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Secure Single-User Authentication System with Facial Identification & Pattern Lock

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Abstract: This work describes a comprehensive user authentication system designed for any kind of application, specifically for use in bank authentication systems, incorporating facial recognition, pattern drawing, and spoof detection techniques. Strong security measures are essential to protecting sensitive financial data in light of the growing dependence on digital banking services. The system provides bank customers with a smooth and user-friendly authentication experience by utilizing well-known libraries like Open-CV and face-recognition in conjunction with Tkinter for graphical user interface (GUI) development. It intends to alleviate potential security weaknesses associated with conventional password-based authentication techniques by encoding face features, making pattern construction easier, and providing effective detection of spoofing efforts. In order to give administrators more insight into system usage patterns and improve security, user action logging is also used. The further study aims at enhancing security in financial applications by exploring multi-factor authentication techniques and optimizing spoof detecting algorithms. By offering a safe and easy-to-use solution for guaranteeing consumer data confidentiality and privacy, this system shows the potential to resolve authentication problems throughout the banking industry.

Keywords*: Virtual Proctoring, Pattern Drawing, Authentication, Spoof Identification, Open CV, Encryption, Decryption, User logs, Convolutional Neural Network, Convolutional Neural Network, NumPy, Pandas, Tkinter, Haarcascade, Facial Recognition, Facial Detection, Sessions control, Cryptography, MySQL Database*

1. Introduction

One essential component of biometric security is facial recognition technology, which makes it possible to identify and authenticate people using only their distinct facial features. This technology's beginnings can be found in the 1960s when forward-thinking academics established the foundation for automated facial recognition systems. The work of Takeo Kanade in the 1970s, which demonstrated the computation of distances between attributes of faces and marked a turning point for science, is one notable accomplishment. The underlying concept behind facial recognition is face detection, which is a sophisticated method of identifying distinct faces in pictures with different orientations. Computer vision has greatly improved this process by using artificial intelligence algorithms to extract, analyse, and interpret information from images.

The core of the proposed Secure Single-User Authentication System is pattern-based authentication combined with facial recognition technology. In order to provide safe access to supervisors, this system blends spoof detection techniques, pattern drawing, and facial recognition in a powerful and user-friendly authentication method. The face detection portion of the system's architecture uses sophisticated algorithms to locate faces in pictures or video frames. The technology compares the detected facial traits with those kept in a database to identify the user after a face has been spotted. In the event that a match is discovered, the user is asked to authenticate by drawing a certain pattern on a graphical user interface.

The system differentiates between authentic users and fraudulent efforts using spoof detection techniques, hence augmenting security. The technology can anticipate and prevent unwanted access attempts by examining face features and looking for telltale indicators of spoofing, such as irregularities in texture or strange motion patterns. Drawing a predetermined pattern for authentication is a prerequisite for pattern authentication, which adds another degree of security. For the purpose of maintaining confidentiality and integrity, this pattern is safely encrypted and kept in the database. Workflow for the system consists of multiple phases: user action tracking for auditing, pattern updates, and lost password functionality. A smooth and dependable authentication process is provided

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by the system, which minimizes any security threats through careful design and development.

For to strengthen security even further, future improvements might concentrate on improving spoof detection algorithms, maximising performance, and investigating multi-factor authentication techniques. To verify the system's efficacy and direct future development efforts, real-world testing and assessment will be essential.

1.1. Abbreviations and Acronyms

Tkinter: Tool kit Interface, Yolo: You Only Look Once, CV: Computer Vision, ROI: Region Of Interest, GUI: Graphical User Interface, CNN: Convolutional Neural Network

2. Method

In chronological sequence, the following features are included in facial and pattern authentication:

A. Spoof – Fake Identification

B. Multiple User Detection

C. Face Detection

D. Face Identification

E. Pattern Authentication

An organized strategy for implementing face recognition-based pattern authentication is the methodology that underpins the code's functioning. The program initializes several necessary libraries and modules, including the OpenCV library for computer vision tasks, the face_recognition library for face detection and recognition, the Tkinter for GUI creation, also before facing is done the process undergoes into spoof detection which checks the liveliness of the being, there is haarcascade frontal face xml library was used in order to get done with the spoof detection and then it gets into the facial recognizing process after that the MySQL connector for database interfaces. It then specifies different functions to achieve particular goals, such as employing the YOLO model for object detection, encrypting and decrypting patterns for security, recording user actions for auditing, encoding faces into numerical representations for comparison, and controlling the pattern drawing interface.

