Class Attendance System Using Viola-Jones Algorithm and Principal Component Analysis

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Abstract. Face recognition is one of the numerous biometrics approaches that can be implemented by smart and automated attendance management systems. The individual identity can be determined by the unique representation of the face structure of each individual face and it cannot be lost, stolen, or reproduced in the same way as other types of identification. Thus, this work is motivated to propose a class attendance system based on face recognition. With current approaches such as passwords, access cards, and identification numbers, face recognition can be used to prevent theft and fraud which can significantly reduce the chances of system hacking. In this proposed work, initially, video framing has been implemented by activating the Universal Serial Bus (USB) camera through a user-friendly interface which was created with Graphical user interfaces (GUI) in the MATLAB software. The image of each student's face that was snapped by using the USB camera will be stored in a dataset. The dataset then will be divided into the training set and testing set. In the detection process, the Viola-Jones algorithm is utilized to detect and segment the image of student's face from the video frame. Next, the scaling of the size of the images is carried out to prevent the loss of information in the pre-processing phase. Then, the Principal Component Analysis (PCA) is utilized in the face recognition process in order to extract the features from facial images.

Keyword: Class attendance system, Face recognition, Viola Jones Algorithm, Principal Component Analysis

1. Introduction

Face Recognition technique is one of the most popular biometric techniques used to recognize individuals and it also has been widely utilized in many fields such as authentication system, transportation and electronic payment [1]. Face recognition is one of the numerous biometrics approaches that can be implemented by smart and automated attendance management systems [2,3].
Facial recognition is also widely used because of its effectiveness in the prevention of fraud, the fight against crime, public safety, and the improvement of customer experience [4]. Face recognition is the method by which the identity of a person can be authenticated by the recognition of a person using their physiological or behavioral characteristics, and this identity can be used to construct a variety of access control systems. The reason why the biometric authentication systems become popular because of these advances in imaging techniques and computing power [5].

The individual identity can be determined by the unique representation of the face structure of each individual face because information about a person's demographics, emotional state, and even likely behaviors can easily be extracted from each face [5]. Furthermore, it cannot be stolen, lost, or reproduced in the same way as other types of identification. The current approaches such as face recognition, identification numbers, passwords and access cards can be used to prevent theft and fraud as well, which can significantly reduce the chances of system hacking [6].

The face recognition system provides a service for the recognition of an individual's face image and the identification of authorized persons, rather than simply examining whether a legitimate identification is used or whether a user's personal password is required [7]. Additionally, there are various types of methods that can be used to recognize and classify the targeted object in the field of pattern or face recognition such as Moment Invariants technique, Principal Component Analysis and Artificial Neural Network [8].

Therefore, this study has proposed a class attendance system by using the face recognition technique based on the Principal Component Analysis (PCA) technique and Viola Jones algorithm.

2. Methodology

External USB camera is used in this project for capturing image of the faces. Then, the features of the detected faces were extracted and the obtain characteristics were classified into a database. The detected face then will be recognizing due to the input that was made at the database. The output image will be display and the attendance of the identified student will be recorded. Fig. 1 shows the block diagram of this research.

![Block Diagram of Class Attendance System.](image-url)
2.1. User Interface
The Graphic User Interface (GUI) acts as the user interface for an application. A Good user Interface can make the program easier to use by providing simple and clear appearance and intuitive controls such as pushbuttons, list boxes, sliders, and menus [9]. The GUI working in a manner that is understandable and predictable, so that the user knows what to expect when he or she performs the action and concentrates only on using the application rather than the mechanics involved [9].

MATLAB GUI is created using the GUIDE tool allows the programmer to layout and modify their GUI properties by selecting and aligning the GUI components to be placed in it. This GUIDE allows the user to create any number of GUI components by first clicking on the desired component and then dragging its outline to the layout area [9].

2.2. Input Image
Students need to register for the class using the user interface that was created on the MATLAB GUI. During the registration process, students need to provide their personal information such as their name, and then the camera will capture a real-time image of the student face. This step was done as the biometric-based system required enrolment of each individual. The training image from the database was used for the process of face recognition using MATLAB R2020a software.

2.3. Face Detection
For the detection phase, the Viola Jones algorithm is utilized in order to identify the face from the video camera recording frame on MATLAB Graphical User Interface (GUI). The Viola-Jones method is known as the first object detection system that offering real-time object tracking [10]. In addition, this algorithm is efficient for real-time use due to fast and flexible in providing a framework with a high detection rate [11].

The Viola-Jones Face Detector contains three main ideas that allow for the development of effective facial recognition that could be utilized in real-time applications such as image integral, feature extraction, classifier with Attentional Cascade Structure and AdaBoost [10].

