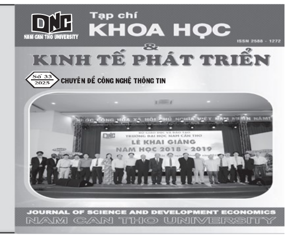
Journal of Science and Development Economics
Nam Can Tho University

Website: jsde.nctu.edu.vn



Development of a facial recognition-based attendance system

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Received: 20/1/2025

Revised: 15/2/2025

Accepted: 1/3/2025

Keywords: *face recognition, face training, LBPH algorithm, recognition, time tracking*

Từ khóa: *chấm công, huấn luyện khuôn mặt, nhận diện, nhận diện khuôn mặt, thuật toán LBPH*

ABSTRACT

This project presents a facial recognition-based time-tracking system that aims to improve the process of monitoring employee attendance. The system utilizes the LBPH (Local Binary Patterns Histograms) algorithm to collect and analyze facial data in real-time, allowing for accurate identification of individuals even in varying lighting conditions and from different angles. To ensure precise time tracking, the system creates unique facial templates for each user, which are securely stored and matched against actual data during check-in. Additionally, the system addresses common challenges such as spoofing and prioritizes data privacy through encryption. The deployment also includes a user-friendly interface for easy management of attendance records and the option to integrate with existing HR systems. By reducing manual errors and saving time compared to traditional time tracking methods, this solution offers an efficient and scalable option suitable for organizations of all sizes.

TÓM TẮT

Dự án này giới thiệu một hệ thống chấm công dựa trên nhận diện khuôn mặt, được thiết kế nhằm tối ưu hóa và tự động hóa quá trình theo dõi sự hiện diện của nhân viên. Sử dụng thuật toán LBPH (Local Binary Patterns Histograms) mạnh mẽ, hệ thống này thu thập và xử lý dữ liệu khuôn mặt theo thời gian thực để nhận diện chính xác từng cá nhân, ngay cả trong điều kiện ánh sáng thay đổi và từ các góc nhìn khác nhau. Hệ thống đảm bảo độ chính xác cao trong việc ghi nhận chấm công bằng cách tạo ra các mẫu khuôn mặt duy nhất cho mỗi người dùng, được lưu trữ an toàn và đối chiếu với dữ liệu thực *tế trong quá trình check-in. Ngoài ra, hệ thống cũng giải quyết các thách thức phổ biến như giả mạo và đảm bảo quyền riêng tư dữ liệu thông qua mã hóa. Việc triển khai bao gồm một giao diện thân thiện với người dùng để dễ dàng quản lý hồ sơ chấm công và khả năng tích hợp với các hệ thống nhân sự hiện có. Bằng cách giảm thiểu sai sót thủ công và tiết kiệm thời gian so với các phương pháp chấm công truyền thống, giải pháp này mang đến một lựa chọn hiệu quả và có thể mở rộng phù hợp cho các tổ chức ở mọi quy mô.*

1. INTRODUCTION

The face recognition-based attendance system has become an effective solution for organizations to optimize time management and minimize errors in the attendance process. Face recognition helps save time for employees while eliminating risks associated with forgetting cards or PIN codes. Attendance is a critical element in human resource management, enabling organizations to monitor and manage employee working hours. Attendance methods have gone through several stages of development, from manual methods to modern technology-based approaches:

- Traditional Method (using pen and paper): For many decades, recording employee in and out times on paper or forms was the most common attendance method. This method, although simple and requiring little initial investment, is prone to errors, fraud (such as proxy attendance), and difficulties in long-term data management and storage.
- Magnetic card or paper card time clocks: With the advent of electronic devices, time clocks using magnetic cards or paper cards helped automate part of the time recording process. Employees simply swipe their cards, and the time is recorded. However, this method still has issues such as card loss or proxy attendance.
- Biometric time clocks: To overcome the limitations of card-based systems, biometric technologies such as fingerprint recognition, iris recognition, and face recognition have been applied. These methods rely on unique biological characteristics of individuals, helping to prevent proxy attendance. However, each technology has its own advantages and disadvantages [1].

