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BABY MONITORING SMART CRADLE SYSTEM WITH EMOTION RECOGNITION

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Abstract - *As we are very familiar with the hurdles faced by Parents to nurture their infant and especially in case if both the parents are working.To give 24 hours of time in such cases is next to impossible.Thus,we need to develop something unique that can help Parents to have a continuous surveillance on the baby and can notify about the same. The objective of this paper is to design a baby monitoring smart cradle with multiple features which helps in monitoring the babies and updates the baby's status to parents. This design encloses the different features like camera monitoring for emotion recognition, automatic swinging of cradle, sensing the wetness of baby's bed, monitoring presence of baby in the cradle and detecting crying voice of baby. All these features encloses a notification module where message about baby's cry, wetness in bed, taking facial emotion of baby and absence of baby in the cradle are sent to parent's email to intimate them about their baby. This system was designed using raspberry pi 3, wet sensor, PIR sensor, sound sensor, cry pattern circuit , and camera. Taking emotions like happy, sad, neutral includes face detection, non-skin region extraction and morphological processing finally,emotion recognition. In this paper, it begins with frame based detection. The image quality is analyzed. Face location is detected using viola-jones algorithm. Extract non-skin regions, Morphological operations are applied to the extracted image to extract the facial feature for recognition of facial emotions.*

Key Words: *Emotion Recognition, Image Quality Metrics, Face Detection, Morphological processing, Raspberry pi 3.*

1. INTRODUCTION

Embedded system is the combination of both hardware and software which is used in today's technology to implement desired function. Today's parents could not spend much of their time in monitoring their babies because of their busy work and lack of time. They always need a care taker as a safe guard for their babies but now technology helps them by providing a smart baby cradle with which they can monitor their babies anytime. This system of baby cradle with applications clearly bears a note that 24 hours security is the most important concern in this design by providing camera thereby baby's facial emotion can be detected and sent to parent's email. It is a purpose-built design with the aspect of providing well being for babies. However, the way by which parents look after their children has changed with the technological breakthroughs [1] [2]. Our design is based on embedded system which encompass monitoring in the ways like when the baby's bed was wet then the message will be sent, and also the presence of baby in the cradle also sensed using PIR sensor. And with these features camera has been connected to take baby's emotion after every 10 minutes which can be adjusted by the parent. It becomes essential to nurse and monitor the infants' health intelligently by studying facial expression features. The facial emotion means to convey feelings, happiness, sadness and the confidence of human. An approach to recognize the facial emotion using skin color segmentation and morphological operations is proposed in this paper. This system uses eco-friendly electronic sensors for detecting the various movements and activities of the child. Also provides various updates of the child to the parent. This system can be marketed among the general audience as it is very reasonable and every person from different backgrounds and culture can afford it.

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 sound sensor 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.

2. 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 cancelling 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 117 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.

S. Amirhassan Monadjemi et al; proposed to enhance the performance of face detection and recognition systems. In face detection step, Skin color segmentation with YCbCr color space is used. Gaussian skin color model is used in color space image to segment the skin and non-skin pixels. Morphological operations are used to eliminate holes formed in eye, mouth, and nose in skin color segments. Gabor features extraction, dimension reduction using PCA, feature selection using LDA and SVM based classification are used to construct an efficient face recognition system with a high recognition rate [7].

Anala M R et al., presented Viola Jones classifier method, Background subtraction method and skin color detection on HSV color spaces.

The Viola Jones classifier method gives good results for detecting faces but it takes more time for the detection and it does not give accurate results. The Background subtraction method and Skin color detection on HSV color space are more efficient when compared to the first method by giving accurate results for detecting faces in motion [8]. Jyoti Kumari et al; proposed a quick survey of facial expression recognition using various feature extraction techniques on JAFFE dataset. The noise is removed in pre-processing. Face detection is done by using viola jones algorithm. The facial component detection, detects the ROI (Region of Interest) for eyes, nose, cheeks, mouth, eye brow, ear, fore-head. The feature extraction techniques such as LBP(Local Binary Patterns), LDP(Local Directional Pattern), LGC(Local Gradient Code), HOG(Histogram of Oriented radients), LGC-HD (based on principle of horizontal diagonal) and LGC-VD (based on the principle of vertical diagonal) are used to extract the feature. K Nearest Neighbor classification methods are used to classify the features into the respective facial expression classes. Feature extraction techniques are compared based on recognition rate. LGC-VD features are best in emotion recognition. The LBP, LGC and HOG perform equally well, and the LDP is worst one[9]. Reza Hassanpour et al; presented an adaptive skin color model based on the gaussian mixture model. Ethnic group images and changing illumination video frames are used for segmentation. YCbCr color space is used to reduce the effects of illumination. Gaussian mixture model is used to represent the features. Model parameter estimation is performed using iterative Expectation Maximization (EM) algorithm. This algorithm is compared to non-adaptive parametric models[10].

