Smart SIDS Early Detection System

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***Abstract*—The development and integration of wearable sensor technologies, wireless communication techniques, and a low-energy-consumption microprocessor enable us to build a product with minimal energy needs, allowing us to construct a product with minimal energy needs. These gadgets can assist parents and clinicians in receiving important medical information, allowing for faster and more efficient methods of saving the lives of newborns who are at risk of syndromes such as SIDS [Sudden Infant Death Syndrome]. This project is an attempt to solve the problem by designing a product from the bottom up and attempting to attain industry-standard performance.**

***Index Terms*—SIDS, data-analytics, early detection, monitoring**

I. Introduction

For clinical research and health monitoring, a wide range of wearable devices, sensors, and data capture technologies for processing and decision support has been created in recent years [1]. With the advancement of sensing technologies, various types of wearable sensors have arisen for various reasons.

Wearable sensor systems can be used to monitor health, which is especially important for infants. Because these small, delicate infants can't express pain or comfort in Neonatal Intensive Care Units (NICUs) or at home, clinicians and parents must constantly monitor their vital signs and physiological parameters to determine their exact health conditions. Preterm newborns and severely ill infants admitted to the NICU require continuous monitoring in the event of apnea, hypoglycemia, sepsis or a sepsis-like infection, seizure, arterial hypotonia, bradycardia, hypoxia, hypothermia, acidosis, and even Sudden Infant Death Syndrome difficulties (SIDS) [2].

The traditional approach of monitoring baby health is mainly done under the supervision of professionals and parents. This strategy necessitates devoted human resources, and clinicians and parents may find it difficult to recognise the infant's possible physiological condition.

SIDS or Cot Death, also known as Crib Death, is defined as the death of a newborn under the age of one year. Even after an autopsy, examination, and investigation of the death site, the cause of death remains unknown, and the clinical history is defined as SIDS [3, 4]. Continuous monitoring of newborn children's vital signs is one technique to uncover the reason of abrupt death.

The term "data fusion" refers to a formal framework for expressing the convergence of data from many sources. It is described as the methods and tools for combining data from a variety of sources [5]. Multi-sensor data fusion is a technique for merging input from multiple sensors into a single output. It's a useful tool in a variety of domains, including robotics, decision-making, image processing, sensor networks, and tracking systems. The core notion of data fusion is so widely employed that it may be found in every aspect of our lives, in a variety of contexts, and with a variety of terminology.

Many countries, notably those in Africa, continue to have high infant mortality rates. Infant mortality disparities between high- and low-income nations are still significant. In 2015, the mortality rate for children under the age of five in low-income countries was 76 deaths per 1,000 live births, about 11 times the rate in high-income countries (7 deaths per 1,000 live births)[6]. During their sleep, an unknown event causes death in infants from birth to the first year of life. We want to monitor the infant's vital parameters continuously for 24 hours at a minimal cost and notice any changes in the baby's physical parameters.

Because the suggested system comprises of numerous sensors, we must aggregate data from diverse sensors in order to provide a more precise evaluation. A system for continuous baby health monitoring will be developed, which will detect vital parameters using wearable sensors and alert if potentially life-threatening events occur, as well as recognise the onset of any disease at a cheap cost. Because the sensors used to assess physical properties differ, data fusion is utilised to combine the readings and get an accurate measurement.

II. Related Work

This section describes the current system as well as a past research of similar efforts.

A. Background

The goal of this study is to offer a solution strategy for avoiding abrupt baby death by monitoring biofeedback. This system sensed and detected a baby's health using real-time data collected via sensors. When suspicious data is found, the system will alert the baby's caregivers.

B. Wearable Technology

The definition of a wearable device is a system in which a computing device accepts and processes input to produce a

meaningful output in order to perform a specific function; it is located in a user's personal area, is controlled by the user, and has operational and interaction constancy, i.e., it works all the time and is always accessible. [7]

The development of wearable sensor technology and systems, as well as the evolution of micro- and nanotechnology systems, has resulted in the emergence of many types of wearable sensors with distinct purposes and jobs.

