sensors would provide continuous, long-term data of vital signs. Diagnosis can be made based on vast amount of data points, trends, and signal patterns as well as transitory and fugitive symptoms.

By exploiting this continuous monitoring feature, we can develop an innovative health monitoring system that not only diagnoses the patient's health status but also predicts the likelihood of emergency and serious conditions.

- ***Patient's location estimation***

The location of the ring wearer can be roughly estimated by the ring sensor. Since the power of the radio transmitter is very small, the signal reaches only in a limited range. Therefore, the detectable signal range is localized and the possible wearer's position is confined within a local range. In the monitoring system, we use two types of receivers: a global receiver and local receiver. The global receiver has a broader range of reception and covers almost the entire house. A local receiver has a narrower range and is located in multiple places in the house. The objective of using many local receivers is twofold:

- ***To cover the entire house.***No matter where the wearer moves within the house, the monitoring signal must be received.
- ***To locate the ring wearer.***Examining which local receiver within the house receives the incoming signal, one can locate the ring wearer. The location of the patient provides useful information, which would supplement physiological measurements. Combining the patient's location information with physiological data, the patient's conditions can be better understood. For detecting emergency situations, for example, the patient's location within the home is critically important. If the ring wearer stays in a bathroom for more than an hour, or stays in a staircase area for half an hour, the physiological variables must be scrutinized to detect a possible emergency case. Furthermore, the patient's location information can be used for interpreting the physiological variables, since the type of the patient's activity is

related to a particular location within the home, i.e., shower room for taking a shower, bed room for rest, staircase for leg motion. Correlating the location and activity information with vital signs would provide much richer information about the patient's health status than simply observing the vital signs alone.

3.8 APPLICATIONS OF THE RING SENSOR

1) In Catastrophe Detection:

- Wireless supervision of people during hazardous operations Eg: military, fire fighting.
- In an overcrowded emergency department

2) In chronic medical condition

- Monitoring the hypertension in cardiovascular disease.
- Chronic surveillance of abnormal heart failure.

3.7 ADVANTAGES AND DISADVANTAGES OF RING SENSOR

ADVANTAGES

- Continuous monitoring
- Right treatment at the right time at right cost
- Easy wear and take off
- Reducing the health care cost

DISADVANTAGE

- Initial cost is high
- Battery life is less

4 SMART SHIRT (WEARABLE MOTHERBOARD)

The Georgia tech wearable motherboard (GTWM) uses optical fibers to detect bullet wounds and special sensors and interconnects to monitor the body vital signs during combat condition. This GTWM (smart shirt) provides an extremely versatile framework for the incorporation of sensing, monitoring and information processing devices.

The principal advantage of smart shirt is that it provides for the first time a very systematic way of monitoring the vital signs of humans in an unobtrusive manner. The interconnection technology has been used to integrate sensors for monitoring the following vital signs: temperature, heart rate and respiration rate. In addition a microphone can also be attached to transmit the wearer's voice data for monitoring locations. Other sensors can be easily integrated into the structure. The flexible data bus integrated into the structure transmits the information from the suite of the sensors to the multifunction processor known as the Smart shirt controller. This controller in turn processes the signals and transmits them wirelessly to desired locations (eg: doctor's office, hospital and battlefield). The bus also serves to transmit information to the sensors (and hence the weaver) from the external sources, thus making the smart shirt a valuable information infrastructure. By enhancing the quality of life, minimizing "medical" errors, and reducing healthcare costs, the patient-control wearable information infrastructure can play a vital role in realizing the future healthcare system. Miniature ring sensors and smart shirt provide a promising approach to guarantee the monitoring of a patient at all times. It is anticipated that these Wearable Biosensors will bring personalized and affordable healthcare monitoring to the population at large, thus leading to the realization of "Affordable Healthcare" to "Anyone" at "Anyplace" Anytime.

4.1 REQUIREMENTS OF SMART SHIRT

Casualties are associated with combat and sometimes are inevitable. Since medical resources are limited in a combat scenario, there is critical need to make optimum use of available resources to minimize the loss of human life, which has value that is priceless. In a significant departure from the past, the loss of even a single soldier in a war can alter the nation's strategy, making it all important to save life. Similarly on the civilian side, the population is aging and the cost of the health care delivery is expected to increase at a rate faster than it is today. With the decreasing number of doctors in the rural areas, the doctor/patient ratio is in certain instances reaching unacceptable levels for ensuring a basic sense of security when they leave the hospital because they feel cutoff from the continuous watch and care they receive in the hospital. This degree of uncertainty can greatly influence their postoperative recovery. Therefore there is need to continuously monitor such patients and give them the added peace of mind so that the positive psychological impact will speed up the recovery process. Mentally ill patients need to be monitored on a regular basis to gain a better understanding of the relationship between their vital signs and their behavioral patterns so that their treatments can be suitably modified. Such medical monitoring of individuals is critical for the successful practice of telemedicine that is becoming economically viable in the context of advancements in computing and telecommunication, likewise continuous monitoring of astronauts in space, of athletes during practice sessions and competition, of law enforcement personnel and combat soldiers in the line of duty are extremely important.

