Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X
IMPACT FACTOR: 7.056

IJCSMC, Vol. 9, Issue. 7, July 2020, pg.64 – 76

A Smart Baby Cradle Based on IoT

Sarah Ahmed Alswedani[1]; Fathy Elbouraey Eassa[2]
[1]King Abdulaziz University, Faculty of Computing and Information Technology
Computer Science Department, Jeddah, Saudi Arabia
sabdullahalswedani@stu.kau.edu.sa
[2]King Abdulaziz University, Faculty of Computing and Information Technology
Computer Science Department, Jeddah, Saudi Arabia
feassa@kau.edu.sa

Abstract— These days, with the increasing demands and responsibilities of life, parents becoming busy most of the time which makes taking care of an infant incredibly difficult task as infants need the attention and supervision of caregivers all the time. However, the advancement of technology has led to the emergence of smart baby cradle as an intelligent system with numerous features to reduce the burden of parents and caregivers. The paper aims to enhance the quality of the existing baby cradle systems by incorporating a new module for managing baby cry. Managing baby cry involves providing analysis for baby cry, and accordingly, triggering the suitable device attached to the cradle. This research paper provides significant attention on detecting baby cry, more accurately, by integrating four-sub modules in the cry classification process including voice analysis, face image analysis, body gesture analysis, and finally decision fusion.

Keywords— Internet of Things (IoT), Smart Cradle, Cry Classification, Voice Analysis, Image Analysis, Body Movement Analysis, Decision Fusion, Software Architecture

I. INTRODUCTION

Nowadays with the increased requirements of living and the busy lifestyle of people, taking care of infants becoming an extremely challenging task as infants need the caregiver's attention and monitoring all the time. However, with the advancement of technology smart baby cradle has emerged to reduce the burden of parents and caregivers. The smart baby cradle is an intelligent system with numerous features such as swing the baby automatically whenever needed, providing live monitoring through a web camera, making an entertainment by playing a song or rotating a musical toy, detecting baby cry, monitoring baby's vital signs, and providing users with notification messages upon detection of an event (e.g. cry, baby wakeup, mattress wetness, etc). The smart baby cradle aims to help parents or caregivers to provide better care for babies and improve baby's safety by providing continuous monitoring for infants. It also aims to enhance the baby's protection from any possible danger. For example, detecting abnormal reading of one of the baby's vital signs, such as getting high body temperature or low level of blood oxygen. Most of the smart cradle systems monitor surrounding temperature and avoid excessive increase or decrease which raises the possibility of SIDS (Sudden Infant Death Syndrome) [1]. Some smart baby cradle systems protect infants from harm and possible death by providing real-time prediction for possible dangerous events such as falling a cover on the baby's face, falling sharp object on baby's bed [2], or falling the baby from bed [3].

Currently, smart cradle systems are based on the Internet of Things (IoT) which encompasses sensors and actuators that are connected over the Internet and provided with the ability to interact with each other and exchange data without human intervention. IoT refers to a network of things (objects) that are connected to the

Internet network. The main basis of IoT is that each object such as sensor or actuator is able to sense some data, identify it, process it, and finally communicate with others [4]. IoT is one of the prominent fields that aims to facilitate human lives and make it more convenient [5]. It aims to control, real-time monitoring, and perform autonomous function and optimization. Thus, it enables seamless remote access to cradle devices. [6, 7]

IoT based smart cradle systems consist of software and hardware components. With respect to the hardware elements, sensors and actuators are used [8]. A smart sensor is a special device that takes some data from the surrounding environment and upon the detection of a particular input, it performs processing on the data before passing it on by using some built-in resources [9]. For smart baby cradle, various types of sensors can be used some for the human body and others for the environment. For example, body temperature sensor, heartbeat sensor, pressure sensor, blood oxygen sensor, bodyweight sensor, and many others are used for monitory baby health [1, 10, 11]. For the baby's surrounding environment, sensors for ambient temperature, sound, smoke, light, moisture, and plenty of others are used [8]. On the other hand, an actuator is a component that produces a change in the system, for example, by making a motion, a warm or a flow [9]. Different actuators are attached to the smart crib such as a musical toy, a sound system such as MP3 player, web camera, speaker, mic, mini-fan, and the rotary electrical motor [1]. All these components are connected via the Internet to provide several functionalities for the smart system. The communication is managed by the middleware module including MQTT Server (Broker), a Storage Server, and a Web Server [6]. MQTT Broker is the communication medium between devices and the middleware [12]

The paper aims to enhance the quality of the existing baby cradle systems by incorporating a new module for managing baby cry. Managing baby cry involves providing analysis for baby cry, and accordingly, triggering the suitable device attached to the cradle.

This research paper has provided significant attention on detecting baby cry, more accurately, by integrating four-sub modules in the cry classification process including voice analysis, face image analysis, body gesture analysis, and finally decision fusion.

The remainder of this paper is structured as follows. In Section II, background information is documented. The related work is presented in Section III. Then, in Section IV, the proposed software architecture is provided. A comparative study is depicted in Section V. Finally, the conclusion and future work are presented in Section VI.

II. BACKGROUND

This section provides an explanation for the commercial off-the-shelf (COTS) components that are used in this research paper.

A. Voice Analysis

Cry signals analysis is known as acoustic analysis and it has got considerable attention from research community for many years. Research studies have provided adequate evidence that cry signals convey information about the newborn physical, as well as, psychological states [13].