Sensors, wearable materials, smart textiles, actuators, power supplies, wireless communication modules and linkages, control and processing units, a user interface, software, and complex algorithms for data extraction and decision-making may all be included in a wearable sensor system. Wearable sensor systems for health monitoring and measurement were developed to perform specific tasks under stringent medical guidelines and with limited hardware resources. A wearable monitoring system should meet the precise specifications determined by the scientist and/or doctor, be light in weight and size, and have no impact on the user's activity and movement, particularly in the case of newborns. Furthermore, the system should remind users of the need of maintaining their safety by prohibiting any form of health danger [8].

Wearable sensor systems must meet a number of requirements, including being dependable, pleasant, and user-friendly, as well as being easy to wear and remove non-washable elements. Also, provide suitable, easy-to-understand feedback on whether the system's components are working well for both parents and hospital staff. It should meet all of the standards and then some. [9]

The medical sector has benefited the most from wearable technologies in recent years. The most important feature of wearable technologies in the health sector is that they provide continuous monitoring and measurement of an infant's health status, as well as gathering information about the infant in real-time.

C. SIDS Cases in Child Death Review (CDR)

Between 2011 and 2015, there were 2,044 baby fatalities in Washington, according to death certificates. There were 334 newborn deaths in the SUID category during this time period, including 256 deaths from SIDS, 23 deaths from unknown causes, and 55 deaths from ASSB. CDR teams looked into 123 (37%) of these fatalities, while 211 were not. [10, 11]

In 2016, around 1,500 children died from SIDS, 1,200 from unexplained causes, and 900 from unintentional suffocation and strangling in bed. The report breaks down the causes of sudden unexpected infant deaths in 2016. Sudden infant death syndrome accounted for 42 percent of cases, with unknown causes accounting for 34 percent and unintentional suffocation and strangling in bed accounting for the remaining 3 percent (24%). [12] Many suggestions for safe newborn sleep are provided by the American Academy of Pediatrics, including the following: [13]

- Room-sharing rather than bed-sharing
- Keeping soft objects and loose linen out of the crib
- Avoiding smoke exposure during pregnancy and after birth
- Avoiding alcohol and illegal drug use during pregnancy and after birth
- Breastfeeding is recommended

Constant monitoring of infant vital signs provides parents with continuous input in attempt to prevent some of the SIDS risk factors.

D. Vital Signs

Vital signs are the initial measurements of the body's physical parameters, as well as their basic functions and how they work. There are many basic signs that doctors, medical professionals, and health care providers must monitor in order to provide information about a person's health status. The four main vital signs measurements in most medical settings are body temperature, heart rate, respiration rate, and blood pressure, and they all play an important role in determining a person's health status. Doctors utilise a variety of medical devices to reflect an individual's overall health condition, such as a thermometer to check fever or body temperature, a blood pressure monitor to measure blood pressure, and a heart rate monitor to assess heart rate.The goal of this wearable system project is to offer parents with accurate, convenient, and real-time updates on their babies' vital signs.

E. Body Heat

Temperature is the most important vital indicator to monitor in order to maintain the baby's safety and well-being. Many parents have had sleepless nights as a result of their newborns' sudden development of fever, which can be triggered by a variety of variables including system illness and physical environment. Infants' immune systems are not fully formed. Additionally, heat and hypothermia can both contribute to SIDS.

Human age and the location in the body where the temperature was measured, human activity, day light or dark time, as well as wellness or illness, all influence the temperature reading. Nonetheless, the average temperature of a baby is between 36 and 38 degrees Celsius, according to popular belief.

There are a variety of methods for measuring and monitoring a body's temperature, including the traditional method of using a thermometer, which is inconvenient and ineffective for long-term temperature monitoring, which is required for baby health monitoring on a continuous basis. Various types of electrical equipment can be used to keep track of temperature on a continuous basis.

F. Pulse Rate

The heart is the most powerful muscle in the body, pumping blood and distributing oxygen throughout the body. Regardless of the fact that the heart rate measurement is just the size of a person's fist, it is critical for giving cardiovascular fitness to infants.