4.2 SMART SHIRT ARCHITECTURE

The George Tech Wearable Motherboard was woven into a single piece garment (an undershirt) on a weaving machine to fit a 38 - 40 chest. The plastic optical fiber is spirally integrated into the structure during fabric production process without any discontinuities at the armhole.

An interconnection technology was developed to transmit information from (and to) sensors mounted at any location on the body thus creating a flexible bus structure. T-connectors are similar to button clips used in clothing are attached to the fibers that serve as data bus to carry the information from the sensors on the body. The sensors will plug into these connectors and at the other end, similar T-connector will be used to transmit their information for m personal status monitor. By making the sensors detachable from the garments, the versatility of the smart shirt has been significantly improved. Since shapes and sizes of humans will be different, sensors can be positioned on the right locations for all users and without any constraints being imposed by the smart shirt. Smart shirt can be laundered without any damage to the sensors. The interconnection technology has been used to integrate sensors for monitoring the vital signs such as heart rate, temperaturerespiration rate etc. In addition, a microphone has been attached to transmit the weaver's voice data in order to monitor locations. Other sensors can be easily integrated into the structure. The flexible data bus integrated into the structure transmits the information from the sensors to the multifunction processor known as the smart shirt controller. This controller in turn processes the signals and transmits them wirelessly to desired locations (battlefield, hospital, doctor's office etc.)- the bus also serves to transmit to the sensors from the external sources, thus making the smart shirt a valuable information infrastructure.

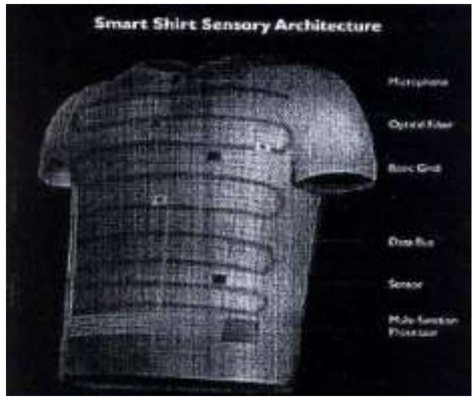


Figure 6 Smart Shirts Sensory Architecture

Generally, smart shirt architecture can be illustrated using a combat soldier who pulls the smart shirt on, attaches the sensors to the smart shirt. The smart shirt functions like a motherboard, with plastic optical fiber and other special fibers woven through the actual fabric of the shirt. To pinpoint the exact location a bullet penetration, a signal is sent from one end of the plastic optical fiber to a receiver at the other end. The emitter and the receiver are connected to a personal status monitor (PSM) worn at the hip level by the soldier. If the light from the emitter does not reach the receiver inside the PSM, it signifies that the smart shirt has been penetrated (ie the soldier has been shot). The signal bounces back to the PSM showing the point of penetration, helping the medical personnel get exact location of the bullet wounds.

The soldier's vital signs such as temperature, heart rate, respiration rate etc are monitored in two ways: through the sensors integrated into the T-shirt and through the sensors on the soldier's body, both of which are connected to the PSM.

Information on the soldier's wound and the condition is immediately transmitted electronically from the PSM to a medical triage unit somewhere near the battlefield. The triage unit then dispatches the right amount of medical personnel to the scene. The George Tech smart shirt can help a physician determine the extent of a soldier's injuries base on the strength of his heart beat and respiratory rate. This information is vital for accessing who needs assistance first the case of numerous casualties.

4.3APPLICATIONS OF SMART SHIRT

- Combat casualty care
- Medical monitoring
- Sports/performance monitoring
- Space experiments
- Fire fighting
- Wearable mobile information infrastructure
- Mission critical/hazardous application

The vital signs information gathered by various sensors on the body travels through the smart shirt controller for processing, from these, the computed vital signs are wirelessly transmitted using the communication information infrastructure in place in that application (eg the firefighters, communication systems, battlefield communication infrastructure, the hospital network) to the monitoring station. There, the back-end data display and management system with a built in knowledge based decision support system and provide the right response to the situation.

4.4IMPACT OF THE SMART SHIRT

The smart shirt will have significant impact on the practice of medicine since it fulfills the critical need for technology that can enhance the quality of life while reducing the health care cost across the continuum of life that is newborns to adults. The smart shirt can contribute to the reduction in health care cost while enhancing the quality of life. For instance, patients could wear the smart shirt at home and be monitored by a monitoring station; thereby removing the hospital stay cost and reducing the overall cost of healthcare and also home setting can contribute to faster recovery. Yet another potential impact of the smart shirt technology is the eventual disappearance of geographical/physical boundaries as barriers for individual seeking the best in healthcare worldwide. The smart shirt technology has the means to provide unobstructed monitoring for individuals and thereby can play a critical role in disease management for the case of large number of individuals at risk for high blood pressure, heart disease, diabetes, chronic bronchitis, and depression by enabling early systematic intervention.