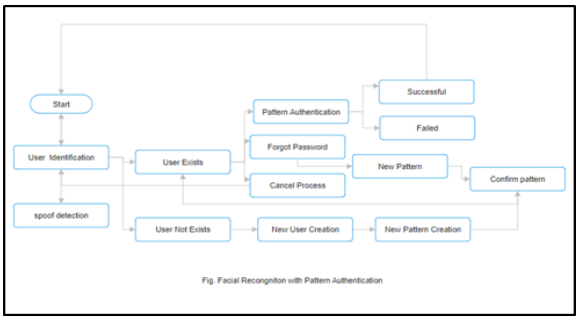

Fig. 1. Architecture for Facial Recognition and Pattern Authentication

The main working principle of the code is to use a while loop to continually record the camera's video stream. With each cycle, the code uses the face-recognition library to recognize faces in the frame. If numerous faces are discovered, a warning message appears to guarantee that only one person is present for authentication. When a single face is identified, the code encodes it into a number representation and checks to see if it exists in the database. If the user is recognized, they are prompted to draw a pattern on the GUI window to complete the authentication process. Users can design their distinctive dot pattern for authentication by using the pattern drawing interface.

Fig. 2. Workflow and Mechanism of Secure Single-User Authentication System with Facial Identification & Pattern Lock

By obtaining a photograph of the user's face and assisting them in creating a pattern, the method makes it easier for new users who aren't already in the database to create a new user profile. After drawing the pattern, the user's face image and the pattern are safely saved in the database. The algorithm also manages various situations, such as session timeouts, and sends out helpful messages to users to help them through the authentication process.

A. Spoof – Fake Identification

To find and stop fraudulent efforts to trick biometric authentication systems, a variety of spoof detection techniques are employed. Typical spoof detection techniques consist of the following:

1) Texture Analysis: In order to find anomalies or inconsistencies that can point to a spoofing effort, this algorithm examines the texture of biometric data, such as fingerprints, iris patterns, or face photographs. For instance, counterfeit fingerprints might not have the regular ridge patterns or strange textures.

2) Motion Detection: To differentiate between real and

phoney samples, motion detection algorithms examine the movement patterns connected to biometric data. For example, motion detection can be utilised by facial recognition algorithms to detect minute motions that distinguish genuine faces from faking still photos or movies.

3) Liveness Detection: To identify if biometric data is originating from a real person or a spoofing effort, liveness detection algorithms evaluate the vitality or liveliness of the data. These algorithms could make use of a number of methods, like analysing voice patterns for indications of natural speech, assessing blood flow or pulse in fingerprint scans, or spotting blinking in facial photos.

4) Reflectance Analysis: In the case of facial recognition systems in particular, reflectance analysis algorithms look at the reflected qualities of the biometric data. These algorithms distinguish between real faces and fake materials like masks or printed pictures by examining the how light interacts with the skin's surface.

5) Frequency Analysis: To identify anomalies that can point to spoofing attempts, frequency analysis algorithms examine the frequency spectrum of biometric signals, such as voice records or heartbeat rates. False voice recordings, for instance, might not have the organic frequency patterns found in real speech.

6) Multimodal Fusion: To improve spoof detection capabilities, multimodal fusion algorithms combine many biometric modalities, such as speech recognition, fingerprint scanning, and facial recognition. The accuracy and dependability of spoof detection can be increased by these methods by utilising complimentary data from other modalities.