Heart rate, also known as heartbeat or heart pulse, is the rate at which the heart pulses and represents the number of times the heart beats. It is measured by the number of heartbeats per unit of time, which is usually measured in beats per minute (bpm). It is a critical physical characteristic since it regulates the entire body. It can be taken or measured from a variety of locations on the body where an artery is close to the surface and a pulse is felt.

Using the palpation method, the most popular areas to monitor heart rate are the wrist (radial artery) and the neck (carotid artery). The heart rate can change with age, disease, or the basic needs of the body, such as the need to absorb oxygen and expel carbon dioxide. The resting heart rate of a newborn is between 80 to 160 beats per minute [14].

Bradycardia is a sluggish heart rate of less than 80 beats per minute. At rest, tachycardia is defined as a heart rate of more than 160 beats per minute.

G. Body Position

Although body position is not considered a crucial indication in and of itself, it does play a significant influence in a person's overall health. Babies spend the majority of their time in their cribs and sleep for far longer periods of time than adults. The babies lack complete control over their bodies. They may be harmed if a tragic event such as SIDS occurs due to their sleeping position. The proper body position can have a direct impact on other vital signs like respiration.

A recent WebMD article sponsored by Johnson's baby put the baby's position at the top of a list of 10 strategies to help prevent SIDS. [15] According to the CDC (Center for Disease Control), SIDS-related mortality have fallen by more than half since SIDS prevention measures were implemented [16].

Knowing the baby's posture is critical to success because the project's major purpose is to help and aid in the prevention of SIDS. Different ways can be used to keep track of the baby's position.

H. Dataset/Literature Survey

Our work involved using data from CDC concerning the stats related to SIDS and helped us understand the various biological and genetic factors also behind SIDS. Following were the main highlights from that data: In the United States, roughly 3,400 sudden unexpected infant deaths (SUID) occur each year. These deaths occur in infants under the age of one year and have no evident cause. The following are the three most usually reported types of SUID:

- Sudden infant death syndrome (SIDS)
- The reason behind is unknown.
- Suffocation and strangulation by accident in bed.

In 2019, around 1,250 children died as a result of SIDS, 1,180 children died of unexplained causes, and 960 children died as a result of unintentional suffocation and strangling in bed.

III. Proposed Design

Because project design is the most significant stage in the development process of any project, it takes a long period in the whole project life cycle.

The system is made up of both hardware and software elements. An embedded system is used in the hardware, and the Arduino IDE, Google FireBase, and Colab are used in the software.

The Arduino microcontroller will receive the sensing signals. The data is delivered to the Google FireBase via an