From the aspect of emotion detection, a significant number of research studies have conducted on the acoustic analysis of an infant's cry [14]. Various artificial intelligence algorithms have been utilized in this matter. For instance, artificial neural networks were used in the system developed by [15], for processing infant cry. However, the researchers in [16], have developed a system using the Bayesian classifier which makes the classification from the perspective of pain. In their study, they used 50 cry recordings 25 of them for babies crying from pain while the other 25 for non-pain reasons. Their classification technique provided a reasonable performance in which the experimental results revealed an accuracy of 75%. The research study in [17] used a combination of methods such as Gaussian Mixture Model – Universal Background Model (GMM-UBM) and i-vectors method. Moreover, some products are available in the market for emotion detection [14]. For example, a system has been invented by Kaoru Arakawa for analysing baby cries in which it can provide a diagnosis for the reason behind baby cry. The system performs an analysis of the waveforms and the frequencies. Three different classicalness is provided by the system including pain, hunger, and tiredness [18]. Moreover, interesting equipment called why Cry has been offered by a Spanish engineer to provide an automatic classification for baby cries [19].

B. Face Image analysis /Image Processing

Facial expressions of a human being convey information about the person's emotions. A research study by Mehrabian [20] states that facial expressions convey 55% of the message. Facial expressions are produced by the changes or movement of certain facial features such as the mouth, the eyebrow, as well as, the eye. Facial expressions recognition results in detecting the basic emotions like anger, happiness, fear, sadness, disgust, and surprise [21]. The process of identifying the baby's emotions from facial expressions involves processing the images and detecting the changes that occur in some of the facial features. Various combinations of facial features could clarify the reason of the baby's cry such as the mouth state whether it is open or closed, the eye state including iris extension and the direction of gaze, and the state of the eyebrows state whether it is getting up or down [22]. This process consists of four phases. In the first phase, the human face is detected from the image or the video. In the second phase, the normalization process is performed for normalizing the face image over the brightness and remove the existing noise. After that, in the third phase, features are reduced, and irrelevant features are eliminated. Finally, facial expressions are classified into various emotions such as sadness, happiness, fear, anger, disgust, and surprise. [21] Various techniques can be used for facial expression recognition. For instance, the Principal Component Analysis (PCA) technique and Fisher's Linear Discriminant.

C. Baby Gesture Analysis

Body gestures which are known as "body language" are one of communications forms that reveal different information regarding the person's feelings, thoughts, and emotions [23]. It involves body posture, the use of personal space, and movements of some parts of the body such as hands, arms, and head [24]. Emotional Body Gesture Recognition (EBGR) is one of the research areas that has gained attention recently. It consists of multiple phases including human detection phase, body pose estimation, feature extraction, and finally emotion recognition. The first phase aims to detect persons in the input file which is considered a challenging task because of the human body nature which is non-rigid. It is essential for the next phase where an estimation for body pose is provided after predicting the locations of a person's joints by identifying various parts of the body such as the hands, the torso, and the head or by mapping a skeleton model to the required image. Finally, a relevant representation is designed for mapping inputs data to a predefined model using one of the pattern recognition techniques [23]. The emotional state of a person is expressed in the position of legs and hands, as well as, the body movement [25]. For example, with fear feeling the body will have a high heartbeat rate which can be noticed from the neck, the arms and legs are moving, the hands or arms are clenched [23]. Various techniques are used for analysing body gestures. For example, in [26], the researchers experimented multiple standard classifiers for classifying body gestures into six emotional classes including anger feeling mixed with either disgust, fear, or happiness, fear feeling mixed with surprise and sadness, uncertainty feeling mixed with fear and surprise, and finally uncertainty feeling mixed with surprise. The results indicate that the Bayesian Net algorithm has the best classification results. Another study in [27] has performed a comparative study between various methods such as 1-nearest-neighbor with dynamic time warping (DTW-1NN), J48 decision tree, and the Hidden Naive Bayes (HNB). According to their study, DTW-1NN provided the best results for classifying body gestures into four emotional categories.

D. Decision Fusion

Decision Fusion approach aims to combine multiple classifiers for improving the classification accuracy. This approach was developed in 1992 by [28]. According to the research study [28], the experimental results indicate that combining several classifiers could significantly improve the classification accuracy. Previous research papers state that this approach could be used in various pattern recognition applications including speech recognition, remote sensing, character recognition, and medical applications as well as many others [29]. This approach integrates different classification results into one result and that is done based on the reliability of the classification algorithms.

III. RELATED WORK

Various research studies have been conducted around the smart baby cradle. The following presents a summary of some of the proposed smart cradle systems.

The authors in [1] developed a smart system for the baby cradle. The system monitors baby crying, moisture condition, and environment humidity and temperature. Based on the measured data, the system automates some actions. For example, upon detection of baby cry, the system will automatically enable the attached motor to swing the cradle, as well as the lullaby toys to entertain the baby. Furthermore, if the room temperature exceeds a threshold (28℃), the system will trigger the attached mini fan to provide a cool temperature surrounding the baby. The system also provides real-time monitoring via wireless cameras. The system enables users to monitor the baby through the camera mobile application and talk to the baby through the built-in microphone. The system also provides users with notifications. The system also designed to enables the users to control the attached devices in which the user can remotely control the cradle to swing manually by the MQTT server or the mobile application. The system also enable user to remotely turn ON or OFF the mini fan, as well as, the musical toy. Real-time monitoring is provided by the system through an external web camera. The system is designed utilizing sensors networks, Wi-Fi-Based Controller Board, and IoT technology. The experimental results showed that the proposed system works successfully for infant care.

