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A Secure and Smart Framework for Monitoring Infants' Safety

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***Abstract*— In this paper, we propose an affordable secure and smart framework which utilizes sensors to measure both infants and surrounding conditions, detects abnormal events of *Sudden Unexpected Infant Deaths* (SUID), and triggers to alarm the parents when the infants need special attention. The framework also provides crucial information to the healthcare providers to make more informed decision, and the collected data can be transferred to the cloud for further analysis with anonymized babies' health information, complying with the United States' *Health Information Portability and Accountability Act* (HIPAA) guidelines.**

Keywords—Baby Monitor, Weable Sensor, SUID, Data anonymization, Anomaly detection

I. INTRODUCTION

Unfortunately, there has not been much success in reducing the number of Sudden Unexpected Infant Deaths (SUID) even in the United States since 2000 [1]. As depicted in Fig. 1, the SUID rate remains almost unchanged from 2005 to 2015, mainly due to the increase of the number of Unknown Cases (UC) and Accidental Suffocation and Strangulation in Bed (ASSB). In order to reduce the SUID rate, baby monitors are available in the market; however, they have limited functionality, are usually rather expensive, and require a smartphone with Internet access, costs of which are not affordable for many low-income families in underdeveloped communities. In addition, none of them are designed for secure data collection with privacy consideration. Moreover, they are not considering baby's surrounding condition which may give important clues for finding cause of SUID.

II. THE PROPOSED SOLUTION

In this paper, we aim to develop an affordable secure and smart framework which utilizes sensors to measure both infants and surrounding conditions to detect abnormal SUID events. On such events, it automatically alarms the parents when the infant needs special attention or extra care while parents are not necessarily aware (e.g., parents asleep). The framework also provides crucial information to the healthcare provider to make more educated decision. Our new framework provides multiple connection options such as phone line and WIFI. The framework is portable so the collected data can be delivered to the healthcare provider and can be transferred to the cloud for further analysis. Furthermore, the framework will anonymize babies' health information, complying with the United States' Health Information Portability and Accountability Act (HIPAA) guidelines (protecting the privacy of the patients), and securely upload the health data to the cloud to be analyzed by end users (e.g., researchers, doctors, parents, etc.).

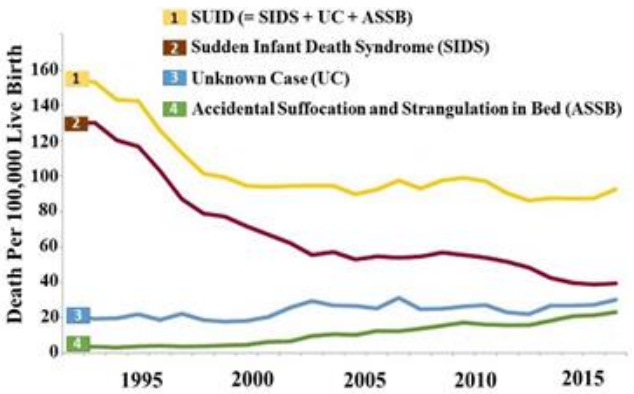

Fig. 1. *Sudden Unexpected Infant Death Rate in the United State [1]*

III. THE CORE RESEARCH

Specifically, we have the following research directions:

Data collection. We collect data directly from infants using wearable device and we collect data from their surroundings through sensors. Special trainings will be in place to ensure the framework is used appropriately.

Sensor accuracy. Sensors will collect inaccurate data due to sensor malfunction, noises, mishandling, etc. By studying the behavior of the sensors, we can optimize sensor's accuracy and minimize the possibility of collecting inaccurate data.

Data anonymization. Once the data is collected through sensors, we need to ensure that the data does not contain any personal identifiable information and perform anonymization process to minimize potential re-identification and protect patients' privacy.

Anomaly detection. Abnormal events are defined and detected within a short-term and long-term period. Depending on the types of the abnormality, the parents and/or healthcare provider are notified in a timely manner.

Clinical evaluation. We provide the collected data and analysis to pediatricians and specialists to assist with the evaluation process and verify the functionality and accuracy of our framework.

Tuning. Based on the results from our clinical evaluation, we tune our parameters and sensors to collect and analyze data more accurately.

Fig. 2. *A General Framework for Monitoring Infants' Safety*

IV. Framework

Figure 2 illustrates the general framework for monitoring infants' safety in our paper. Specifically, a Baby Sensor, which is deployed on the body of the baby, includes major sensing components such as: a thermometer sensor (MSP430 [4]) to check temperature, pulse oximetry sensor (OPT101 [2]) to measure heart rate and oxygen levels, and an *Inertial Measurement Unit* (IMU- MPU9250 [3]) to check activity and body orientation to allow detection of potentially fatal sleeping postures. The Baby Sensor will use a low-power Bluetooth link to report sensed data to the Base Station at home. The Base Station has five notable functions: (1) *Monitoring a baby sensor and baby room conditions*, (2) *detecting anomalies*, (3) *alarming parents instantly via Internet, phone line, and beep alarms from the Base Station*, (4) *reporting periodically to the SUID server with encrypted data*, and (5) *charging the Baby Sensor*. The collected information is communicated to both the SUID server and parents' phones via a Base Station. Using baby monitor interfaces including automated voice system, text, apps and SUID Web portal, parents can check their baby's real-time data and summarized report such as heart rate, oxygen levels, activity rate, and etc. The accumulated records will help pediatricians perform better medical examinations and have a more accurate and faster diagnosis for infants. In addition, this data will contribute to reducing the SUID rate and help researchers discover causes and effects in unknown cases with additional information they gain about baby's surrounding conditions.

The current baby monitors available in the market do not have all of the features we propose, such as: 1) Collection of surrounding conditions 2) Customizability 3) Providing additional analysis of the data 4) Flexibility in data collection and notification (e.g. smartphone, Internet, phone line, or in person) so the framework would be affordable to underdeveloped communities.

Notification Types. There are three different levels of notification in our framework:

- **Life-threatening:** Notifications that are sent by the base upon detection any serious anomaly such as extreme low oxygen level. These notifications are treated life threatening and will notify the parents via base alarm, sending text message to cell phones and if no actions are taken in response also have the ability to notify the healthcare provider or even emergency responders.
- **Warning**: These are not life-threatening notifications but according to the patterns detected by the base and/or data stored in the cloud some irregularities are detected (e.g. uncomfortable degree room). These warnings are sent to the smartphone or texted to the cell phone, and will also be stored in the cloud.
- **Suggestion:** These types of notifications are only sent to the healthcare provider and stored in the cloud and won't be sent to the parents. These are mainly patterns that are recognized only by the cloud through excessive data mining and would be given to the healthcare provider as suggestions (e.g. the infant's sleeping time during the week is getting shorter and shorter).

V. Conclusions

The secure smart framework for monitoring infant's safety is affordable and can assist low-income families in underdeveloped communities without proper tele-communication infrastructure to closely monitor the babies. The information provided by this framework to the healthcare provider would be an asset in assisting them to make a smarter decision based on an ongoing monitoring process of the babies and their surrounding environment conditions. It will help researchers discover causes and effects in unknown SUID cases with additional information, and will eventually contribute to reducing the SUID rate. The proposed technology advances research in main areas of health studies, socio-economic studies, big data analytics, wearable computing and privacy-preserving data mining.

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