An Intelligent Mobile Agents System for Sudden Infant Death Syndrome Monitoring

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***Abstract* –Sudden Infant Death Syndrome (SIDS) usually happened for new born. It typically occurs associated with a period of sleep. The cause (or causes) of SIDS is still unknown. Deprived of oxygen, parental alcohol consumption and over-heating are environmental risk factors of SIDS. In this paper, an intelligent method for preventing sudden infant death based on Arduino system is proposed.**

The proposed method will mainly consist of intelligent software incorporated with hardware components such as sensors to sense and detect important physical signals i.e. infant breath, infant temperature and heart rate and accordingly pass these recording data to Arduino device. In addition, parents will wirelessly receive Multimedia Messaging Service (MMS) via Global System for Mobile communication (GSM) in real time. Such message will carry the recorded data as well as a warning when problems occurred. A prototype is designed and developed which gives a reliable and efficient real time infant monitoring system that can play a vital role in reducing the SIDS occurred and save an infant's life.

Keywords: SIDS, Infant Monitoring, Multi-Agents, Arduino System

I. INTRODUCTION

Sudden Infant Death Syndrome (SIDS) is the expression used to symbolize the sudden, ambiguous death of an infant due to unknown causes. In the past, SIDS was sometimes called "crib death", even though cribs themselves do not cause SIDS. Researchers estimate that SIDS is the cause of about 2,500 infant deaths each year [1]. In addition, in the United States, each year, at least 4,500 babies die unexpectedly without any apparent cause [2].

The main cause of SIDS is still unknown; researchers have find out trends in SIDS deaths that may help them explain this ambiguous mortal problem. In fact, there are several hypotheses and risk factors that have been suggested as causes of SIDS. For instance, it has been hypothesized that exposure of babies to tobacco smoke and sleeping prone are at a higher risk of SIDS than babies who are not exposed to the tobacco smoke and sleeping in the supine position [3].

Up to date, there is no direct way to treat or reduce infant mortality during sleep. On the other hand, all researchers have concluded a set of guidance and advice for parents on how to protect their infants and reduce the risk of sudden death syndrome during his/her sleeping. Examples of such guidance and crucial steps to prevent this deadly occurrence as follow; always put the infant on the back when sleeping; do not smoke at home; do not let the baby sleep in your bed; parents' alcohol enhances fatigue through the night and it could reduce the level of mental awareness in the parents and avoid the overheating on infant room.

In fact, it is widely noted that 20 percent of SIDS deaths occur while the infants are being cared for in non-parental child care settings. From this 20 percent, two-thirds of these deaths occur in family child care, and the remaining deaths happen in child care centers and in the care of relatives [4]. Due to that, it is important to give more attention to the previous percentage and found an autonomous solution used to give a warning to reduce and prevent SIDS deaths occurring.

With current revolution in wireless sensor networks and advent of low-power embedded systems, the ability to build a service system is increased. Such a system will help the human to collect environmental signals that will be used to solve specific problems such as SIDS problem. In addition, this revolution help to implement wireless sensor networks, allowing easily interfaced, programming and configured sensors to be placed anywhere indoor or outdoor. The sensor observations intelligently analyzed and transported over large distance via networks.

Multi-Agent System or Smart Agent Group is a system which divides rules between agents for fast execution and treatment of more tasks in one time (Parallelism) [5]. An agent, however, is an extremely high-level software abstraction which provides a convenient and powerful way to describe a complex software entity. Rather than being defined in terms of methods and attributes, an agent is defined in terms of its behavior [6]. This is important because

programming an agent-based system is primarily a matter of specifying agent behavior instead of identifying classes, methods and attributes. It is much easier and more natural to specify behavior than to write code [6].

Agents are now widely discussed by researchers in mainstream computer science, as well as those working in data communication and user interface design. A multi agent system is a system that consists of a number of agents, which is tract with each other, typically by exchanging messages through system or between different systems. By this, agents are capable of sensing their environment (via sensors), and have a repertoire of possible actions that they can perform (via effectors or actuators) in order to modify their environment. In addition, a multi agent system is a dynamic society made up of a number of intelligent agents, so it is an intelligent society [6].

In this fast revolutionary world, there is an essential need to find out a special method to help taking care of infants and being able to monitor them even if the parents are busy at work or doing something else. This research focuses on monitoring the heart rate, the level of oxygen and finally the temperature of the infant twenty four hours a day. In addition, it will send warning message to the mobile phone of the person who is in charge of monitoring the infant if there is anything abnormal. Furthermore, an intelligent method based on intelligent software cooperating with hardware will need to take an autonomous action in case of any critical situation such as deprived of oxygen which mainly will happen if the infant turned on his stomach during sleeping.

