

Automated Attendance and Intruder Monitoring Through OpenCV Facial Recognition

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ABSTRACT – Traditional paper-based attendance methods are inefficient and prone to errors, especially in large groups. This study proposes using facial recognition technology to secure door entry and monitor attendance, addressing issues like proxy attendance and time consumption. The system uses OpenCV and Python modules to detect and authenticate faces against a pre-registered database, logging attendance information in real-time. Unrecognized faces trigger an intrusion notice sent to a registered email, enhancing security. This dual application improves both attendance accuracy and entry control automation.

Keywords - Automated Attendance, Face Recognition, Security System, Real-time Authentication, Intrusion Detection, OpenCV, Python, Efficient Attendance Management, Facial Authentication, Secure Door Access Control, Email Notifications, Unwanted Access Prevention, Proxy Attendance Elimination, Attendance Logging.

I. INTRODUCTION

Applications like credit and debit card verification, security systems, and criminal identification in public spaces rely heavily on the use of human faces. This study's main goal is to develop a facial recognition system that can someday outperform human ability. The emphasis is mostly on frontal human faces, making use of the advantages of several face recognition algorithms. People are able to identify faces right away when they recognize them. For practical uses, numerous face identification algorithms have been created to mimic this innate capacity. While global face recognition systems use the full face, local face recognition systems employ certain facial traits to identify a person.

Over time, these methods have been incorporated into different algorithms, such as neural network-based algorithms, to account for the complexity of facial traits. Computer vision, which seeks to electronically simulate human vision, is closely related to artificial intelligence, which has been developing quickly in recent years. Computer vision must be able to recognize, detect, and analyze images similarly to human vision. For instance, a self-driving car needs to recognize, interpret, and respond to a human crossing its path.

Coordination, memory, retrieval, reasoning, estimation, and recognition are all part of vision, and cv emulates these functions. Manually recording attendance in an educational setting is labor-intensive and prone to inaccuracy.

Conventional approaches entail lines and wait times, while current biometric solutions also need more time for user engagement. The goal of this study is to use Python and OpenCV to build an automated attendance system that recognizes faces. Real-time facial recognition and detection by the technology will replace manual attendance recording. This approach tackles problems such as proxy attendance, where students sign in for absent classmates, ensuring the real person's presence.

The integrity and dependability of attendance data are improved by precise and effective face detection and recognition, impacting student performance monitoring and academic assessment. The technique ensures that only enrolled students who are present in the classroom are accounted for, mitigating the issues associated with traditional methods. As a result, attendance records gain more legitimacy, improving transparency and accountability in the educational system.

The goal is to identify faces in a collection of training photographs and locate matching data to indicate attendance with precise timestamps. If an unidentified face is found, an intrusion notice is delivered, enhancing security. Applications encompass image database research, financial services, security, law enforcement, human-machine interaction, and intruder warnings. The study covers system architecture, data gathering and storage, facial recognition and detection, system integration, performance optimization, security precautions, user interface design, and testing and validation to guarantee accuracy and reliability under varied circumstances.

II. LITERATURE SURVEY

Paper 1: Design and Implementation of Classroom Attendance System Based on Video Face Recognition

Authors: Z. -h. Lin and Y. -z.

Description: Classroom attendance, as an indispensable part of teaching activities, plays a very important role in classroom teaching. Classroom attendance can effectively supervise students to attend classes on time and ensure the quality of classroom teaching. However, the current classroom attendance is mainly achieved by the way of teacher's name-calling, which will cause a lot of waste of classroom time.

The system uses a camera installed in the classroom to obtain classroom video information. For the collected video information, it is first divided into a frame of static pictures, and from the pictures, several pictures with clear face and better light are selected for face recognition, and finally the recognition results are aggregated and merged. In order to solve the influence of the location of the camera on the recognition results, the system can be combined with the platform control system to control the rotation and focusing of the camera through the platform, and further improve the recognition accuracy.

