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An Intelligent Wearable Device for Monitoring Sudden Infant Death Syndrome

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ABSTRACT: Sudden Infant Death Syndrome (SIDS) is one of the leading causes of infant death in their sleep. We matched various emerging research fields for the development of Baby Night Watch to increase the safety of infants. Developed as part of the European Texas Instruments Innovation Challenge (TIIC) 2015, this Smart Wearable System (SWS) comprises of the following elements: a Wearable IOT App, a Portal and the H Medical Interface. The Wearable IOT App is a wearable sensor node installed into a chest belt and is capable of measuring the following parameters: body temperature, pulse and breathing levels, and body position. Its collection of details sent to the Gateway using ZigBee technology after limited data processing and is available to the consumer via the H Medical Gui. The unit can activate an alert, noticeable and audible nearby if a vital event occurs, and transmit a warning notification to a mobile application. The Baby Night Watch is an important tool for medical studies as it helps previous physiological data to be visualized and transmitted to various application forms. Experimental tests have shown that the SWS have the potential to identify life-threatening situations for an infant.

Keywords: Internet of Things, Smart Textiles, Smart Wearable System, Sudden Infant Death Syndrome, Syndrome.

INTRODUCTION

Sudden Infant Death Syndrome (SIDS) is one of the leading causes of infant death and was the main motivator for developing a Smart Wearable System (SWS) capable of increasing baby health. The initiative is a mix of emerging technologies such as: wearable devices; smart textiles; embedded systems; wireless communications; online interfaces; and mobile applications intended to track babies while they are asleep. The SWS consists of a Wearable IOT device, a Gateway, and an H Medical Interface. The Wearable IOT Unit, in the shape of a chest harness, is the sensor device and is responsible for monitoring body temperature, pulse and respiration levels, and body position. A collection of criteria is essential to define SIDS situations and to determine the sleep quality.

Throughout night, doctors say the babies should sleep on their back and they should not sleep on their stomach because the children are especially vulnerable to SIDS due to the risk of asphyxiation. We have therefore established an algorithm for continuous monitoring of the infant's sleep position. This algorithm is based on data from an accelerometer and can identify all four possible positions of the infant during the sleep: lying on the back; lying on the side of the infant; lying on the stomach. In fact, irregular breathing behavior and heart rate are the two major signs that SIDS may be about to occur. The average breathing rate for newborns varies from 30 to 60 breaths per minute, 40 breaths per minute for babies, and drops after the first year to 24 to 30 breaths per minute. We used the same 3D accelerometer to measure the breathing rate and built a low-complexity algorithm with low overhead. The heart rate is determined by our method by the use of silk electrodes, knitted in the chest belt and with specialized electronics. The textiles have proven to be an excellent interface for bio-signal sensing, as they are flexible, stretchable and body-conforming (increasing the infant's physical comfort),

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making them an interesting solution for omnipresent, continuous health monitoring. The normal heart rhythm for babies is more than 100 beats per minute. We use a tiny contactless infrared temperature sensor for body temperature control.

SYSTEM DESIGN AND ARCHITECTURE

In this section we will discuss the architecture and the design methodologies that were chosen for the development of the Baby Night Watch.

System Overview:

The Fig. 1 Illustrates the Baby Night Watch model, which shows the numerous elements and communication technologies used. The Wearable IOT Device gathers various types of physiological data and transfers them to the Gateway, which is within the wearable IOT Device's contact range. Such off body contact is rendered over the 2.4 GHz Industrial Science and Medical (ISM) band using the IEEE 802.15.4-plugin wireless transceiver system, SOC CC2530. The gateway software analyzes all of the Wearable IOT Device's information. The Gateway will start buzzing and sending alarms to the Cloud Storage Center when an unexpected event occurred. The cloud holds the data and connects with the H Medical Gui and its related mobile applications. The H Medical Gui allows users to monitor the baby's status, access previously stored details, interpret the information collected, and export information in different file types.

