VOL. 10, NO. 9, MAY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A PERVASIVE PLATFORM FOR MONITORING EXOGENOUS STRESSORS TO FOREWARN THE POSSIBLE OCCURRENCE OF SIDS

Siva Pujitha Mareddy and A. Vimala Juliet
Department of ICE, SRM University, Tamil Nadu, India
E-Mail: msivapoojitha@gmail.com

ABSTRACT

The statement “SIDS is not Predictable but Preventable” emphasizes the need to adopt proactive measures for reducing the risk of Sudden Infant Death Syndrome (SIDS). One of the important strategies for effective management of SIDS risk is to provide a safe environment for infants. By nullifying the important link of external and environmental triggers referred to as exogenous stressors, the risk of SIDS can be reduced. This work presents a scheme for monitoring the exogenous stressors like prone sleeping position, exposure to cigarette smoke, exposure to ammonia gas (built up due to frequent urination in diapers), infant ambient temperature and infants body temperature which are attributed to the possible occurrence of SIDS. These parameters will be monitored through a host of sensors placed around the cradle. We intend to encash on the increasing role of smart phones and tablets as platforms for health interventions. These smart devices are entrusted with the task of receiving, processing, displaying the values of the parameters and producing necessary alarms when required. In order to accomplish the above mentioned task, an application has been developed for the devices working on android platform using android version 4.1. All necessary communication protocols are established between the sensing system and the smart devices through this application.

Keywords: SIDS, exogenous stressors, smart devices, android platform.

1. INTRODUCTION

Infant health and infant care practices are often seen as indicators for the status of health care in any society. Infant care practices pose a lot of challenges that require different levels of interventions at home, hospital and at the community level. These challenges can be effectively surmounted by proper use of technology. One such challenge that has remained elusive for conquer is to understand the mechanisms which lead to Sudden Infant Death Syndrome. SIDS is the sudden death of an infant below one year, which remains unexplained after a thorough case investigation, including review of the medical history, performance of a complete autopsy and examination of the death scene [1]. SIDS may happen to healthy infants without any identifiable physiological preconditions and it usually happens during sleeping without any warning signs, such as crying or suffering [2], also known as crib death. SIDS is the leading category of infant deaths between the ages of two weeks and one year and accounts for one-third of all deaths after the newborn period [3]. The causes of SIDS are unknown, but it is agreed in the medical community that SIDS is a combination of several risk factors. The Triple Risk Model (see Figure 1) is a hypothesis that supports the above statement. It states that SIDS can occur when three risk factors come together: a vulnerable infant, critical development period and exogenous stressors [4].

The first factor in the “triple risk model” is a vulnerable infant which has an underlying defect or abnormality. Factors producing a vulnerable infant include genetic abnormalities of serotonin (5-HT) neurons and pregnancy related factors like low birth weight, preterm birth and maternal smoking [5].

The second factor critical development period encompasses the rapid growth phases that occur during infants first 6 months of life. It is considered to be a time of vast physiological change and instability for an infant system. During this period, many changes occur in homeostatic controls such as sleeping, blood pressure, breathing, heart rate and body temperature [4].

The third factor exogenous stressors are external or environmental challenges that a normal infant can overcome and survive but an already vulnerable infant may not. These stressors include the risk factors such as prone sleep position, overheating, secondhand tobacco smoke exposure, suffocation due to loose and soft bedding. Exogenous risk factors most likely interact with those parts of the nervous system that protect the infant from life-threatening events [4].

The evidence that triple risk model can be used for modeling SIDS prevention strategies is found in a study published in the year 2010 in the Journal of the American Medical Association. It showed that 95% of SIDS cases had one or more of the risk factors, 88% had two or more and 93% had at least one exogenous stressor which could have been eliminated so that it would have reduced the risk of SIDS to a great extent [6]. This information supports the statement that “SIDS is preventable” [5]. Since we cannot prevent both the vulnerability of infant which occurs due to genetic predisposition and the critical development period which is the first 6 months of infants life the only way for us to prevent SIDS is to try and control the exogenous stressors.