![Flow of Viola Jones Algorithm](image)

**Figure 2.** Flow of Viola Jones Algorithm
2.4. Feature Extraction

The feature extraction technique is the main component in face recognition or shape analysis where it has been used to extract the features in an image either the global or structural approach [12]. This work has proposed a real-time recognition system based on Principal Component Analysis (PCA) and Viola Jones Algorithm. These techniques are used to generate the ‘eigenfaces’ and the Euclidean distance classification technique is utilized to compare the data obtained for each image. The PCA technique is utilized to extract the feature from real image generated from a cropped and resized face image [14]. It also one of the successful techniques for pattern recognition [11]. Besides, this technique is a classical linear technique to reduce the data dimensions and select an optimal base that can be utilized in order to represent an image vector. This image vector is given by the eigenspace developed from the non-zero eigenvalues from the covariance matrix of the entire image [15]. This technique also the most popular liner-unsupervised dimensionality reduction algorithm [13].

There are a few steps in the PCA method to extract the image feature. The image scale, length (N), and height (M) are not so important for PCA. This is because PCA mostly handles total number of images, n instead of MN. The various steps to calculate eigenfaces are as follows:

2.4.1. Step 1: Prepare the training faces.
Obtain the face images I1, I2, I3, I4, ......, In (training faces). The representations of the face must be centered and of the same proportions.

2.4.2. Step 2: Set up a data set.
Each face image in the database is converted into a vector and located in a training set S.

\[ S = \{\Gamma_1, \Gamma_2, \Gamma_3, ..., \Gamma_n\} \]

Dimension Reduced Matrix

\[
\begin{bmatrix}
\Gamma_1 & \Gamma_2 & \Gamma_3 & \Gamma_N \\
G_1 & \Gamma_2 & \Gamma_3 & \Gamma_N \\
\end{bmatrix}
= \begin{bmatrix}
a_{11} & a_{12} & ... & a_{1n} \\
a_{21} & a_{22} & ... & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{MN1} & a_{MN2} & ... & a_{MNN}
\end{bmatrix}
\] (1)

2.4.3. Step 3: Calculate the average vector of the face.
The average face vector (\(\varphi\)) is calculated based on the formula:

\[ \varphi = \frac{1}{n} \sum_{i=1}^{N} \Gamma_i \] (2)

\[
\begin{bmatrix}
a_{11} + a_{12} + ... + a_{1n} \\
a_{21} + a_{22} + ... + a_{2n} \\
\vdots \\
\end{bmatrix}
\]

\[ = \frac{n}{n} \begin{bmatrix}
\end{bmatrix} \] (3)

2.4.4. Step 4: Subtract the mean/average face vector.
The original faces are subtracted with the average face vector and the output result is stored in the variable \(\Phi_i\)

\[ \Phi_i = \Gamma_i - \varphi \] (4)
2.4.5. Step 5: Calculate the covariance matrix.

The covariance matrix is used to calculate the eigenvectors and eigenvalues. However, $AA^T$ have an $MN \times MN$ dimension that is extremely large to calculated. $AA^T$ and $A^T A$ have the same eigenvalues and their eigenvectors can be related as $u_i = Av_i$.

$$C = \frac{1}{n} \sum_{i=1}^{N} \Phi_i \Phi_i^T = AA^T, (MN \times MN)$$

$$A = [\Phi_1 \Phi_2 \cdots \Phi_n], (MN \times n)$$

where $A$ is the matrix of the concatenation of the column vectors after removing the mean face.

2.4.6. Step 6: Obtain the eigenvectors and eigenvalues.

$$u_i = Av_i , i = 1, 2, 3, \ldots, n - 1$$

$u_i$ is the eigenvector of $AA^T$ whereas $v_i$ is eigenvector of $A^T A$. Eigen values of $A^T A$, are calculated and sorted. Eigen values less than 1 are eliminated so the number of non-zero eigenvectors may be less than (n-1). Eigen face is the principal component distribution of facial image.

2.4.7. Step 7: Projection of facial image to Eigen face.

$$\Omega_i = UT(\Gamma_i - \varphi), i = 1, 2, \ldots, n - 1$$

In order to produce the projected image $\Omega_i$, the facial expression was projected on the Eigen Face using the equation. $\Gamma_i - \varphi$ as the centered vector which the mean face is removed.

Steps 1 to 7 are used to train the training image set and only step 1, 2, 3, 4 and 7 is required for the test image. Step 5 and step 6 are not required for the test image, as the Eigen face is only required to be computed once during training. The Mahalanobis Distance is used as distance classifier to calculate the shortest distance between the projected image and projected test image for recognition.