According to [30] a smart system for a baby crib is proposed based on IoT technology. The system is designed to keep working and busy parents aware of their babies through a mobile application. The developed system provides real-time vision monitoring which is accomplished using the wireless camera. The proposed system also has the capability of sending notification messages to the user upon detection of wetness in the bed.

Upon detection of baby movement on the bed, the system initiates the cradle to oscillate automatically by the rotating motor which is actuated by the body movement. The system is also designed to push alarms to the users when the baby wakes up.

With respect to [31], the system is proposed to help parents to track their children. The system detects the cradle temperature, cradle wetness, and baby cry. If the temperature readings exceed a particular level (39°C), a notification message is sent to the parents. In the case of baby cries, the cradle will automatically start to swing in addition to music autoplay through the speaker to soothe the baby. The system is also designed to provide the users with a warning message through the blynk server. Furthermore, it enables users to set the feeding time of the baby, so the users receive notifications messages at the required time.

The researchers in [3] introduced a smart system for baby bed with the Internet of Things capabilities. The system is designed to detect the motion, crying, and current position of the baby. The system aims to enhance the baby's safety by monitoring the baby and reducing the possibilities of one of the causes for sudden death which is falling from the cradle. The system provides a baby monitoring with capabilities to identify if the baby is approaching the bed boundaries, and accordingly, in case of any abnormal state, the system will notify the users via the email. The system is utilizing image processing for analysing baby's motion and detecting the boundary of the bed. The system is using Raspberry Pi B+ module to process the videos taken by pi camera. RPi module provides more advantages compared to Arduino and Microcontroller. The system is designed to reduce the chances of the baby's falling from the bed.

In [2], the researchers proposed a baby watching system based on IoT smart sensing and deep learning machine techniques. The system provides monitoring for infant body conditions such as heartbeat, breathing, body temperature, sleeping posture, as well as the surrounding conditions such as dangerous/sharp objects, light, noise, humidity, and temperature. The proposed system can analyse and predict the obvious dangerous conditions and then provides application's users with notification messages indicating the level of emergency ranging from lowest to highest in which highest needs real-time response from the users. The experimental results have proved its effectiveness for infant care.

The authors in [32] introduced an intelligent baby cradle that is supported by various sensors to collect important biological data regularly. The proposed system includes various sensors such as heart rate sensors, smoke sensors, temperature sensors, weight sensors, and ultrasonic sensors. An automatic alert is sent to the nearest hospital via email if an abnormality is detected in the measure data. The system also monitors the surrounding environment and it provides an alarm if dust or dangerous gas is detected. The system is equipped with a detection module that detects the crying of the baby and automatically starts to swing. The system is designed using electronic sensors, Arduino, GSM module, and IoT.

IV. The Proposed Solution

The proposed architecture for the smart baby cradle is provided in this section. The general software architecture consists of five main modules as shown in Fig. 1. The architecture is designed using web service technology. This style is chosen since it provides support for the proposed system's non-functional requirements which are Development Time, Maintainability, and Availability. A description of the web services used in the proposed architecture is provided below. More details regarding the components can be found in Section II.

A. Login Module

This module is responsible for handling user registration and login operations.

B. Baby Cry Management

This module is the main contribution of this paper. It is designed to manage baby cry by providing an analysis for baby cry which enhances the quality of baby care. Since each reason behind baby cry needs to be managed in a different way, the cry reason should be identified first before taking any action. Thus, this module consists of two internal modules: Cry Classification and Device Control, as shown in Fig. 2. The Cry Classification sub-module is designated for analysing baby cry and detecting the cry reason and the second module is for managing the attached devices to the baby cradle. The module is designed to first invoke the Cry Classification sub-module and based on its result the suitable device will be initiated by the Device Control sub-module. It means based on the baby cry classification from the Cry Classification module, the suitable device of the baby's cradle will be triggered by Device Control sub-module. Furthermore, this module provides a notification to the users about the cry of the baby in addition to the detected reason.

For example, if the baby is crying and fear emotion is detected by the Cry Classification sub-module, then this module will send a request to the Device Control sub-module to turn on the attached MP3 to play a song by the mother's sound, or any kind of sound or music which could help to pacify and entertain the baby. This module also provides the parents with notification messages about the baby cry in addition to the predicted reason. Fig. 3 depicts the sequence diagram for baby cry management operations while Fig. 4 presents the algorithm for baby cry management operations.

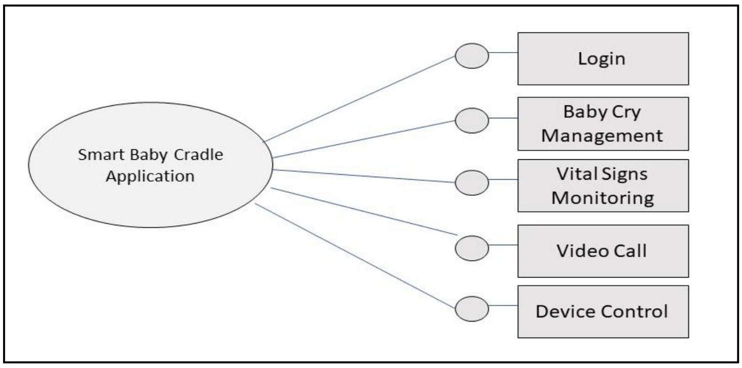

Fig. 1 Software architecture of smart baby cradle application

1) *Cry Classification:* Newborns crying is their only way of communication, expressing their needs and emotional states [33]. There are various possible reasons of a baby cry occurrence which could be, for example, feeling of pain, fear, hunger, anger, discomfort, sleepiness, or the need for attention [19] [17]. Thus, understanding the reason behind the baby's cry is very significant to satisfy the baby's needs. However, it is very difficult for unexperienced parents or caregivers to realize the reason of the baby's cry. Therefore, automatic classification for baby cry is proposed in the smart baby cradle which will enhance the quality of baby care systems.