Ajit Danti et al; proposed to recognize the facial expressions based on mouth feature. JAFFE database images are used to recognize the expressions. Median, average and wiener filters are applied to the image for enhancing the image quality. Sobel, canny, prewitt edge detectors are applied on the image to detect edges and SUSAN operator is applied to detect corner for different features. Area, height and width of the mouth features are extracted for expression recognition. 25 images of three persons with four facial expressions are selected for processing. Different facial expressions (1 is happiness, 2 is neutral, 3 is sadness, 4 is surprise) are classified based on the range of classified based on the range of statistical values [11].

3. METHODOLOGY AND PROPOSED WORK

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].

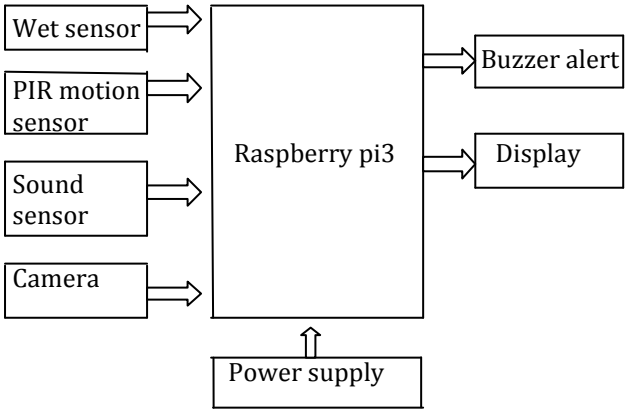


Fig -1: Block Diagram of the proposed System

Sound sensor 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. A Pi camera which is another distinctive feature of this system will also be mounted on the system to get the facial emotion of the baby. 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. The Raspberry Pi camera module can be used to take high-definition video along with still photographs, time-lapse and slow-motion video cleverness [12]. The system also comprises an LCD display and a buzzer as shown in hardware arrangement of figure 2. Once the sound sensor will detect crying 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 an image output of the babies' present emotion.

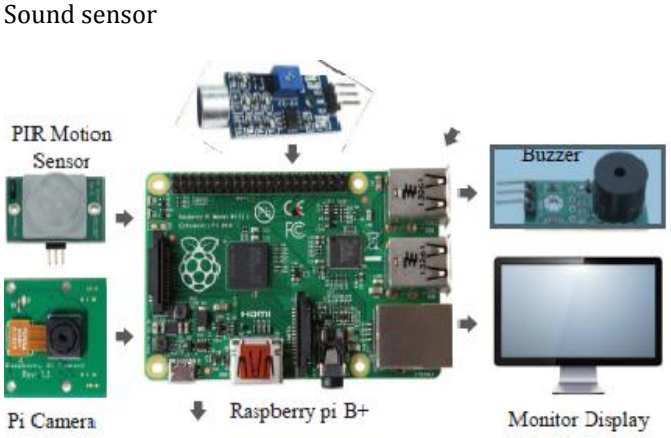
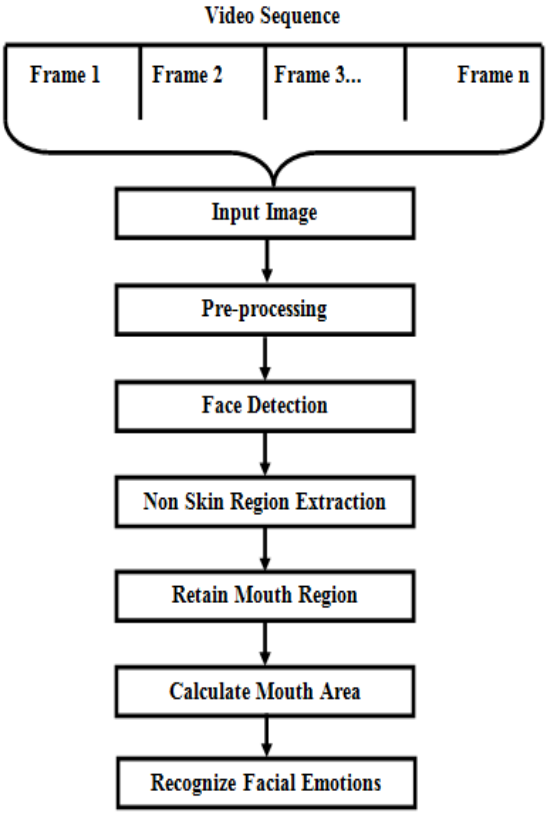


Fig -2: Hardware arrangement of the proposed system

In this research work, a novel face emotion recognition system from video frames is proposed. Detection and recognition of emotion depends on the input video frames taken. The quality of the image is found using image quality metrics. Initially Face region is detected from the human face by Viola Jones algorithm and skin color segmentation with RGB color space is used to extract the face skin and non skin regions. After the segmentation, morphological operations are applied to extract the boundary of the non skin regions namely eyes and mouth. Then the emotions are recognized by calculating the area of the mouth region. The proposed methodology involves; image acquisition, pre-processing, face detection, segmentation, morphological processing and area calculation.