In this paper, a multi-agent system for intelligently monitoring infant baby has been created and designed. Such system mainly consists of five mobile agents cooperate and communicate together to manage such intelligent monitoring. The proposed multi-agents system facilitates the search for infant status (sleeping or waking up), sensors status, informing ambulance services, and parent warning. Furthermore, infant monitoring prototype has been designed and implemented based on physical sensors and Arduino controller. Such system used as a sensory input to multi-agent system. Finally, an integrating Multi-agent System with sensory input for intelligent infant monitoring system has been proposed.

II. PROPOSED SYSTEM

In this research, the design of a mobile-agents system for reducing and preventing SIDS deaths is proposed. An intelligent concept for mobile agents is proposed that would deal with any abnormal infant situations in an independent and efficient way, with different agents cooperating and communicating through message exchange, each agent is specialized in specific tasks of the requested services. Five types of agents have been proposed to deal with these services in hierarchical way.

A. System Components

The intelligent infant monitoring system would consist of both hard and soft parts. The overall system which is composed of two subsystems software and hardware is illustrated as follow.

A.1 Software Part

The selected architecture for the multi-agent system in this paper is the Belief, Desire and Intention (BDI) architecture in which decision making depends upon the manipulation of data structures representing the beliefs, desires, and intentions of the agent. The Prometheus methodology [7] was used to develop the mobile-agents system of the proposed system. As a result of this detailed process, five agents were developed; Decision maker agent, Sleep- Wake up agent, Ambulance agent, Warning agent, Database agent and Sensors agent. These agents are selected according an iterative to process where data coupling diagrams and agent acquaintance diagrams were used. Based on the proposed design, the agents would communicate together through passing messages.

Figure 1 presents the agents' interaction diagram for the infant monitoring system. The agents and their roles are as follows. The decision maker agent intelligently analyses the output of the sensors status agent for the following purposes, (i) reach a decision regarding current sensors status, (ii) inform the parent about their infant status (in sleeping mode or waking up), (iii) inform the parent about any abnormal circumstances of their infant i.e. high temperature, irregular pulse rate, lack of oxygen.

The database agent is also initiated for collecting all important information from other agents i.e. heart rate, infant temperature, and infant breathing. This information will be useful in emergency cases and will be a valuable medical history for future analysis and health monitoring.

The Sleep- Wake up agent initiated to receive the collected data from the motion sensor then summaries the status of the infant, the infant sleeps with no motion, the agent counts its respiration frequency and, in favorable conditions, pulse rate. Based on this and in case of any slight movements, the parent will be informed by a message. On the other hand, wake-up condition is characterized by long term movements of high amplitude.

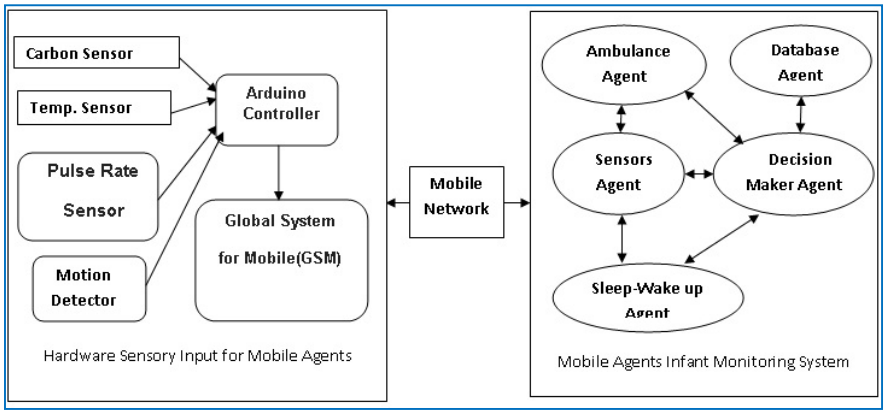

Figure 1. Agents' Interaction Diagram for Infant Monitoring System

A message carrying such information will be passed to decision maker agent to make a suitable decision. The Ambulance agent initiated to inform the decision maker agent about any critical emergency situations and essential needed to contact the ambulance. An algorithm is proposed to determine any critical case based on the sensory inputs as following.

i. Receive all sensors reading by sensors agent.
ii. Analyze such readings.
iii. Based on previous step, do the following:
   a. If the readings in normal range which will be decided by physician, the normal action will be recorded.
   Else
   b. If the readings in abnormal range but not critical, the parent will be informed via message.