This web service is used to classify baby cry and detect the baby's emotion to understand the reason behind baby cry. This web service was designed based on the scientific concept that human emotions are reflected not only on the voice but also on facial expressions and body gestures. Thus, the reason that causes the baby to cry will reflect on his facial expressions, as well as, his body movement in addition to the frequency of his voice. Accordingly, for accurately detecting the baby's emotions during crying and classifying the event of cry to one of the well-known reasons, combinations of analysis should be performed. This combination is adopted to improve classification accuracy and that is based on the experimental results of this study [34] which indicates the effectiveness of the integrating facial expression, as well as, body gesture. Another study [35], recommends the combination of facial expression and body gesture for effective analysis.

Therefore, this web service is composed of a combination of voice analysis, face image analysis, and body movement analysis. Each of these analysis approaches is provided by an independent web service. Accordingly, this web service consists of four internal web services. Three for providing analysis for different aspects including Voice Analysis, Face Image Analysis, and Body Movement Analysis. The analysis provided by these web services is performed simultaneously and independently, to classify the crying event into one of the types such as anger, fear, colic, sleepiness, and discomfort. The classification results of the three web services are fused into a single reason for the cry by the fourth web service which is called Decision Fusion. The internal components of this web service are depicted below in Fig. 5. The sequence diagram for the baby cry classification module is presented in Fig. 6 and the algorithm for this module is provided in Fig. 7. The details for internal web services are provided below.

Voice Analysis

This web service is needed for processing and analysing cry signals using one of the well- known artificial intelligence classifiers to detect the baby's emotions.

Face Image Analysis

The face image analysis module will take the facial image of the baby crying and process it to detect the reason behind the crying. The analysis process involves detecting the changes that occur in some of the facial features such as the mouth, the eyes, and the eyebrows.

Baby Movement Analysis

It is used for analysing the body gestures of the baby during crying in order to detect the emotional or health status of the baby which will help classify the baby cry more accurately.

Decision Fusion

For combining the decisions of multiple classifiers into a common decision, Decision Fusion is used. The output results of the three modules: sound analysis, image analysis, and video analysis will be the inputs for the Decision Fusion module which will perform the integration for the results based on the reliability of the classifier's performance.

2) Device Control: The main objective of this module is to make a control over the attached devices such as the musical toy, MP3 player, web camera, speaker, mic, mini-fan, and the rotary electrical motor. This module provides control to turn ON/OFF the attached devices.

C. Vital Signs Monitoring

This module aims to provide monitoring for the baby's vital signs such as body temperature, heartbeat rate, blood oxygen level (SpO2), and blood pressure. In case any abnormality is detected in the sensors' readings, this module should provide notification messages to notify the users about the baby's healthy state. In some cases, a suitable device should automatically turn on to provide some help. For example, if the baby's temperature is above the normal readings, the attached mini fan should automatically start working to provide a cool temperature surrounding the baby which could help to lower the baby's temperature and cool the baby.

D. Video Call

The objective of this module is to provide additional monitoring by allowing users to view the baby's real-time status through the wireless camera.

