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Design and Development of a Smart Baby Monitoring System based on Raspberry Pi and Pi Camera

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***Abstract*—This project presents a baby monitoring system for busy parents so that they can ensure the proper care and safety of their babies. This system can detect the baby's motion and sound; especially crying and video output of baby's present position can be displayed on a display monitor so that the mother or another responsible person can watch the baby while away from him or her. This baby monitoring system is capable of detecting motion and crying condition of the baby automatically. The Raspberry Pi B+ module is used to make the total control system of the hardware, condenser MIC is used to detect baby's crying, PIR motion sensor is incorporated to detect baby's movement and Pi camera is used to capture the baby's motion. A display is used to have video output of sleeping baby. Finally, the developed hardware is tested to analysis the capability of detecting the motion and crying sound of baby as well as the video output. This proposed system can provide an easier and convenient way for busy parents in terms of taking care of their babies.**

Keywords—Baby Monitoring System, Raspberry Pi, Pi Camera

I. Introduction

The baby monitoring system is a kind of alarm system which can detect babies' movements and activities and can convey the message about the condition of babies to the concerned authority via a radio or mobile or even a display. Since the very beginning of humanity, families have had instincts to secure their babies from probable dangers and risk. However, the way by which parents look after their children has changed with the technological breakthroughs [1] [2]. They are now thinking about adopting the technological and engineering inventions for getting advantages and benefits in terms of safety issues of their babies. In this era when parents are busy with their career, a modern baby monitoring system can be a solution for handling babies properly instead of keeping them in babies' day care centers or appointing a nanny for them.

Monitoring a baby continuously is really a tough job as well as it is not possible for the parents to carry out their babies all the time with them especially while working. Hiring a caregiver for the non-stop monitoring of babies is an option when parents are busy at home or in the working places or as an alternative solution is day care center. But these two methods may not be commodious for parents according to their demands. Most importantly parents do not get surety about their babies' safety in both of the cases. In this perspective, a baby monitoring device can be the best solution to remove the anxiety and stress of the parents.

In this paper, we have designed a baby monitoring system using Raspberry Pi whereas all the previous systems were developed using either Microcontroller or Arduino. The Raspberry Pi is a full-fledged credit card sized computer which consists of 512 MB RAM and 700 MHz microprocessor while Arduino is 8-bit AVR microcontroller based board which comprises of hardware prototype platform and Arduino language along with IDE and libraries [3]. Raspberry Pi B+ module is used in this project which has a great advantage over microcontroller based projects [2] [4]. This baby monitoring system consists of condenser MIC to detect baby's crying with a PIR motion sensor to detect baby's movement along with a Pi camera to capture baby's motion. A display is attached to the system to have the video output along with the sound of the baby.

II. Literature Review

A baby monitoring system is introduced in [1] by Soukaina Bangui, Mohammed El Kihal and Yassine Salih-Alj. This system is proposed to provide an enhanced noise canceling system to overcome the sound pollution in order to make babies' rooms more comfortable.

A new approach of an automatic monitoring system for baby's care has been presented in another paper [2] which is a microcontroller based project. The authors have designed a low-cost baby monitoring system which can detect sound when a baby cries and is attached to a cradle which swings automatically once the system detects a sound and the cradle does not stop until the baby stops crying. A camera is also mounted on the top of the cradle to get the video output of the surroundings of the baby. Another baby monitoring system has been presented by Savita P. Patil, Manisha R. Mhetre based on GSM network [4]. This system can monitor body temperature, moisture, pulse rate and movement of a baby and deliver the obtained data to the parents using the advantage of GSM network. However, this system is controlled by a microcontroller whereas Raspberry Pi is used for controlling purpose of the system that has been presented in this paper.

Prof. Kranti Dive, Prof. Gitanjali Kulkarni have presented a paper [5] on designing of a system for monitoring infants based on the embedded system. It consists of door sensor, LDR based light sensor and voice detection module for doing the job of

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monitoring infants. The output of the sensors is displayed through LEDs and an alarm is attached to the system to give an alert. To prevent Sudden Infant Death Syndrome of a baby, Ziganshin E. G., Numerov M. A., Vygolov S. A. have proposed a baby monitoring system using ultra-wideband (UWB) technology [6]. This system is developed mainly with a purpose of diagnosis of obstructive sleeping disorders of babies which is known as sleep apnea.

