

# BABY MONITORING SYSTEM USING WIRELESS SENSOR NETWORKS

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## Abstract

*Sudden Infant Death Syndrome (SIDS) is marked by the sudden death of an infant during sleep that is not predicted by the medical history and remains unexplained even after thorough forensic autopsy and detailed death investigation. In this we developed a system that provides solutions for the above problems by making the crib smart using the wireless sensor networks (WSN) and smart phones. The system provides visual monitoring service through live video, alert services by crib fencing and awakens alert, monitoring services by temperature reading and light intensity reading, vaccine reminder and weight monitoring.*

## Keywords:

WSN, Temperature, Light, Haar Classifier, Smart Crib

## 1. INTRODUCTION

Sudden infant death syndrome (SIDS) is marked by the sudden death of an infant that is not predicted by medical history and remains unexplained after a thorough forensic autopsy and detailed death scene investigation [1]. As infants are at the highest risk for SIDS during sleep, it is sometimes referred to as cot death or crib death. Typically the infant is found dead after having been put to bed, and exhibits no signs of having suffered [2]. SIDS was the third leading cause of death of infant mortality in the U.S. in 2011. According to the Centers for Disease Control and Prevention, SIDS deaths have been declining since 1988 [3]. The cause of SIDS is unknown, but some characteristics associated with the syndrome have been identified and appear to interact with other characteristics: The Triple-Risk Model states that SIDS occurs when an infant with an underlying, biological vulnerability who is at a critical developmental age is exposed to an external trigger [4].

SIDS prevention strategies include: putting the infant to sleep on his/her back, a firm mattress separate from but close to caregivers, no loose bedding, a relatively cool sleeping environment, using a pacifier, and avoidance of exposure to tobacco smoke [5]. The "Safe to Sleep" campaign is considered a significant public health success, credited with leading to a measurable reduction in SIDS rates [6].

Infanticide and child abuse cases may be misdiagnosed as SIDS due to lack of evidence, and caretakers of infant with SIDS are sometimes falsely accused [7][8]. Accidental suffocations are also sometimes misdiagnosed as SIDS and vice versa. Grief support for families impacted by SIDS is particularly important because the death of the infant is typically sudden, without witnesses, and requires an investigation.

## 2. RISK FACTORS

The cause of SIDS is unknown. Although studies have identified risk factors for SIDS, such as putting infants to bed on their stomachs, there has been little understanding of the

syndrome's biological process or its potential causes. The frequency of SIDS does appear to be influenced by social, economic, and cultural factors, such as maternal education, race or ethnicity, and poverty. SIDS occurs when an infant with an underlying, biological vulnerability who is at a critical developmental age is exposed to an external trigger [4]. The following risk factors generally contribute either to the underlying biological vulnerability or represent an external trigger.

Placing an infant to sleep while lying on the stomach or the side increases the risk [5]. This increased risk is greatest at two to three months of age. [5] Elevated or reduced room temperature also increases the risk. As does excessive bedding, clothing, and soft sleep surfaces, and stuffed animals. Bumper pads may increase the risk and as there is little evidence of benefit from their use; they are not recommended [5].

Sharing a bed with parents or siblings increases the risk for SIDS. This risk is greatest in the first three months of life, when the bed is soft, when more than one other person is present, or when the bed partners are using drugs or alcohol or are smoking [5]. The risk remains however even in parents who do not smoke or use drugs. The American Academy of Pediatrics thus recommends "room-sharing without bed-sharing", stating that such an arrangement can decrease the risk of SIDS by up to 50%. Furthermore, the Academy recommended against devices marketed making bed-sharing "safe", such as in-bed co-sleepers.

Addressing the sensor nodes has been a challenge that still prevails. Unlike the conventional ipv4 and ipv6 standards, sensor nodes cannot be addressed by any known standard. It is necessary that an addressing scheme has to be explicitly proposed in order to address the individual nodes in a wireless sensor networks.

