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Children's Transportation Safety System Using Real Time Face Recognition

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Abstract: In this paper we presents a visual system for monitoring children entering and leaving the school bus. It enhances the safety of children during their daily transportation in school bus. The system contains two parts, entry monitoring and exit monitoring. The basic idea is to detect each child using real time face detection algorithms and subsequently utilize face recognition algorithms to determine the actual identification of children when they enter into and leaves the bus. Hence the system identifies the child who fail to get down from the bus. This information will be communicated to his/her parents by issuing an alert message. The system is mainly useful in situation where air conditioned buses are used, that when the bus comes to a halt the temperature inside the bus will rise and when small children forget to get down from the bus it may lead to death. A complete prototype of the proposed system was implemented and tested to validate the system functionality. The results show that the system is promising for daily transportation safety.

Keywords: Face detection, Face Recognition, Principal Component Analysis (PCA), AT commands.

I. INTRODUCTION

Children safety is the prime factor of concern to their parents. Despite the best safety measures, children, due to their lack of skills to protect themselves, may end up in a situation that endangers their life. In this paper, we focus on the risk associated with the daily bus trip to and from school. There have been previous incidents where a child forget to get down from the bus and eventually die because of suffocation [1-2]. To improve transportation safety, some schools employ a bus supervisor to look after the children inside the bus. Nonetheless, human oversight or supervisor absence may still lead to a heartbreaking ending as in the previously cited stories. This paper presents a system to monitor the daily bus pickup/drop-off of children to enhance the overall safety of the daily bus transportation to/from school. The system aims at automatically detecting when a child boards or leaves the bus and issue an alert message when a child does not leave the bus to reduce the parents' concerns about using the bus for the daily transport of their children without being lost or forgotten.

A. Literature Survey

This section presents the most related work to the problem addressed in this paper. A system to track children using a child module that transmits the tracking information to a database and a mobile device is proposed in [3]. The disadvantages of this system are wide-scale deployment is expensive and the module may not be convenient for children.[4] is about a tracking system that utilizes Android terminals that communicate among themselves using Bluetooth technology to form clusters. The clusters communicate the relevant information using WLAN. The major drawback of this system is that the deployment cost is very high. There are commercial systems for tracking children such as Bluetooth-based tracking devices which are designed to be worn by children as a bracelet or a necklace [5]. In these tracking systems, these devices can be connected with a mobile application and if the child went outside a range specified by the parents, it can alert them. If the child walked outside this range, the device will send an alert to the parent. In addition, the application sends the location of the child by using a geographical map. One disadvantage of this type of applications is that they work only in a limited range.

Other products may rely on biometric features such as the Kid track biometric system in which the children scan their palms across a palm reader when they enter the bus [6]. It uses an infrared light to image the palm unique pattern. It uses green and red LEDs to ensure the scan works. Then, the scans are sent for cross-referencing against a secure database of pre-registered users' patterns. Based on this, the administration can find the information of that bus, where and when it tracked the child, and where the bus was at that time. The disadvantages of this approach is that it is not automatic and difficult for young children to place their palms correctly on the scanner. This may lead to inaccurate data if the scanner did not detect a child's palm.

II. OVERVIEW

The system consist of two webcams which are placed inside the school bus, in which the video frames were recorded continuously. The face of children entering and leaving the bus were detected using face detection algorithm and recognized by using face recognition algorithm (PCA). If someone inside the bus does not get down, the system identifies the child and send an alert message immediately to concerned authority through GSM.

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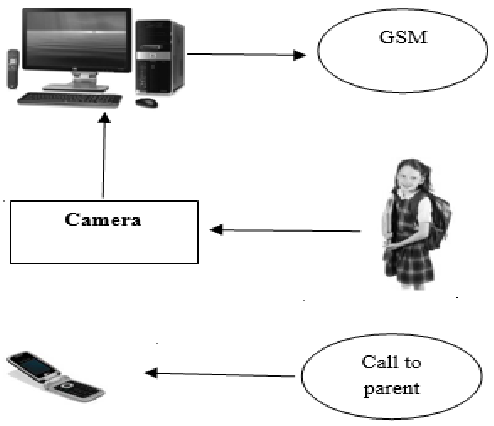

Fig. 2.1. Block Diagram

The system is designed with the following engineering requirements:

- The system should detect each child and recognize when every child boards or leaves the bus.
- The system should have a database to store each student's information.
- The communication should be fast and reliable.