Figure-1. The Triple Risk model for SIDS.

2. MONITORING OF EXOGENOUS STRESSORS

SIDS is thought to occur when a vulnerable infant in critical development period experience stress from exogenous stressors. So, proper monitoring of these stressors forms a very important part of effective SIDS prevention strategy. Some of the exogenous stressors that are extensively studied in the literature and considered as major risk factors associated with SIDS include infants exposure to tobacco smoke from parental smoking [8] [9], temperature abnormalities of the baby and its ambience [10], prone sleeping [7] and exposure to ammonia build up due to frequent urination by the infant [11].

The first step in controlling the influence of these exogenous stressors in SIDS is to monitor them effectively. It is imperative to use technology for monitoring these exogenous stressors and alert the parents about the conditions that may result in possible occurrence of SIDS. The fact that most of SIDS death happen during sleep adds an extra dimension in active intervention by the parent. This extra dimension necessitates the use of a health delivery platform that is closely integrated to one's life. The best device that ably suits this requirement is a mobile phone. As people relationship with their mobile phones are often deeply personal, they can reduce the barriers to adoption and also increase the acceptance of phone-based health interventions. Hence, we have designed a system that incorporates the capability of mobile phone for effectively monitoring the exogenous stressors.

3. SYSTEM DESIGN

The designed system comprises of four main units, a) The sensor unit b) The processing unit C) The transmission unit d) The end devices. The block diagram of the system is shown in Figure-2.

The Sensor unit includes the sensors mounted on the crib for monitoring the infant. The processing unit processes the sensor signals and provide necessary interface to alarms and also furnishes data to the Transmission unit in a suitable format. The transmission unit is devoted to the Bluetooth transmission through a commercially available Bluetooth transmission module. Transmitted data can be acquired by any device with Bluetooth capabilities. In order to demonstrate the validity of the system, a smart phone equipped with Android has been used as an end-device. A suitable software (Application) has been developed to show the acquired data. The system also incorporates a local display and alarms at crib for effective alarm and annunciation practice. The snap shot of sensors and other units mounted on crib is shown in Figure-3.

A. Description of sensor unit

Epidemiological studies have shown that the age and season of death are factors strongly correlated with the SIDS rate. The contribution of radioactive heat exchange to SIDS can be very large. A non contact IR temperature sensor MLX 90614 is used for sensing the temperature. MLX 90614 is a medical grade temperature sensor capable of providing an accuracy of ±0.1° C. The sensor has a 17 bit inbuilt ADC which enables the sensor to provide a very high resolution and accuracy. The sensor has an operating range of -20 °C to 120 °C and provides a typical resolution of 0.14 °C. The sensor measures both the ambient temperature and the object's temperature in its Field of View (FOV).Two types of sensors are used in this work, one sensor has a FOV of 10 degrees and another has a FOV of 90 degrees. Two sensors are used to measure the temperature of the infant; one sensor is aligned near the head and other near the body. The outputs of these sensors are fed to the controller unit for further processing.

Detecting the movement of infant helps in preventing infant roll over, to detect and monitor infants movement we use Zilog's ePIR™ Motion Detection Zdots® in this work. It operates in voltage range of 2.7 volts to 3.6 volts consuming a typical current of 3.6 mA and supplying output drive current of 25 mA. In traditional motion detection sensors, critical information is lost about the PIR sensor health and stability. With a direct interface to the PIR sensor, the Zilog's ePIR™ Motion Detection Zdots SBC is able to dynamically monitor the PIR signal to determine when it has stabilized. This significantly reduces the required power-on stabilization time. The ePIR Motion Detection Zdots SBC uses a Fresnel lens to break up the radiated IR energy into multiple concentrated images which are refracted on to the element of the PIR sensor to generate a signal based on the change in energy. This sensor is used to detect the movement of infant and its output is fed to the processing unit.