Paper 2: Automatic Attendance System using Face Recognition

Authors: S. K. Sarangi, A. Paul, H. Kishor and K. Pandey

Description: Attendance in an educational institution for students is the most challenging part of the virtual platform. It wastes a lot of effort and time when it is done manually. There was also a lot of fake attendance due to lack of a good attendance system. The face is the most important thing which identifies a human. Therefore, in this paper, we work on an attendance system using a face detection algorithm in real-time using the frontal face recognition concept. In this paper, we describe an efficient algorithm of Haar cascade using an open-source image processing framework known as OpenCV and works on an attendance system using a face detection algorithm in real-time using the frontal face recognition concept.

Paper 3: Automatic Attendance Management System Using Face Detection and Face Recognition

Authors: Varsha, M., Chitra Nair

Description: Attendance plays a major role in every education system. Taking attendance of students manually can be a great burden for teachers. It may cause many problems like loss of time, repetition, incorrect markings, and difficulties in marking them. To avoid this, there is a need to design an automatic system that overcomes the issues with the traditional attendance system. There are many automatic methods available for this purpose like fingerprint systems, RFID systems, face recognition systems and iris recognition systems, etc. But among these Face Recognition proved to be more efficient. The main objective of this paper is to propose a model that captures images from videos, detect and recognize the faces, predict the recognized face, and then marks attendance. SVM is used to predict the face of the person from the image.

Paper 4: Enhancing Automatic Attendance System using Face Recognition

Authors: A. Bhattarai, S. Dhakal and A. K. Timalsina

Description: Designing an automated class attendance system requires the feature of uniquely detecting each person of the class room. Furthermore, such system should be resistant to varied illumination in the classroom. The recent works on face net and vggface2 provide promising results in producing high quality facial embeddings as feature vectors. The paper discusses the methodology to identify individual students uniquely. To achieve this, the Support Vector Classifiers are used.

The dataset of about 11 classes each with about 1000 faces are used. From the original dataset, two more datasets are created: one with varied contrast and the other with varied contrast and noise. Further, embeddings of these datasets are created and supplied to four proposed models built using Support Vector Classifiers and Neural Network: Tuned SVC with RBF Kernel, SVC with linear kernel, Simple NN and CNN. Although all four models performed similarly on the clean dataset, tuned SVC with RBF kernel is more resilient to noise and variation in contrast.

Paper 5: Automatic Attendance System Using Face Recognition

Authors: Harshad Patil, Heena Khan, Saquib Ansari, Saimohan Sahu

Description: Student attendance is essential in the learning process. To record student attendance, several ways can be done; one of them is through student signatures. The process has several shortcomings, such as requiring a long time to make attendance; the attendance paper is lost, the administration must enter attendance data one by one into the computer. To overcome this, the paper proposed a web-based student attendance system that uses face recognition. In the proposed system, Convolutional Neural Network (CNN) is used to detect faces in images, deep metric learning is used to produce facial embedding, and to classify student's faces. Thus, the computer can recognize faces. From the experiments conducted, the system was able to recognize the faces of students who did attend and their attendance data was automatically saved. We can send the attendance file through email by just clicking the button.

Paper 6: Smart Attendance Monitoring System (SAMS): A Face Recognition Based Attendance System for Classroom Environment

Authors: Shubhobrata Bhattacharya, Gowtham Sandeep Nainala, Prosenjit Das and Aurobinda Routray

Description: In the present academic system, regular class attendance of students' plays a significant role in performance assessment and quality monitoring. The conventional methods are practiced in most of the institutions are by calling names or signing on papers, which is highly time-consuming and insecure. The system is developed by the integration of ubiquitous components to make a portable device for managing the student's attendance using Face Recognition technology. An automated attendance system for human face recognition in real time background for a college to mark the attendance of their employees and students. So Smart Attendance using Face Recognition is a real world solution which comes with day to day activities of handling employees.

III. METHODOLOGY

A. System Architecture

The architecture of the automated classroom attendance system integrates software and hardware to facilitate attendance monitoring. Strategically positioned cameras at each entry point record broadcasts of images or videos of students.

The software implements the Histogram of Gradient algorithm within the OpenCV framework to analyze these images, facilitating the detection and recognition of faces in real-time. Student facial profiles are stored in a centralized database, which serves as a point of reference for the purpose of verification. By comparing captured features to these profiles, attendance is confirmed and students are marked as "present" in a designated file.

