Volume: 21, Issue: 1
Page: 20-31
2023

International Journal of Science and Business

Journal homepage: ijsab.com/ijsb

IJSAB International

AI Based Baby Nursing Robot

Tarun Debnath & Pallab Kanti Podder

Abstract

Childcare is a tough job for every parent. In a joint family, parents get support from the grandparents, who spend most of their time with the baby. The situation is quite different for those who live in urban. Parents, who remain busy at day time in their job, become tired after their work, and baby caring at that particular time becomes quite impossible for them. More specifically the situation for job holder parents having twin babies cannot be imagined easily. This situation can be solved partially by a baby nursing robot, which can provide basic support needs for a baby. Already a lot of work has been done before and researchers are working to get a perfect solution. This paper focuses on the AI-based baby nursing robot which is an automated baby rocker capable of classifying baby cry to understand baby's needs. After the sound classification, it provides necessary functions for the baby such as baby rocking, and baby entertainment functionality while in the cradle, and in case of a hungry cry it will take the baby to its parents. In addition, the proposed system can provide baby urination information through GSM to the parent's mobile. Also, it can provide some necessary information such as Gas leakage, Smoke detection, and Temperature, Humidity and CO level of the home environment. The robot will raise an alarm immediately and take the baby to the parents if it detects any unsafe situation detected by the sensors.

IJSB
Accepted 22 January 2023
Published 27 January 2023
DOI: 10.5281/zenodo.7574912

Keywords: *AI, Baby, Robot, Childcare, Nursing, Baby cry, Cry classification.*

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1. Introduction

Infants or toddlers need parents' attention for every hour of each day, in this modern era, parents are involved in firm exploitation, office ferment, and personal work. So, they cannot provide enough time to take care of their children due to their involvement in the above activities. Grandparents and caregivers are the only two options available for working parents. With consideration of social media, some incidents like caregivers' attacks on infants in a cruel way are reported frequently. Because this reason the necessity to protect baby with minimal human interference arises (Kavitha et al., 2019). A baby nursing robot with some artificial intelligence can solve this problem of the service holder parents. Already a lot of work on this task is still ongoing by the researchers. Such a comprehensive analysis was conducted between the traditional techniques and autonomous robotic applications by (David et al., 2022). In another study, the author discusses the ethics of robotic applications (Li & Meng, 2022). This paper concludes that the robotic approach to baby caring is important these days but a lot of research is necessary to do that. By addressing the importance of robotic care for parents, we proposed a methodology for baby nursing through an automated baby nursing robot that has Intelligence. To do so, at first the baby's cry is detected through a transducer shown in Figure 2. Through which the mechanical sound signal is converted to its electrical nature for further processing. By analyzing the signal intensity or signal amplitude level the sound signal is classified as Discomfort/ Tired/ Hungry/ Belly Pain/ Burping cry (Symon et al., 2017; Joshi & Mehetre, 2017). From this research, it is found that each type of cry has a different amplitude level that maintains a pattern. In this work, the amplitude level is mapped into its analog value as well as the amplitude level, and generated analog value maintains a proportional relationship between each other. If the classification is detected as discomfort/ tired cry then the baby cradle robot will entertain the baby through rocking for one minute. After completing the rocking function the robot will take the baby to its mother immediately by following the predefine line (Pakdaman et al., 2010; Kalbande & Koche, 2018). Finally, after reaching the bedside, the robot will restart its rocking functionality for four minutes. If the cry is determined to be a Hungry cry, the robot will transport the infant to the mother for feeding. Similarly, if the infant experiences stomach pain or require burping, the robot will promptly take the baby to its mother utilizing the line follower. To ensure safety environment, we have developed a safety alarm system. From this, we can observe temperature, humidity, Liquefied Petroleum Gas (LPG) leakage, smoke, and Carbon Monoxide (CO) in the baby's cradle robot environment through sensors (Gupta et al., 2019). The DHT11 sensor was utilized to monitor humidity, temperature, and CO, LPG, and smoke detected by the MQ-2 sensor in the room environment (Nasaruddin et al., 2019). If the parameters show any unexpected observations or LPG/ smoke is detected, an alarm will sound to alert the parents about their kid. To make the system usable our last concern is the baby's urine detection. A baby diaper will usually cure the problem, but using one for an extended period of time can cause a rash on the baby's skin. So, a urine detection and mobile call generation system is developed for detecting a baby's urination situation. If the associated circuitry detects urine on the specially designed urine mat then two mobile calls will be generated successively to a predefined number with a 1-minute delay interval. The proposed system is developed and implemented for monitoring and caring device of the baby in real-time.