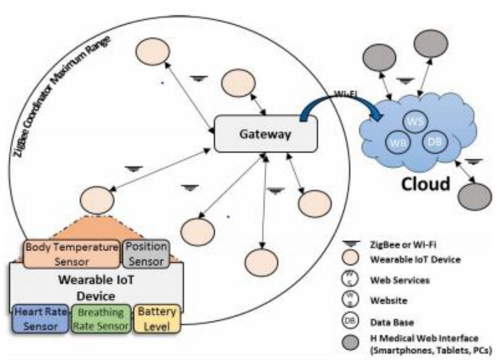

Fig.1: Overview of the Baby Night Watch

Wearable IOT Device:

The Wearable IOT Device [1], [2]acquires the infant's physiological parameters, parses it, and sends the processed data via ZigBee wireless technology[3], [4] to the Gateway using the Texas Instruments CC2530 SOC. The ZigBee platform chosen for this project was the Z-Stack API. GBAN's GB2530-L (CC2530 with small form factor) is used to reduce the size of the package. A PCB has been designed to make it more convenient with shortened measurements (4.3x3.8x0.9 cm). Because the device is battery-operated, it uses a power supply system that includes the TI TPS6060 to optimize energy use and battery life. The final PCB will be shown in Fig. 2. Because the battery voltage can be 3.7V (full battery charge) and the highest voltage that can be read from an ADC pin on the CC2530 SOC is 3.3V (buck-boost supplied voltage), the battery voltage was determined using a resistor divider. A P-MOSFET was used to enable / disable this reading circuit to minimize the power consumption of the Wearable IOT Device.

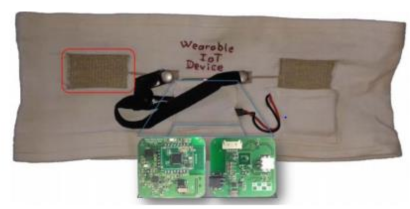

Fig.2: Wearable IOT Device: Illustration of Chest Belt with the Textile Electrodes

Heart Rate Sensor:

A two-electrode sensor[5], [6] design was chosen for the chest band, based on the patent, such textile electrodes were made. A MERZ MBS seamless knitting machine knitted the electrodes using a silver-coated textured Elitex polyamide elastic yarn with low electrical resistance (in the order of tens of Ω/m)wearable chest belt composed of textile electrodes and conductive leads (to connect these elements to the analog frontend). Especially voluminous structure was created for the electrode area, which separates the electrode region from the rest of the fabric and thus increases the interaction between skin and textile electrode. An AD8232 was used to introduce the heart rate stimulation circuitry and the heart rate monitor was configured in chaotic environments to track weak bio potential signals. The

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Instrumentation Amplifier has a 100 V / V gain. With regard to cutoff frequencies, the two-pole high-pass filter block implemented eliminates motion artifacts and drift caused by varying electrode-skin polarization and contact noise while the additional two-pole low-pass, using a SallenKey configuration, reduces line noise and other interference.

Infant's Posture:

The LSM330DLC inertial sensor[7], [8] from STMicroelectronics was used to monitor the location of the infants during night. We didn't use the built-in gyroscope in this phase. The LSM330DLC has three independent acceleration channels, a full-scale dynamically user-selectable range, and a serial interface for SPI / I2C. From the Fig. 3 Infants ' different positions will easily recognize the force exerted to each axis by the earth's gravity. On the basis of the details shown in Fig. 3, we developed a position recognition algorithm. To minimize the small fluctuations that can occur between accelerometer readings, a threshold value was defined that allows the tilt angle in which a position is defined to be controlled. The working principle of the proposed algorithm is therefore: if the reading of the accelerometer in one axis is higher than the value of the threshold and the reading of the other axis is lower than the defined threshold, the position is set by the read values.