Popular biometric technologies for attendance include:

- Fingerprint recognition: One of the most common biometric methods, fingerprint recognition is easy to use and relatively low in implementation costs. However, it can encounter difficulties in environments with dust or moisture, when employees' fingerprints become smudged or damaged. Common algorithms include Minutiae Matching and Ridge Matching [2],[3].
- Iris recognition: Iris recognition technology is highly accurate and nearly impossible to forge. However, this system is often expensive and may not be comfortable for employees who must look directly into the camera at close range. The system uses techniques such as Gabor Wavelets to analyze and encode iris features, creating a unique "iris code" for each individual [4].

- Face recognition: Unlike the other methods, face recognition is a contactless, convenient approach that can be applied in many environments. This technology is becoming increasingly popular due to advances in machine learning algorithms and feature extraction techniques. Research has shown that face recognition technology is highly effective for attendance in businesses [5].

Facial recognition:

Face recognition technology is a biometric method that converts the facial features of an individual into mathematical data and stores it as a faceprint (facial trace). In simple terms, this technology enables the identification of a specific individual from images or videos [6]. Among the main methods developed for face recognition are Principal Component Analysis (PCA) [7], Linear Discriminant Analysis (LDA) [8], and Elastic Bunch Graph Matching (EBGM) [9]. PCA is a commonly used statistical method for dimensionality reduction by extracting the principal components from multidimensional data. In contrast, LDA is a supervised machine learning technique used for multi-class classification by reducing the number of features in the data, thereby optimizing machine learning models. EBGM, on the other hand, divides the face into a network of nodes, with approximately 80 points for each face, to identify features such as the distance between the eyes and the shape of the cheekbones. However, this method requires precise computation of the distances between the nodes and is often combined with PCA or LDA to enhance performance.

In this study, we propose a new face recognition method that combines shape and texture information to represent face images. Unlike the EBGM method, our algorithm directly extracts facial feature vectors in the form of histograms. The process begins by dividing the face image into smaller regions, followed by extracting Local Binary Pattern (LBP) features, a technique commonly used in computer vision to describe texture. LBP relies on shape characteristics and provides a way to describe the local structure of an image without being affected by lighting changes. Introduced in 1994, LBP has been widely applied in areas such as object recognition, face detection, and texture classification, thanks to its simplicity and effectiveness [10].

Face description with local binary patterns:

All images are represented as matrices. The basic component of an image is a pixel. An image is made up of a set of pixels. Each pixel is a small square, and by placing them together, we can form a complete image. A single pixel is considered the minimal information in an image. For each image, the value of the pixels ranges from 0 to 255. Each pixel consists of three values: R, G, and B, which represent the basic colors of red, green, and blue. The combination of these three basic colors creates all the colors in the image, so we conclude that a pixel has three channels, one for each basic color [11]. Due to the remarkable computational efficiency and good texture discriminating properties of the LBP operator, it has garnered significant attention since its introduction. LBP has been used in various applications, including visual tracking, texture-based segmentation, image retrieval, face recognition, and texture classification. The LBP operator operates in a 3×3 neighborhood, using the center value as a threshold. The LBP code is generated by multiplying the thresholded values by the weights provided by the corresponding pixels. Then, the binary LBP code is converted into a decimal number using equations to represent a unique spatial pattern [12]:

$$LBP_{P,R} = \sum_{p=0}^{P-1} s(g_p - g_c)2^p$$

$$s(x) = \begin{cases} 1, & x \geq 0 \\ 0, & x < 0 \end{cases}.$$

2. RESEARCH METHODS

Now that we have a basic understanding of facial recognition and the LBPH algorithm, let's delve into the implementation steps of this method.

2.1 Parameters

LBPH relies on four primary parameters:

- Radius: The radius is used to construct the circular Local Binary Pattern and represents the area around the central pixel. It is typically set to 1.
- Neighbors: This indicates the number of points used to build the circular Local Binary Pattern. Note that including more points increases computational cost. This parameter is generally set to 8.
- Grid X: Refers to the number of cells along the horizontal direction. A higher number results in a finer grid, increasing the dimensionality of the feature vector. The default value is often 8.
- Grid Y: Indicates the number of cells along the vertical direction. Similar to Grid X, this parameter enhances the level of detail in the feature vector. It is usually set to 8.

2.2 Training the algorithm

The first step is to train the algorithm. This requires a dataset containing facial images of the individuals to be recognized. Each image must be assigned an ID (which can be a number or the person's name) so that the algorithm can use this information to identify the input image and provide results. Images of the same person must share the same ID. Once the training dataset is prepared, we can move on to the computational steps of LBPH.