Maternal age - SIDS rates decrease with increasing maternal age, with teenage mothers at greatest risk. Delayed or inadequate prenatal care Low birth weight - in the United States from 1995-98, the SIDS death rate for infants weighing 1000-1499 g was 1.89/1000; for a birth weight of 3500-3999 g, it was only 0.51/1000. Premature birth- increases risk of SIDS death roughly fourfold. From 1995-1998 the U.S. SIDS rate for births at 37-39 weeks of gestation was 0.73/1000; the SIDS rate for births at 28-31 weeks of gestation was 1.39/1000 A lack of breastfeeding is linked to SIDS. Genetics plays a role, as SIDS is more prevalent in males. There is a consistent 50% male excess in SIDS per 1000 live births of each sex. Given a 5% male excess birth rate, there appears to be 1.15 male SIDS cases per 2 female, for a male fraction of 0.61. This value of 61% in the US is an average of 57% black male SIDS, 61.2% white male SIDS and 59.4% for all other races combined. Note that when multiracial parentage is involved, infant "race" is arbitrarily assigned to one category or the other; most often it is chosen by the mother. The X-linkage hypothesis for SIDS and the male excess in infant mortality have shown that the 50% male excess could be related to a dominant

X-linked allele, occurring with a frequency of 1/3 that is protective of transient cerebral anoxia.

### 3. WIRELESS SENSOR NETWORKS

Many sensors connect to controllers and processing stations directly, an increasing number of sensors communicate the collected data wirelessly to a centralized processing station. Therefore a wireless sensor has not only a sensing component but also an on board processing, communication and storage capabilities. Sensor nodes communicate not only with each other, but also with a base station (BS).

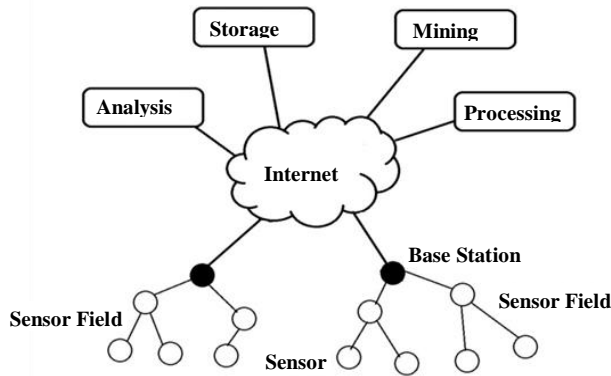


Fig.1. Wireless Sensor Networks

In collaboration with Rockwell Science Center, University of California, proposed to the concept of wireless integrated network sensor (WINS). Smart dust project (Khan et al.1999) was proposed at university of California, Berkley focused on design of extremely small sensor nodes called mote.

The well-known IEEE 802.11 family of standards was introduced in 1997 and is the most common wireless networking technology for mobile systems. It uses different frequency bands, the 2.4-GHz band is used by IEEE 802.11b and IEEE 802.11g, while the IEEE 802.11a protocol uses the 5-GHz frequency band. IEEE 802.11 was frequently used in early wireless sensor networks and can still be found in current networks when bandwidth demands are high (e.g., for multimedia sensors).

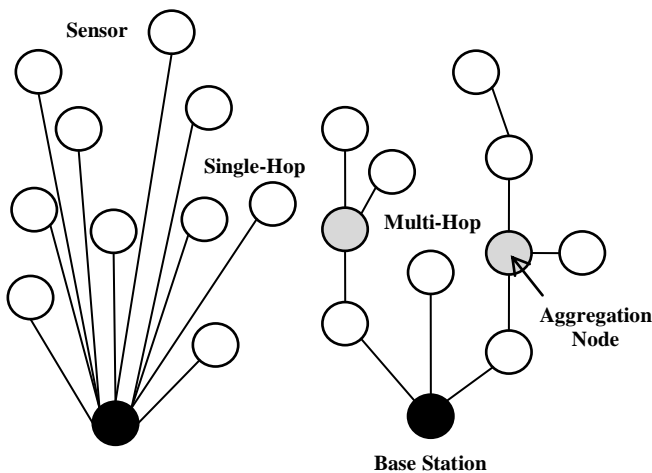


Fig.2. Single-hop and multi-hop communication in sensor networks

### 3.1 SENSOR NODE

A sensor node is made up of four basic components a sensing unit, a processing unit, a transceiver unit and power unit. Sensing units are subdivided into ADC and Controller.

