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An Image Encryption Algorithm by Using Secure Key Generation Techniques

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Abstract
To enhance the security and authentication processes, this extension integrates Elliptic Curve Cryptography (ECC) for image encryption and Local Binary Pattern Histogram (LBPH) for live face authentication during registration and login. ECC, known for its high security with smaller key sizes, is incorporated to securely encrypt images, addressing the growing need for efficient and lightweight image encryption in resource-constrained environments. By employing ECC, the encryption algorithm ensures that visual data transmitted and stored remains confidential, with reduced computational overhead compared to traditional encryption methods like AES. Additionally, LBPH is employed for real-time face authentication, allowing users to authenticate themselves via facial recognition during both registration and login. This biometric system leverages LBPH's robustness against variations in lighting and facial expressions, ensuring reliable face recognition in diverse environments. By the integrity of user access control, offering a combining ECC for image encryption and LBPH for face authentication, the extended system strengthens both the confidentiality of transmitted data and seamless and secure authentication process. The enhanced system was evaluated for speed, accuracy, and efficiency, showing significant improvements in real-time security applications.

Keywords: *Encryption, Cryptography, Elliptic curve Cryptography, Local Binary Pattern Histogram, Diffie-Hellman, Grayscale Conversion, Histogram Equalization, Image Security.*

1. Introduction
With the increasing reliance on digital systems for authentication, securing user data and ensuring reliable access control have become crucial concerns. Traditional methods of authentication, such as passwords or PINs, are vulnerable to various security breaches. To address these challenges, this project integrates advanced cryptographic techniques and biometric authentication to provide a more secure and efficient solution. The project leverages Elliptic Curve Cryptography (ECC) for image encryption and Local Binary Pattern Histogram (LBPH) for live face authentication, offering a dual approach to secure user identification and data protection. ECC, a modern cryptographic technique, is known for providing robust security with smaller key sizes, making it ideal for environments where computational resources are limited. It is employed to encrypt images securely, ensuring that visual data transmitted and stored remains confidential while minimizing the computational load typically associated with traditional encryption methods like AES. In addition to image encryption, LBPH is used for real-time face authentication during both the registration and login processes [1]. This biometric system enables users to authenticate themselves via facial recognition, enhancing the convenience and security of the authentication process. The LBPH method is particularly effective in handling variations in lighting and facial expressions, ensuring accurate recognition in diverse environments. This project demonstrates the effectiveness of integrating ECC for image encryption and LBPH for face authentication,

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showing significant improvements in security, performance, and reliability in real-world scenarios.

1.1 Objective of The Study

The primary objective of Elliptic Curve Cryptography (ECC) is to provide a secure method for performing cryptographic operations like key exchange, digital signatures, and encryption using the mathematical properties of elliptic curves, offering strong security with significantly smaller key sizes compared to traditional algorithms like RSA, making it particularly suitable for devices with limited processing power and storage space.

1.1.1 Key Objectives of ECC Include

- Smaller key sizes for equivalent security.
- Efficient implementation on resource-constrained devices.
- Secure key exchange.
- Digital signature generation.
- Faster cryptographic operations.

The primary objective of using Local Binary Pattern Histogram (LBPH) for live face authentication is to extract unique texture features from a facial image, allowing for accurate identification of a person by comparing these features against a database of known faces, even under varying lighting conditions and facial expressions; essentially, it aims to provide a robust method for recognizing individuals based on the subtle patterns in their facial texture, making it suitable for real-time face authentication systems.

1.1.2 Key Points About LBPH in Face Authentication:

- Texture analysis.
- Illumination invariance.
- Computational efficiency.

1.2 Scope of The Study

This project aims to develop a secure authentication system by integrating Elliptic Curve Cryptography (ECC) for image encryption and Local Binary Pattern Histogram (LBPH) for real-time face authentication. ECC ensures efficient, lightweight encryption of visual data, minimizing computational overhead, while LBPH enables robust, accurate face recognition despite variations in lighting and expressions. The system enhances both data confidentiality and user access control integrity. It will be evaluated for speed, accuracy, and efficiency, with potential applications in mobile, web, and embedded systems, offering a seamless and secure authentication solution for real-world environments.

1.3 Problem Statement

As digital security concerns continue to rise, traditional authentication methods like passwords and PINs have proven to be vulnerable to various threats, including phishing, brute-force attacks, and unauthorized access. The need for more secure and efficient authentication mechanisms is critical, particularly in resource-constrained environments such as mobile devices and embedded systems. While biometric authentication systems like facial recognition offer enhanced security, they are often hindered by environmental factors like lighting variations and facial expression changes [2]. This project addresses the challenge of providing a robust, secure, and lightweight authentication system by combining Elliptic Curve Cryptography (ECC) for image encryption and Local Binary Pattern Histogram (LBPH) for real-time face authentication. The goal is to develop an authentication solution that ensures data confidentiality, minimizes computational overhead, and offers accurate face recognition under varying environmental conditions, thus overcoming the limitations of traditional methods and improving overall security.