Table 1. Organization of Employee Database Storage

Employee ID	Number of faces
1	30
3	30
…	…

Table 2. Organization of face and feature data storage

Employee ID	Face file name	Face feature string
1	User.1.1	0.0078125, 0.0068359375…
1	User.1.2	0.0137741044, 0.0174471997…
1	User.1.3	0.0146923782, 0.00918273628…
…	…	…
2	User.2.1	0.0562130176, 0.0177514795…
2	User.2.2	0.0793650821, 0.0136054419…
2	User.2.3	0.0599999987, 0.0149999997…
…	…	…

Table 3. Organization of training data storage

Face feature string	Output label (Employee ID)
0.0078125, 0.0068359375…	1
0.0137741044, 0.0174471997…	1
0.0146923782, 0.00918273628…	1
…	…
0.0562130176, 0.0177514795…	3
0.0793650821, 0.0136054419…	3
0.0599999987, 0.0149999997…	3
…	…

Process of Comparing Trained Images with Face from Time Clock Camera:

- The facial features from the camera are extracted.
- These features are compared to the pre-stored feature strings in the training database.
- The corresponding employee ID is retrieved as the employee's unique identifier (ID).
- The ID is used for the time attendance system to record the employee's working time.

2.3 Applying the LBP operation

The first computational step in LBPH is to create an intermediate image that better represents the original image by emphasizing facial features. This is achieved using the sliding window concept, based on the parameters of radius and neighbors. The illustration below demonstrates this process:

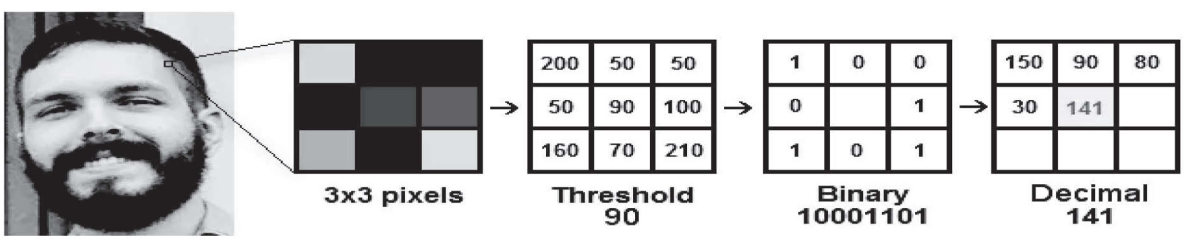

Fig 1. Illustration of the LBP algorithm

Based on the image above, let's break it into smaller steps for better understanding:

- Extract a portion of the original image, such as a 3x3 pixel window.
- Represent this window as a 3x3 matrix, where each element corresponds to the grayscale intensity of a pixel (ranging from 0 to 255).
- Use the central value of the 3x3 matrix as a threshold.
- Compare the grayscale intensity of the 8 neighboring pixels with the threshold value:
- If the neighboring pixel's intensity is greater than or equal to the threshold, assign it a binary value of 1.
- If the neighboring pixel's intensity is less than the threshold, assign it a binary value of 0.
- Concatenate the binary values of the 8 neighboring pixels into a binary string in a specific order (e.g., row-wise).

- Some methods may use a different order (e.g., clockwise), but the final result is usually similar.
- Convert the binary string into its corresponding decimal value.
- Assign the calculated decimal value to the central pixel of the 3x3 window.
- Repeat the above steps for every pixel in the original image to create a new LBP image.
- Extend the LBP method by using different radii and numbers of neighbors to enhance the feature representation of the image.
- The resulting LBP image will better reflect the original image's features, especially edges and details.

Note: LBP is a simple yet effective technique for feature extraction in images and is widely used in applications like facial recognition, image classification, etc.