Pseudo Code of the Proposed System

1. Capture each student's image
2. Apply Viola-Jones algorithm
3. Extract the ROI in Rectangular Bounding Box
4. Convert to grayscale and apply histogram equalization
5. Resize to 100x100
6. In order to update database, store in the database otherwise apply PCA
7. Communicate through GSM

A. Image Capture

The Camera is mounted at a distance from the entrance of the bus to capture the frontal images of the students. The captured image is of the size 640x480 to avoid resizing of the image in the back-end as we observed resizing may sometimes results in poor performance.

B. Face Detection

A proper and efficient face detection algorithm always enhances the performance of the face recognition system. Out of different algorithms are proposed for face detection such as Face geometry based methods, Feature Invariant methods, Machine learning based methods etc., Viola and Jones proposed a framework which gives a high detection rate and is also fast. Viola-Jones detection algorithm is efficient for real time application as it is fast and robust. [9] Hence we chose Viola-Jones face detection algorithm.It makes use of Integral Image and AdaBoost learning algorithm as classifier. It was observed that this algorithm gives better results in different lighting conditions.

C. Pre-processing

The detected face is then extracted and subjected to pre-processing. This pre-processing step involves histogram equalization of the extracted face image. It is then resized to 100x100. Histogram Equalization is one of the most common Histogram Normalization technique. This improves the contrast of the image as it widens the range of the intensities in an image by making it more clear.

D. Database Development

The database development phase consists of image capture of every child and extracting the bio-metric feature, in this case it is face, and later it is enhanced using pre-processing techniques and stored in the database. In this project the images of each child in different angles, different expressions and also in different lighting conditions are taken. A database of 20 children with 30 images of each has been collected.

E. Face Recognition

Face recognition system is a computer application and it automatically verifies and identifies a person from an image or a video. This is achieved by comparing selected facial appearance from the image database. The accuracy of face recognition depends heavily on the quality of the input image or the pose and expression of the person in the image. Also the image captured has background along with it. Hence there will be illumination changes. This lighting is a major element which can affect the recognition process. Even though complete removal of illumination may not be achieved, there are some algorithms which can be used for the extraction of features from the image and comparing or matching it with that of images in the database. Here PCA algorithm is used for face recognition.

F. Communication

To achieve communication, a GSM module is added to the system. It can quickly send SMS messages to the corresponding mobile number stored in the database. So the parent can be informed very fast.

GSM (Global System for Mobile Communications, originally Group Special Mobile), is a standard developed by the European Telecommunication Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular network used by mobile phones.

It became the de facto global standard for mobile communications with over 80%market share.The GSM standard was developed as a replacement for first generation (1G) analog cellular networks, and originally described a digital, circuit-switched network optimized for full duplex voice telephony. Here GSM sim800 is used. Its features include:

- Bands: GSM 850MHz, EGSM 900MHz, DCS 1800MHz, PCS 1900MHz
- Coding schemes: CS-1, CS-2, CS-3, CS-4
- Tx power: Class 4 (2W), Class 1 (1W)
- Small package: 23 * 23 * 3mm
- Power supply voltage: 3.4 - 4.4V
- Lowe power: down to 1mA in sleep mode
- TCP/IP TCP/IP AT firmware

- Operating temperature: -40C do +85C
- Support up to 5*5*2 Keypads
- One full function UART port, and can be configured to two independent serial ports.
- One USB port can be used as debugging and firmware upgrading.
- Programmable general purpose input and output.
- One SIM card holder.
- Wire Antenna (SMA connector with GSM Antenna Optional)
- Built in Network Status LED.