III. Methodology

Figure 1 shows the working method of the proposed baby monitoring system. Raspberry Pi B+ module will be used here as the central controlling unit. The Raspberry Pi is a low-cost credit card sized microcontroller, which can provide data when plugged into a monitor [3] [7]. B+ model of Raspberry Pi has some advantage over another previous model and this model's 4 USB ports are available as well as it has 40 GPIO (General Purpose Input/Output) pins along with micro SD card socket alter of full-size SD [7].

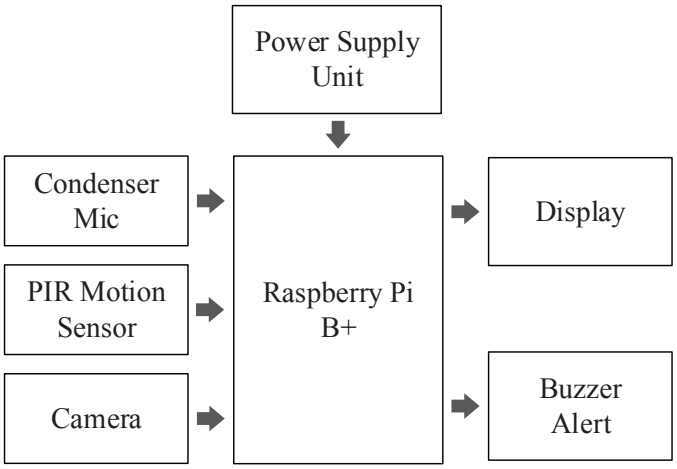


Fig. 1. Block Diagram of the proposed System

Condenser MIC will be associated with this project to detect the baby crying and gives a signal about it to the Raspberry Pi. This system will also consist of a PIR motion sensor to sense the baby's movement. PIR sensors are made of a pyroelectric sensor that can detect levels of infrared radiation. Everything emits some low-level radiation, and if the thing is hotter, it emits more radiation [8]. A Pi camera which is another distinctive feature of this system will also be mounted on the system to get the video output of the surroundings of the place where the baby will be kept. The Raspberry Pi Camera Module is a custom designed add-on for Raspberry Pi and it will be attached to Raspberry Pi by way of one of the two small sockets on the board upper surface [9]. The Raspberry Pi camera module can be used to take high-definition video along with still photographs, time-lapse and slow-motion video cleverness [10]. The system also comprises an LCD display and a buzzer as shown in hardware arrangement of figure 2. Once the condenser MIC will detect any sound, it will deliver a signal to the Raspberry Pi, Raspberry Pi will allow the camera to turn on, and the information obtained from the camera will be sent to the controlling unit. Raspberry Pi will then process the data and send it to the LCD display as a video format. At the same time, it will activate the buzzer and consequently, buzzer will give an alarm. The same thing will happen when the PIR sensor will detect any movement of the baby. Thus, the system will alert the concerned parents about their babies' condition via both an alarm and the video output of the babies' present situation.

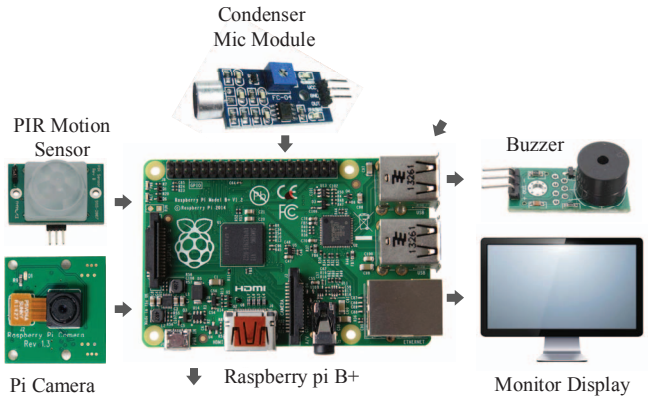


Fig. 2. Hardware Arrangement of the proposed System

IV. Design And Implementation

A. Circuit design

Figure 3 shows the circuit diagram of a baby monitoring system which comprises of Raspberry Pi (Model B+ V1.2), PIR sensor, Condenser MIC (LM393), Piezo Buzzer and Raspberry Pi Camera Rev 1.3. The Raspberry Pi Model B+ Board contains a single 40-pin expansion header labeled as 'J8' providing access to 28 GPIO pins, 8 ground pins and 4 power pins [7].