*Controller:* The controller performs tasks, processes data and controls the functionality of other components in the sensor node. While the most common controller is a microcontroller, other alternatives that can be used as a controller are: a general purpose desktop microprocessor, digital signal processors. A microcontroller is often used in many embedded systems such as sensor nodes because of its low cost, flexibility to connect to other devices, ease of programming, and low power consumption.

*Transceiver:* Sensor nodes often make use of Industrial Scientific Medical (ISM) band, which gives free radio, spectrum allocation and global availability. The possible choices of wireless transmission media are radio frequency (RF), optical communication (laser) and infrared. Lasers require less energy, but need line-of-sight for communication and are sensitive to atmospheric conditions. Infrared, like lasers, needs no antenna but it is limited in its broadcasting capacity. Radio frequency-based communication is the most relevant that fits most of the WSN applications

*External Memory:* From an energy perspective, the most relevant kinds of memory are the on-chip memory of a microcontroller and Flash memory-off-chip Random Access Memory (RAM) is rarely, used. Flash memories are used due to their cost and storage capacity. Memory requirements are very much application dependent.

*Power Source:* A wireless sensor node is a popular solution when it is difficult or impossible to run a mains supply to the sensor node. However, since the wireless sensor node is often placed in a hard-to-reach location, changing the battery regularly can be costly and inconvenient. An important aspect in the development of a wireless sensor node is ensuring that there is always adequate energy available to power the system.

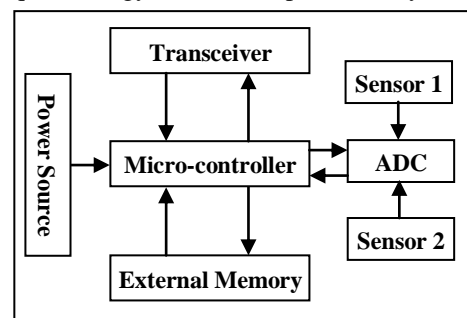


Fig.3. Components of a sensor node

*Sensors* are hardware devices that produce a measurable response to a change in a physical condition like temperature or pressure. Sensors measure physical data of the parameter to be monitored. The continual analog signal produced by the sensors is digitized by an analog-to-digital converter and sent to controllers for further processing. A sensor node should be small in size, consume extremely low energy, operate in high volumetric densities, be autonomous and operate unattended, and be adaptive to the environment.

## 4. OVERVIEW OF THE SYSTEM

The system consists of a crib with wireless sensor nodes and application for a smart phone. Fig.4 shows the architectural view of the system.

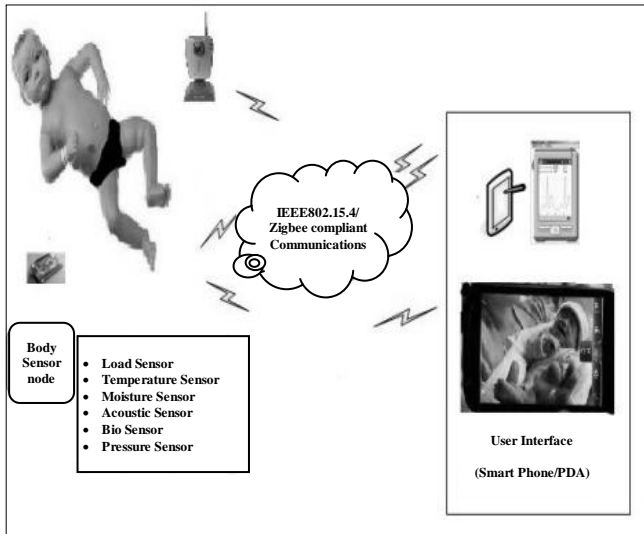


Fig.4. Smart Crib

The baby is placed in a crib. And the various sensors like acoustic, temperature, light intensity are placed on various parts of the crib. They are connected to a sink node through an IEEE 802.15.4 Zigbee network. An IP camera is also placed in the crib. This IP camera's video feed can be accessed universally from anywhere using the IP address of the particular camera.