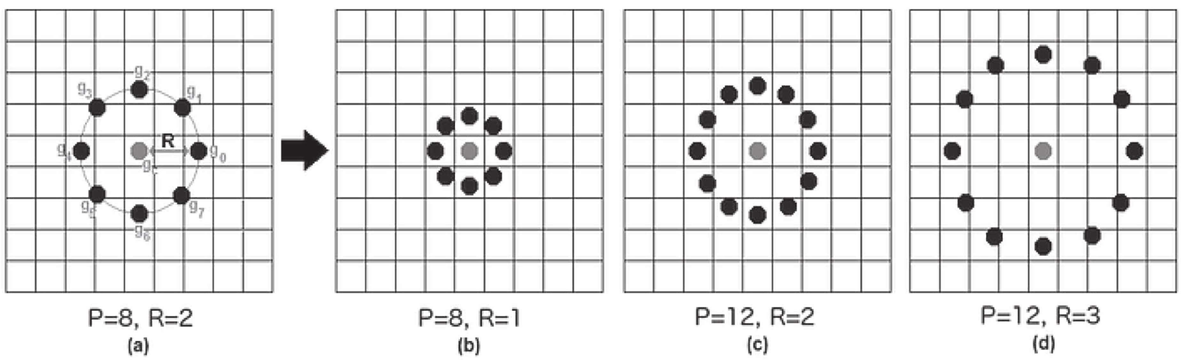

Fig 2. Pixel description

This can be implemented using bilinear interpolation. If some data points lie between pixels, the values of the 4 nearest pixels (2x2) are used to estimate the value of the new data point.

2.4 Extracting the histogram

Using the image generated in the previous step, we can utilize the Grid X and Grid Y parameters to divide the image into multiple grids, as illustrated below:

Fig 3. Extracted histogram visualization

Based on the image above, we can extract the histogram of each region as follows:

- Since the image is in grayscale, each histogram (from each grid) contains 256 bins (0–255), representing the frequency of each pixel intensity.
- These individual histograms are then concatenated to form a larger histogram. For example, if the grid is 8x8, the final histogram will have 8×8×256=16,384 bins.
- This final histogram effectively represents the features of the original image.

The LBPH algorithm primarily operates in this way.

2.5 Performing facial recognition

At this stage, the algorithm has been trained. Each histogram generated serves as a representation of a training image in the dataset. For an input image, the same steps are repeated to generate its corresponding histogram. To identify a match for the input image, we simply compare its histogram with those from the training set and return the image with the closest histogram.

There are several approaches to compare histograms (calculate the distance between two histograms), such as:

- Euclidean Distance
- Chi-Square Test
- Absolute Differences, etc.

In this example, we can use the commonly applied Euclidean distance, which is calculated using the following formula:

$$D = \sqrt{\sum_{i=1}^{n} (hist1_i - hist2_i)^2}$$

Thus, the output of the algorithm is the ID of the image whose histogram is the closest match. The algorithm should also return the computed distance, which can be used as a measure of "confidence."

Do not be misled by the term "confidence," as a lower confidence value indicates better results. This means the distance between the two histograms is smaller. We can use a threshold and the "confidence" value to automatically estimate whether the algorithm has correctly identified the image. It can be assumed that the algorithm has successfully recognized the image if the confidence value is smaller than the defined threshold.