Algorithm

- Convert video into frames.
- Read the input video frame image
- Convert the image into grayscale image.
- Enhance the input image with median, wiener and gaussian filters.
- Find the best filter based on PSNR, RMSE values.
- Apply viola-jones algorithm to detect the face region.
- Use bounding box method and crop the face region.
- Use threshold value to extract non skin regions.
- Apply morphological operations to extract continuous boundaries of non-skin region.
- Mask the boundary from the original image.
- Extract the mouth region.
- Area is calculated from extracted mouth region.
- Recognize facial emotions based on the value of area.



3.1 Image Pre-Processing

The aim of pre-processing is to improve the quality of the image. During acquisition, some unwanted blur and noises are occurred in the video due to out of focus. These noises are cleaned up with the help of filters. In pre-processing stage, Median filter, Wiener Filter and Gaussian filters are applied to reduce the noises from the image and the filtered outputs are analysed using the image quality metrics Peak Signal to Noise Ratio (PSNR) and Root Mean Square Error (RMSE). The input image is pre-processed by these filters.

3.2 Face Detection

The input image may have number of objects in its background like human, building, tree etc. Paul Viola and Michael Jones presented a fast and robust method to detect faces with 95% accuracy and less computing time. This face detection framework is capable of processing images extremely rapidly while achieving high detection rates. The cascade object detector is used to distinguish people's faces, noses, eyes, mouth and upper body. By default, the detector is configured to detect faces.

3.3 Face Cropping

After the face region is identified by the bounding box, the cropping function is used to crop the face region from the input human image. The coordinates of a rectangle will define the crop area. *% rect* is a four-element position vector [xmin ymin width height] specifies the size and position of the crop area. This cropped face is detected iteratively with viola jones algorithm to eliminate the background effects like shirts etc.

3.4 Image Segmentation

Skin color is the most vital feature in human face. Since the emotions are to identified from the non-skin regions, The main goal of this work is to extract the non-skin regions like mouth and eyes from the image. It requires an appropriate color space for segmentation. RGB color space is one of the most used color spaces for processing. By applying thresholding technique to the RGB image the skin and non-skin pixels are easily discriminated. The threshold values applied are given below

$$R > 95 \;\&\&\; G > 40 \;\&\&\; B > 20$$
$$\max(R,G,B) - \min(R,G,B) > 15$$
$$|R-G| > 15 \;\&\&\; R > G \;\&\&\; R > B$$

Fig-4: Skin color segmentation

3.5 Morphological Processing

The next step of the face emotion recognition system involves morphological processing to refine the non skin regions extracted from the segmentation step. To perceive and recognize human faces, the prominent characteristics or features with their geometric distribution will be extracted. Morphological operations reduce the unwanted skin parts and background noises from the segmented image.

3.5 Masking

Masking is also known as spatial filtering. The edge boundary is a mask. In this stage, boundary extracted image is applied on the cropped face image in order to check whether the mask fits the cropped image exactly. The mask applied image is shown in Figure 5

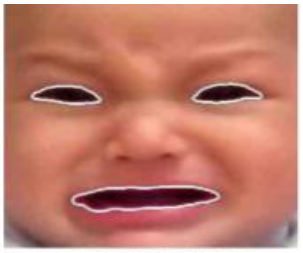


Fig-5: Mask applied image

3.6 Emotion Recognition

Recognition of the emotion is based on the mouth region. The area of the mouth region is calculated based on the number of pixels multiplied with the pixel width (0.26458333) and the minimum and maximum value of the mouth region area based on the emotions is tabulated below.

Table-1: Classification of Emotions based on Mouth Area

Facial emotions	Mouth area in mm	
	Min Value	Max Value
Neutral	3	4
Smile	11	17
Cry	5	10

3.7 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 sound sensor 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.

3.8 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.

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. Consequently, Raspberry Pi will collect the information regarding the baby's condition and emotion from the feedback of the camera and then send the information. 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.

4. 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. 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 sound sensor and another way is by using PIR motion sensor.

Since the baby is sleeping, there has been no crying voice detected by sound sensor and that's why there is no output. When the baby is awake from sleeping and starts to cry, sound sensor 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.

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.

For experimentation, a video of child with 810 frames and three different emotions is recorded. Video frame is taken as an input image and then filtering techniques are applied on it for noise removal and to calculate the image quality metrics. The face is detected from an input image and the segmentation technique is applied to the detected face and then the morphological operations are applied to extract only the mouth region for geometric feature calculation. Finally, the facial emotion is identified based on the filled mouth region area.

5. CONCLUSION

A baby monitoring smart cradle system with emotion recognition 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 facial emotion recognition for baby's protection. The system has been successfully overcome some of the aspects of the present technologies by the use of the emotion recognition. 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 sound sensor 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. 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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