WEARABLE HEALTH MONITORING SYSTEM FOR BABIES

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ABSTRACT

A mother, with new born baby if needs to be away from baby due to employment, household work, shopping, etc. in that case health status intensifies the stress for mothers. The number of approx. 7,00,000 life births in the world is overshadowed by a large number of infant deaths for various reasons like apparently life threatening events (ALTE) or sudden infants death syndrome (SIDS). Continues monitoring of physiological parameters and notification updates is need of current scenario. Child health status is important aspect and health monitoring system is ultimate solution for that. The new era wearable technologies can be easily adoptable for monitoring systems. Wearable health monitoring system with fully integrated sensors can sense the physiological parameters and accordingly, synchronize the real time data to user application. The mobile application will help user to get real time body temperature and heartbeat count of the baby. It will also provide health and report analysis as well as emergency notifications.


1. INTRODUCTION
The number of infant deaths occur due to improper care taken. Mothers with newly born baby have to stay away from their babies due to various reasons. During such situation, health status of babies is hard to detect. The sudden fall and increase in physiological parameters may cause sudden infants deaths syndrome (SIDS) and may lead to Apparently Life Threatening Events [1]. The aim of the project is to incorporate sensory functions in the wearable hardware making it capable of measuring the physiological parameters (temperature and heart beats) accomplishing the need of continuous health monitoring. The microcontroller based hardware includes integrated sensors for the parameters heart rate, temperature. It will notify for the potential life threatening events, also recognize the development of any disease. The hardware will be able to output the analogue values of sensed data which in turn will be synchronized with cloud server via middleware architecture. Wearable hardware will communicate with middleware architecture through wireless communication. The necessary data processing on the cloud storage will identify the critical conditions as well as will create reports. The final component of the system, i.e. mobile application is featured with real-time notification, alerts in the critical situation. It will show the continuous health status.

![System overview](image)

**Figure 1.1** System overview

2. BACKGROUND FINDINGS

2.1. Information for mothers
Many women often involved in domestic tasks as well as income generating activities. So, woman with new born baby can’t be with baby all the time. They may get caught in extreme case of distress. Parents show some interest to understand various reactions given by children like, what child is trying to communicate, need to know the health status of children when parents are away from them, necessary actions which should be taken when critical condition arrives on child.
2.2. Benchmarks
A list of benchmark has been created to compare the biological signs which sensor system is going to handle. Accordingly, the alert will be given to the end user.

<table>
<thead>
<tr>
<th>Location</th>
<th>Normal Temperature</th>
<th>Fever temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armpit</td>
<td>35.5 - 37.0° C</td>
<td>&gt; 38.5° C</td>
</tr>
<tr>
<td>Skin</td>
<td>29.0 - 34.0° C</td>
<td>&gt; 35.2° C</td>
</tr>
</tbody>
</table>

Table 2.2.2 Heart rate temperature benchmark

<table>
<thead>
<tr>
<th>Age</th>
<th>Normal heart rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>100 – 160 BPM</td>
</tr>
<tr>
<td>0 – 5 Months</td>
<td>90 – 150 BPM</td>
</tr>
<tr>
<td>6 – 12 Months</td>
<td>80 – 140 BPM</td>
</tr>
<tr>
<td>1 – 3 years</td>
<td>80 – 130 BPM</td>
</tr>
</tbody>
</table>

The benchmark stated above are used are used as initial setting in the system.

2.3. Existing system technologies
Advancements in wireless sensor network have introduced some technologies. The early developed smart jacket for neonatal monitoring which uses biosensor belt for monitoring, heart frequency, body movements, heart rate, body temperature. The smart jacket technology was limited for clinical usages. It was embedded with Bluetooth for communication over short range. Health tracker and Health gear are some wearable wireless technologies which monitor baby’s vital signs and notify to parents. Wireless-Crib monitor that uses Breath-Optics technology focuses on respiratory system of body and accordingly sends alerts[2].These technologies haven’t implemented any support system. Digitally enhanced cordless Telecommunication Technology which sends live images and also voices of baby to parent’s display unit. Very little information about vital signs is delivered to parents. The ubiquitous GSM based system comprised of wearable hardware device which senses the physiological parameters of baby and send it to centralized server. The centralized server is for data analysis, storage and intelligent support system. The sensed data is sent to sever where it is checked for abnormal conditions. Accordingly, SMS is sent to parent. In case of critical situation expert system sends alert. The watch designed to monitor health by measuring body temperature and heart rate. It uses infrared sensors which put on forehand and phototransistor to measure heartbeats [3].Sensory vest for babies is one wired technology where the vest includes integrated sensors for heart rate, humidity, temperature, respiration. The vest needs to connect to data acquisition unit. A Bluetooth-enabled in home patient monitoring system implements Bluetooth based architecture which communicates with healthcare center via internet for early detection of Alzheimer’s disease[4].There is hardly any system which measures vital signs of babies and delivers the information to parents in an intelligent way.
3. DESIGN AND IMPLEMENTATION