A Smartphone application is developed to access and process all the information acquired from these equipments from the crib. The application process the information and raises alerts to ensure that the baby is taken care.

Features of the system are visual monitoring service, alert service, health monitoring service, bed wet monitoring, vaccine reminder, weight monitoring.

### 4.1 VISUAL MONITORING SERVICE

The activities of the baby can be viewed through a smart phone (remotely we can monitor baby in the crib).

Streaming video is a video/audio data transfer technique to allow steady and continuous processing by a client. The audio stream is compressed using an audio codec such as MP3 or AAC. The video stream is compressed using a video codec such as H.264 or VP8.

If the camera is available, a Live Video feed will be displayed. Video will be shown at VGA resolution (640 × 480) if viewing your camera from a PC on the same local network, or at QVGA resolution (320 × 240) if viewing your camera from a PC on a remote network.

### 4.2 ALERT SERVICE

Crib fencing is a service in which the baby is continuously monitored to have a regular check whether the baby is positioned inside the crib. This service is complimented by Visual service.

The baby's position in the crib is detected from the image frames of the baby (aided by video streaming) through the analysis of the frames using "HAAR CLASSIFIER ALGORITHM". The analysis is performed by finding the various coordinate points of the baby's face are detected based on the haar classifier and if the coordinates are out of the fencing area then an alert is raised to the smart phone application.



Fig.5. Live video of the baby

### 4.3 MONITORING SERVICE

Parents and caregivers can take steps to reduce the risks of Sudden Infant Death Syndrome (SIDS) during the colder months, when infants are at higher risk, according to the National Institutes of Health.

These include avoiding overheating an infant during nap or sleep time; placing the infant on his or her back to sleep; placing infants to sleep on a firm, safety approved mattress; keeping toys, blankets, and other loose objects out of the crib, and never smoking around an infant.

In cold weather, parents and caregivers often place extra blankets or clothes on infants, to keep them warm. But over bundling may cause infants to overheat, increasing their risk for SIDS, according to the National Institutes of Health.

"Parents and caregivers should dress infants in light clothing for sleep and keep rooms at a temperature comfortable for adults" said Alan E. Guttmacher, M.D., director of the NIH's Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD). Infants are sensitive to extremes in temperature and cannot regulate their body temperatures well. Studies have shown that multiple layers or heavy clothing, heavy blankets, and warm room temperatures increase SIDS risk. Infants who are in danger of overheating feel hot to the touch.

For more than a decade, the NICHD and its partners, the American Academy of Pediatrics, the Maternal and Child Health Bureau of the Health Resources and Services Administration, the First Candle (formerly SIDS Alliance) and the Association of SIDS and Infant Mortality Programs, have led the Back to sleep campaign. Back to Sleep advises parents and caregivers on how to reduce the risk of SIDS.

Unless there's a medical reason not to, infants should be placed on their backs to sleep, on a firm, safety-approved crib mattress covered by a fitted sheet with no blankets or fluffy bedding under or over them. If a blanket must be used, it should reach no higher than the baby's chest and be tucked in under the crib mattress. The baby's crib and sleep area should be free of pillows and stuffed toys, and the room temperature should be kept at a level that feels comfortable for an adult.

The temperature of the crib is continuously monitored and the recordings are sent to the smart phone application periodically.

#### 4.4 LIGHT INTENSITY READING

Constant exposure to artificial lighting may damage the development of premature baby's biological clocks, research suggests. Tests showed exposing baby mice to constant light keeps the master biological clock in their brains from developing properly. Researchers said this could contribute to an increased risk of mood disorders, such as depression. The researchers say their findings suggest special care baby units should try to minimize a baby's exposure to artificial lighting - possibly by using a day/night cycle. Each year about 14 million premature babies are born worldwide, and many are exposed to artificial lighting in hospitals.

Previous research has found infants from neonatal units with cyclic lighting tend to begin sleeping through the night more quickly, and gain weight faster than those from units with constant lighting. In all mammals the master biological clock is located in an area of the brain called the suprachiasmatic nuclei (SCN). It influences the activity of many organs, including the brain, heart, liver and lungs and regulates the daily activity cycles known as circadian rhythms. The SCN is filled with special clock neuron cells whose activity is synchronized follow the 24-hour day/night cycle. The Vanderbilt team had already shown SCN neurons in adult mice begin drifting out of a phase after the animals were exposed to constant light for about five months. This is accompanied by a breakdown in their ability to maintain their normal nocturnal cycle.