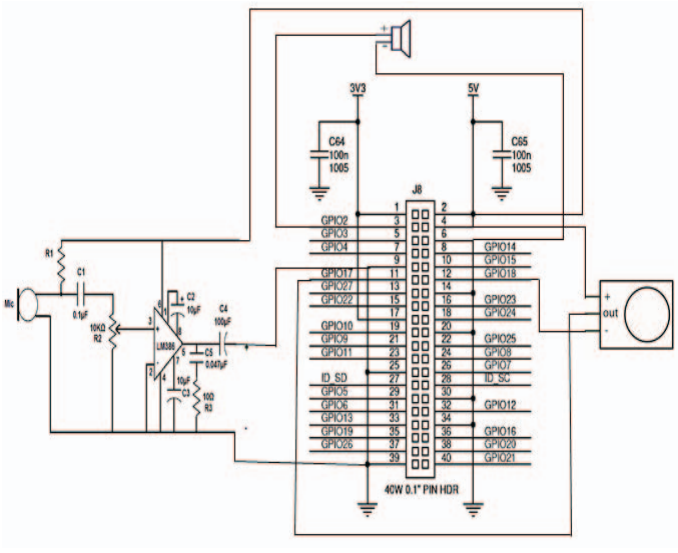


Fig. 3. Circuit diagram of baby monitoring system

The output of condenser microphone is connected with 17 number GPIO pin and the output of PIR sensor is connected with 27 number GPIO pin of Raspberry Pi. The output of buzzer is connected with GPIO 3 pins of Raspberry Pi. There is a Pi camera module, which is linked to the Raspberry Pi with

the camera slot. The ribbon cord of Pi Camera has to be inserted into camera slot to attach the Pi Camera with the Raspberry Pi board as shown in fig 4.

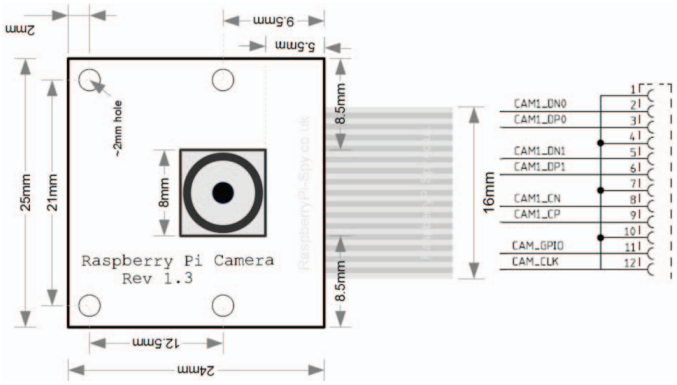


Fig. 4. Pi camera interfacing with the system

B. Circuit operation

The PIR sensor senses motion and always used to detect human movement within predetermined range. At first, the PIR sensor senses the baby motion and then the information is passed through the 22 number GPIO pin of Raspberry Pi. The GPIO is used as an output. When there is no motion detected, the GPIO is set low, and the buzzer gives no alarm. If the PIR motion sensor detects the baby motion, it outputs generates a 5-volt signal to the Raspberry Pi through it's GPIO and the buzzer gives an alarm. Similarly, the condenser MIC picks up sound signals from baby and transforms them into electrical signals. The signal is passed through 14 number GPIO pin. If the baby is crying, the GPIO is set high and the buzzer gives the alarm. If the baby is sleeping, the GPIO is set low and the buzzer remains silent. Raspberry Pi shows up with two first-rate connectors on board. One is in between Ethernet and HDMI, another is close to GPIO. The one, which is nearer to Ethernet connection, is Camera Serial Interface (CSI). This CSI is directly attached to the Raspberry Pi GPU that can process images devoid of ARM intervention. The overview of the baby monitoring system is illustrated in figure 5.