![Diagram](http://www.iaeme.com/IJCET/index.asp)

**Figure 3.1 Architecture Diagram**

The overall system architecture is shown in figure no. 3.1. This system consists of following basic components:

1. Wearable Hardware device that will detect the biological conditions like temperature of baby and send this analogue data to middleware device.
2. Middleware Device will convert the analogue data to digital and monitor the parameters with conditional programming. It will also synchronize the data with cloud server and this device is can be used as local data storage. For this device, we are implementing an application which will perform tasks such as conditional programming, push notifications in case of emergency.
3. Cloud Server will save the Real time data to the server and provide Real time notification and push notification server to cross platform applications.
4. Mobile Application which is specially designed to provide the real time monitoring of baby. This application will also able to provide detailed analysis and report generation on physical condition of baby.

Basically we are implementing wireless wearable device and there are multiple possibilities of design of this wearable system. We can design this device like a hand glove, locket, vest, socks. We have chosen hand glove over other designs for our suitable size and structure of hardware and parameters like temperature and heart rate can be easily monitored on the hand of baby. Temperature sensor will be along the wrist line and heart rate sensor will sense from tip of finger. In this initial stage we are monitoring only heart rate and temperature of body. We can also monitor other physical parameters like sweat, movement, etc. Now we will see description of all the components and their working.

3.1. Wearable Hardware Device

Wearable hardware is combination of multiple hardware devices such as Aurdino Lilypad, Sensors, Bluetooth Module, Battery. We will discuss every single part one by one.

3.1.1. Lilypad 328

We are using Lilypad 328 ATmega328P main board is Microcontroller and Important device for providing sensor input to the middleware device. It is a basically 5V Board.
3.1.2 Sensors and Data acquisition

This system consists of two hardware sensors which are basically a temperature sensor and heart rate sensor. We will discuss sensors one by one.

3.1.2.1 Temperature Sensor

We are using DS18B20 Digital temperature sensor probe for sensing temperature value from the wrist line. This sensor as 9~12 adjustable resolution and accuracy over the range of -10c to +85c: ±0.5c. Power supply range for the sensor is 3.0V-5.5V. So Temperature sensor provides values to microcontroller and those values are analogue. And send further to middleware device to convert it into digital values.

3.1.2.2 Heart Rate Sensor

After considering the benefits of time saving and trade off with cost in using a commercially available heart rate monitor, it has been estimated that the amount of time saving may not be significant due to the process needed to understand the data format used in these commercially available products before the microcontroller can be programmed to use these data. Additionally, most of the commercially available products are designed for different purpose. A large number of the heart rate monitor watches are designed for sportsman to monitor their heart rate during their training, the ergonomic tends to be adult-orientated and the information is displayed on the sensor unit. This sensor is integrated optical amplifying circuit and noise eliminating circuit heart rate sensor. Sensor can be put on the finger or earlobe, through interconnected line can be connected to the Aurdino. Power supply voltage is 3.3V~5V. And LED wavelength is 609Nm.

3.1.3. Bluetooth Module HC-05

We are using Bluetooth module for transmitting the data wirelessly to middleware device. This module supports Master & Slave mode serial communication and works on frequency 2.4Ghz~ 2.524Ghz. Power supply voltage required is 3.7V-5V.
3.1.4. Battery
As in initial phase we are using a coin cell as a power source to the wearable device. And in upcoming changes we are going to use rechargeable lithium ion battery.

3.2. Middleware Device and Software
Middleware device is used here to provide conditional programming and to store the data locally. Middleware device will be the having Bluetooth connectivity to connect to the wearable device and also which will provide access to the cloud computing for further processing of data. Middleware devices are key factors of this system as they will be connected to wearable device all the time and monitoring the data inputs. According to the data inputs provided by middleware device with Bluetooth connectivity, Middleware application or software will come into play. And this middleware software will use conditional programming on physical parameters like temperature and heart rate. Middleware application or software will also store the input data accordingly. The important work which middleware device will do is, processing the analogue input values and convert them to digital values. And after converting the values into digital format, application will update the values to cloud server as well as local storage.

3.2.1. Middleware Device
This middleware device will be having following characteristics:

1. Mobile: According to the various conditions, the middleware device should be portable and should support mobility.
2. Processing Capacity: The middleware device should have processing capacity to convert the input data to digital format and to implement conditional programming, it should take the decisions accordingly.
3. Wireless connectivity support: With wireless connectivity such as Bluetooth, wearable device will establish connection with middleware device.
4. Internet connectivity support: Middleware device must have internet connectivity get the access to cloud services and to interact with other services in the system architecture such as emergency services.

We are using Raspberry Pi 3 as a middleware device which have all the characteristics as required. We are interfacing Wifi and Bluetooth module with Raspberry pie 3, as Raspberry Pi 3 supports windows 10 for IoT OS. We are implementing Windows 10 application as a middleware software platform. Before Raspberry Pi 3, we used Raspberry Pi 2 with interfaced wifi module and Bluetooth Low energy module.