3. Results and Discussion

In this work, the class attendance system using face recognition is designed by prioritizing user-friendly interface concepts and developed using MATLAB GUI (Graphical User Interface). The user interface is designed with a user-friendly concept in mind for this designated framework, where it only uses the menu button to function in order to make it easier for the user to understand. Several menu buttons are designed in the interface, each providing specific functions.

Students need to make a registration before taking any attendance to ensure that their face images were stored in the system database for the recognition process. After the recognition process is complete, the attendance of the recognized student will be displayed at the user interface and be wrote in notepad which includes the student’s name, date, and time of the attendance was taken. The results as follow:
3.1. User Interface
When a user clicks the system icon of the MATLAB GUI, the system will run and display the user interface of the class attendance system. The user interface was designed as the Figure 3 below, where the user can find the menu button at the top left of the interface and the time and date for the day will be displayed when the user clicks the date and time button.

![Figure 3. User Interface](image)

3.2. Face Detection
In the process of registration, students need to make sure that only their face is inside of the frame. This is because the camera will not capture any image if there is more than one face detected in the same video frame. USB camera will on and display the image of the student in the interface as Figure 4. The system will do face detection using the Viola-Jones algorithm and captured the face image of the student. Students need to manually key in their full name in the provided pop-up section after the interface gives a preview of their face image on the interface.

Once the students have completed the registration process, the names of the students with their specific image names will be stored as info.m file in the MATLAB workspace, where the system will know the student’s name for the specific face image.

![Figure 4. Face detected and displayed on user interface](image)

3.3. Face Recognition
In the recognition process, a button was created in the user interface menu which is the Update button. The function of the update button is to train the latest images that have been recorded in the database by using the PCA. In this phase, the system will be performing the PCA to enhance the face extraction and the eigenvalues that were calculated by the algorithm were saved into the MATLAB workspace for future use.
3.4. Attendance Taken
Take Attendance button used to prepare the camera and to execute the face recognition system automatically based on the face detected. The system will detect a face in the video frame and the detected face was captured and displayed in the user interface.

The captured face is then performed feature extraction using PCA and the eigenvalues from the captured images were compared to the images in the database to find the most similar eigenvalue. Images with the most similar eigenvalue is then displayed in the user interface and the student is being recognized. The name of the student will be displayed and attendance were taken and write to Notepad as Figure 6.

![Figure 5. Real Time Face Recognition](image)

![Figure 6. Attendance recorded in Notepad file.](image)

3.5. Access to Database
The database button allows the user to view the face database inside the folder database in the laptop and attendance database. Delete button allows the user to choose either to delete the database or to delete current attendance. Students can use the delete database button to delete any images inside the database. This button was created due to some reason such as the images were blurred or to delete any images of students that drop the subject. The delete attendance button is designed to ensure that attendance for the next day will not be written in the same Notepad file. Lastly, the exit button were created to close the system.

3.6. Discussion
Based on the result, the purpose attendance system has successfully recorded the face images by using the face recognition technique. This technique has been used to identify the student image’s individually and compared the real-time captured image with stored images in the database.

At the initial stage, the Yale face database has been used to test the proposed system. This database has been selected because it consists of one hundred and sixty-five images of fifteen individuals with multiple conditions. However, this database is made up of only grayscale images. Therefore, the own database consists of colour images with three categories which are high-quality set, blurred images
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and clearer images have been used. The blurred and clearer images happened due to the illumination situation. Therefore, the image is suggested to be captured in one place with the same amount of lighting in order for the system to operate successfully.

The Viola-Jones object detection algorithm has been utilized in this work in order to identify and localize a face image from a video frame. Subsequently, the important features have been extracted by using the PCA based on the detected face and the data were stored in the MATLAB workspace.

4. Conclusion
This work has developed a class attendance system using face recognition based on the Principal Component Analysis technique and Viola-Jones algorithm. The main objective of this system is to mark and record the attendance in an efficient way without having to physically call out the name of every student. Besides, the attendance will directly be stored in the database without having taken care of a physical record and it can save time. The system also will help save plenty of paper which is wasted every school in maintaining attendance of the students in colleges throughout the world. In conclusion, the proposed system successfully detects and localize the face image and recognize the individuals by contrasting their test image detected from the live video frame with the train image using a user interface through MATLAB GUI.

Acknowledgement
The author would like to acknowledge the financial support from Faculty of Electronic Engineering Technology (FTKEN) and Research Management Centre (RMC) from the Universiti Malaysia Perlis.

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