The following liveliness detection algorithm is used in this research, algorithm defined below

Spoof Detection Algorithm:

Function Name: detect_spoof (frame, faces)
Input: Frame (image or video frame), faces (list of detected faces' coordinates)
Output: Boolean value indicating whether a potential spoofing attempt is detected or not

Algorithm:

1. Iterate over each detected face in the provided frame.
2. Extract the region of interest (face) from the frame using the provided coordinates.
3. Perform spoof detection analysis on the extracted face region (e.g., texture analysis, motion detection, etc.).
4. Define a threshold value for the spoof detection analysis (e.g., mean intensity threshold for texture analysis).
5. Calculate the relevant feature(s) from the face region and compare it against the predefined threshold.
6. If the feature value is below the threshold, it might indicate a potential spoofing attempt.
7. If any of the detected faces exhibit spoofing signs, return True.
8. If no potential spoofing signs are detected for any of the faces, return False.

Pseudo code:

```
Function detect_spoof (frame, faces):
  spoof_threshold = predefined_threshold_value

  for each face in faces:
    face_roi = extract_face_region (frame, face)
    feature_value = calculate_spoof_feature(face_roi)

    if feature_value < spoof_threshold:
      return True

  return False
```

Fig. 3. Algorithm for Spoof Detection

B. Multiple User Detection

Numerous methods exist for identifying numerous people within a system, particularly when it comes to facial recognition and identification. Among these mechanisms are a few of them:

1) Face clustering: is the process of assembling similar-looking faces into groups that correspond to the same person. The method determines whether more than one person is present in the scene by grouping faces that are similar to each other.

2) Facial Landmarks Detection: Algorithms for facial landmarks detection pinpoint important facial features like the mouth, nose, and eyes. The system can identify the presence of numerous faces and their relative placements by examining the spatial distribution of these markers inside an image or video frame.

3) Face tracking: Over time, algorithms that track face movement within a video stream are used. When several people arrive or leave a place, the system may identify it by examining the trajectories of the faces it has observed.

4) Depth Sensing: Technologies that rely on depth cameras or structured light to sense depth can give scene-specific depth information. The system can identify many users and distinguish between faces that belong to different people by evaluating the depth data.

5) Contextual Data: In order to deduce the presence of numerous users, systems can also make use of contextual data, such as the ratio of the number of faces detected to the area's size or the presence of users interacting with the system at the same time.

In this study, the facial Landmark and its location method that follows is defined below.

Face Locations Algorithm:

Input: img (an image as a numpy array),
number_of_times_to_upsample (how many times to upsample the image looking for faces),
model (which face detection model to use. "hog" is less accurate but faster on CPUs. "cnn" is a more accurate deep-learning model which is GPU/CUDA accelerated if available. The default is "hog")
Output: A list of tuples of found face locations in CSS (top, right, bottom, left) order

Algorithm:

1. If the provided model is "cnn":
   1.1. Use the internal function _raw_face_locations with the provided image, number_of_times_to_upsample, and "cnn" model to obtain raw face locations.
   1.2. For each face detected in the image using the "cnn" model:
      1.2.1. Convert the rectangle coordinates of the face into CSS format (top, right, bottom, left) using _rect_to_css function.
      1.2.2. Ensure that the CSS coordinates are within the bounds of the image using _trim_css_to_bounds function.
   1.3. Return a list of tuples representing the CSS bounding boxes of the found face locations.
2. If the provided model is not "cnn" (i.e., "hog" or any other model):
   2.1. Use the internal function _raw_face_locations with the provided image, number_of_times_to_upsample, and the specified model to obtain raw face locations.
   2.2. For each face detected in the image using the specified model:
      2.2.1. Convert the rectangle coordinates of the face into CSS format (top, right, bottom, left) using _rect_to_css function.
      2.2.2. Ensure that the CSS coordinates are within the bounds of the image using _trim_css_to_bounds function.
   2.3. Return a list of tuples representing the CSS bounding boxes of the found face locations.

Function:

```
face_locations(img, number_of_times_to_upsample=1, model="hog"):
  if model == "cnn":
    return [_trim_css_to_bounds(_rect_to_css(face.rect), img.shape) for face in _raw_face_locations(img, number_of_times_to_upsample, "cnn")]
  else:
    return [_trim_css_to_bounds(_rect_to_css(face), img.shape) for face in _raw_face_locations(img, number_of_times_to_upsample, model)]
```

Fig. 4. Algorithm for Face Location

C. Face Detection:

These are typical facial detection algorithms. A few well-known ones are:

1) Haar-Cascade Classifier: it is a machine learning system that detects objects by training a cascade function with a large number of positive and negative images. While it is quick, deep learning-based techniques might be more accurate.