This architectural design provides adaptability by permitting software updates in response to changing requirements and scalability by integrating additional cameras or processing units. In its entirety, this intuitive system integrates state-of-the-art technologies to ensure precise and effective attendance tracking, thereby augmenting the educational atmosphere. An automated attendance management system that makes use of facial recognition technology is the subject of this study. For feature extraction and face recognition, the system employs the Histogram of Oriented Gradients (HOG) algorithm and a Support Vector Machine (SVM) classifier, respectively. This section details the methodology employed throughout the various stages, comprising image capture, pre-processing and feature extraction, and ultimately, face recognition using HOG.

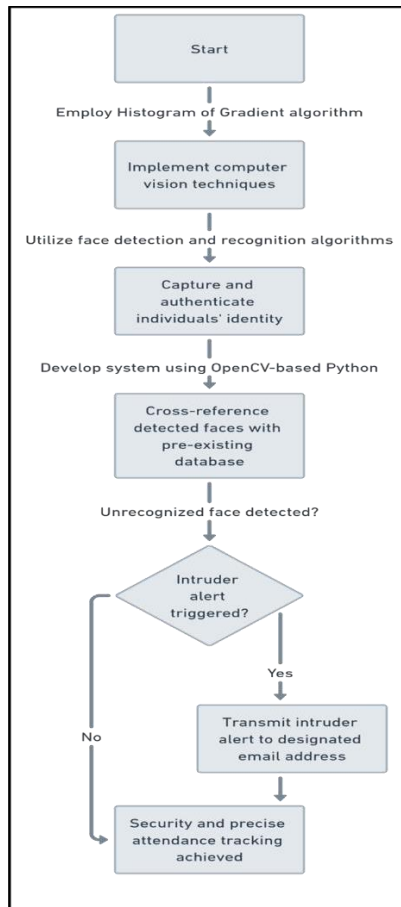


Fig 1. System Architecture

B. Image Capture

The initial stage involves capturing high-quality facial images for accurate recognition. This can be accomplished through a strategically placed webcam or a built-in camera within a computer system.

The system configuration should prioritize capturing clear and well-lit images to optimize the performance of subsequent processing stages. Factors such as illumination conditions, background complexity, and camera resolution all influence the quality of captured images. Techniques like altering camera settings or implementing background subtraction algorithms can be employed to mitigate potential challenges and ensure optimal image acquisition.

Furthermore, considerations should be made for capturing diverse visage variations within the student population. This includes capturing frontal face poses while accommodating potential variations in head orientation, facial expressions, and the presence of occlusions, such as spectacles or headwear. Encouraging pupils to maintain a neutral expression and a frontal pose during image capture can improve the accuracy of the recognition model. Additionally, collecting multiple images per pupil under varying lighting conditions can enhance the robustness of the system in real-world scenarios.

C. Face Recognition Algorithm

This section delves deeper into the face recognition process employed in our system, specifically concentrating on the integration of the **Histogram of Oriented Gradients (HOG)** algorithm for feature extraction and the Support Vector Machine (SVM) classifier for recognition. We will examine the underlying mathematical concepts, visualize the process through equations and figures, and discuss the strengths of this approach for classroom attendance management.

1) Pre-Processing of HOG Algorithm:

a) *Grayscale conversion*: Converting the captured images from RGB (Red, Green, Blue) color space to grayscale simplifies the processing pipeline and reduces computational complexity. Facial features are primarily defined by intensity variations, rendering grayscale images sufficient for effective feature extraction using HOG.

b) *Normalization*: Normalizing the intensity values of the grayscale images ensures uniformity across the dataset. This mitigates the impact of varying lighting conditions on pixel intensities and improves the efficacy of subsequent feature extraction algorithm.

c) *Resizing*: Images are resized to a predetermined resolution to standardize the input for the feature extraction algorithm. This assures consistent feature representations across the dataset and facilitates efficient processing within the system.