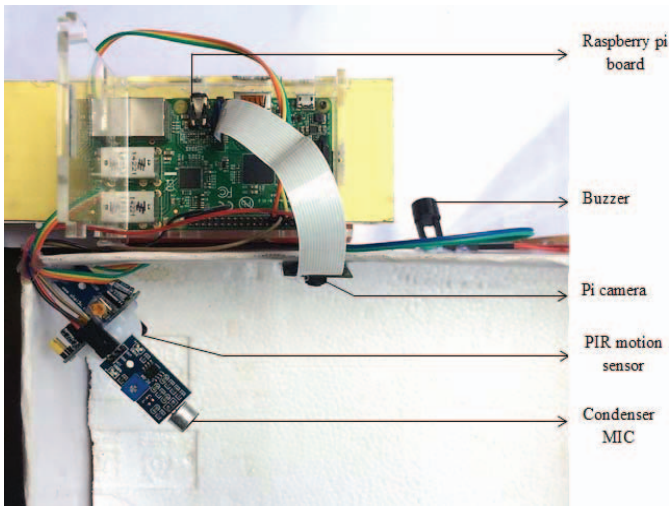


Fig. 5. Overview of baby monitoring system

C. Software development

Python language is a programming language which has been applied to configure Raspberry Pi after installing the Raspbian Operating System in an SD card. In order to make eligible Raspberry Pi uses Pi camera, library files of Pi camera have been installed into the system. Figure 6 shows the flowchart of an operating method of the baby monitoring system.

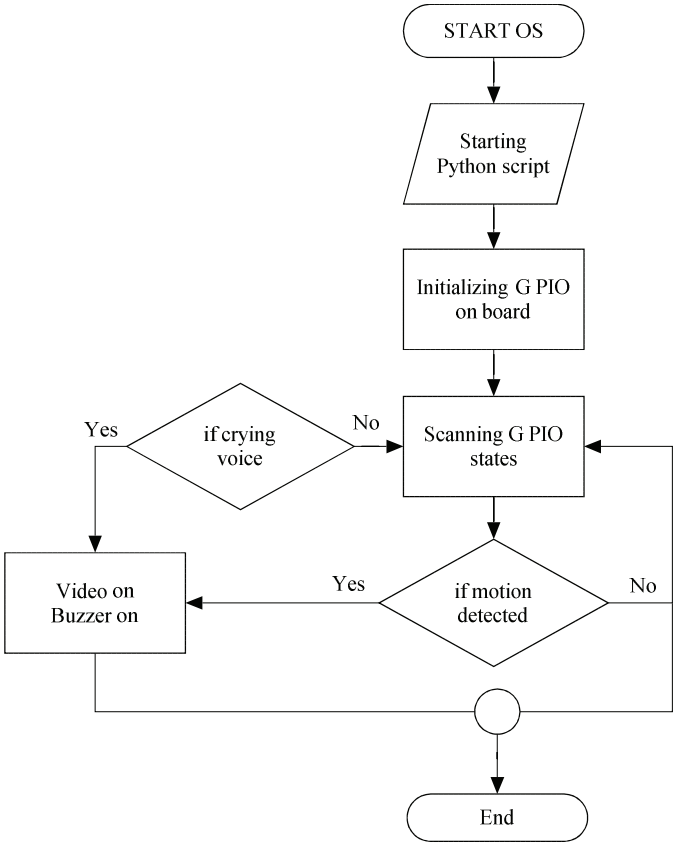


Fig. 6. Flow chart of Baby monitoring system

After starting the operating system when Raspberry Pi will be powered up, it will initialize the python script. The General-Purpose Input/Output (GPIO) port will then activate to operate. The operating system will scan the GPIO states. If any crying voice is detected the Raspberry Pi will send a signal to the camera and it will be turned on. Consequently, Raspberry Pi will collect the information regarding the baby's condition from the feedback of the camera and then send the information to the LCD display.

Simultaneously the information will be delivered to the buzzer to provide the emergency sound. Same thing will happen when the PIR sensor will detect any motion, the feedback will be sent out to the LCD display along with the buzzer to be activated. And if no sound or motion will be detected, the LCD display and buzzer will remain turn off and the operating system will go again for scanning the GPIO states according to the program.

V. Result Analysis

The Raspberry Pi camera transmits data through an incredibly fast Camera Serial Interface (CSI-2) bus right away to the System-on-Chip (SoC) processor [7]. It can do this by means of a 15-pin ribbon cable which is also regarded as Flexible Flat Cable (FFC), as well as connects to the Raspberry Pi board through the surface mount ZIF 15 socket. The PIR sensor is manufactured of sensitive IR and capable of detecting warm body; for example, a human or animal by leading to a positive differential change. When the warm body departs the sensing area, the opposite incident happens; the sensor causes a negative differential change. The test result of the baby monitoring system can be obtained by two ways. One way is by using Condenser MIC and another way is by using PIR motion sensor.