2. Proposed Methodology

The project is initiated to solve the baby nursing issue for a parent who remains busy in the daytime in their office and wants primary support from an automated system for their baby when they are at home. The proposed system will solve their problem. At first, we developed a mechanical baby rocker which includes four motors with a hard rubber wheel for movement. The device is capable to carry one baby. We created five functions for the baby those are integrated with the robot. The entire process of our proposed method is illustrated in the following flow diagram Figure 1.

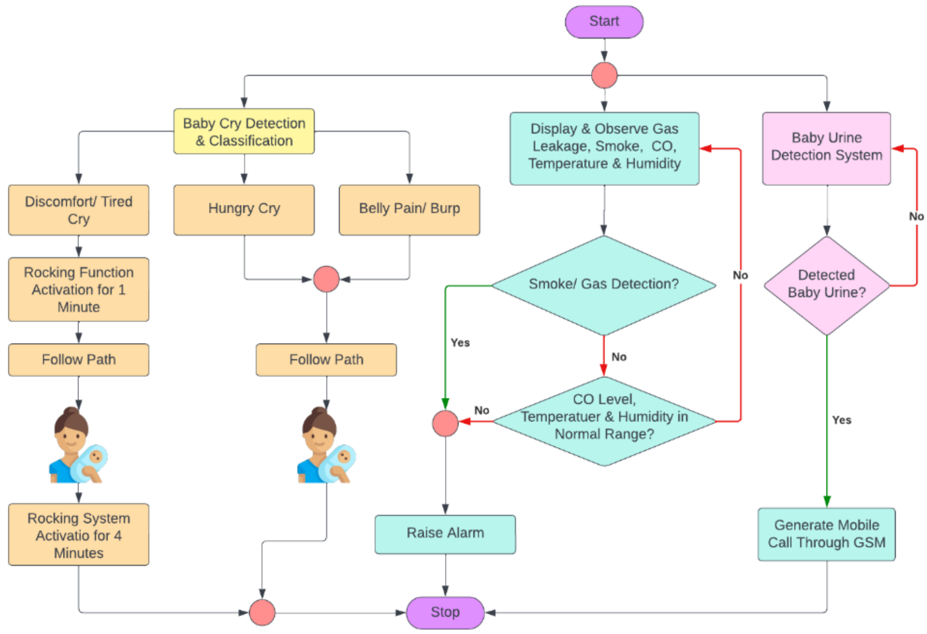

Figure 1: Flow diagram of our proposed baby nursing robot

2.1 Proposed Architecture

The baby cry detection and control system, automated swing module, smoke, and gas detection arrangement, urine detection scheme, and automated movement system are all part of the cradle's architectural design. The following is a full description of the individual phases:

2.1.1 Cry Detection and Control System

Five things can make a baby cry. The infant may be hungry, it may have gas, needs the mother's affection, feel discomfort with urination or other problem, and belly pain (Myakala et al., 2017). The baby wet case is solved using GSM in a later section and the rest four types of cries can be grouped mainly into two categories. One type of cry involves the mother's assistance, while another can be handled by entertaining the infant, such as rocking the baby in the cradle. To differentiate the cries, we played all the sounds and observed the analog output data from the sound sensor. The observed data shows discomfort data provides the peak amplitude is lower than the other types of cry. While the other cry shows peak amplitude is comparatively higher. It provides a lower analog value pattern in the total range of 0 to 1023. The rest of the sound provides comparatively high analog values in the same range. The change is programmed to detect and classify the cries using a PIC16F877A microcontroller. The system analyzes the baby's cry based on these parameters and takes appropriate action. So, in case of the mother's need the robot can understand the need and take the baby to the mother using the line follower function if needed. This can be defined as the intelligence of the device. Similarly, if a discomfort cry is detected the rocking function will be performed at first and after a certain interval for example 1 minute the robot will take the baby to the parents using a black line drawn on a white surface.

Figure 2: Sound detection Module

2.1.2 Automatic Swing Module

When the baby cry is recognized and predicted to be a discomfort cry, the robot will begin swinging utilizing a high torque gear motor. The rocking function is performed using a pic16f877a microcontroller and a 5-volt DC-operated relay. The relay holds power to energize the motor coil for a particular time and then releases the required contact to de-energize the motor coil. The rocking functionality can be visualized in Figure 3.