2) Convolutional neural networks (CNNs) are used by deep learning-based detectors to identify faces. For face identification applications, models such as Single Shot Multibox Detector (SSD), You Only Look Once (YOLO), and Faster R-CNN are frequently utilised. Although they may need more processing power, they give great precision.

3) Faces and facial landmarks can be simultaneously detected by MTCNN (Multi-task Cascaded Convolutional Networks), a face detection system based on deep learning. It is renowned for managing faces of all sizes and positions with accuracy and efficiency.

4) RetinaFace: This face detection method, which also relies on deep learning, is effective in identifying faces in tough circumstances like occlusion, extreme orientations, and scales that differ.

The choice is based on various criteria such as real-time processing limits, computational resources, and accuracy requirements. Every technique has merits and drawbacks. Here in this face detection we have used CNN and Haarcascade Algorithm

Face Detection Algorithm:

Input: Image (as a numpy array), Number of times to upsample, Model (e.g., "hog" or "cnn")

Output: List of tuples representing face locations in CSS format (top, right, bottom, left)

Algorithm:
If the model is "cnn":
1.1. Use a deep-learning model to detect faces in the image.
1.2. Convert the detected face rectangles into CSS format (top, right, bottom, left).
1.3. Ensure that the CSS coordinates are within the bounds of the image.
1.4. Return a list of tuples representing the CSS bounding boxes of the detected faces.
If the model is not "cnn" (e.g., "hog"):
2.1. Use a traditional face detection model (e.g., Histogram of Oriented Gradients) to detect faces in the image.
2.2. Convert the detected face rectangles into CSS format (top, right, bottom, left).
2.3. Ensure that the CSS coordinates are within the bounds of the image.
2.4. Return a list of tuples representing the CSS bounding boxes of the detected faces.

Pseudo code:

```
Function detect_faces(image):
    # Preprocess the image if necessary (e.g., convert to grayscale)
    processed_image = preprocess_image(image)

    # Detect faces in the processed image using a face detection model
    detected_faces = face_detection_model.detect(processed_image)

    # Post-process the detected faces if necessary (e.g., filter out small faces)
    filtered_faces = postprocess_faces(detected_faces)

    return filtered_faces

# Helper function to preprocess the input image
Function preprocess_image(image):
    # Implement preprocessing steps if needed (e.g., convert to grayscale)
    processed_image = convert_to_grayscale(image)
    return processed_image

# Helper function to post-process the detected faces
Function postprocess_faces(detected_faces):
    # Implement postprocessing steps (e.g., filter out small faces)
    filtered_faces = []
    for face in detected_faces:
        if is_valid_face(face):  # Check if the detected face meets certain criteria
            filtered_faces.append(face)
    return filtered_faces

# Helper function to check if a detected face is valid
Function is_valid_face(face):
    # Implement criteria to determine if the detected face is valid (e.g., size, aspect ratio)
    if face.width >= MIN_FACE_WIDTH and face.height >= MIN_FACE_HEIGHT:
        return True
    else:
        return False
```

Fig. 5. Algorithm for Face Detection

D. Face Identification

To identify and identify faces in real-time video streams, the facial identification system explained in this study combines machine learning algorithms with computer vision techniques. Using the Haar-cascade classifier, which recognizes faces based on predetermined features, the system uses the Open-CV library to recognize faces. Following the detection of faces, the system uses the face-recognition library, which uses a face recognition model based on deep learning to encode facial attributes into numerical representations known as face encodings. Afterward, the discovered faces' identities are ascertained by comparing these encodings with pre-existing encodings kept in a database. Furthermore, to improve security and dependability, the system has a spoof detection mechanism in place to recognize possible spoofing efforts. The approach offers flexibility and user customization by enabling the development and storing of user patterns as an alternative authentication method. All things considered, the system offers a strong foundation for facial recognition with applications in user authentication, access management, and security.