The light intensities are measured in lux (The SI unit for measuring light intensity) and periodically sent to the Smartphone application.

#### 4.5 VACCINE REMINDER

The Smartphone application has vaccine reminder for the baby; the reminders are set in accordance with the date of birth of the baby. This includes various vaccine reminders like polio, hepatitis etc.

#### 4.6 WEIGHT MONITORING

The weight monitoring is done by the sensors placed on the crib and the periodical measurements are recorded. These values are archived, which may be useful for medical analysis.

### 5. EQUIPMENTS

*Sensor Gateway:* The gateway provides Base Station for Wireless Sensor Networks. It also has a USB Port Programming

for IRIS/MICAz/MICA2 Hardware Platforms. In addition it also Supports JTAG code debugging.

The MIB520CB provides USB connectivity to the IRIS and MICA family of Motes for communication and in-system programming. Any IRIS/MICAz/MICA2 node can function as a base station when mated to the MIB520CB USB interface board.

In addition to data transfer, the MIB520CB also provides a USB programming interface. The MIB520CB offers two separate ports: one dedicated to in-system Mote programming and a second for data communication over USB. The MIB520CB has an on-board processor that programs Mote Processor Radio Boards. USB Bus power eliminates the need for an external power source.

#### Specifications:

- *USB Interface* - Baud Rate: 57.6 K, Male to Female USB cable.
- *Mote Interface* - Connectors: - 51-pin, Indicators - Mote LED's: Red Green, Yellow.
- *Programming Interface* - Indicators: - LEDs - Power Ok (Green), Programming in Progress (Red), Switch to reset the programming processor and Mote.
- *Jtag Interface* - Connector: 10-pin male header.
- *Sensor Board:* MDA100

The MDA100CB sensor and data acquisition board has a precision thermistor, a light sensor/photocell and general prototyping area. Designed for use with the IRIS, MICAz and MICA2 Motes, the prototyping area supports connection to all 51 pins on the expansion connector, and provides an additional 42 unconnected solder points for bread boarding.

The MTS 300CB is a flexible sensor board with a variety of sensing modalities. These modalities include Light, Temperature Acoustic and Sounder. The MTS 300CB is for use with the IRIS, MICAz and MICA2 Motes.

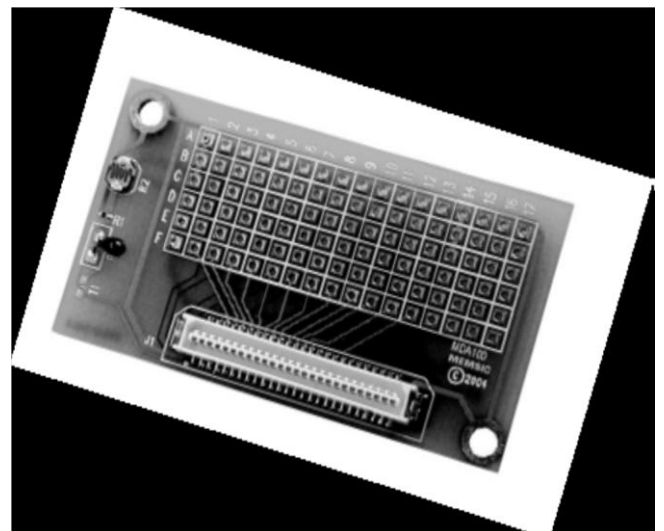


Fig.6. MDA100CB Sensor Board

#### 5.1 CAMERA

The wireless IP camera is used for live video streaming. The DCS-930L IP camera is used for this project. The DCS-930L is

a stand-alone system with a built-in CPU, requiring no special hardware or software such as PC frame grabber cards.