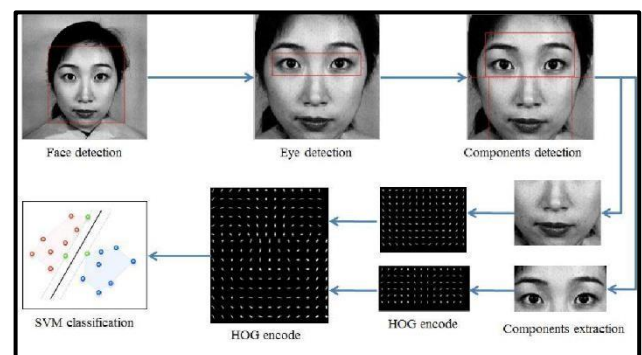


Fig 2. Face Detection and Feature extraction using HOG

2) Feature Extraction with HOG Algorithm

The HOG algorithm plays a crucial role in deriving informative features from facial images. It focuses on capturing the local gradients within an image, essentially analyzing the intensity changes across various regions. These gradients often correspond to edges and shapes in facial features, such as the eyes, nostrils, and mouth.

a) Cell and Block Division

The image is divided into smaller rectangular regions called cells. Typically, cells have a dimension of 4x4 or 8x8 pixels. Groups of adjacent cells are further combined into larger rectangular blocks (e.g., 3x3 cells per block).

b) Gradient Calculation

Within each cell, the gradient magnitude (intensity) and orientation (direction) are computed for each pixel. This is often accomplished using filters like Sobel filters.

c) Histogram Construction

A histogram is constructed for each cell, capturing the distribution of gradient orientations within that cell. The histogram typically divides the gradient orientations into predefined angles (e.g., 9 bins for 0 to 180 degrees).

d) Block Normalization

To mitigate the influence of illumination variations, normalization techniques like L2-norm or contrast normalization are applied to each block's histogram. This assures that the feature representation is less sensitive to lighting conditions.

e) Feature Vector

Finally, all normalized histograms from a block are concatenated to create a single feature vector representing that block. This process is repeated for all blocks in the image, resulting in a comprehensive HOG feature vector that captures the overall gradient distribution and local edge information across the entire image.

Mathematically, the gradient magnitude (G) and orientation (θ) for a pixel at location (x, y) can be calculated using the following equation:

$$G(x, y) = \sqrt{G_x^2(x, y) + G_y^2(x, y)} \quad \theta(x, y) = \tan^{-1}(G_y(x, y) / G_x(x, y))$$

where G_x and G_y represent the gradients in the x and y coordinates, respectively.

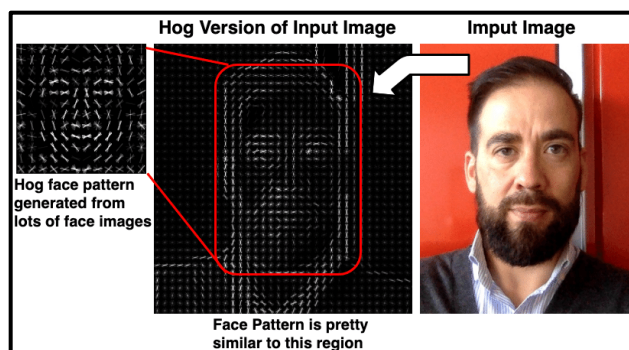


Fig 3. Face Description of an Input Image using HOG

3) SVM Classification for Face Recognition:

Once the HOG features are extracted, they serve as input for the SVM classifier, which conducts the task of face recognition. Here's a closer look at this stage:

a) SVM Training

The SVM is a supervised learning algorithm that learns to classify data points based on labeled training data. In our case, the training data consists of facial images with corresponding student IDs (labels). During training, the SVM constructs an optimal hyperplane in a high-dimensional feature space that separates the feature vectors (HOG descriptors) belonging to distinct classes (individual students). This hyperplane maximizes the margin between the closest data points of each class.

b) Classification

For recognizing an unknown visage, the HOG feature vector is extracted from the captured image. This feature vector is then projected onto the same high-dimensional space where the SVM model was trained. The SVM then classifies the unknown data point based on its proximity to the learned hyperplane. The class (student ID) associated with the closest hyperplane is considered the recognized identity.