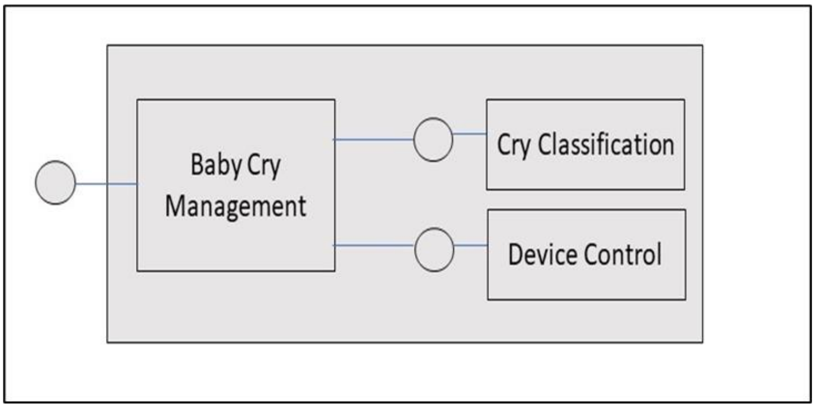

Fig. 2 The Internal web services of baby cry management web service

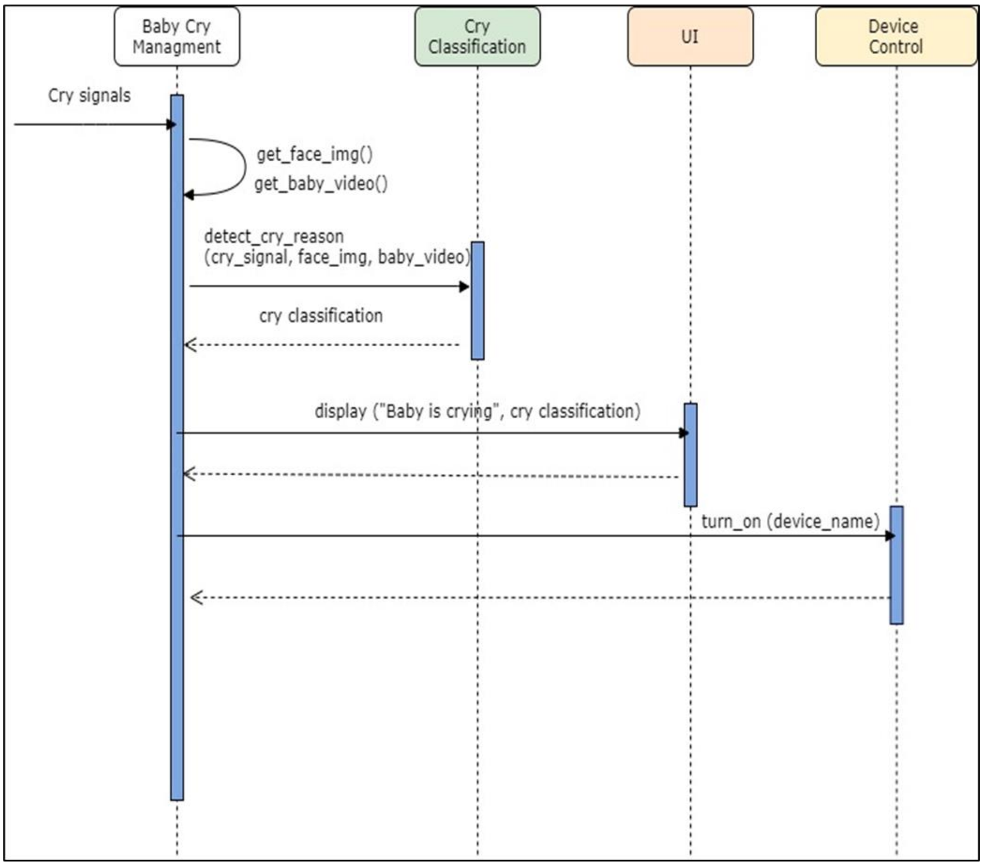

Fig. 3 Baby cry management sequence diagram

```
Algorithm 1: Baby Cry Management Algorithm
Input:  Cry signals, face_img, and baby_video.
Output: A classification for baby cry,
        Turn on suitable device
        Notification message is displayed on the screen.
   1.if cry signal is received then
   2.   get_face_image( )     /*get face image for crying baby*/
   3.   get_baby_video( )     /*get video for crying baby*/
   4.   if face_image AND baby_video is received then
   5.       /*invoke Cry Classification web module*/
   6.       detect_cry_reason(cry_signal, face_img, baby_video)
   7.       if classification is received then
   8.            /*1. display notification message to the users*/
   9.            display("Baby is crying", cry classification)
   10.           /*2. invoke Device Control module*/
   11.            turn_on(device_name)
   12.      else
   13.           1. Repeat detect_cry_reason(cry_signal, face_img, baby_video)
                     until classification result is obtained
                 2. Go to 7
   14.      end if
   15. else if face_image is not received then
   16.          1. Repeat get_face_image( ) until result is obtained
   17.          2. Go to 6
   18.  else if baby_video is not received then
   19.          1. Repeat get_baby_video( )until result is obtained
   20.          2. Go to 6
   21.  else
   22.       1. Repeat get_face_image( ) until result is obtained
   23.       2. Repeat get_baby_video( )until result is obtained
   24.       3. Go to 6
   25.  end if
   26. else
   27.   keep checking for cry signal
   28.end if
```