Supporting TCP/IP networking, HTTP, and other Internet related protocols. The DCS-930L can also be integrated easily into other Internet/Intranet applications because of its standards-based features. The DCS-930L offers wireless 802.11n and Ethernet/Fast Ethernet connectivity, making the DCS-930L easy to integrate into your existing network environment.

The DCS-930L works with a 10Mbps Ethernet based network or 100Mbps Fast Ethernet based network for traditional wired environments, and works with 802.11n routers or access points for added flexibility. Directly connecting to another computer, for peer-to-peer communication, using wireless network adapters on each computer, such as two or more DCS-930L wireless network Cardbus adapters. Video will be shown at VGA resolution (640 × 480) if viewing your camera from a PC on the same local network, or at QVGA resolution (320 × 240) if viewing your camera from a PC on a remote network.

#### Specification:

- WIRELESS CONNECTIVITY - 802.11b/g/n Wireless with WEP/WPA/WPA2 security.
- SDRAM - 32 MB.
- FLASH MEMORY - 4 MB.
- VIDEO CODECS - MJPEG, JPEG for still images.
- VIDEO FEATURES - Adjustable image size and quality, Time stamp and text overlay, Flip and Mirror.
- RESOLUTION - 640 × 480 at up to 20 fps, 320 × 240 at up to 30 fps, 160 × 120 at up to 30 fps.
- LENS - Focal length: 5.01 mm, F2.8.
- SENSOR - VGA 1/5 inch CMOS Sensor.

## 5.2 SETUP

The sensor boards are placed on the crib along with the IP camera. The Live video streaming is done with Smartphone application is shown in the Fig.7.



Fig.7. Video steaming on Smartphone

The Haar-Like features detection algorithm is used to detect the baby in the crib. Once the baby is detected its position in the crib are identified and proper alerts are raised on the application in Smartphone based on the position.

The sensor boards continuously measure the temperature and light intensity readings. Alerts are raised only if they cross the threshold limits. The periodical measurements are recorded and sent to the Smartphone application and alerts are raised if required.

The live feed from the IP Camera is captured and processed using the Haar-Like features detection algorithm. The baby's face is detected using the algorithm and if no face is detected for a threshold period of time an alert is raised to the Smartphone application. This is shown in the Fig.8.



Fig.8. Temperature and Light Intensity Readings

The above figure shows the temperature and light intensity readings being sent to the Smartphone as push notification.

The sensor packets are processed by the sink nodes and the information are extracted in XML format. This extracted information are processed and sent to the Smartphone Application through Google Cloud Messaging Service.

The Google Cloud Messaging delivers the information is delivered in the form of push notification. This makes the parent (owner of the Smartphone to receive the messages even when the phone is switched off or unreachable by the telecom network).

## 5.3 ALGORITHMS

The Haar-Like features detection algorithm is used to detect the baby in the crib. Once the baby is detected its position in the crib are identified and proper alerts are raised on the application in Smartphone based on the position.

Haar-like features are digital image features used in object recognition. They owe their name to their intuitive similarity with Haar wavelets and were used in the first real-time face detector. The main purpose of using features instead of raw pixel values as the input to a learning algorithm is to reduce the in-class while increasing the out-of-class variability compared to the raw data and thus making classification easier. Features

usually encode knowledge about the domain, which is difficult to learn from the raw and finite set of input data.

A very large and general pool of simple haar-like features combined with feature selection therefore can increase the capacity of the learning algorithm. The speed of feature evaluation is also a very important aspect since almost all object detection algorithms slide a fixed-size window at all scales over the input image. As we will see, our features can be computed at any position and any scale in the same constant time. Only 8 table lookups are needed.