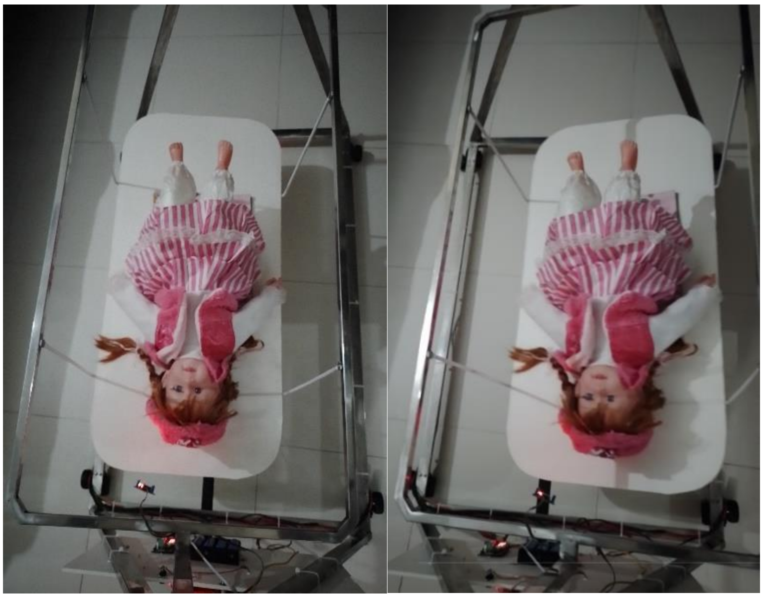

Figure 3: Baby swing functionality of the system

2.1.3 Line Follower Functionality

A PIC16F877A microcontroller and an MG-996R standard servo motor execute this operation. Generally, servo motors are available in two types. These are continuous servo and standard servo. The standard servo can rotate from 0 to 180 degrees only whereas the continuous servo can rotate from 0 to 360 degrees in a continuous manner. As a result, we used four continuous servo motors to create the robot structure. Moreover, the structure has a weight and will increase its weight after having a baby in it. So, we have taken a metal gear modified Tower Pro MG996R servo motor. Now, the kid's room may have some furniture and other devices. That is why the robot requires a path to travel or obstacle avoidance. We choose the line following solution as a safe solution for a predefined path. As a path, a black line will be created on the white surface of the room. The custom cradle is shown below.

Figure 4: Baby cradle frame

The system is capable to take the baby to its mother in case of any emergency or in case of the mother's attention. The embedded software will handle the control operation for line followers as needed. After reaching the baby's mother the robot will play a buzzer to confirm its existence and ends its entire operation.

2.1.4 Safety-Assurance Arrangement

The safety ensures arrangement is designed to measure Temperature, Humidity, CO Level, LPG Gas leakage, & Smoke Detection in the environment air. This is accomplished by two sensors, the MQ-2 and the DHT-11. The MQ-2 sensor shows the parameters in the Particles Per Million (PPM) unit. The module includes a 20x4 LCD Display which displays all the above-mentioned measurements through this display. If any observation is found such as gas or smoke detection or CO level increase the buzzer module raises an alarm immediately to inform the parents about the environment (Al-Haija et al., 2013). Another common phenomenon in Bangladesh is that the temperature falls at late night and due to sleepiness conditions, we can understand the situation very hardly. This problem is addressed for the baby and solved in the project. The temperature variation in the room will be detected by the temperature sensor and analyzed by the microcontroller seen in Figure 5. The alert will sound through a buzzer if there are any temperature-related irregularities. The following Figure 5 shows the safety assurance arrangement test for the system.

Figure 5: Smoke, Gas & CO detection system circuitry

2.1.5 Urine Detection and Call Generation

A very common baby cry is the discomfort cry, which can occur due to various reasons. Such a reason is an urination problem. This can be also called a baby wet condition. This is usually solved by a diaper. But most of the time, long time diaper usage may create a rash. Leaving a baby in a wet condition may cause baby rash and no one wants to do that at all. So, the detection of baby urine after urination, faster detection can be achieved through a mobile call and this can be achieved by the GSM module. The system includes a customized urine sensor made of copper tape, a comparator module, a microcontroller, and a SIM900A GSM Module (Mukherjee et al., 2019). In dry conditions the resistance between the two copper conductors becomes high and the sensor provides a high analog value in the 10-bit resolution which is about 800. If the baby becomes wet, the resistivity decreases and the sensor provides an analog value of about 250. The comparator compares this value to a threshold value that can be adjusted. In this project, we have set the value to 512. As a result, the comparator circuit provides logic 1 for dry conditions and logic 0 for wet detection. An Arduino Uno microcontroller is used to realize this logic from the comparator circuit and depending on the logic a mobile call will be generated immediately for support by exploiting the necessary AT commands. In this way, the entire system works together to solve the problems relating to babies' take care. The customized urine detection sensor is shown in Figure 6 and the call generation control section can be shown in Figure 7.