The output of condenser MIC has been shown in figure 7 and figure 8. In figure 7(a) baby's sleeping condition has been shown. Since the baby is sleeping, there has been no crying voice detected by MIC condenser and that's why there is no output. In figure 7(b) initial condition of MIC condenser has been shown. Figure 8 shows the final condition of MIC condenser output. Since the baby is awake from sleeping and starts to cry, condenser MIC receives an input signal from baby and sends it to the raspberry pi. Raspberry Pi receives an active high signal, which means baby is crying. Then raspberry pi decided to activate the Pi camera module and buzzer. In figure 8(a), the Pi camera shows the output of baby's present status on the display. At the same time, buzzer gives an alarm for the output. Figure 8(b) shows the active high condition of MIC condenser output. Since an output has been found from the input; it means there has an active high condition. The display shows that "Baby crying 0".

The full form of PIR is Passive Infrared. PIR motion sensor is comprised of a Fresnel lens, an infrared detector along with supporting detection circuitry. Typically the lens of the sensor targets any infrared radiation existing around it in the direction of the infrared detector. Our bodies produce infrared heat; therefore, this heat is also picked up by the sensor. The sensor results in a 5-volt signal for an interval of one minute once it detects the existence of a person. It provides a tentative range of recognition of about 6-7 meter which is extremely sensitive. While the PIR motion sensor picks up a person in its range, it delivers an output of a 5-volt signal to the raspberry pi via its GPIO [8].

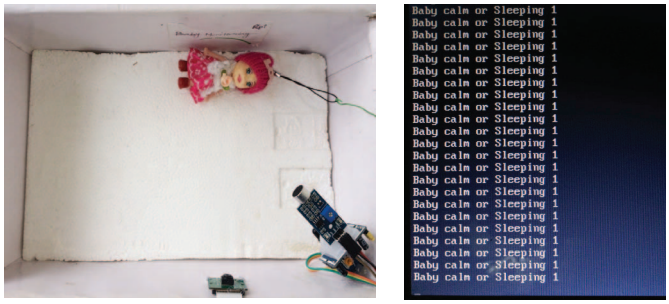
(a) (b)

Fig. 7. Initial condition of MIC condenser output (a) Sleeping condition of baby b) Initial condition of display

(a) (b)

Fig. 8. Final condition of MIC condenser output (a) Display output (b) Active high condition

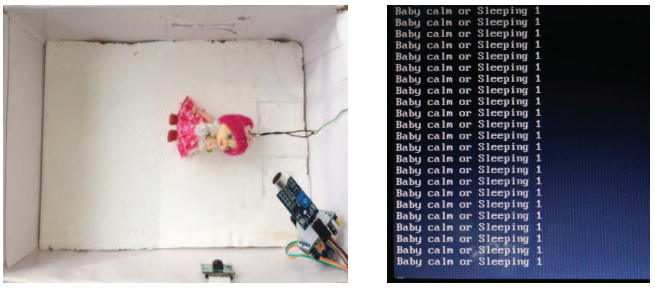
The output of PIR motion sensor has been shown in figure 9. Since there has no movement found of baby position, the PIR motion sensor do not get any input in figure 9(a). In figure 9(b), initial condition of PIR motion sensor output has been shown.



(a) (b)

Fig. 9. Initial condition of PIR motion sensor output (a) Sleeping condition of baby (b) Initial condition of display

Figure 10(a) shows the intermediate condition between the initial and final state of PIR motion sensor output. In case of little movement of baby, it is not sufficient to get input from PIR motion sensor and there is no output shows on the display.