4.5 SMART SHIRT FUTURE TRENDS

By providing platform for a suite of sensors that can be utilized to monitor an individual unobtrusively, Smart shirt technology opens up opportunities to develop adaptive and responsive systems that can think and act based on users condition, environment and stimuli. Thus, the rich vital signs delta steam from the smart shirt can be used to design and experiment real-time feedback mechanism (as part of the smart shirt system) to enhance the quality of care for this individual by providing appropriate and timely medical inspections. Certain individuals are susceptible to anaphylaxis reaction (an allergic reaction) when stung by a bee or spider and need a shot of epinephrine (adrenaline) immediately to prevent above illness or even fatalities. By applying advancement in MEMS (Micro-Electromechanical Systems) technology, a feedback system including a dry delivery system can be integrated into the smart shirt. Of course mechanism to guard against inadvertent administration of dry can be built as part of the control system. Likewise, the smart shirt represents yet another significant milestone in the endeavor to save and enhance the quality of human life through the use advance technologies.

4.6 UPCOMING APPLICATIONS OF WEARABLE BIOSENSORS

- ***Wearable Sensor For Preventing Road Accidents***

Road safety is the most important issue worldwide as it has led to the loss of precious lives. To solve this problem, various sensing techniques has been developed like measuring of vehicles characteristics (steering wheel etc), environmental conditions (fog, dark etc.), driver'sbehavioural pattern. Wearable computers has played a major role in continuous monitoring of the measures for avoiding road accidents and these computers also helps in providing the information to the recovery agencies whenever a road accident takes place. The major cause for the road accidents is the consumption of alcohol by the driver, long driving hours, lack of sleep, drowsiness etc. However, Wearable devices are not the final solution for avoiding road accidents but other measures such as facial expression recognition, speech recognition for estimating the driver's emotional state.

- ***Biosensors for Hypertension***

Hypertension is a disease related to genetic and environmental origins that causes the direct changes on the vasculature that includes smooth muscle cell proliferation. This disease is a multi-factorial and requires long life treatment. In this case, various biosensors are used in the

body that automatically controls the blood pressure as high blood pressure leads to heart attacks. Baroreceptors are the parameters that acts as a wearable biosensor for continuous monitoring of blood pressure as it can change every minute. The function of baroreceptor includes the regulation of blood pressure through various techniques like modification of the sympathetic output, loss of afferent baroceptor stimulus, baroreceptor resetting etc.
due to ageing, diet, atherosclerosis changes the vascular physiology that further changes the sensitivity of baroreceptor which in turn impacts the blood pressure and heart rate control.

- ***For Wound Healing Monitoring***

Wearable biosensors are in demand as they are developed as immune sensors for continuous monitoring of the wound healing technique which is based on Ph change and on the concentration of inflammatory proteins like CRP (C-reactive protein). In this sensing technique, the hydrogels that are used swells whenever there is a change in the surroundings. The detection principle is based on an optical signal, probing refractive index change. The sensor acts as a patch that is an optical sensing system and includes a white LED and a spectrometer for detection.

- ***A utomatic Stress Recognition***

To prevent the chronics physiological stress, the technologies are there to recognize the stress automatically that leads to the introduction of wearable biosensors that are much comfortable to wear. In this stress recognition technique, the loss function of support vector machines is modified to encode an individual's capability to feel more or less stressed. This has been proved in a case study in which skin conductance of employees was monitored in nine call centres during one week of their regular work. This leads to the conclusion that employees in this type of environments are frequently interact with angry and frustrated customers that leads to higher stress levels.

- ***Wearable Sensors to Improve Breathing***

Breathing is a naturally occurring phenomenon. By deep breathing in a slow and regular manner, our heartbeat becomes smooth and regular, the blood pressure becomes normal, which drops the stress hormones and the muscles relaxes. Here, the breathing monitoring system is being developed to improve the breathing techniques, by monitoring thoracic and abdominal movements

5 CONCLUSION

This paper is basically the comprehensive view of most of the applications of wearable biosensors usually used in our daily life. As it consists of various applications such as ring sensor, smart shirt, health care, wound monitoring, preventing road accidents and so on. For every individual's consideration, many applications and techniques of these sensors are introduced.
The ring sensor and smart shirt are effective, comfortable and mobile information infrastructures that can be made to the individual's requirements to take advantage of the advancements in telemedicine and information processing. Wearable systems are totally non-obtrusive devices that allow physicians to overcome the limitations of ambulatory technology and provide a response to the need for monitoring individuals over weeks or months. Just as special-purpose chips and processors can be plugged into a computer motherboard to obtain the required information processing capability, the ring sensor and smart shirt are information infrastructures into which one can "plug in" the desired sensors and devices, thereby creating a system for monitoring vital signs in an efficient and cost effective manner. The future trend in smart shirt has shown that it is possible to develop adaptive and responsive systems that can think and act based on users condition, environment and stimuli. It is possible to develop a biosensor that will not only detect problem but also administer the right solution, a feedback system including a dry delivery system can be integrated into the smart shirt. Of course

mechanism to guard against inadvertent administration of dry can be built as part of the control system.

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