Face Identification Algorithm:

Input: Face image, Face database
Output: Identity label (if recognized), or None (if not recognized)

Algorithm:
Extract facial features from the input face image using a feature extraction algorithm (e.g., Dlib).
Compare the extracted features with the features of known faces stored in the face database.
If a match is found with a high degree of similarity and the corresponding identity label is present in the database:
3.1. Retrieve the identity label associated with the matching face from the database.
3.2. Return the identity label.
If no match is found, or if the similarity is below a certain threshold, or if the identity label is not present in the database:
4.1. Return None to indicate that the face is not recognized.

Pseudo code:

```
Function identify_face (face_image, face_database):
    extracted_features = extract_features(face_image)  # Extract features from the input face image
    for face_record in face_database:  # Iterate through each face record in the database
        database_features = face_record['features']  # Extract features of the face from the database record
        similarity_score = compare_features(extracted_features, database_features)  # Compare features
        if similarity_score >= SIMILARITY_THRESHOLD and face_record['identity'] is not None:
            # If similarity score meets threshold and identity label is present
            return face_record['identity']  # Return the identity label
    return None  # Return None if no match is found or identity label is not present

# Helper function to extract facial features from an image
Function extract_features(face_image):
    # Implement feature extraction algorithm (e.g., Dlib)
    features = dlib.extract_features(face_image)
    return features

# Helper function to compare facial features
Function compare_features(features1, features2):
    # Implement feature comparison algorithm (e.g., Euclidean distance)
    similarity_score = calculate_similarity(features1, features2)
    return similarity_score
```

Fig. 6. Algorithm for Face Identification

E. Pattern Authentication

In order done with authentication these are the steps need to under go by the user

1. Pattern Creation:

a. The user interacts with a graphical interface that displays a grid of dots when they construct a pattern.

b. An additional degree of protection is offered by the user-only unique colour assigned to each dot in the grid.

c. The user creates a pattern by choosing a set of dots and drawing lines between them in succession.

d. The dots are color-coded, and the relationships between them form a pattern that can only be understood by the user.

2. Maintaining and Encrypting Patterns:

a. It is transformed into a string representation once the user has finished creating their pattern.

b. Using the Fernet encryption methodology, which uses symmetric encryption with a secret key, the pattern string is encrypted to guarantee data security. In the database is the encrypted pattern and the user ID. Enhancing data privacy and integrity, encryption blocks unwanted access to the patterns that have been saved.

3. Pattern-Based Verification:

a. The user must recreate their pattern within a predetermined amount of time in order to complete the authentication process.

b. An encrypted pattern linked to the user ID is stored, and it is compared to the drawn pattern.

c. To obtain the original pattern for comparison, decryption is carried out using the secret key.

d. Through comparison, the user's identification is verified and the drawn pattern is confirmed to match the stored pattern.

4. Safety of Data Storage:

a. Sensitive user data is shielded from unwanted access by encrypted patterns stored in the database.

b. The saved patterns can only be retrieved and decoded by individuals who possess the necessary decryption key.

c. The risk of data breaches and illegal pattern access is reduced by this security solution.

5. Interface for Users and Interpretation:

a. Pattern construction and authentication are made simple and intuitive by the graphical interface.

b. To create distinctive and customised patterns, users choose dots according to their colour and spatial arrangement.

c. Only those who are familiar with the color-coding method will be able to precisely replicate the pattern, which is defined by the order in which the dots are selected.

d. This increases security since even if someone were to look at the dot selections, they would still have difficulty understanding the pattern if they are not familiar with the colour scheme.

To sum up, in order to provide strong authentication while protecting user privacy and system integrity, the pattern authentication procedure combines user interaction with a secure storage mechanism and a graphically encoded pattern representation.

Pattern Authentication algorithm:

Function Name: authenticate_user (user_id, entered_pattern)
Input: User ID, Entered Pattern (list of integers)
Output: Boolean (True if authentication successful, False otherwise)

Algorithm:

1. Retrieve the stored pattern associated with the given user_id from the database.
2. Decrypt the stored pattern using the encryption key.
3. Compare the entered pattern with the decrypted stored pattern.
4. If the entered pattern matches the decrypted stored pattern, return True (authentication successful).
5. Otherwise, return False (authentication failed).