Commercially available Gas sensors are used in our design. These sensors primarily operate on the principal of change in conductivity due to change in concentration of gasses being measured. The presence of CO_2 and CO because of smoking in the room is measured by using the sensor MGX 802. The sensor has a range of 0PPM – 10000 PPM and can be operated by 5 volts DC supply. An MQ 137 electrochemical sensor is used for sensing the ammonia concentration. MQ137 gas sensor has high sensitivity to Ammonia, also to other organic amine. The sensor has a range of 5PPM - 500 PPM and can be operated by 5 volts DC supply.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

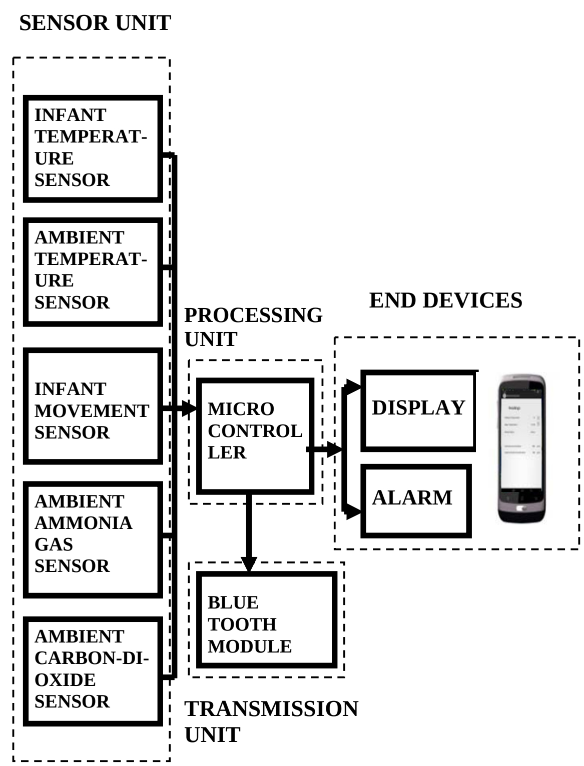

Figure-2. The block diagram of the system design.

B. The processing unit

A PIC 16f877A microcontroller is used as the embedded component. The PIC16F877A is self programming and also features 256 bytes of EEPROM data memory, 2 Comparators, an ICD, 2 capture/compare/PWM functions, 8 channels of 10-bit Analog-to-Digital converter and a synchronous serial port which can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). It has a wide operating voltage range (2.0 - 5.56 volts) and high sink/source current (25mA). All of these features make it an ideal choice for this system.

This microcontroller being the brain of the system is responsible for receiving, processing and transmitting the necessary information. It has to receive the inputs from various sensors, process the information by performing comparison with the predefined threshold values and transmit the information to the end devices. The microcontroller should also take care of necessary interfacing through the Bluetooth module by presenting the data to be transmitted in a manner eligible for transmission by the Bluetooth module. The temperature sensor MLX90614, delivers 0.1°C measurement accuracy in the object temperature range of 36°C - 39°C. It has on-chip amplification, signal processing, and conditioning circuit. We have interfaced the temperature sensor to the PIC16F877 microcontroller using the I2C port on the microcontroller, which supports SM Bus voltage levels. Upon command, the microcontroller reads the temperature sample stored in the RAM of the MLX90614 through the I2C port and then converts and stores it in its RAM as two 8-bit unsigned integers. The processing unit also reads the data from other sensors like the motion sensor and the gas sensors. In regard to sensing the movement the output pin of the ePIR motion sensor goes low whenever it detects movement, the PIC detects these transitions and gives the motion status of the infant. Similarly the gas sensors are also interfaced to the PIC through analog ports available. The threshold values for parameters being monitored are fed to the controller's memory through a program. The controller then compares the value of the variables being monitored in reference to their threshold. Whenever the monitored value crosses the threshold the controller outputs a voltage so that an alarm is raised. The UART module of the PIC is used to transmit the data through the Bluetooth module for further interface with end devices. The PIC also drives a LCD display provisioned for display of the monitored parameters.