   Else
   c. If the readings in abnormal range and critical which will be decided by physician, a critical message will be passed to ambulance services holding the infant address as well as his/her medical record.

The sensors agent responsibility is to collect and analyze the sensors readings, and then pass the needed information via message to ambulance, sleep- wake up, warning and database agents.

A.1.1 Analysis, Design and Implementation

As a result of comparing many methodologies [8]-[9], it has been noticed that Prometheus methodology is an appropriate methodology to design and implement an infant monitoring system using multi agent approach.

In this research, the Prometheus methodology is used in determining the specifications of the proposed system. In the system specification phase, the goals of the system were identified, case scenarios were developed, the functions of the system were illustrated, and the interface between the system and its environment in term of actions and percepts were specified. Based on the Prometheus methodology, five agents were developed. These agents would communicate through messages. The architecture design of such system has been illustrated. The agent's rules also are configured based on the system requirements. The details of designing proposed system are illustrated below.

A.1.2 System Specification

During system specification, system description must be elaborated and explored, to provide a sound basis for system design and development. In the proposed system, the infant monitoring agents system is described as with six distinct phases in which the system must operate: sensors collect data from infant body in real time, Arduino received and analyzed the collected data, determine infant status mode (sleeping or waking up), Determining the medical condition of the infant (normal, abnormal or critical state), inform parents about the medical condition of the infant and inform the ambulance in critical condition.

During the first and second phases, the sensors agent will communicate with sensory input via Arduino to collect all needed data about the medical condition of the infant then send such information via message to ambulance agent and concurrently to sleep-wake up agent. In phase three, the sleep-wake up agent will decide the infant is in sleeping mode or wake up mode based on collected parameters

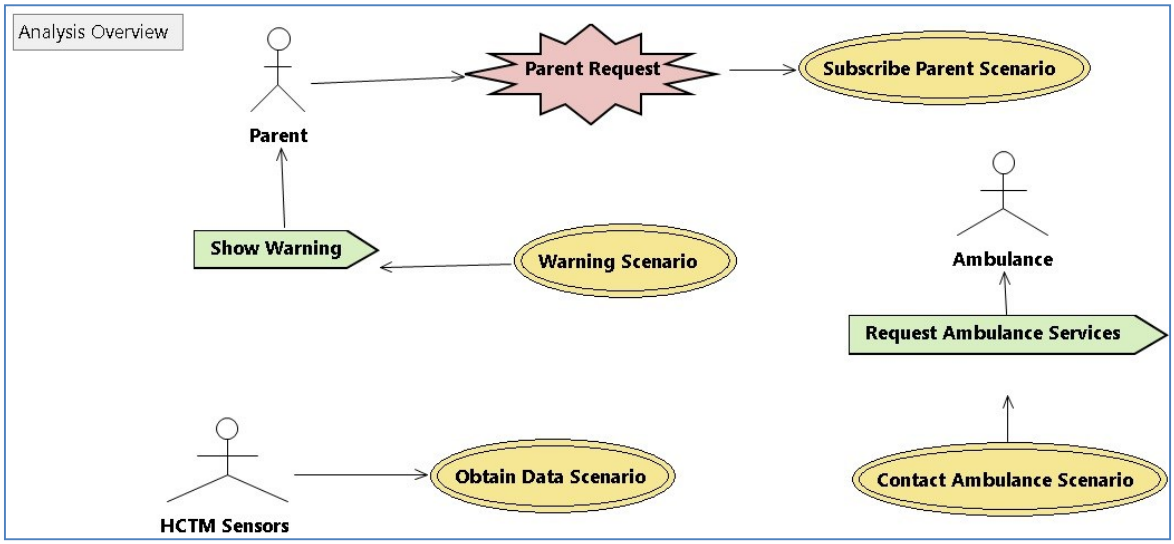

Figure 2. Analysis Overview Diagram

from sensors agent i.e. long term movements of high amplitude, slight movements. In phase four, the ambulance agent will decide the medical condition of the infant by applying the algorithm which is proposed above. In last two phases, the decision maker agent will inform the parent about the infant's condition and accordingly contact the medical services in case of critical situations. Finally, agent's rules would be used to make a final decision based on all previous analysis results.