Pseudo code:

```
def authenticate_user (user_id, entered_pattern):
  stored_pattern = decrypt_pattern_from_database(user_id) # Retrieve stored pattern from database
  decrypted_pattern = decrypt_pattern(stored_pattern) # Decrypt the stored pattern
  if entered_pattern == decrypted_pattern:
    return True # Authentication successful
  else:
    return False # Authentication failed
```

Fig. 7. Algorithm for Pattern Authentication

Computer vision methods are used by the facial identification system described in the code to detect and recognize faces in real time. For feature extraction and comparison, it makes use of Open-CV libraries, specifically LBPH and Haar-cascades. The system uses a webcam to take face picture captures, preprocesses them, and compares them to templates that are saved. It uses encryption methods for sensitive data storage to guarantee data security. For user engagement, the system also has a graphical user interface. All in all, it offers a thorough approach to facial recognition that takes into account both technological features and UI design.

3. Results and Discussion

The system's output is a highly efficient and safe authentication method that offers smooth access control by using pattern recognition, spoof detection and facial recognition. The user-friendly graphical user interface (GUI) streamlines the authentication process for users by guiding them through the generation and verification of patterns. The pattern sketching interface adds an extra degree of security, and the system's facial recognition capabilities allow for quick and accurate identification of authorized users.

Comprehensive user action logging helps administrators by giving them insight into system usage patterns and login attempts. Because of its dependability and resilience, the system improves security and user satisfaction and may be used for a variety of applications that need safe access management.

In a nutshell, the system effectively accomplishes its goal of delivering a trustworthy, intuitive, and safe authentication solution by utilizing the recognition of facial features and pattern-drawing tactics.