Fig. 4 Baby Cry Management Algorithm

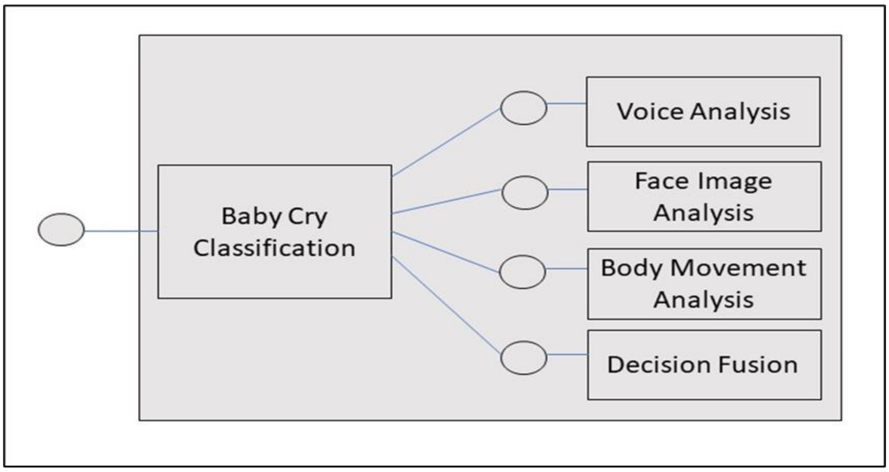

Fig. 5 The internal web services of cry classification web service

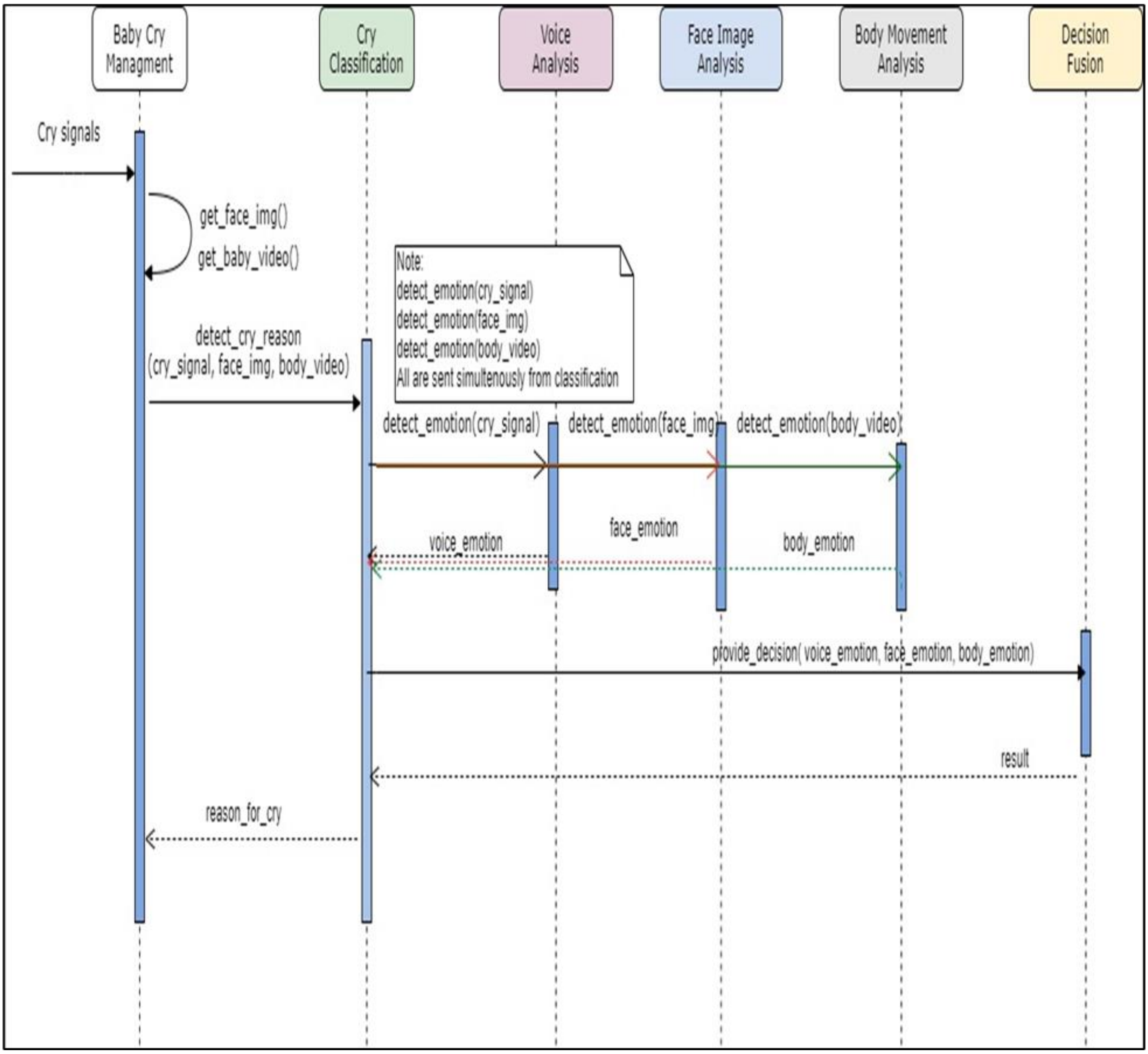

Fig. 6 Cry classification sequence diagram

```
Algorithm 2: Baby Cry Classification Algorithm
Input:  Cry_signal, face_img, and baby_video.
Output: A classification for baby cry
   1. if cry_signal, face_image and baby_video is received then
   2.    /* invoke Voice Analysis module*/
   3.    detect_emotion(cry_signal)
   4.   /* invoke Face Image Analysis module*/
   5.    detect_emotion(face_img)
   6.   /* invoke Body Movement Analysis module*/
   7.    detect_emotion(body_video)
   8.      if emotion classification is received from Voice Analysis AND
   9.        Face Image Analysis AND Body Movement Analysis then
   10.          /* invoke Decision Fusion module*/
   11.            provide_decision (voice_emotion, face_emotion, body_emotion)
   12.            if result is received from decision fusion then
   13.            return the result (classification for baby cry)
   14.            else
   15.            Go to 11
   16.            end if
   17.      else if result not received from Voice Analysis then
   18.           1. Repeat detect_emotion(cry_signal) until result is obtained
   19.           2. Go to 11
   20.      else if result not received from Face Image Analysis then
   21.           1. Repeat detect_emotion(face_img) until result is obtained
   22.           2. Go to 11
   23.       else if result not received from Body Movement Analysis then
   24.           1. Repeat detect_emotion(body_video) until result is obtained
   25.           2. Go to 11
   26.       else if result not received from Voice Analysis AND Face Image Analysis then
   27.           1. Repeat detect_emotion(cry_signal) and
                          detect_emotion(face_img) and until both results are obtained
   28.           2. Go to 11
   29.        else if result not received from Voice Analysis and Body Movement Analysis then
   30.           1. Repeat detect_emotion(cry_signal) and detect_emotion(body_video) and
   31.             until both results are obtained
   32.           2. Go to 11
   33.        else if result not received from Face Image Analysis and Body Movement
   34.        Analysis then
   35.           1. Repeat detect_emotion(face_img) and detect_emotion(body_video) until
   36.              both results are obtained
   37.         2. Go to 11
   38.         else
   39.             Go to 3
   40.         end if
   41. else keep checking for cry signal
   42. end if
```

Fig. 7 Baby Cry Management Algorithm

E. Device Control

This module aims to provide control over the attached devices such as a musical toy, MP3 player, web camera, speaker, mic, and the rotary electrical motor in addition to the electrical sensors. It allows users to control connected devices through the Internet using the mobile application. This feature is made available with the help of the Internet of Things technology (IoT).