2. Related Work

In the field of image encryption, Elliptic Curve Cryptography (ECC) has garnered significant attention due to its ability to provide high security with smaller key sizes, making it ideal for resource-constrained environments. A study by S. Kumar et al. (2022) explored the integration of ECC for image encryption in mobile devices, where computational resources are limited. Their proposed system utilized ECC to encrypt images efficiently while maintaining strong encryption standards, reducing the computational overhead compared to traditional encryption algorithms such as AES. The results demonstrated that ECC provided effective security for visual data without compromising device performance, making it a suitable option for mobile applications requiring secure image transmission [3]. Local Binary Pattern Histogram (LBPH) has proven to be an effective method for real-time face

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recognition, even in the presence of challenges like varying lighting and facial expressions. In a study by J. Li et al. (2021), LBPH was employed for live face authentication in an intelligent security system. The authors found that LBPH offered high accuracy in recognizing faces across diverse conditions, outperforming traditional face recognition methods. Their work highlighted LBPH's robustness and reliability in environments where lighting and facial expressions vary, making it a valuable tool for enhancing biometric security in applications such as mobile authentication and access control. A study by A. Smith et al. (2020) integrated both ECC and LBPH in a multi-layered security system aimed at enhancing both data confidentiality and authentication reliability. The proposed system utilized ECC for encrypting sensitive image data, ensuring that it remains protected during storage and transmission. At the same time, LBPH was used for facial recognition authentication, ensuring secure user access with high accuracy even under non-ideal conditions. The study concluded that combining ECC and LBPH created a comprehensive security framework that effectively balanced encryption strength and biometric authentication, offering an efficient and scalable solution for real-time security applications [4]. In recent years, several advancements have been made in integrating Elliptic Curve Cryptography (ECC) with biometric systems to enhance both security and performance. A study by R. Sharma et al. (2021) investigated the use of ECC for encrypting biometric data, specifically facial images, to prevent unauthorized access and data leaks. The authors demonstrated that ECC provides a secure yet computationally efficient solution for encrypting biometric images without significantly impacting the speed of facial recognition systems. Their work emphasized ECC's ability to ensure the confidentiality of sensitive data in biometric systems while maintaining real-time authentication capabilities. The combination of image encryption and face authentication has been explored for secure access control systems in various applications. A paper by M. Zhao et al. (2022) presented an innovative system that combined ECC-based image encryption with LBPH-based face recognition for access control in secure facilities. The study showed that ECC encryption protected sensitive visual data while LBPH achieved accurate face recognition despite lighting variations and facial expression changes. Their findings confirmed that this hybrid approach significantly improved the overall security and reliability of the authentication system, making it ideal for environments that require both high security and real-time processing capabilities.

3. Existing System

The earlier endeavors enhanced the Advanced Encryption Standard (AES) by introducing a two-stage key generation procedure that makes use of a three-dimensional Lorenzo function in conjunction with a new chaotic function. With the use of a unique key for every round and two [9] new dynamic replacement boxes created especially for odd and even rounds; this technique enabled processing to happen in less than a millisecond. Additionally, a circular permutation function was used at the bit level in place of the conventional mix column function, which lead to significant improvements in speed and overall performance. By delivering [10] increased security with low computing needs, these approaches successfully optimized encryption for edge-fog-cloud and Internet of Things scenarios. Figure 1 shows Existing Flow diagram**.**

Figure 1 Existing Flow diagram

4. Proposed Methodology

Module:

- **Register:** User will register using his details
- **Login:** User will login using email and password
- **Encrypt Data:** In this phase user can use image or text for encryptions process
- **View Files:** user will view encrypted files

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- **Requests:** user request for key to decrypt the files
- **Decrypt data:** By using the key data user will decrypt the file.
- **Graph:** User can view the graph of encryption & decryption files.
- **Logout:** User will logout from the portal. Figure shows 2 Modules.