Typically, using Prometheus, the development of the system specification begins with identifying the external entities (referred to as actors) that will use or interact in some way with the system, and the key scenarios around which interaction will occur. This is done by utilizing Prometheus Design Tool (PDT) using the analysis overview diagram as shown in Figure 2. PDT is a graphical editor which supports the design tasks specified within the Prometheus methodology for designing agent system [10].

A.1.3 Functionalities

The functionalities of the proposed intelligent agents system are described, where six functions were defined; check the infant temperature, check the infant breath, determined the infant mode (sleeping or waked up, determined the medical condition of the infant, inform the parent and send notification message to the ambulance. All these functionalities have been designed in PDT tools and configured as roles. Figure 3 illustrates these roles with their corresponding percepts and actions.

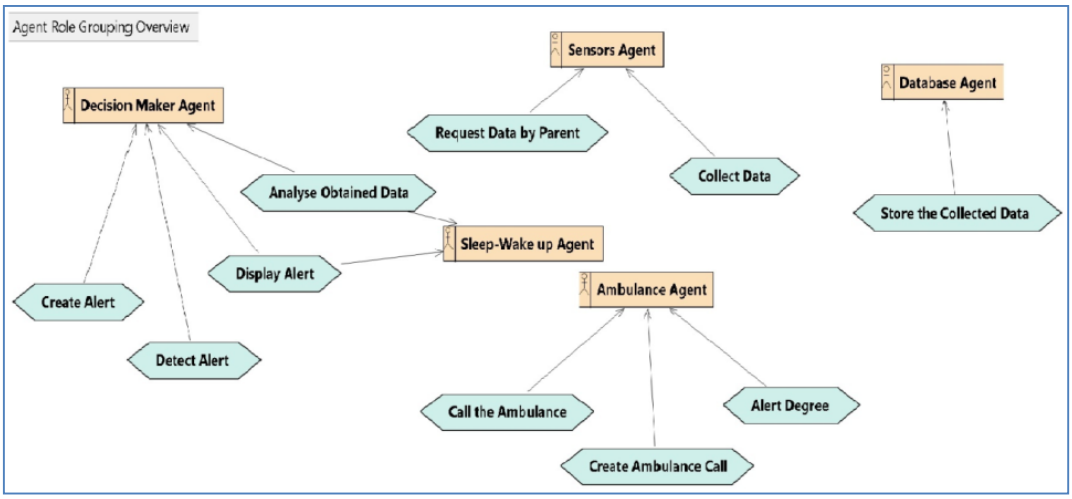

Figure 3. Agent Role Diagram

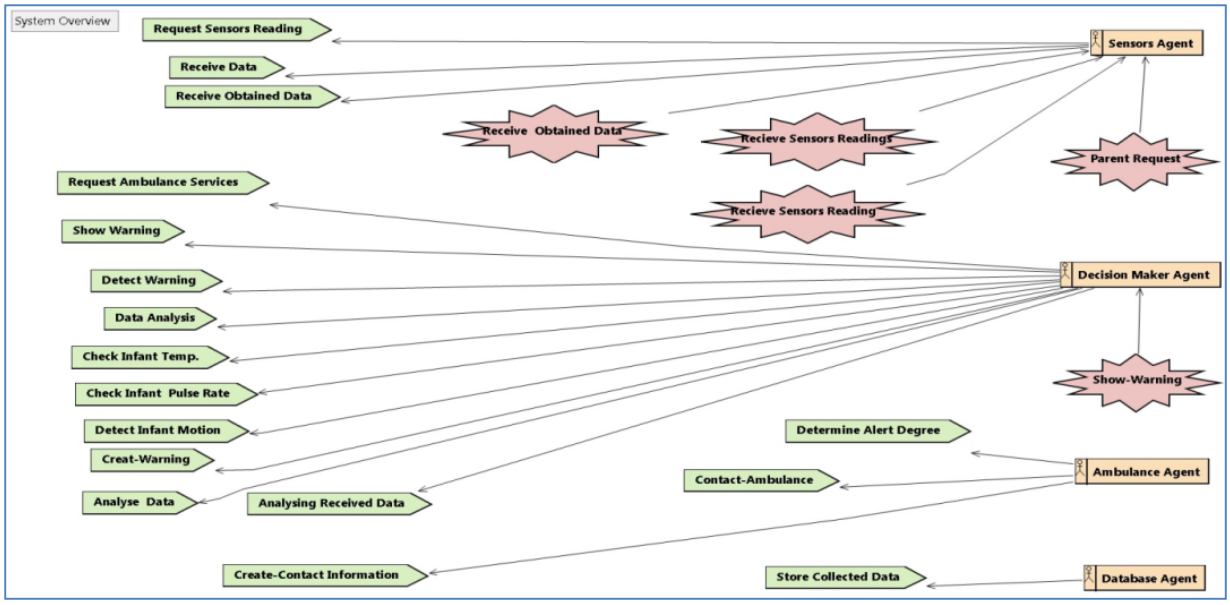

Figure 4. System Overview Diagram

A.1.4 Scenario Development

Developing scenarios is one of the convenient ways that show the sequence of steps that take place within the system. Scenarios become even more important in the case of community-managed resources that are shared among many agents. They are used primarily to illustrate the normal running of the system and it also can be useful when used to indicate what is expected to happen when something goes wrong. Four scenarios were developed; obtain data, warning, inform parent and contact ambulance scenarios. The steps and sequences of these scenarios are configured. All the previous scenarios have been developed using the PDT tool. In addition, the initial set of goals for the proposed infant monitoring system are configured and implemented using the PDT.