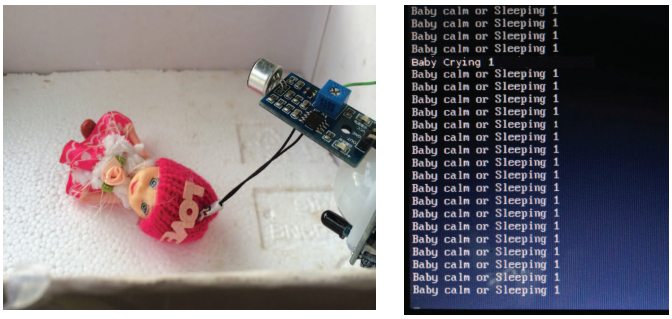


(a) (b)

Fig. 10. Intermediate condition of PIR motion sensor output (a) Baby position (b) Display output

Figure 11(a) shows the final condition of PIR motion sensor output. In this case, the baby movement is sufficient to get input from PIR motion sensor. After getting input from PIR motion sensor it activated the camera and there is an output shows on the display. Figure 11(b) shows the active high condition of PIR motion sensor output. Since an output has

been found there from the input; it means there has an active high condition. The display shows that is “Baby crying 1”.



(a) (b)

Fig. 11. PIR motion sensor final output (a) Video output (b) Display output

VI. Comparison With Previous Work

An analytical comparison of our developed system has been done with the other existing systems which have been mentioned earlier in the paper; is provided in the following.

In [1] we can see that Soukaina Brangui, Mohammed El Kihal and Yassine Salih-Alj have presented a paper regarding noise canceling system for controlling and monitoring the baby’s environment. This is a microcontroller based project where noise canceling system has been developed to remove the noise of the previously developed systems and to present a comprehensive monitoring and controlling environment for baby. In our system Raspberry Pi, B+ module has been used for controlling process; a condenser MIC is employed to detect the crying sound of a baby and the obtained data will be monitored by an LCD display.

In [4] Savita P.Patil, Manisha R have worked on baby monitoring system which monitors the vital parameters of baby’s body and sends the information to the parents via mobile using GSM technology. Also in this system microcontroller is used for controlling purpose which is less effective than Raspberry Pi. This system will transfer data in the mobile but in our system, data will be transferred to the LCD display so that all concerned people can see directly the baby’s present situation.

Another paper has been presented on an automatic baby monitoring system using a microcontroller in [2]. Rachana Palaskar, Shweta Pandey, Ashwini Telang, Akshada Wagh, Ramesh M. Kagalkar have proposed this system mainly to monitor a baby when no one inside the baby’s room. They have applied this device into a cradle including a camera which can detect baby’s uncomfortable situation and cry; as well as it can swing automatically once a crying sound is detected and won’t go in standstill position till the crying sound stops. So, this system is attached to the cradle of the baby whereas our system is incorporated with the Raspberry Pi board which makes the device simple and it can be moved from one place to another place without any hassle. One more important thing is that we have used Raspberry Pi camera which has slow motion video cleverness and has the ability to take high definition video whereas in their proposed baby monitoring system just normal video camera is employed.

VII. Conclusion

After completing the paper successfully regarding emergency health monitoring system using wearable technology [11]; a new enthusiasm had come and an idea to had been plotted to implement an automatic system for baby monitoring to remove the anxiety of the parents. This project is the consequence of that initiative.

An automatic baby monitoring system is the best solution for parents to observe their babies in this busy era. It is just an approach of taking the advantages of modern technology which has no effect on daily activities of the parents. As we said in the introduction, our aim is to develop a monitoring system which will provide a high level of baby’s security as well as whose security technique is unique. That's why we have chosen video monitoring for baby’s protection since video monitoring is unique and cannot be imitated or fabricated. The system has been successfully overcome some of the aspects of the present technologies by the use of the video streaming technology. In this paper, a baby monitoring system has been designed which is able to detect motion using the PIR motion sensor in different conditions without any operator. Therefore, it can detect the baby’s position automatically. In addition, it can detect whether the baby is awake or asleep. Not only that, a condenser MIC is incorporated with the system to sense the baby’s crying condition. From the above experiments, it can be said that, this suggested baby monitoring system has much better output from the previous projects.

This system is designed using Raspberry Pi B+ module which is a credit card-sized microcomputer and has huge advantages over Microcontroller or Arduino. Moreover, Raspberry Pi is a low-cost chip which can make the system cheaper than other existing systems. This system can provide both audio and video output at the same time. It can be applicable for the home environment as well as in the hospital or baby nursing care. Effective use of this system can remove the anxiety and monotony of the parents. The safety issue of the baby is also confirmed in this system. Although this system is implemented, further improvement and modification of the system can be done.

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