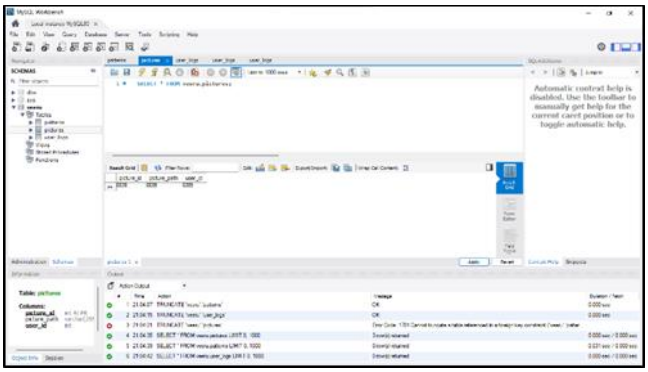

Fig. 8. When user is not existing in the database

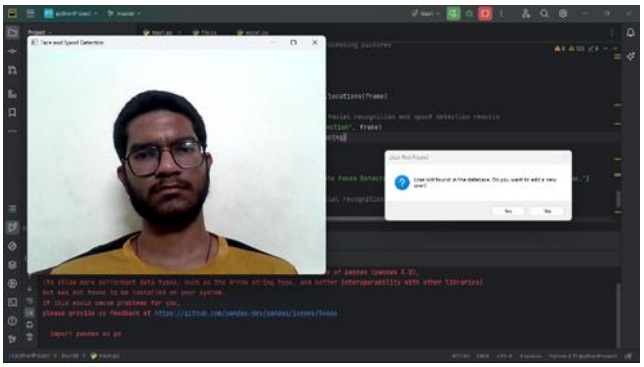

Fig. 9. It asks user to create new picture or not

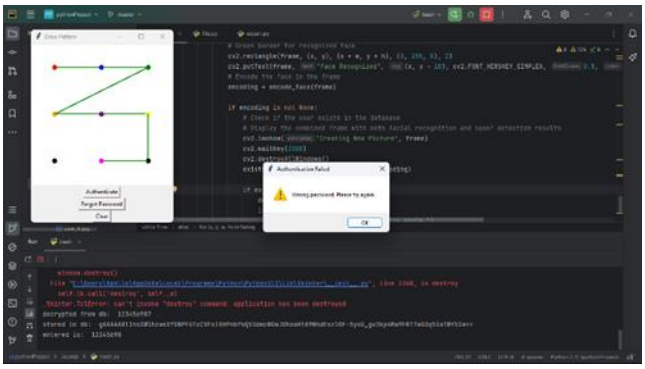

Fig. 10. Asks for new pattern to add in database

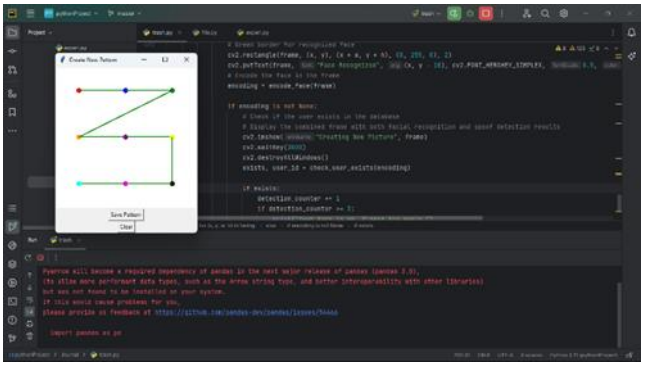

Fig. 11. Pattern drawing using numbers from keyboard and clicked on save pattern button to store in database

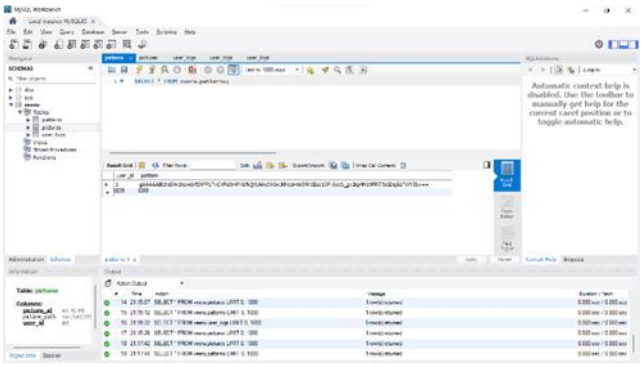

Fig. 12. The pattern is encrypted and stored in the database

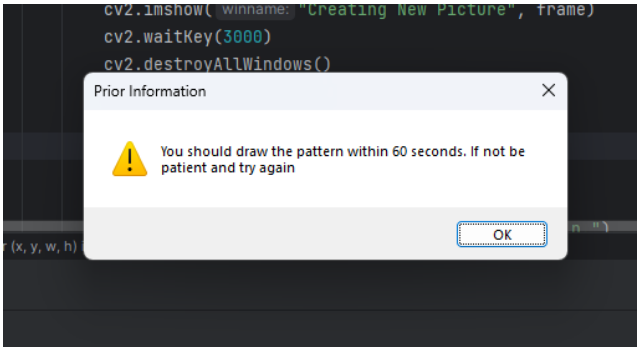

Fig. 13. Session timeout alert when user takes more than 60secs, user need to complete the authentication with on time, else it starts from the beginning.

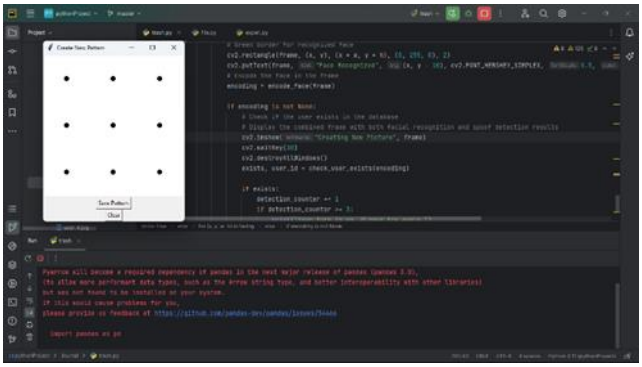

Fig. 14. if user drawn a wrong pattern it alert that it was wrong, if the pattern drawn wrongly more than 3 times it again process starts from beginning