A.1.5 Detailed Design

In detailed design phase, the agents interact to achieve the goals associated via their roles and associated goals. A generic detailed design describes agents in terms of capabilities, or modules. These capabilities are then finally specified in terms of plans and events, which are of necessity more specific to the implementation paradigm or platform, than the preceding steps. At this point the abstract design of the system was completed, since the structure, the functions and the internal design had been reached. The final system overview and system role overview are illustrated in Figures 4 and 5.

At the end of the design process the system is ready for implementation. It will be reached using agent speak Language (JASON) software.

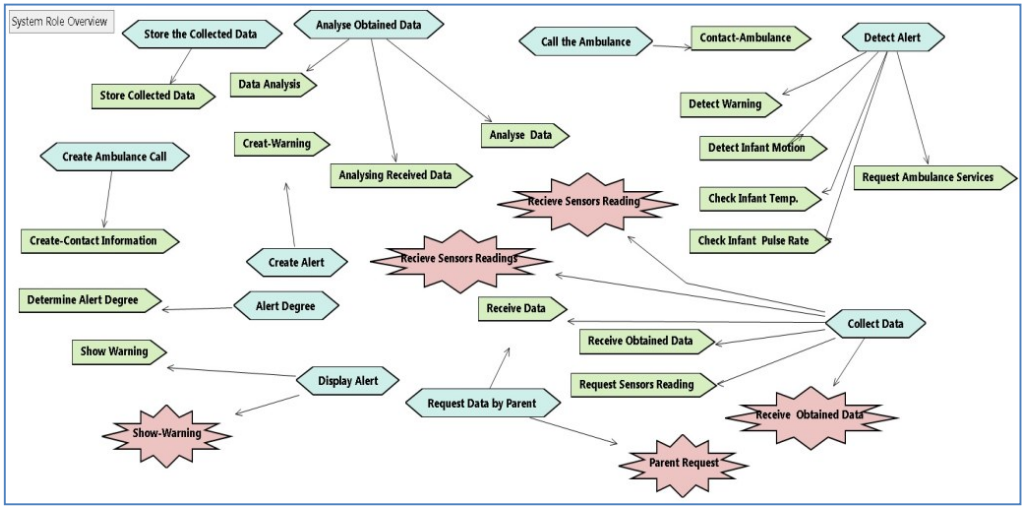

Figure 5. System Role Overview Diagram

A.2 Hardware Parts

The infant monitoring prototype is implemented and where its hardware components would consist of Arduino system, GSM module, temperature sensors, pulse rate sensor, motion detector and carbon sensor. The implemented prototype mainly consists of two parts: the mobile device and Arduino unit. The hardware components were selected based on system analysis and requirements. The sensors were connected to Arduino pins. In addition, The GSM module was interfaced and connected with Arduino board to wirelessly send the sensors readings via message through mobile networks. The agents' software will be embedded on mobile device. In addition, Arduino unit responsibilities are collecting sensors readings; processing data gathered from the sensors and pass it through GSM to mobile device. Figure 6 shows selected components of the prototype.

The Arduino was programmed using the C-code language written on the Arduino platform. The software written on the platform was uploaded to Arduino controller using Arduino IDE software.