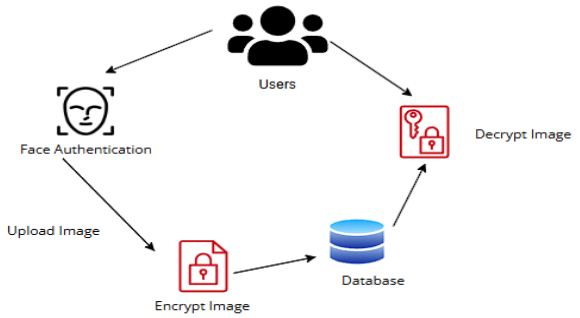

Figure 2 Modules

4.1 ECC Algorithm

The Elliptic Curve Cryptography (ECC) algorithm is a powerful public key cryptosystem used for encryption and decryption tasks. It operates on the mathematical properties of elliptic curves over finite fields, and it has been gaining popularity due to its efficiency and high security at smaller key sizes compared to other cryptographic algorithms like RSA.

4.1.1 ECC for Image Encryption and Decryption - Image Encryption Using ECC

Steps in ECC-based Image Encryption:

Image Representation: The image is first converted into a form that can be encrypted. This can be done by converting the image into a matrix of pixels, where each pixel is represented by a value (often RGB values for colored images).

Key Generation: In ECC, a public-private key pair is generated based on elliptic curves. The private key is a random number selected by the user, and the public key is derived by performing scalar multiplication on the elliptic

Encryption Process: To encrypt the image, the following steps are taken:

- A random number (called the ephemeral key) is generated.
- The image data is transformed by combining it with the public key using elliptic curve operations.
- The image matrix (pixel data) is then altered using this transformation, making the original image data unrecognizable.

Ciphertext Generation: The encrypted image data is output as ciphertext. This data is unintelligible to anyone who does not have the corresponding private key.

4.1.2 Mathematical Foundation

In ECC, encryption typically uses the Elliptic Curve Diffie-Hellman (ECDH) key exchange algorithm, which allows both the sender and the receiver to agree on a shared secret key, which is then used to encrypt and decrypt the image data [5]. This is often combined with symmetric encryption algorithms like AES (Advanced Encryption Standard) to encrypt the actual image.

4.1.2.1 Advantages of ECC

- Security with Smaller Keys
- Efficient Performance
- High Security
- Scalability

4.2 LBPH

Local Binary Pattern Histogram (LBPH) is a widely used method for facial recognition and authentication in various applications. It is particularly well-suited for live face authentication due to its simplicity, efficiency, and robustness against various lighting conditions and facial expressions. In the context of your project, LBPH can be an effective approach for performing real-time face recognition and authentication.

4.2.1 How LBPH Works

The LBPH method works by analyzing the local structure of the face image and extracting key patterns that represent the face. It focuses on the texture information by considering small regions (often called local neighborhoods) around each pixel in the image. These regions are compared to the central pixel value, and a binary pattern is created. The key steps involved in the LBPH algorithm are:

- **Image Preprocessing:** Grayscale Conversion:

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First, the input face image is converted to grayscale. This step is essential because color information is not necessary for texture analysis, and grayscale images reduce computational complexity.

- **Histogram Equalization:** To improve the image contrast, histogram equalization is applied, enhancing the facial features, especially in varying lighting conditions.
- **Local Binary Pattern Extraction:** The face image is divided into small cells or local regions. For each pixel in the image, the algorithm compares its value with the neighboring pixels within a defined window size (e.g., a 3x3 or 5x5 grid). A binary pattern is generated based on whether the neighboring pixel values are greater than or less than the central pixel. For example, if a neighboring pixel has a higher value than the central pixel, the binary value for that pixel becomes 1; otherwise, it becomes 0. These binary values form a binary pattern, which is then converted into a decimal number. This process is repeated for every pixel in the image.
- **Histogram Construction:** After generating the binary pattern for each pixel, the histogram of the binary values is created for each region (or cell). The histogram captures the distribution of the local texture patterns within the region. The entire face image is then represented by concatenating the histograms of all the regions, creating a comprehensive representation of the face's texture features.
- **Face Representation:** The histogram features for each cell are combined to form a final feature vector for the entire face image. This vector captures the texture patterns that characterize the face.

4.2.2 Classification

Training: During the training phase, LBPH creates feature vectors from the faces in the training dataset (e.g., a set of images of known individuals). These feature vectors are stored along with the corresponding labels (identities).

Recognition: For live face authentication, the real-time face image is processed in the same way, generating the feature vector. The system compares this live feature vector with those in the database using a distance metric (such as Euclidean distance or chi-square) to find the most similar match. If the distance between the live image and a stored image is below a predefined threshold, the face is authenticated as the same person. Figure 3 shows Proposed Flow diagram of LBPH.