C. The transmission unit

The objective of the Bluetooth module is to provide connectivity between the microcontroller and the end devices. The Bluetooth module sends the data from the controller to be read by the application installed in the smart phone or a tablet. The Bluetooth module BlueLINK is used in our work. BlueLINK is a compact Bluetooth Module (5V Serial TTL) that has built-in Voltage regulator and 3V3 to 5V level converter that can be used to interface with 5V Microcontrollers. The module has only 5 pins (Standard 2.54mm berg strip) VCC, GND, TX, RX and RESET. As the BlueLINK module is factory configured in Transparent Mode there is no command required for normal operation. The Bluetooth module operates at a frequency of around 2.4 GHz and can support transmission in the range of 9600 bps-115200 bps. The module is connected to UART module of the PIC 16f877 with a baud rate setting of 9600.

Figure-3. The snap shot of sensors and other units mounted on the crib.

D. The end devices

The end devices convey the status of the exogenous stressors being monitored to the stake holders.

VOL. 10, NO. 9, MAY 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

A buzzer is used to raise alarms when these exogenous stressors cross the predefined threshold values. A 16 *2 LCD module is used to display the value of the parameters being monitored. This LCD module is fixed in the monitoring system mounted on the crib. We use an android enable smart phone as the display device. Similarly an android enabled tablet can also be used to display the parameters being monitored. A tablet will be of much help especially when the system in used in hospitals or tertiary health centre. A smart phone being multifunctional can be manipulated in a variety of way to announce the status of the monitored parameters. Being a personal device it helps in seamless integration of a monitoring system with its stakeholder; the parent in our case.

4. RESULTS AND DISCUSSIONS

A pervasive platform is designed to monitor certain exogenous stressors to reduce the possible risk of SIDS. This device is capable of serving as an effective warning system that can forewarn the possible trigger of SIDS. An application is designed for Android platform to integrate the monitoring system to the parent's mobile phone, turning it into an effective alarm and display device.

This Android Application for monitoring the exogenous stressors is developed to read and display the parameters acquired from the microcontroller such as infant's body temperature, ambient temperature, movement of the infant, ammonia concentration and carbon-di-oxide concentration in an android enabled smart phone or tablet pc through a Bluetooth. Application is developed in the runtime environment of the Dalvik Virtual machine (DVM).The current release of the environment uses Linux kernel version 2.6. The Dalvik VM relies on the Linux kernel for underlying functionality such as threading and low-level memory management. The Android Version for the development of this application is 4.0 (Ice Cream Sandwich).

Bluetooth connectivity being the primary link, the first task of the application is to check whether the Bluetooth adapter in the smart device is enabled or not. The Bluetooth adapter of the smart device is enabled by the application if it is not in the enabled state. The application then starts discovering the remote devices for the connectivity. The Bluetooth connectivity of the smart device is ensured to be enabled as long as the application runs in the background.

In case of failure in the blue tooth connectivity between the cradle and the mobile platform, either because of loss of power or because of any other factor, a notification is announced on the mobile platform. In order to achieve the automatic notification functionality, the application should run in the background without hindering any other activity performed on the smart device. The application is developed in such a way that the process cannot be terminated or interfered with other services which are running simultaneously with this service. If at all the service has to be terminated, it can be done only by the user using the android system in master mode.

When the connection between the monitoring system and smart device is enabled via Bluetooth, the home screen of the application appears in parent's smart phone (see Figure-4(a)) with two options in it a) Baby Readings and b) Alarm. The screen shots of the application being run on a mobile platform are given in Figure-4.