2.6 Use case diagram

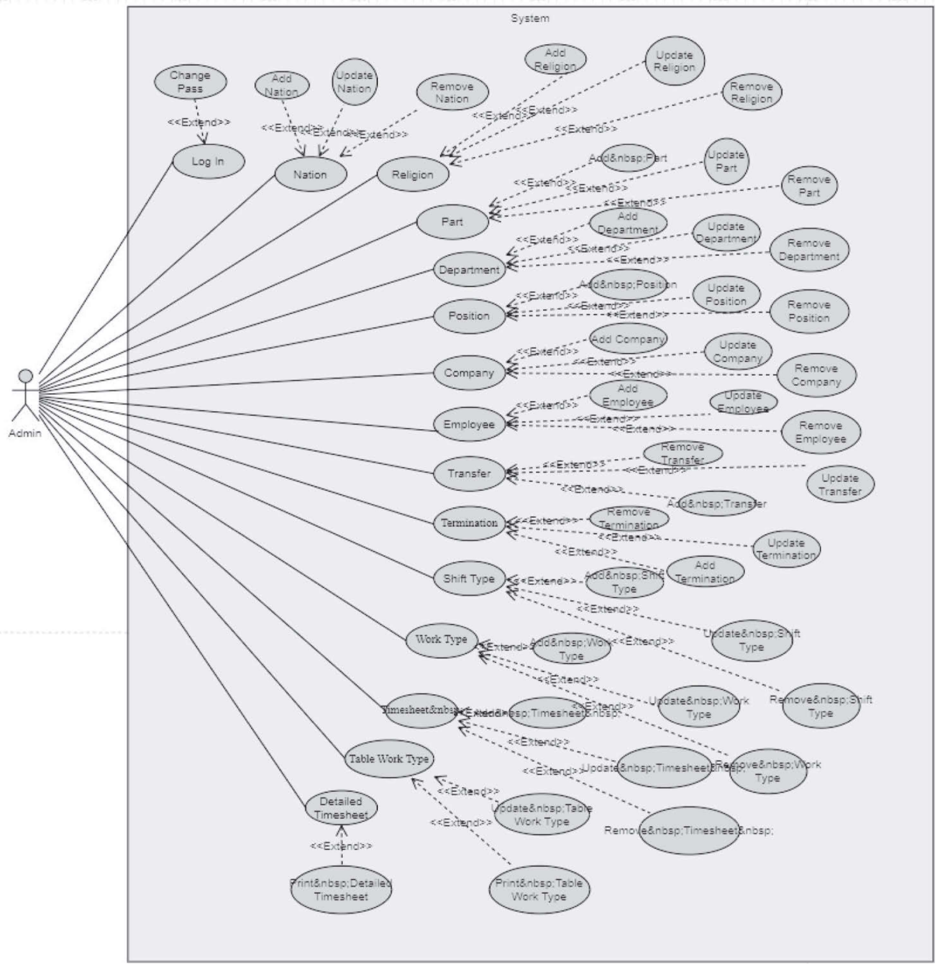

Fig. 4. Use case diagram

3. RESULTS AND DISCUSSION

Facial recognition-based timekeeping software is a modern and efficient solution for managing employees' work hours. By utilizing advanced facial recognition technology, this system can accurately and quickly identify employees' faces, automatically recording their check-in and check-out times without the need for human intervention.

Advantages of Using the LBPH Algorithm:

- LBPH is one of the simplest facial recognition algorithms.
- It can effectively represent local features in an image.
- It can achieve good results, particularly in controlled environments.
- The algorithm is robust against monotonic grayscale variations.
- LBPH is supported by OpenCV, an open-source library for computer vision.

Here are some simulated images demonstrating the performance of the facial recognition-based timekeeping system.

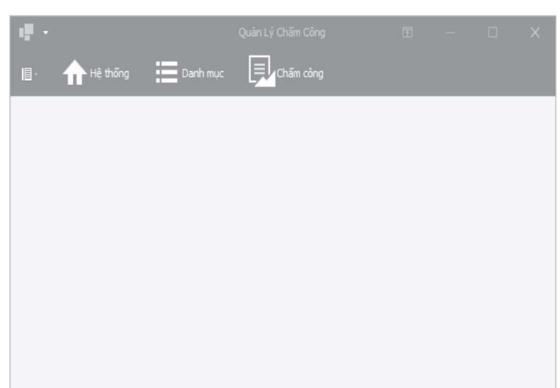

Fig. 5. Home page interface

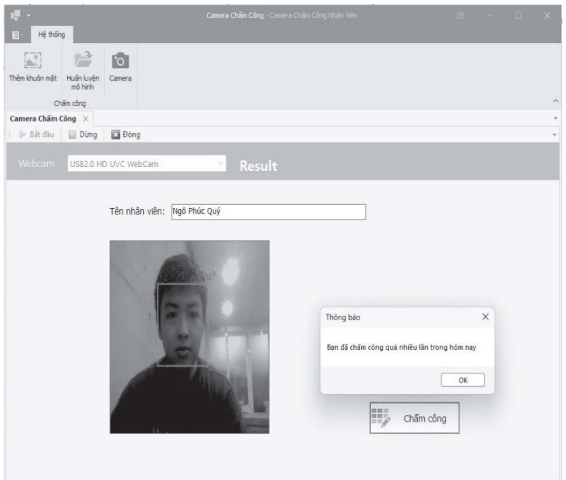

Fig. 6. Attendance camera simulation interface

4. CONCLUSION

The facial recognition-based attendance system offers several benefits, including high accuracy, time efficiency, strong security, easy management, convenience, and fraud prevention. However, it also has limitations such as high costs, privacy concerns, environmental impact, reduced accuracy due to appearance changes, and the need for regular maintenance. To overcome these challenges, improvements should focus on algorithm optimization, enhanced security, system integration, cost reduction, and user experience enhancement. Recommendations include assessing actual needs, conducting pilot testing, training employees, ensuring regular updates, and partnering with reputable technology providers. Completing the project enhances expertise, programming skills, project management abilities, problem-solving, research capabilities, real-world application knowledge, career opportunities, and personal development.

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