III. FACE DETECTION AND RECOGNITION

A. Viola-Jones Face Detection Method

This method consists of three main steps. The first step of the Viola-Jones face detection algorithm is to turn the input image into a new image representation called an integral image that allows a very fast feature evaluation. The used features are reminiscent of Haar basis functions. The Viola-Jones method analyzes a 24*24 sub-window using features consisting of two or more rectangles. Each feature results in a single value which is calculated by subtracting the sum of the white rectangle(s) from the sum of the black rectangle(s) [12]. The different types of features are shown in Figure 2.

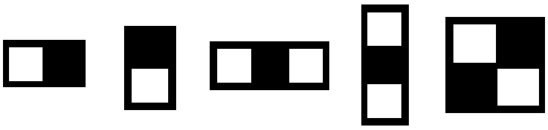

Fig.3.1. Different types of features

For a fast processing of these features, the integral image representation is used. This is done by making each pixel equal to the entire sum of all pixels above and to the left of the concerned pixel [7]. It is calculated by the following equation

$ii(x , y) = \sum_{x'\leq x, y'\geq y} i(x', y')$ [10]

where ii(x , y) is the integral image and i(x , y) is the original image. The integral image can be computed in one pass over the original image by using the following pair of recurrences:

$s(x , y) = s(x , y - 1) + i(x , y)$
$ii(x , y) = ii(x - 1 , y)+ s(x , y)$

wheres(x , y) is the cumulative row sum, $s(x , -1) = 0$, and $ii(-1,y = 0)$. The second step is constructing a classifier in order to select a small number of important features using AdaBoost learning algorithm.

AdaBoost is a machine learning boosting algorithm capable of constructing a strong classifier through a weighted combination of weak classifiers [12]. A weak classifier is calculated by the following equation

$$h(x, f, p, \theta) = \begin{cases} 1 & \text{if } pf(x) < p\theta \\ 0 & \text{otherwise} \end{cases}$$

where x is a 24*24 pixel sub-window of an image, f is the applied feature, p indicates the direction of the inequality, and θ is a threshold that decides whether x should be classified as a positive (a face) or a negative (a non-face).The final strong classifier is obtained after applying the adaboost algorithm detailed in [10]. In the third step, the cascaded classifier is used to determine whether a given sub-window classifier is definitely not a face or maybe a face. The cascaded classifier is composed of stages in which each consists of a strong classifier. The concept is illustrated with two stages in figure 3.

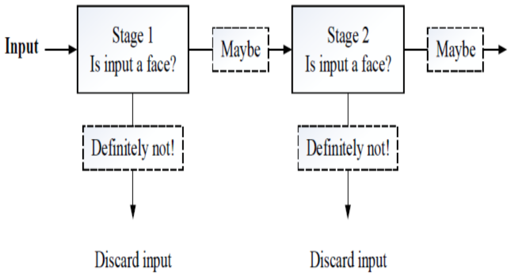

Fig.3.2. Cascaded classifier [9]

B. Principal Component Analysis

To extract the relevant features of facial images, Principal Component Analysis (PCA) method is used. Face Recognition based on PCA is generally referred to as the use of Eigenfaces. Eigen faces are Principal Components of the distribution of faces, or equivalently, the Eigen vectors of the covariance matrix of the set of the training images, where an image with Nby N pixels is considered as a point in N^2dimensional space [8].The PCA algorithm is shown in the following steps:

Step-1. Firstly, the image matrix I of size (N x N) pixels is converted to the image vector Γ of size (P x1) where P = (N x N).
Training Set: $\Gamma = [\Gamma_1\Gamma_2 \dots \Gamma_M]$

Step-2. Average face image is calculated by each face differs from the average by $\Phi_i = \Gamma_i - \Psi$
Difference Matrix: $A = [\Phi_1\Phi_2 \dots \Phi_M]$

Step-3. A covariance matrix is constructed as:
$C= AA^T$, where size of Cis (P×P).