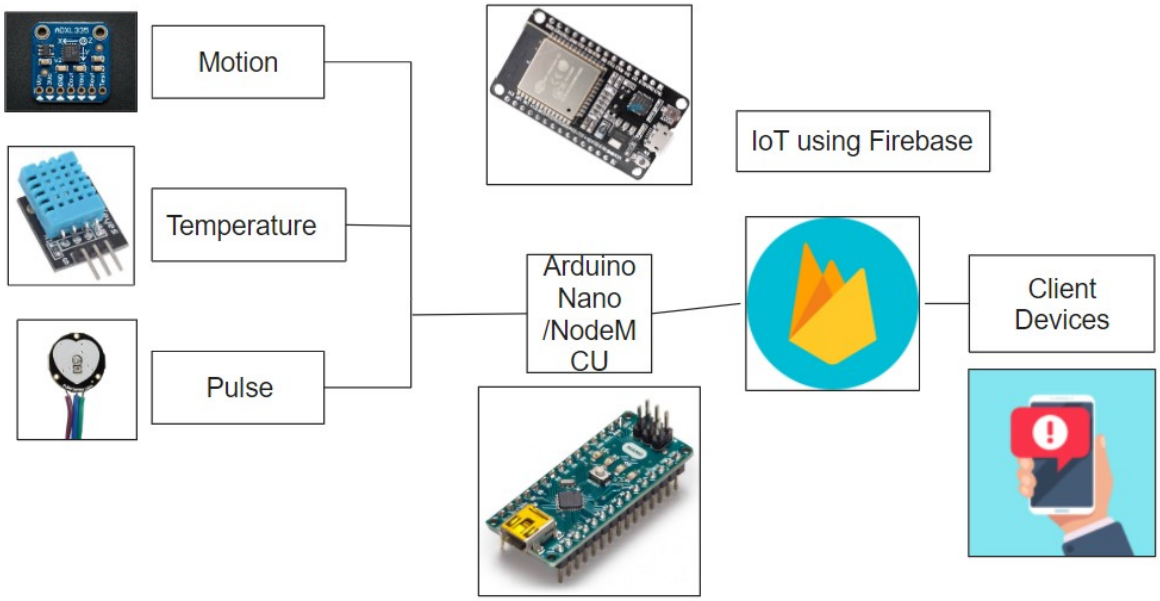

Fig. 1. System Block Diagram

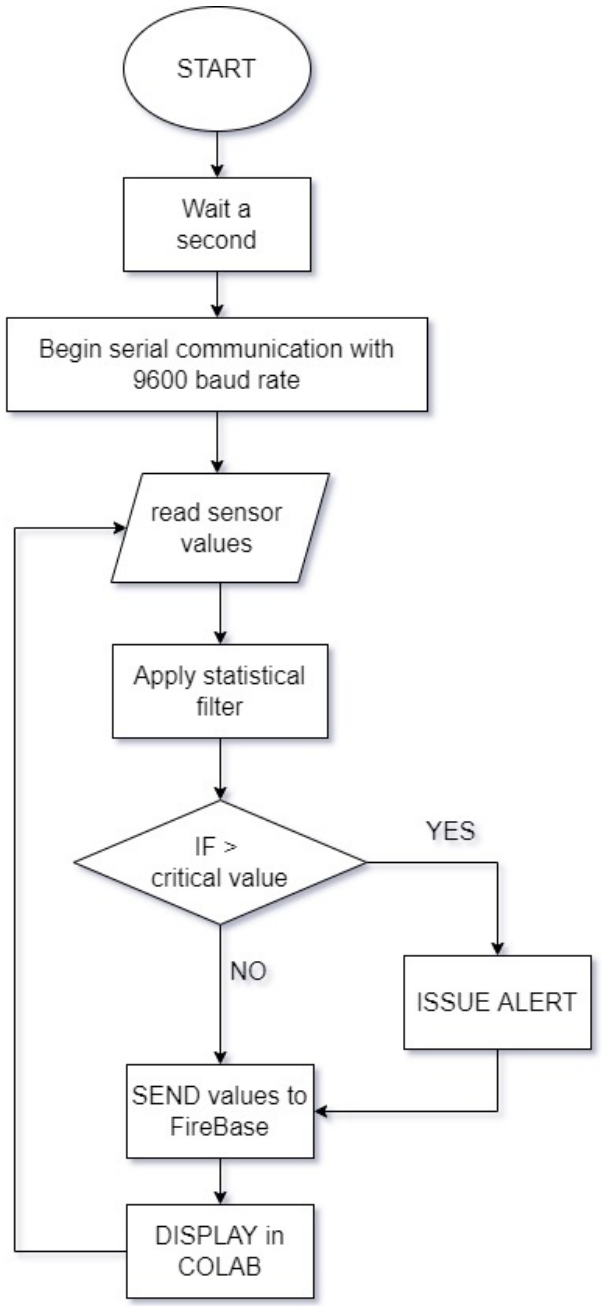

Fig. 2. System Flow Chart

esp8266 in the transmitting section. The appropriate alarm is triggered if the readings exceed a crucial range. Figure 1 shows the temperature sensor, pulse sensor, and acceleration sensor, as well as the microcontroller.

A. System Flow Chart

A pictorial representation of the actions and decisions required to perform newborn vital sign monitoring, as shown in Figure 2. The flow chart for the newborn monitoring system procedure is shown below.