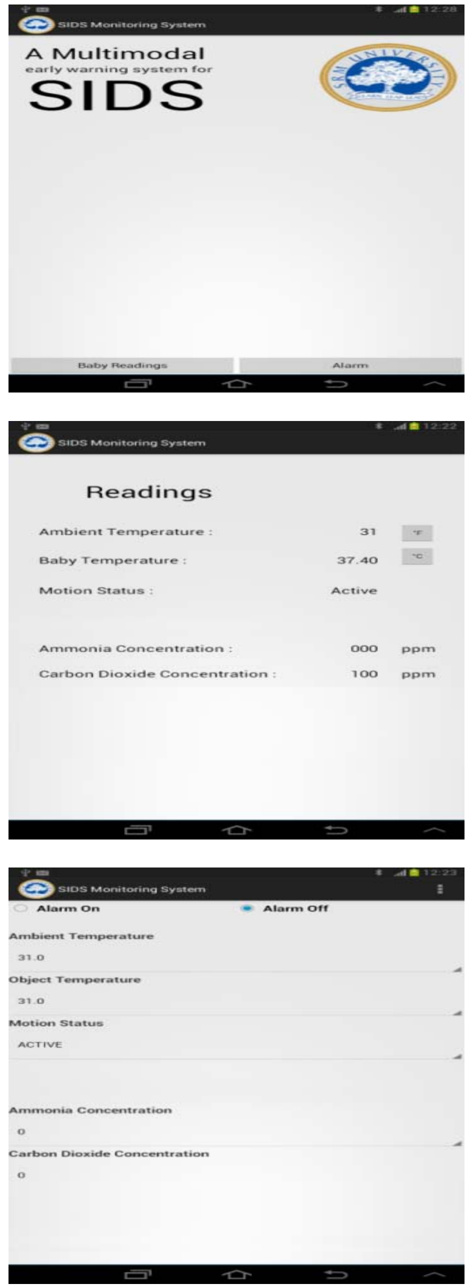

Figure-4. Screen shots of the application designed to monitor exogenous stressors. (a) Home screen of application (Top), (b) Display of parameters (Middle), (c) Alarm functions (Bottom).

Table-1. Default threshold values set for alarm activation.

S. No.	Parameter	Threshold
1	Infant Motion Status	180°
2	Infant body Temperature	36.5°C - 37.4°C
3	Ambient Temperature	35.5°C
4	Ambient CO_2 Concentration	150 ppm
5	Ambient Ammonia Concentration	20 ppm

When the Baby Readings function is selected, the application starts to retrieve the data from the micro controller and displays them in real time; it also activates the alarm as and when necessary. When the data is retrieved from the monitoring system mounted on the crib device, it is converted into the strings and it is displayed in the User-Interface of the mobile phone as depicted in the screen shot (see Figure-4(b)). By selecting the Alarm function, the application also has the option of varying the threshold values of alarm, the screen shot is shown in Figure-4(c). This feature is inbuilt to give the user the flexibility of varying the threshold limits to produce necessary alarms, as per the advice of the health care professional. Under default condition the threshold value set for each parameter being monitored is listed in the Table-1.

Table-2. Important specifications of the communication protocol.

S. No.	Feature	Value/Status
1	Mode of data transfer	Continuous-Asynchronous
2	Baud rate	9600
3	Clock speed	12 Mhz
4	Distance of Bluetooth Transmission without obstruction (Walls)	20 Metres
5	Distance of Bluetooth Transmission with obstruction (Walls)	8 Metres
6	Frequency of communication	2.4 Ghz

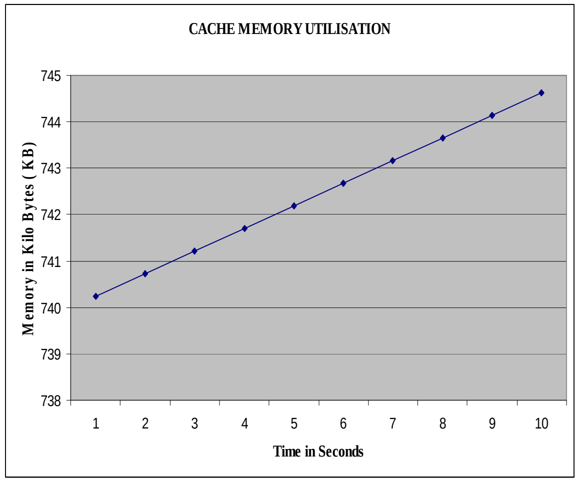

Figure-5. Cache memory utilization over a period of 10 seconds.

With regard to the communication between the monitoring system mounted on the crib and the smart platform, the data is transmitted asynchronously and continuously. The important features of the communication protocols are listed in Table-2.