- This covariance matrix is very hard to work with due to its huge dimension that causes computational complexity.
- The covariance matrix with reduced dimensionality is

$L = A^TA$, where size of Lis (M×M).
In order to obtain the eigenvectors of the original covariance matrix, it can be calculated by the following equations:
$A^TAX_i = \lambda_i X_i$

By multiplying both sides of the above equation with A,
$AA^TAX_i = A\lambda_i X_i AA^T(AX_i) = \lambda_i(AXi)$

- $AX_i$are the Eigenvectors of the covariance matrix which is denoted byUi and eigenvalues λi are the same for the two covariance matrix.

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Step-4. A face image can be projected into this face space by
$\Omega_k = U_k^T \Phi_i$

Step-5. Test image vector: Γt
Mean subtracted image vector:
$\Phi_t = \Gamma_t - \Psi$

The test image is projected into the face space to obtain a vector:
$\Omega = U_k^T \Phi_t$

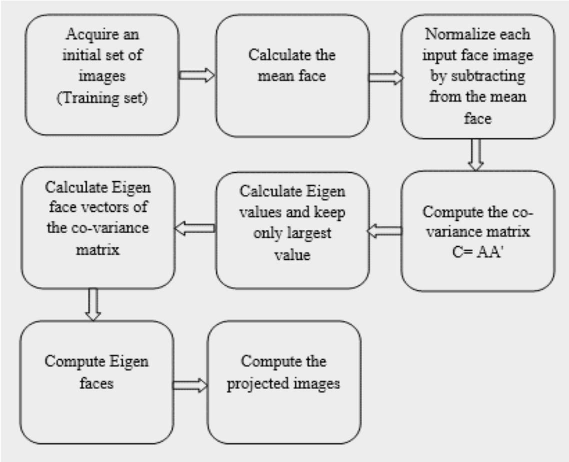

Fig. 3.3. Features Extraction using PCA

C. Classification
Classification is finding the minimum distance between the test image and the training images. The face with minimum Euclidian distance shows the similarity to test image. The distance of test image **Ω** to each training image is called Euclidean distance and is defined by,

$\varepsilon_k^2 = \| \Omega - \Omega_k \|^2$ [12]

By choosing a threshold value ϴ that is the maximum acceptable value for known images and comparing it with the minimum ε_k**,** test image can be recognized as known or unknown face image.

If $\varepsilon_k(\min) \geq \Theta$, the test image is recognized an unknown face.

If $\varepsilon_k(\min) < \Theta$, the test image is a known face.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The simulation of this project was implemented using the Matlab2015b software. Initially a facial database is constructed which is made to store around 30 images of each child. More training images may be stored if required.


Fig.4.1. Database Creation

Database Creation can be done by capturing images using webcam. While making the database folder, the captured images are applied and cropped by face detection module in order to obtain the only facial parts of all images with different directions.

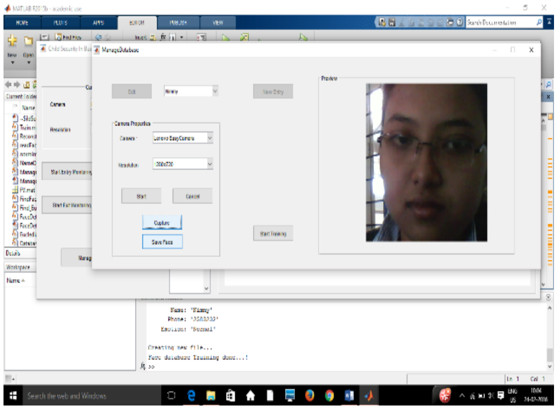
Fig. 4.2. Viola Jones face detection

All training images are reshaped and converted into 100x100 grayscale images by using resize and rgb2graymatlab built-in function. Mean centered (or subtracted) images are evaluated by subtracting average image from the original training image. The eigenvectors corresponding to the covariance matrix define the Eigen faces which look like ghostly faces. Since 30 training images are used, 30 eigen faces are obtained.