V. COMPARATIVE STUDY

The proposed system is designed in a way that aims to enhance its functionality by combining a newly proposed module with some of the available modules in the literature of smart cradle systems. The newly designed module is a consolidation of various existing components.

This section provides a summary of the features provided by the proposed smart cradle system in comparison with some of the available smart cradle systems in the literature. An outline for the comparison is provided in Table I.

VI. CONCLUSIONS

In this paper, a software architecture for a smart baby cradle IoT based system was proposed. The proposed solution aims to improve the quality of the existing baby care systems by understanding the reason behind baby cry which is very significant to satisfy the baby's need. The proposed solution provides a new module for managing baby cry with few operations using two sub-modules. First, providing analysis for baby cry to detect and understand the reason behind baby cry, accordingly and based on the cry cause the module soothes the baby by triggering the suitable device attached to the cradle. This module also provides a notification to the users about the cry of the baby in addition to the detected reason. This research has also provided significant attention on detecting baby cry more accurately by integrating four-sub modules in the cry classification process including voice analysis, face image analysis, body gesture analysis, and finally decision fusion.

For future work, the objective is to extend the system functionality by involving medical cases or disorders in the system. For example, adding a module for early detection of some medical cases/disordered that can be observed from baby cry. In general, exploiting baby's big data resulting from continuous monitoring in providing comprehensive analysis for baby's habits, predicting possible diseases, early detection of disorders, discovering some patterns will be very crucial since this field is not yet explored by the scientific community.

TABLE I
COMPARISON BETWEEN THE PROPOSED SMART BABY CRADLE AND OTHER SMART SYSTEMS

Reference / Features		The proposed system 2020	[1] 2019	[30] 2019	[31] 2019	[3] 2019	[2] 2018	[10] 2018	[8] 2017
Baby Cry Detection		✓	✓	✓	✓	✓	×	✓	✓
Baby Cry Analysis		✓	×	×	×	×	×	×	×
Face Image Analysis		✓	×	×	×	×	✓	×	×
Body Movement Analysis		✓	×	×	×	✓	×	×	×
Decision Fusion		✓	×	×	×	×	×	×	×
Cry Management	Auto play	suitable device	- swing motor -musical toy	-swing motor -musical toy -mic	- swing motor -music	×	×	×	- swing motor -music -rotating toy
	Notification	✓	✓	✓	✓	✓	✓	✓	✓
Device Control		✓	✓	✓	×	✓	×	✓	✓
Vital Signs Monitoring		✓	×	×	✓ temperature only	×	× heartbeat temperature	✓ Temperature Heartbeat	×
Video Call		✓	✓	✓	×	×	×	×	✓

REFERENCES

[1] W. A. Jabbar, H. K. Shang, S. N. Hamid, A. A. Almohammedi, R. M. Ramli, and M. A. Ali, "IoT-BBMS: Internet of Things-Based Baby Monitoring System for Smart Cradle," IEEE Access, vol. 7, pp. 93791-93805, 2019.

[2] C. Lai and L. Jiang, "An Intelligent Baby Care System Based on IoT and Deep Learning Techniques," the year, 2018.

[3] Y. K. Dubey and S. Damke, "Baby Monitoring System using Image Processing and IoT," 2019.

[4] A. Kaur and A. Jasuja, "Health monitoring based on IoT using Raspberry PI," in 2017 International Conference on Computing, Communication and Automation (ICCCA), 2017, pp. 1335-1340: IEEE.

[5] M. Chen, Y. Ma, J. Song, C.-F. Lai, and B. Hu, "Smart clothing: Connecting human with clouds and big data for sustainable health monitoring," Mobile Networks and Applications, vol. 21, no. 5, pp. 825-845, 2016.

[6] A.-R. Al-Ali, I. A. Zualkernan, M. Rashid, R. Gupta, and M. AliKarar, "A smart home energy management system using IoT and big data analytics approach," IEEE Transactions on Consumer Electronics, vol. 63, no. 4, pp. 426-434, 2017.

[7] V. Pardeshi, S. Sagar, S. Murmurwar, and P. Hage, "Health monitoring systems using IoT and Raspberry Pi—a review," in 2017 International Conference on Innovative Mechanisms for Industry Applications (ICIMIA), 2017, pp. 134-137: IEEE.

[8] M. P. Joshi and D. C. Mehetre, "IoT based smart cradle system with an Android app for baby monitoring," in 2017 International Conference on Computing, Communication, Control and Automation (ICCUBEA), 2017, pp. 1-4: IEEE.

[9] R. H. Bishop, "Introduction to Sensors and Actuators," in The Mechatronics Handbook - 2 Volume Set: CRC Press, 2014.

[10] S. S. Bachhav and D. N. B. Chopade, "IoT Based HealthyBaby Cradle System," 2018.