III. Discussion and Results

In recent years, agent-based technology becomes a powerful tool for healthcare industry applications. As a computational paradigm, multi-agent systems (MASs) provide a good solution for autonomous monitoring in real time. The Multi-Agent System (MAS) approach provides a powerful platform for modeling and solving real world problems such as SIDS problem. The objective of this research is to propose, design and develop innovative solution to offer a more proactive and reliable system to reduce and prevent occurring of SIDS. A framework methodology was selected to deal with such problem in an effective and smart way. In addition, the specific agent architecture along with the internal workings of each agent has been discussed and commented as well as the method of communication between the agents. In the proposed system, negotiations between different presented agents help the system to improve current SIDS treatment methods by giving an efficient decision.

Real-time sensors reading seem to be the most promising way to inform about the medical conditions of the monitoring infant. The implementation of the prototype of infant monitoring system has been done in this work. The real-time readings of the sensors are sent wirelessly through GSM to the mobile device where such readings will be used as sensory input to the proposed multi agent's system.

After implementing the prototype, the Arduino unit responds to the received data from sensors. The GSM module was used to communicate with mobile device. Samples of achieved results from the prototype are illustrated in Figure7.

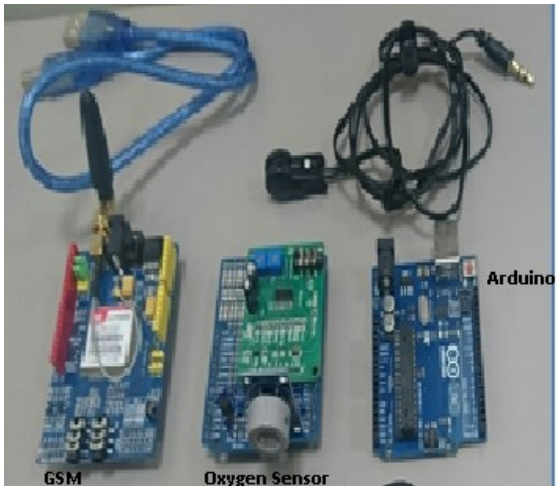

Figure 6. Hardware Components of the Prototype

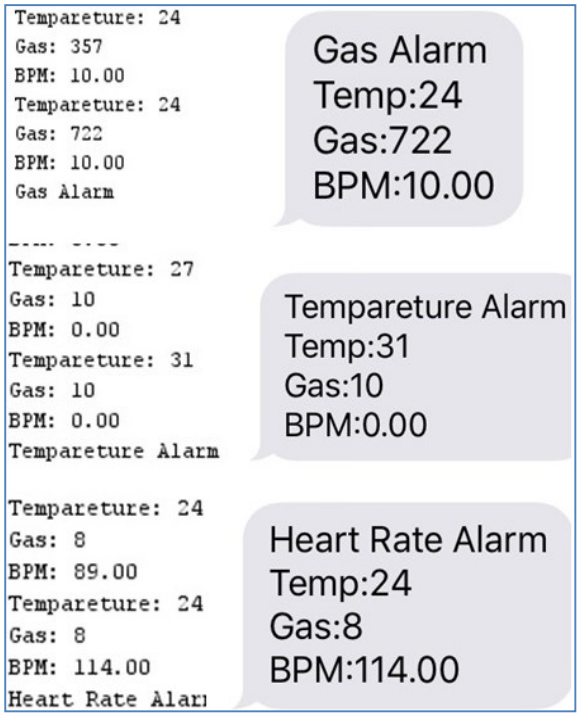

Figure 7. Samples of Prototype Output

Figure 7 shows samples of three sensors readings (Gas, Temperature and Heart Rate) where the alarm occurred in case of abnormal reading with 100% accuracy.

IV. Conclusion

One of the most difficult current challenges for infant with SIDS problem is how to monitor them and the rapid detection of any change in the status of their sleep or temperature as well as the discovery of breathing problems and have an immediate report on this. Such challenge will lead to many problems and cause troubles for the infant. In this paper, an intelligent infant monitoring system using multi-agents approach is proposed and designed. A new dynamic method for infant sleeping/wake up mode is

presented. A prototype of agents sensory input is implemented and tested.

The researcher attempted to replace the current infant monitoring method with an intelligent method based on agents system that would use the agent's features to maximize the potential quality of monitoring services, reduce the time needed to inform about any abnormality. Furthermore, a new technique was investigated that would help to dynamically contact the ambulance services in case of any critical case. Such proposed solution will reduce stress on the healthcare system, as well as the cost of providing efficient and reliable services.

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