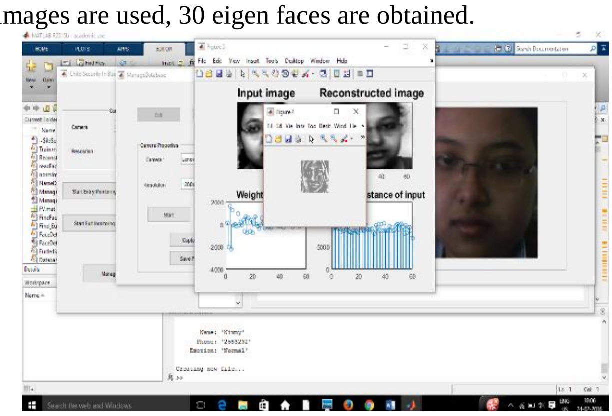

Fig. 4.3. Training of database

The main part of the project is face recognition. For that, the trained and test images are projected onto the face space where the eigenfaces are the coordinates or dimensions to find their respective euclidian distance. By comparing the euclidian distance of all projected trained images with the projected test image, minimum distance between them which shows similarity to test image is obtained. By this way, the facial image recognition was done.

Face recognition is done when children enter into and exit from the bus. During entry monitoring; the system recognises the children who entered the bus using real-time face recognition.

It then creates an entry list. During exit monitoring, the system recognises the children who leaves the bus and creates an exit list.

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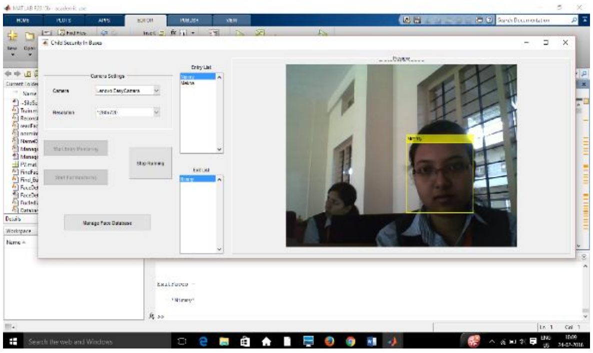

Fig. 4.4. Face recognition

Both entry list and exit list are then compared and identifies the missing children and an alert message will be sent to the mobile number of guardians already saved in the system. GSM modem is used to send data from the bus unit to the parents mobile. GSM is located in the bus unit to send SMS which contains the information about the child. First, the communication was tested using Terminal program by sending SMS from the GSM modem using AT commands. The mobile receives the SMS that was sent by the GSM modem as shown in the figure.

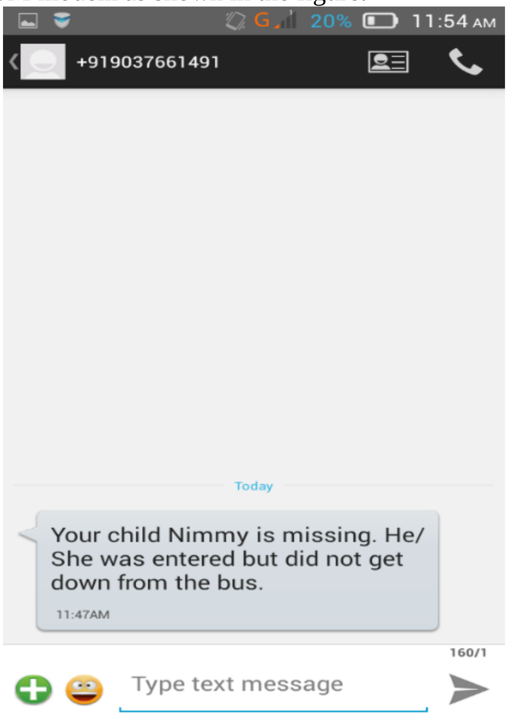

Fig.4.5. Alert message

V. CONCLUSION

This paper presents a children's transportation system to monitor pick-up/drop-off of children to enhance the safety of children. The system employs on a face recognition mechanism. A call service has been added to the system to warn the parents if any child is missing. The above experimental analysis was carried out on different persons and in various different illumination settings with various postures. The future scope would be to extend a modified version of the above program to also include Child monitoring system during transportation, Attendance Monitoring etc.

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