3.2.2. Middleware Software
Middleware software is backbone of this overall system. Below are few tasks this software will perform:

1. Converting analogue input to digital values with processing the algorithm
2. Conditional signaling and programming
3. Local data storage
4. Cloud data synchronization
5. Emergency Notifications

We are using Windows 10 for IoT as operating system. And we have developed an application on the .net platform with C# language. Here is the program algorithm:
Step1: Reader reads values from sensors and using 10-bit ADC those values are converted into binary.
Step2: Bluetooth Pairing is done for transmission of data with Middleware device Bluetooth listener.
Step3: In the middleware device, after receiving, data is written in text files using writer. And then this data is further used by Middleware application for processing.
Step4: When new data is written into the text file, system receives a function call where this function contains further processing of data. The raw data of temperature and heart rate is converted integer values and then those values are converted to standard values using functions which includes input parameters of hardware.
Step5: While the time of first run of application, information of baby like age of baby, parent contact number and doctor information is acquired from user in the mobile application. This information is used to fetch child physiological benchmarks.
Step6: This standard values are then compared to benchmark values of temperature and heart rate. If then value compared is in safe benchmark limits, then the current data is stored along system time. If the value compared is not in benchmark limits, then the push notification function is called and push notification is activated on user mobile phone application.
Step7: After value comparison, the values are synchronized with Real TimeSych function of cloud computing. Where data is stored into cloud storage.
Step8: Above steps are repeated until the reader is getting data from sensors.

3.3. Cloud Server
With Microsoft azure platform we are implementing real time cloud synchronization and push notification system in case of emergency situations. For push notification service we are using Microsoft Push Notification Service (MPNS). Microsoft azure provides database and other web API services with subscriptions. In order to use this services one need to have account of Azure portal.

Microsoft Stream Analytics provide real-time stream processing in the cloud and we can perform real-time analytics for internet of things solution. Also we are using SQL-based language for rapid development of multiple factors which we are implementing in mobile application like graphs, pie charts, detailed analysis, etc.

3.4. Mobile Application
Mobile application in initial phase, will provide real-time synchronization of physical values such as temperature and heart rate. Mobile application is connected to Microsoft Azure web API for implementing stream processing for real time data synchronization. Mobile application can provide graphs and other statistical data related to baby health. Also there are many implementations we can do with mobile application.

In this system, we have used windows phone for initial phase, as we are completely focusing on windows platform. And later we are planning to make the application available to other mobile OS also.

Push notifications are one of the important factor in mobile application. With conditional programming in the middleware software, push notifications are sent to the mobile.
As for now, we are connecting wearable device to middleware and through middleware, we are getting information on the mobile application. In future scope we are minimizing the centralized ability of the overall system and we are minimizing that limitation to make to more useful in emergency scenarios. So we are planning to connect the wearable device directly to the mobile phone application. We will discuss the scenario here.

Suppose baby and the mother are outside home and travelling. In such scenario, we can minimize the dependency of middleware device and with direct connection between wearable hardware and mobile phone, the mother can easily monitor the physical parameters of the baby in the go.

Another application of mobile application is, we have implemented analysis of physical parameters and the data which is analyzed is useful for doctors to diagnose and they can will come to know the exact condition of the baby. So we think it is more useful for doctors as well as parents.

4. RISK ANALYSIS
The system has some constraint factors. The hardware device is a wearable system. Baby movement couldn’t make it stable all the time which will not definitely fail the system but it could give wrong readings. So, this fact needs to be considered. The design of the wearable device should be done in order to make it stable. The power management is an important factor in wireless sensor network. The device needs power to run the sensors and other hardware circuitry. Device may shut down if running out of battery, so, it could dysfunction the device from collecting the data. As, the wearable device is powered by battery module, power management is a critical factor. The device should be charged from time to time. Internet is the media through which data transfer is done. Data update, data synchronization may not occur due to low internet connectivity. It is recommended to have stable internet connectivity for the system. The sensors integrated in the hardware device may fail to collect data due to improper functioning. Proper checking of sensors is necessary while integrating into hardware. As, the system is comprised of wireless network, stealing the data may happen. Data in wrong hands may lead to risk to health of babies. So, security is another factor to deal.

5. CONCLUSION AND FUTURE PLAN
In this paper, we have introduced a health care monitoring system for babies which can enhance the quality of infant-parent communication. With the help of short range Bluetooth communication middleware hardware receives data from hardware device which further synchronized with cloud server. The data processing is done at cloud server and accordingly push notifications, alerts will be made available to the user on the mobile phone application. The real time service is provided by the system. So, the system can reduce the communication gap between mother and the baby. In future, extra services like medication reminder, health care support, health management can be implemented. Also, additional physiological parameters can be added.

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