To make the device suitable for real time application, the application receives data from the monitoring unit for every 250 milliseconds. The application initially occupies a memory of around 740 KB and whenever the value of a parameter being monitored is updated, the cache memory allocation increases by around 16 bytes to 24 bytes. Since the data is updated every 250 milliseconds, the mobile platform has to handle a huge volume of data in a very short span of time.

The chart depicted in Figure-5 clearly indicates the quantum of data that has to be handled by the user device for every second over a period of 10 seconds, this may subsequently lead to stack over flow and result in parsing errors within a short period of time. In order to avoid this error, the application is so designed to cleanse the stack for every cycle of data updation, so as to have a continuous monitoring without any time limitation or limitations in terms of device memory.

CONCLUSIONS

In this work we have used the infiltration of android based smart platforms in the society to design a monitoring system for exogenous stressors to forewarn the possible occurrence of SIDS. The system has targeted application towards various stake holders at different levels like home, hospital and tertiary health care centers. The application developed also has the capability of communicating the exact location of the baby in distress to a particular medical professional by way of geotagging. The address of the baby in distress is sent to a registered medical professional through a text message for expert medical opinion. The use of smart devices has ensured seamless integration with the life style of the user, thereby enhancing the flexibility and ease of operation helping in timely intervention. Inclusion of physiological parameters like oxygen saturation, heart rate and breath rate is suggested for future work making the system multimodal and more effective in aiding the prevention of SIDS.

ACKNOWLEDGMENT

The authors would like to thank Dr. Latha, who provided critical review on the manuscript

REFERENCES

[1] Marian Willinger, L. Stanley James, Charlotte Catz. "Defining the Sudden Infant Death Syndrome (Sids): Deliberations of an Expert Panel Convened by the National Institute of Child Health and Human Development," Pediatric Pathology, 1991, vol. 11(5), pp. 677-684.

[2] J.C. Chiao, L.C. Hsu. Wireless sensor system and method. Google Patents, 2011, US Patent 7,961,093.

[3] B.H. Kim. Sudden infant death syndrome monitor. Google Patents, 1996, US Patent 5, 505, 199.

[4] Filiano J.J, Kinney H.C. "A Perspective on Neuropathologic Findings in Victims of the Sudden Infant Death Syndrome: The Triple-Risk Mode," Biol Neonate, 1994, vol. 65(3-4), pp. 194-197.

[5] Edwin A. Mitchell. "SIDS: past, present and future," Acta Paediatrica, 2009, vol. 98(11), pp. 1712-1719.

[6] Jhodie R. Duncan, David S. Paterson, Jill M. Hoffman, David J. Mokler, Natalia S. Borenstein, Richard A. Belliveau, Henry F. Krous, Elisabeth A. Haas, Christina Stanley, Eugene E. Nattie, Felicia L. Trachtenberg, Hannah C. Kinney, Jill M. Hoffman. "Brainstem Serotonergic Deficiency in Sudden Infant Death Syndrome," JAMA, 2010, vol. 303(5), pp. 430-437.

[7] R.Y. Moon. "SIDS and Other Sleep-Related Infant Deaths: Expansion of Recommendations for a Safe Infant Sleeping Environmen," PEDIATRICS, 2011, vol. 128(5), pp. 1030-1039.

[8] Ola Hafstrom, Joseph Milerad, Kenneth L. Sandberg, Hakan W. Sundell. "Cardiorespiratory effects of nicotine exposure during development. Respiratory Physiology and Neurobiology," 2005, vol. 149(1-3), pp. 325-341.

[9] Murray L Nusbaum, Myron Gordon, Devra Nusbaum, Mary Armao McCarthy, Damon Vasilakisc. "Smoke alarm: a review of the clinical impact of smoking on women," Primary Care Update for OB/GYNS, 2000, vol. 7(5), pp. 207-214.

[10] Andrew James Lyon. Thermoregulation/ Environment. Textbook of Clinical Pediatrics, 2012, 2nd edition, pp. 187-193.

[11] J.W. Tyler. "Cot-death: The ammonia factor," Medical Hypotheses, 1985, vol. 16(1), pp. 61-64.