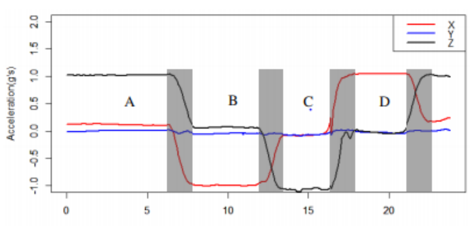

Fig.3: Acceleration Variance on Each Axis over Positions Changes

Breathing Rate sensor:

The same 3D accelerometer [9], [10]mentioned above is used [21]±[24] to calculate the breathing rate. The 3D accelerometer sampling rate was set at 10 Hz as it acquires the data at least ten times greater than the signal's average frequency (60 breaths per minute). Fig. 4 Illustrates the data acquired over a period of one minute on one of the accelerometer axes. Because of the enormous variations of the original signal between each sample (represented by the red line), a smoothing algorithm based on the sliding window technique was used, with a 10-sample window or 1 second window (black line above).

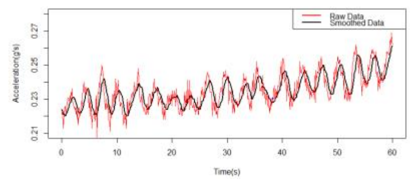

Fig.4: Smoothed and Unsmoothed Data Acquired from the 3D Accelerometer

Body Temperature:

An infrared thermopile sensor[11], [12] (TMP007) was used to measure the infant's body temperature. The TMP007's greatest advantage is that it can calculate the infant's body temperature without any contact with the skin of the infant's. This makes our system less invasive, more relaxed, and we don't have to deal with the problem of inappropriate skin-sensor communication. This system includes a low-power wireless interface (I2C / SMBus). Using the I2C interface, an API was developed and added to the Z-stack API using the bit banging technique.

Gateway:

A Beagle Bone Black[13], [14] is serving as a portal with a Debian Wheezy file enabled. To provide network services, a lighted application with PHP 5.1 was built on it. A protection has been designed and implemented for the Beagle Bone Black, with a buzzer, RGB driven, push-button and CC2530 as shown in Fig. 5. A Serial Port authentication protocol has been used for communicating between the CC2530 and the Beagle Bone. Once an emergency situation is detected, the RGB led and the Buzzer is used to notify the user. Various colors are used to notify users of the event that took place. For linking the Gateway to the router, the wireless USB adapter TL-WN725N is used.

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Fig.5: Gateway: Shield Placement on the Beagle Bone Black

H Medical Web Interface:

Fig. 6 Designed to help the consumer access the information collected / processed from the SWS, the H Medical Web Interface[15] is presented. PHP, SQL, JavaScript, HTML5 and CSS3 built the web interface. The main idea was to develop a full user interface that works independently of the OS on any computer. Some of the processing power was switched to the user's side to develop an interface that runs in a development board like the Beagle Bone Black. Some background PHP applications have been created to collect information from the web interface and deal with the database connection. Additionally, the H Medical Web Interface allows the user to create tables, time-lapse images, and export data to different file types. It also allows new apps to be introduced and several babies to be tracked.

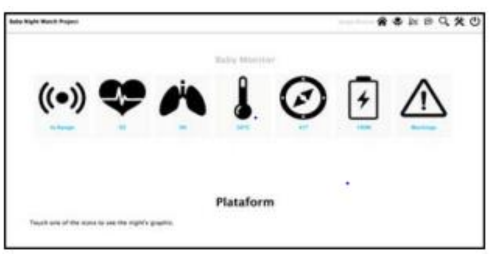

Fig.6: H Medical Web Interface

CONCLUSION

The Baby Night Watch is capable of detecting unexpected events and tracking several clinical factors, making it a valuable diagnostic device for identifying SIDS, and a safe in-house baby monitor. The project proved that a huge number of parameters can be measured with a small amount of hardware, enhancing the infant's user experience and safety. The Wearable IOT Device's data rate is in the range of 35 bytes per minute, which is conveniently enabled by ZigBee. The project is about ensuring baby safety and security. The system uses the Wi-Fi module to make the home space secure. Within a lightweight embedded system, it offers a computer with robust smart features. The challenges faced in developing the device were the more precise communication between different sensors. Only through powerful Wi-Fi communication can it submit accurate information.

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