IV. Experimentation and results

The programme was ran after wiring and writing the code. The performance features of the esp8266 WI-FI module and Arduino MCU-based temperature sensor, heart rate sensor, and 3-axis accelerometer and gyroscope were tested in two scenarios. The first test involved dealing directly with sensor readings. The sensor data was sent through a python code that returned a probability of SIDS and fuse sensor data in the second test. As a result, other users' and decision-making have become more accurate and reliable. The readings from each sensor are displayed on the Google Colab.

A. Google FireBase and Colab

This design makes use of Firebase Realtime Database (Firebase), a cloud-based NoSQL database that allows users to sync and save data in real-time. Users collaborate across devices and construct serverless apps) to display the various sensor data received from the mobile phone by the receivers. Both public and private data can be accessed. Data can be seen in a web browser or through a mobile application by authorised users using a user id and password. The data that FireBase has received can be evaluated and represented graphically.

Three fields are used in this project. The body temperature is displayed in field 1, heart rates are displayed in field 2, and a position is displayed in field 3.

B. Statistical Filter

A statistical algorithm is used to these sensor values (written in python). This algorithm aids in the prediction of SIDS in babies and the provision of appropriate care.

The algorithm was created using data and statistics from the Centers for Disease Control and Prevention's "Division of Reproductive Health, National Center for Chronic Disease Prevention and Health Promotion." The National Center for Health Statistics provides public-use data files for independent research and studies, as well as annual mortality statistics.

There are several datasets available.

- Birth data files.
- Period linked birth-infant death data files.
- Birth cohort linked birth-infant death data files.
- Mortality multiple cause data files.
- Fetal death data files.

The following variables are taken into account while predicting SIDS in our project:

- **Angle:** SIDs are more likely to occur if a newborn sleeps on his or her stomach or side rather than on his or her back. At the age of two to three months, the chances are better.
- **Child Age:** SIDs are more common in children under the age of one. When sharing a bed with parents or siblings during the first three months, the danger is greatest. As a result, the American Academy of Pediatrics advocates "room sharing without bed sharing," claiming that it can reduce the incidence of SIDs by up to 50
- **Race:** In 2009, death rates for Asian/Pacific Islanders ranged from 20.3 per 100,000 live births to 119.2 per

100,000 live births for Native Americans/Alaska Natives. When compared to the general population of the United States, African American infants had a 24 percent higher risk of SIDS-related death and a 2.5 higher incidence of SIDS than Caucasian infants.

- **Gender:** In each sex, there is a 50 percent male excess in SIDS per 1000 live births.
- **Parental Behaviour:** The consumption of alcoholic beverages by parents has been associated to SIDS, according to one study. SIDs are more common in children whose mothers have smoked during pregnancy. Between not smoking and smoking one cigarette per day, the risk of death doubles. Nicotine derivatives induce neurodevelopmental problems.
- **Room Temperature:** The risk is also increased by an abnormally high room temperature.
- **Baby Condition:** A substantial risk factor is low birth weight.

Google Research's Colaboratory, or "Colab" for short, is a product. Colab is a web-based Python editor that allows anyone to write and run arbitrary Python code. It's notably useful for machine learning, data analysis, and education.

The authors of this study used Google Colab to run a statistical algorithm and display the likelihood of SIDS in babies. It can also be used to show all of the sensor values in FireBase's database.

V. Conclusion and Future Work

A. Conclusion

The system is designed to detect a problem of sudden death and assist parents in monitoring the newborn vital sign data using low-cost hardware and software. The results of this study were obtained using the ESP32 module, which conditioned and transmitted a baby's vital signs to a cloud-hosted NoSQL database via an in-built ESP-8266 WI-FI module. Any browser can easily display vital signs. The buzzard alarm will sound (optionally), and an emergency SMS will be sent to the emergency contact in the prototype.

B. Future Work

This wearable system was created for a low cost and with only a few sensors; however, the number of sensors should be increased in the future. Blood Pressure, Respiratory Rate, and other parameters are examples of these. The vital signs measurements must be shared with a nearby hospital, and a database for each child must be created and saved on a hospital server to simplify baby health monitoring at an early age. Additionally, the GPS technique may be used to immediately handle a baby's location in an emergency case to send an ambulance even if no one is near the baby.

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