D. Dataset Development

This study employed a facial recognition dataset for training and testing the Automated Attendance Tracking System. The dataset comprised individual student images stored in a designated directory with filenames corresponding to the student's name (e.g., "John_Doe.jpg"). These images were pre-processed to extract facial features suitable for recognition. Subsequently, a Support Vector Machine (SVM) classifier was trained on the extracted features and corresponding student labels. During system operation, student faces are detected and encoded, enabling for comparison with the trained classifier. This process facilitates real-time attendance tracking, where a successful match generates a time-stamped attendance record for the identified pupil.

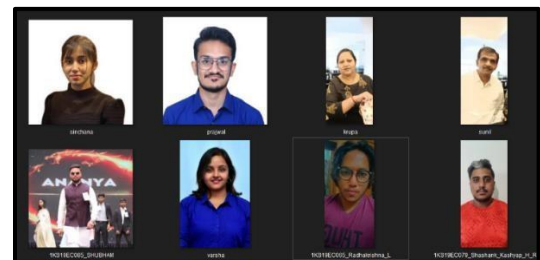


Fig 4. Images in the Dataset

E. Implementation

This study proposes an automated attendance management system utilizing facial recognition technology. This system offers several advantages over traditional attendance marking methods, including efficiency, accuracy, and the elimination of manual processes.

1) Core Libraries and Functionalities:

The system uses a number of libraries to accomplish its features. NumPy (numpy) allows for numerical computing, OpenCV (cv2) does image processing and video capture duties.

The system's facial recognition features are built on top of the face_recognition library. To record attendance statistics, the datetime library makes it easier to retrieve system timestamps.

To improve the user experience, pyttsx3 is also employed to provide text-to-speech notifications upon student recognition. Smtplib allows for the delivery of email notifications with intrusion alerts in order to enhance security.

2) Special Features:

This study incorporates two distinctive features to enhance the system's capabilities. First, personalized name announcements: upon successful facial recognition, the system retrieves the corresponding student's name and announces it using a text-to-speech library (e.g., pyttsx3). This personalized approach fosters a more welcoming classroom environment and provides immediate attendance confirmation for students. Second, intruder alert with email notification: in the event of an unrecognized face, indicating a potential intruder, the system triggers an alert mechanism. An email notification containing a timestamp and image snapshot is promptly sent to designated personnel's email addresses using the smtplib library, ensuring timely intervention and enhancing security measures.

3) Flow of the System:

a) Data Set Development

A dataset of student images is created, with each image named uniquely corresponding to the student's name (e.g., "John_Doe.jpg").

b) Face Detection

The system employs the Histogram of Oriented Gradients (HOG) algorithm to detect faces within captured video frames. HOG analyzes local gradients and shapes for facial region identification under varying lighting conditions.

c) Face Landmark Estimation

Following face detection, key facial landmarks (eyes, nose, mouth) are located. These landmarks serve as anchor points for subsequent alignment and recognition tasks.

d) Face Encoding

Alternative methods like Local Binary Patterns (LBP) or Scale-Invariant Feature Transform (SIFT) are used for facial feature encoding. These techniques extract discriminative features and encode them into compact descriptors (face encodings).

e) Classification using SVM

A Support Vector Machine (SVM) classifier, trained on labeled facial data with corresponding encodings, classifies faces based on their encoded features.

f) Attendance Marking and Intruder Alert

Upon successful recognition, the system retrieves the student's name, marks their attendance with a timestamp, and optionally announces the name. Unrecognized faces trigger an intruder alert, sending an email notification with a timestamp and image snapshot.

g) Name Display

The recognized student's name is displayed on the screen, or "Unknown" is displayed for unrecognized faces.

This study's implementation of personalized name announcements and intruder alerts with email notifications distinguishes it from existing facial recognition attendance systems. These features enhance the user experience for students and provide an additional layer of security for administrators.