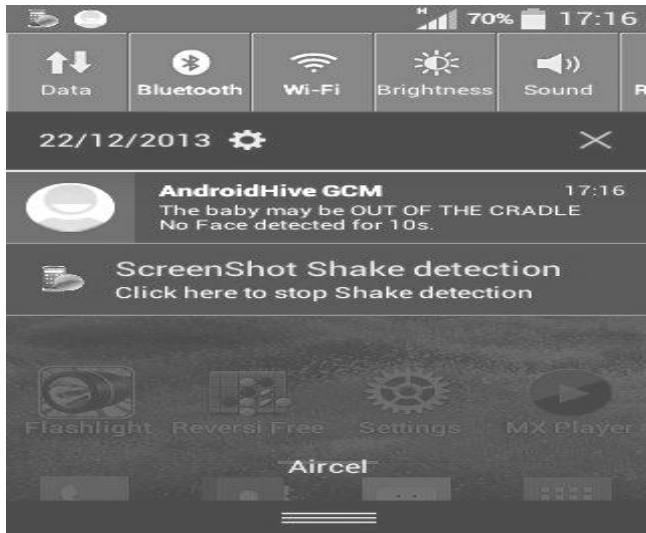


Fig.9. Out of Cradle Alert

A cascade of classifiers is degenerated decision tree where at each stage a classifier is trained to detect almost all objects of interest (frontal faces in our example) while rejecting a certain fraction of the non-object patterns [5]. For instance, in our case each stage was trained to eliminate 50% of the non-face patterns while falsely eliminating only 0.2% of the frontal face patterns; 13 stages were trained. In the optimal case, we can expect a false alarm rate about and a hit rate about.

Let us assume that the basic unit for testing for the presence of an object is a window  $W \times H$  of pixels. Also assume that we have a very fast way of computing the sum of pixels of any upright and  $45^\circ$  rotated rectangle inside the window. A rectangle is specified by the tuple with  $r = (x, y, w, h, \alpha)$ ,  $0 \leq x, x + w \leq W$ ,  $0 \leq y, y + h \leq H$ ,  $x, y \geq 0$ , and its pixel sum is denoted by  $\text{RecSum}(r)$ .

Each stage was trained using the Discrete Adaboost algorithm. Discrete Adaboost is a powerful machine learning algorithm. It can learn a strong classifier based on a (large) set of weak classifiers by re-weighting the training samples. Weak classifiers are only required to be slightly better than chance. Our sets of weak classifiers are all classifiers which use one feature from our feature pool in combination with a simple binary thresholding decision. At each round of boosting, the feature-based classifier is added that best classifies the weighted training samples. With increasing stage number the number of weak classifiers, which are needed to achieve the desired false alarm rate at the given hit rate, increases.

## 6. RESULTS

The temperature readings were collected from the baby monitoring. The temperature of the cradle over a period of 24 hours has been shown in the Fig.10.

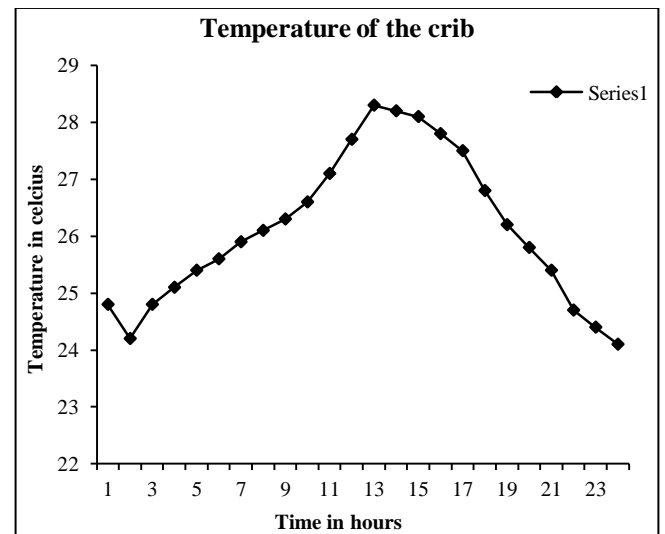


Fig 10. Temperature of the crib

## 7. CONCLUSION

It is hereby implemented a set of sensor networks and IP Camera to monitor the baby in the crib. The proposed Smart Crib has the capabilities to measure the light intensity on the crib, temperature of the crib and positions of the baby periodically and the record the readings. The Smartphone application is also capable of raising alerts based on the recorded values. The smart crib is also designed in such a way that it can identify most of the symptoms of the Sudden Infant Death Syndrome like varying temperature, light intensities and the weight of the baby.

As an extension to this work, we can deploy the smart crib system in the day care centre for baby and crib fencing can be used to monitor babies in home or crèche.

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