Figure 6: Customized urine detection sensor

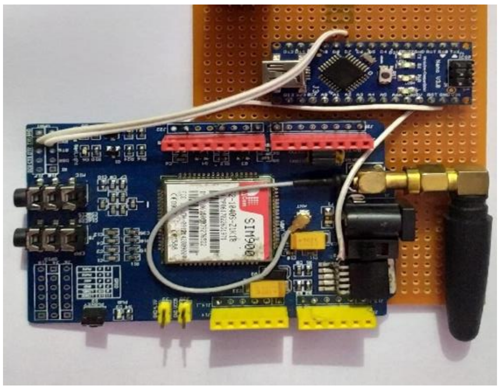

Figure 7: Urine detection circuit using Arduino Nano and Sim900 GSM Module

2.1.6 Automated Movement System

Our baby nursing robot uses line-following technology for its navigation. The line sensing method is not a new or innovative way but the application of line follower in baby nursing can be considered as an innovative way of baby nursing. A black surface absorbs the light and a white surface reflects the light. Maximum reflection is achieved from a white surface and minimum reflection is achieved from a black surface. So, to find the line, we will exploit this quality of light. An Infrared Ray (IR) sensor or an LDR (Light-Dependent Resistor) can be used to detect light. We chose the IR sensor because of its superior precision. Five IR sensors arrangement are installed on the robot's Front side at center alignment to detect the line. The robot is then positioned on the line so that it can use any sensor combination from all the possible combinations. The possible combinations and corresponding actions are defined in the PIC microcontroller and the particular action is taken against a particular sensor output combination. The actions are to provide logic combinations to the L298 motor driver for the servo-driving mechanism. To power up the motor driver we have used a separate 12volt dc power supply with a common ground configuration. By using the aforementioned technique, the robot is navigated by operating the wheels that are attached to the motors, and controlled.

2.2 Processing and Control Technology

To construct the entire system we have used two types of microcontrollers as the processing and control technology. One is a PIC microcontroller from a microchip and another is Arduino. Here, the PIC16F877A microcontroller is used as the main decision device. It is used for controlling all of the system except the safety assurance device and urine detection. A microcontroller (MCU for microcontroller unit) is a small computer on a single VLSI integrated circuit (IC) chip. It contains a numerous processor, 368 bytes RAM, 256 bytes ROM, and operates in 4 to 5.5 volts along with programmable input/output peripherals. (Bermoy & Salvan, 2022). These microcontrollers are mainly used to design embedded applications. An SoC (System on a Chip) may connect the external microcontroller chips as the motherboard components, but a SoC usually integrates the advanced peripherals like a graphics processing unit (GPU) and Wi-Fi interface controller as its internal microcontroller unit circuits (Podder et al. 2021). The PIC16F877A Microcontroller Pin-Out diagram is given in Figure 8 (a).

Another microcontroller, Arduino Nano is a small, complete, and breadboard-friendly board, based on the ATmega328P and was released in 2008 shown in Figure 8(b). These microcontrollers are popular nowadays because of their vast libraries. These microcontrollers operate at 16 MHz, having 2KB Static Ram, 32 KB Flash memory, and 30 header pins for controlling i/o devices. The large range of operating voltage of this microcontroller is 5-20 volts (Nano, 2018).