[11] D. N. F. M. Ishak, M. M. A. Jamil, and R. Ambar, "Arduino based infant monitoring system," in IOP Conference Series: Materials Science and Engineering, 2017, vol. 226, no. 1, p. 012095: IOP Publishing.

[12] T. Lee, S. Jeon, D. Kang, L. W. Park, and S. Park, "Design and implementation of intelligent HVAC system based on IoT and Bigdata platform," in 2017 IEEE International Conference on Consumer Electronics (ICCE), 2017, pp. 398-399: IEEE.

[13] L. Abou-Abbas, C. Tadj, and H. A. Fersaie, "A fully automated approach for baby cry signal segmentation and boundary detection of expiratory and inspiratory episodes," The Journal of the Acoustical Society of America, vol. 142, no. 3, pp. 1318-1331, 2017.

[14] S. Matsunaga, S. Sakaguchi, M. Yamashita, S. Miyahara, S. Nishitani, and K. Shinohara, "Emotion detection in infants' cries based on a maximum likelihood approach," in Ninth International Conference on Spoken Language Processing, 2006.

[15] O. F. Reyes-Galaviz and C. A. Reyes-Garcia, "A system for the processing of infant cry to recognize pathologies in recently born babies with neural networks," in 9th Conference Speech and Computer, 2004.

[16] H. Baeck and M. Souza, "A Bayesian classifier for baby's cry in pain and non-pain contexts," in Proceedings of the 25th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (IEEE Cat. No. 03CH37439), 2003, vol. 3, pp. 2944-2946: IEEE.

[17] I.-A. Bğnicğ, H. Cucu, A. Buzo, D. Burileanu, and C. Burileanu, "Baby cry recognition in real-world conditions," in 2016 39th International Conference on Telecommunications and Signal Processing (TSP), 2016, pp. 315-318: IEEE.

[18] K. Arakawa, "System and method for analyzing baby cries," ed: Google Patents, 2002.

[19] S. Ntalampiras, "Audio pattern recognition of baby crying sound events," Journal of the Audio Engineering Society, vol. 63, no. 5, pp. 358-369, 2015.

[20] A. Mehrabian, "Communication without words," Communication theory, pp. 193-200, 2008.

[21] J. Rani and K. Garg, "Emotion Detection Using Facial Expressions-A Review," International Journal of Advanced Research in Computer Science and Software Engineering, vol. 4, no. 4, 2014.

[22] P. Pal, A. N. Iyer, and R. E. Yantorno, "Emotion detection from infant facial expressions and cries," in 2006 IEEE International Conference on Acoustics Speech and Signal Processing Proceedings, 2006, vol. 2, pp. II-II: IEEE.

[23] F. Noroozi, D. Kaminska, C. Corneanu, T. Sapinski, S. Escalera, and G. Anbarjafari, "Survey on emotional body gesture recognition," IEEE transactions on affective computing, 2018.

[24] S. Mitra and T. Acharya, "Gesture recognition: A survey," IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), vol. 37, no. 3, pp. 311-324, 2007.

[25] C. Shan, S. Gong, and P. W. McOwan, "Beyond Facial Expressions: Learning Human Emotion from Body Gestures," in BMVC, 2007, pp. 1-10.

[26] J. Deutscher, A. Blake, and I. Reid, "Articulated body motion capture by annealed particle filtering," in Proceedings IEEE Conference on Computer Vision and Pattern Recognition. CVPR 2000 (Cat. No. PR00662), 2000, vol. 2, pp. 126-133: IEEE.
[27] G. Castellano, S. D. Villalba, and A. Camurri, "Recognising human emotions from body movement and gesture dynamics," in International Conference on Affective Computing and Intelligent Interaction, 2007, pp. 71-82: Springer.
[28] L. Xu, A. Krzyzak, and C. Y. Suen, "Methods of combining multiple classifiers and their applications to handwriting recognition," IEEE transactions on systems, man, and cybernetics, vol. 22, no. 3, pp. 418-435, 1992.
[29] C. Y. Suen, "Recognition of totally unconstrained handwritten numerals based on the concept of multiple experts," in Proc. 1st International Workshop on Frontiers in Handwriting Recognition, April 1990, 1990, pp. 131-143.
[30] S. Ramesh, S. Hanidia Misbah, P. Bhavani, and H. Mamtha, "A Smart Baby Cradle," Global Journal of Computer Science and Technology, 2019.
[31] M. Shasna, K. Mathilakam, M. M. Kabeer, N. N. Nazar, and N. Ashok, "Infant cradle monitoring system," 2019.
[32] S. Kumar and S. Anirudh, "Smart Baby Cradle Using Arduino and IoT," Advance and Innovative Research, p. 53, 2018.
[33] I.-A. Bănică, H. Cucu, A. Buzo, D. Burileanu, and C. Burileanu, "Automatic methods for infant cry classification," in 2016 International Conference on Communications (COMM), 2016, pp. 51-54: IEEE.
[34] N. Ambady and R. Rosenthal, "Thin slices of expressive behavior as predictors of interpersonal consequences: A meta-analysis," Psychological bulletin, vol. 111, no. 2, p. 256, 1992.
[35] H. K. Meeren, C. C. van Heijnsbergen, and B. de Gelder, "Rapid perceptual integration of facial expression and emotional body language," Proceedings of the National Academy of Sciences, vol. 102, no. 45, pp. 16518-16523, 2005.