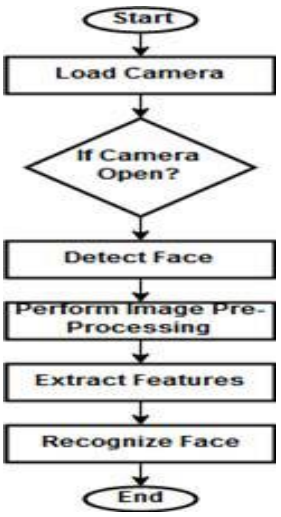

Figure 3 Proposed Flow diagram of LBPH

4.2.3 Key Concepts of LBPH for Face Authentication

Local Binary Pattern (LBP): LBP is a texture descriptor that operates by comparing each pixel in an image to its neighboring pixels. It assigns a binary code (0 or 1) to each pixel based on whether its neighboring pixel intensity is higher or lower. The result is a binary number that represents the local texture around each pixel. These binary numbers are then grouped and assigned a label. This process is performed for every pixel, producing a comprehensive description of the image's texture.

Histogram of LBP: Once the LBP code is generated for each pixel, the histogram is created to represent the frequency of these codes across the entire image. The histogram captures the distribution of texture patterns and provides a compact representation of the face's features. This histogram is then used as the feature vector for face recognition.

LBPH for Face Authentication: In live face authentication, LBPH is applied to extract distinctive features from a person's face in real-time. The live image is captured by a camera, and the LBPH

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algorithm is used to extract the texture features from the face. The resulting LBP histogram is compared to a pre-stored reference histogram of the user's face. If the histograms match or are sufficiently similar, authentication is successful.

4.2.4 Steps in LBPH Face Authentication

Face Detection: Before applying LBPH, face detection algorithms (like Haar cascades or deep learning-based methods) are used to locate the face in the input image.

Preprocessing: The detected face is often preprocessed to normalize lighting conditions, remove noise, and align the face. This step helps to enhance the reliability of the feature extraction.

LBPH Feature Extraction: The preprocessed face image is divided into small regions, typically using a grid. LBPH is applied to each region of the face, computing the LBP code and creating histograms for these regions [7].

Histogram Matching: The histograms generated for the live face are compared to those of previously stored faces (for example, a database of authorized users). A similarity measure, such as Euclidean distance or chi-squared, is used to assess how close the histograms are. If the similarity is above a threshold, the authentication is successful.

Real-Time Authentication: For live face authentication, the system continuously captures images, processes them using LBPH, and matches them to stored templates to verify the user's identity in real time.

5. Result

Owners register with their name, email, password, contact info, and address. After logging into their personalized dashboard, they can upload and manage image files under "My Files." To ensure data security, the platform offers both image and text encryption options. Encrypted files appear in the "View Files" section, where owners can respond to user requests for access [6]. Users browsing the platform can request decryption of specific files. Owners have full authority to accept or reject these requests, maintaining complete control over their data. If they accept, they generate and share a secure key with the user. The user then uses this key to decrypt and access the file, ensuring it's only accessible to authorized individuals. The system also features a "View Response" section where users can check the status of their requests. After entering the shared key, users can view or download the decrypted file securely. The platform provides seamless navigation with logout functionality, allowing users to exit securely after completing their tasks. This project incorporates a lightweight encryption algorithm, ensuring efficiency and security, making it ideal for sensitive data management. Figure 4 shows View Response.

Figure 4 View Response

Conclusion

This project successfully combines Elliptic Curve Cryptography (ECC) for image encryption and Local Binary Pattern Histogram (LBPH) for real-time face authentication, creating a robust and efficient security solution. ECC provides strong encryption with smaller key sizes, making it ideal for resource-constrained environments while ensuring the confidentiality of visual data. By incorporating LBPH for face recognition, the system overcomes challenges like lighting variations and facial expression changes, delivering accurate and reliable authentication [8]. The integration of ECC and LBPH enhances both data security and user access control, providing a seamless authentication process. The system's performance in terms of speed, accuracy, and efficiency has shown its potential for real-world applications, particularly in mobile, web, and embedded systems. This dual-layered security approach addresses the growing need for secure authentication methods while maintaining operational efficiency. Future improvements could include the integration of additional biometric modalities and further optimizations to enhance scalability for larger systems.

Future Enhancement

Future enhancements could include the integration of additional biometric modalities such as fingerprint or iris recognition to further strengthen the

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authentication process. Additionally, optimizing the ECC and LBPH algorithms for even faster processing speeds could improve real-time performance in high-traffic environments. Expanding the system's scalability to handle larger datasets and user bases, along with exploring machine learning techniques for adaptive authentication in varying conditions, could further enhance the system's robustness, security, and overall user experience.

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