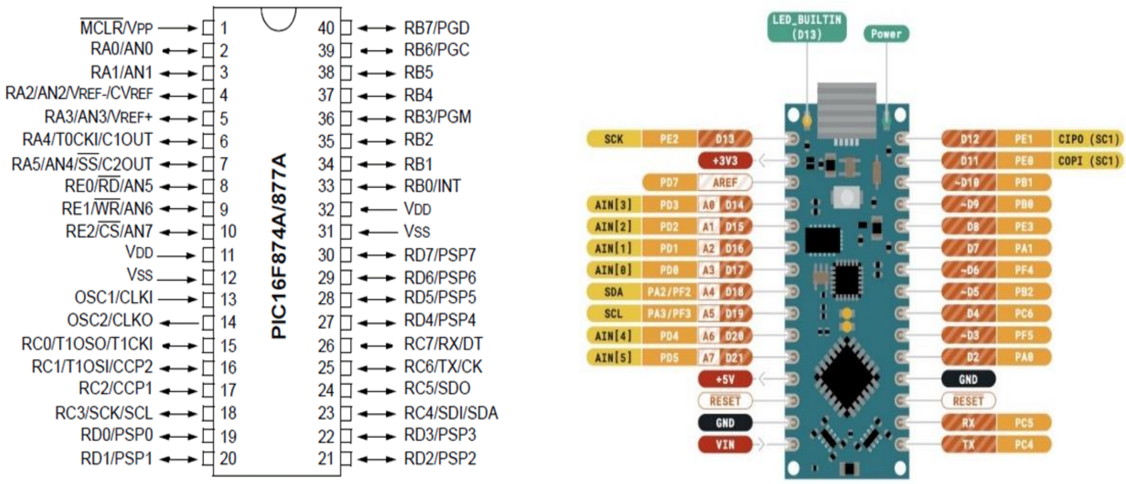

Figure 8: (a) Pin-Out diagram of PIC16F877A (b) Pin-Out diagram of Arduino Nano

3. Result and Discussion

The proposed system can detect a crying sound and it can classify the cry sound into three major classes based on the signal amplitude or intensity level. In this section, we will discuss the mechanism behind this classification. First, we have used a secondary LCD display shown at the bottom of the Figure 10, from which a crying sound is played and the analog values are displayed and noted after processing with the elimination of noise in the normal room environment. These cries are taken from the dataset and then observed by our system. Each sound was donated by the individual parents and its length is 7 to 8 seconds (Donateacry-corpus, 2019). We collected the analog value at every 150ms and kept these values in an array then the maximum and minimum analog values is noted for further processing. These analog values can be observed in table-1 given below. From the table some decisions are made:

i) The *maximum analog value* of Belly Pain/ Burp starts from 700 and *the minimum analog value* starts from 95 to 200 on average.

ii) The *maximum analog value* of Hungry Cry starts from 500 and *the minimum analog value* starts from 125 to 180 on average.

iii) The *maximum analog value* of Discomfort/ Tired Cry does not cross 500 and *the minimum analog value* starts from 80 to 125 on average.

Based on these observations the classification is done through programming and the system can classify a crying sound as either a Belly Pain/ Burp cry, Hungry Cry, or Discomfort/ Tired Cry.

Table 1: Audio sound parameters range and corresponding action required.

Sl.	Audio file	Minimum Analog Value	Maximum Analog Value	Sound Category	Action Required
1.	69BDA5~1.mp3	116	762	Belly Pain	Take to parents
2.	D6CDA1~2.mp3	92	760	Belly Pain	Take to parents
3.	D6CDA1~3.mp3	152	763	Belly Pain	Take to parents
4.	D6CDA1~1.mp3	212	761	Belly Pain	Take to parents
5.	643D64~1.mp3	167	419	Belly Pain	Take to parents
6.	5AFC6A~1.mp3	117	758	Burp	Take to parents
7.	7E4B9C~2.mp3	97	659	Burp	Take to parents
8.	AF3088~1.mp3	103	608	Burp	Take to parents
9.	79FF40~1.mp3	209	760	Burp	Take to parents
10.	AEA8AE~1.mp3	267	760	Burp	Take to parents
11.	C249BC~2.mp3	168	758	Hungry Cry	Take to parents
12.	CDA99F~1.mp3	175	583	Hungry Cry	Take to parents
13.	D1E236~2.mp3	126	651	Hungry Cry	Take to parents
14.	D6CDA1~2.mp3	179	500	Hungry Cry	Take to parents
15.	7A2222~3.mp3	175	680	Hungry Cry	Take to parents
16.	7B0E16~1.mp3	81	356	Discomfort	Try Entertain
17.	10A404~1.mp3	85	393	Discomfort	Try Entertain
18.	64ACB3~2.mp3	121	642	Discomfort	Try Entertain
19.	D6CDA1~3.mp3	82	290	Discomfort	Try Entertain
20.	D1CB71~1.mp3	99	495	Discomfort	Try Entertain
21.	F258A8~1.mp3	77	300	Discomfort	Try Entertain
22.	03ADDC~1.mp3	104	383	Tired Cry	Try Entertain
23.	06C4CF~3.mp3	97	424	Tired Cry	Try Entertain
24.	7A2222~1.mp3	76	374	Tired Cry	Try Entertain
25.	79FF40~1.mp3	114	298	Tired Cry	Try Entertain
26.	B2AABC~1.mp3	83	307	Tired Cry	Try Entertain