IV. RESULTS

The experimental outcome of this facial recognition system for attendance management demonstrates its effectiveness in identifying individuals with a high degree of accuracy. The system leverages a robust recognition algorithm that extracts key facial features and utilizes them for classification. This approach allows for successful recognition despite variations in factors such as hair, facial hair, and eyewear. Furthermore, the system exhibits adaptability in handling diverse lighting conditions and background clutter, ensuring consistent performance in real-world scenarios. To enhance security, we implemented an intruder detection mechanism. In instances where an unidentified face is encountered, it is labeled as "unknown," and an alert is triggered as shown in Fig 6. This alert can be configured to send an email notification with relevant details, including timestamps and captured images, to designated personnel Fig 7.

One of the special features of this system which we developed is its personalized announcement capability. Upon successful recognition of a registered user, the system can be programmed to deliver a welcoming message using a text-to-speech engine. This feature can be particularly beneficial in educational environments, fostering a more welcoming atmosphere.

The experimental results showcase the system's potential for streamlined and secure attendance management. Its ability to accurately recognize faces under various conditions, coupled with intruder detection and personalized announcements, positions it as a valuable tool for organizations seeking to improve attendance monitoring processes.

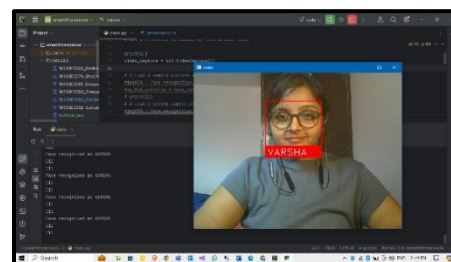


Fig 5. Facial Recognition and Personalized Name Announcement of Person

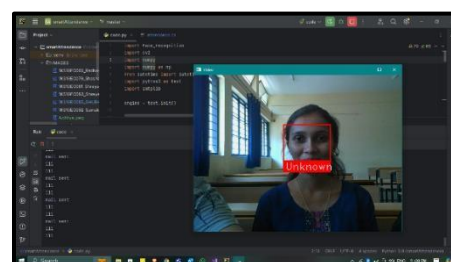


Fig 6. Detection of Unknown Face

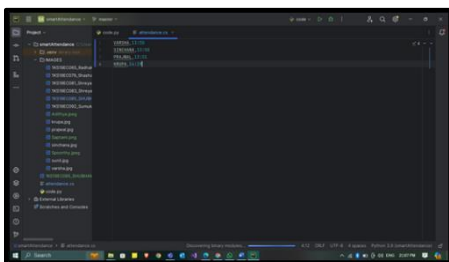


Fig 7. Tracking Attendance with Time Stamp

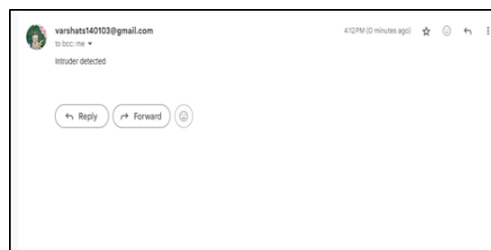


Fig 8. Intruder Alert Email Notification

V. CONCLUSION

The study presented a facial recognition system designed for real-time face detection and identification in attendance management applications. The system exhibited robustness and accuracy by leveraging advanced algorithm like Histogram of Oriented Gradients (HOG) for feature extraction. This approach enabled successful recognition across diverse facial features and under varying lighting conditions. To bolster security, the system incorporated an intruder detection mechanism. Upon encountering unidentified faces, it triggered alerts, potentially including email notifications with timestamps and captured images. This feature empowered personnel to promptly address potential unauthorized access attempts. The findings of this study suggest that the proposed facial recognition system has significant potential for real-world applications in security, surveillance, and access control domains. Its ability to deliver reliable and efficient facial recognition makes it a valuable tool for these domains.

Looking ahead, future endeavors could refine the system's intruder alert functionality by incorporating snapshot capture. This would provide users with visual context during security incidents, allowing for more informed decision-making and response strategies. Additionally, the integration of advanced machine learning techniques could be explored to push the boundaries of facial recognition accuracy and performance. Furthermore, the system's capabilities could be expanded to encompass multi-modal biometric authentication, offering a more robust and secure user authentication experience by combining facial recognition with other biometric modalities. By continuously developing and refining facial recognition technology, researchers can create increasingly sophisticated systems that enhance security, streamline processes, and provide valuable insights across various application domains.

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