Our proposed system considers different environmental parameters for baby nursing. Firstly, it can detect the urination of the baby. It also considers LPG leakage, CO level in the air, smoke, humidity, and temperature of the room where the baby will be nursed. If any of the parameters of LPG, CO gas, smoke, humidity, and temperature reach an unsafe level, the robot will sound an alarm to alert the parents. This circuitry can be shown in the following Figure 9:

Figure 9: Ensuring safety by monitoring different environment parameters (LPG, CO gas, smoke, humidity and temperature)

From the table-1 case no. 1 to 10 & 11 to 15 baby needs the parent's support. In this situation, the nursing robot detects belly pain/ burp and hungry cry respectively. In both cases, it follows the line to reach the parents. It is safe because the embedded program ensures all motors are in off condition at all 1 or 0 sensor logic. It will navigate only to the marked area. The detection can be realized from Figure 10.

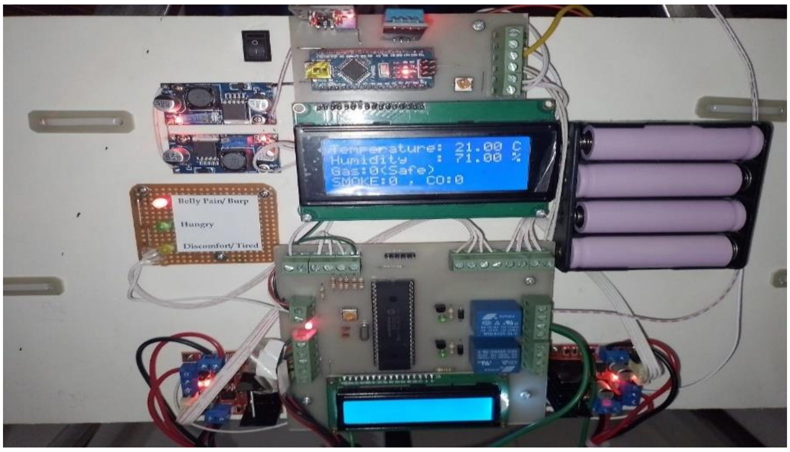

Figure 10: Detection of Belly Pain/ Burp cry after sound play through LED

Figure 11: Detection of Discomfort/ Tired cry after playing sound through LED

For 16-26 no. case Discomfort/ Tired mode is detected and the baby entertainment function is played. After baby entertainment, the robot will take the baby to the parents by line follower navigation. It never continuously moves outside of the marked area. However, as it was a discomfort/ tired cry. After taking the baby to the parents it will restart the rocking function for the next 4 minutes. This can be realized from figure 11 and the path that goes to the parents can be visualized in Figure 12 (a) & (b).

Figure 12: (a) Path for traverse of Baby Nursing Robot (b) Line detection of the cradle.

The following Figure 13 demonstrates the entire baby nursing robot setup.

Figure 13: The proposed baby nursing robot.

4. Conclusion

The baby nursing robot can help working parents with basic support for handling babies in this technology-driven age. We developed an automated baby rocker which is capable of classifying the cry sound and informing the parents about the baby's need. Moreover, it helps us to detect baby urine, provides rocking functionality, and finally generates alert tone in any possible risk. When the baby needs the mother's love or it is hungry, the robot takes the baby to its mother. All the above mentioned technologies have been developed, implemented, and tested in real-time. By considering all the issues, the system can be termed as an example of AI and we can say that the baby nursing robot is developed based on Artificial Intelligence. However, at this moment, the proposed system cannot learn anything which can be solved in the near future. We are working to implement more advanced features like entertainment based on the facial expression of the baby. In the future, the proposed system can be further improved by advanced frontier technologies like Machine Learning (ML) or Deep Learning.

Acknowledgment
This research was supported under the Innovation Grant in Information and Communication Technology by the ICT Division, Posts and Telecommunications Ministry of Bangladesh. Tracking number: 19IF12650.

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Cite this article:

Tarun Debnath & Pallab Kanti Podder (2023). AI Based Baby Nursing Robot. *International Journal of Science and Business, 21*(1), 20-31. doi: https://doi.org/ 10.5281/zenodo.7574912

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