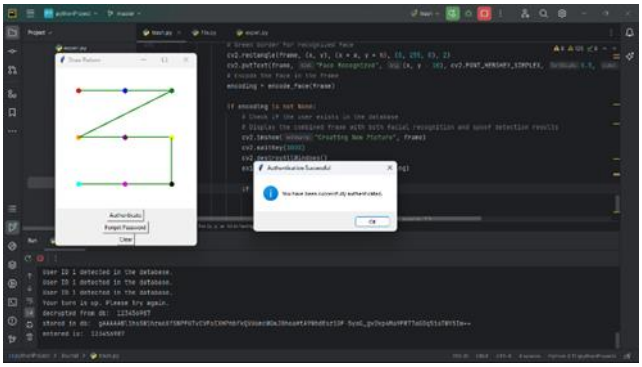

Fig. 15. Pattern Authentication or validation

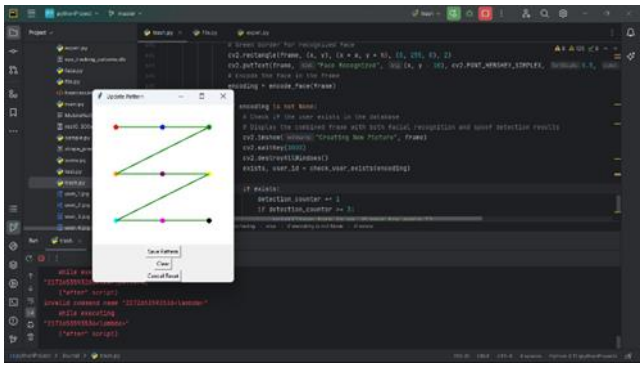

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Fig. 16. User clicked on forgot password button and also in the above picture user drawn new pattern to update with the old

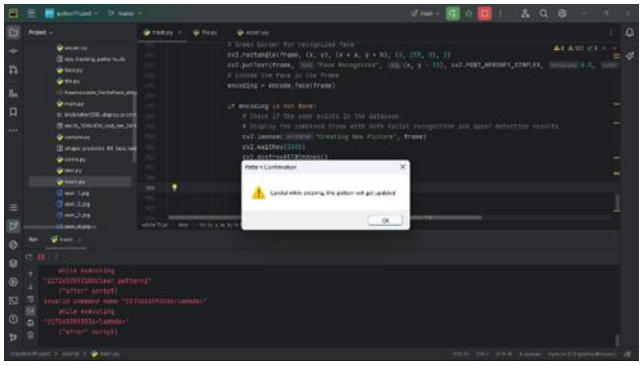

Fig. 17. Alerts user that cautious on entering the password for the 2nd time

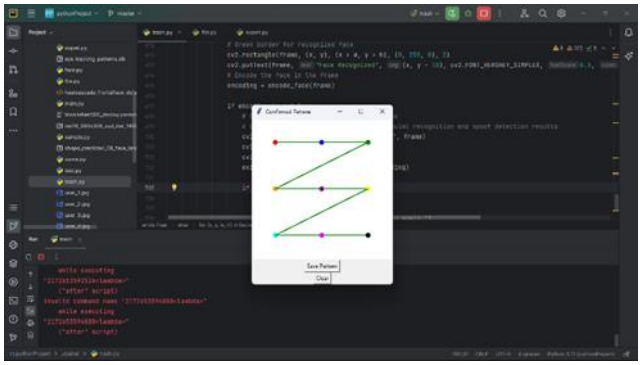

Fig. 18. Confirming the 2nd password and it compares with first if those are not matched then it alerts the user and process starts from the beginning

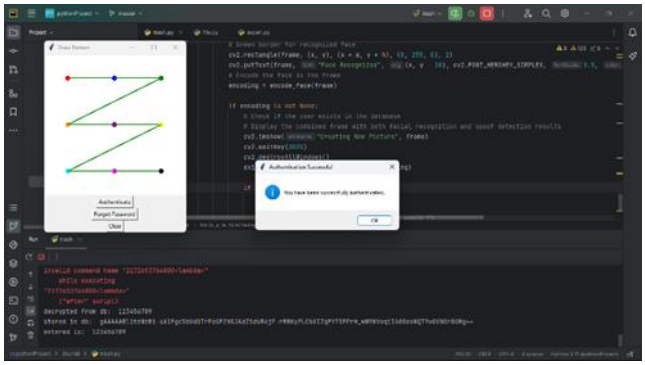

Fig. 19. New pattern was Updated with old one

Fig. 20. After Updating it starts from the beginning, in the above picture it is check whether the person is fraud or not and if observed beneath User id is compared with the face if exits it returns detected in the console itself else throw for new entry.

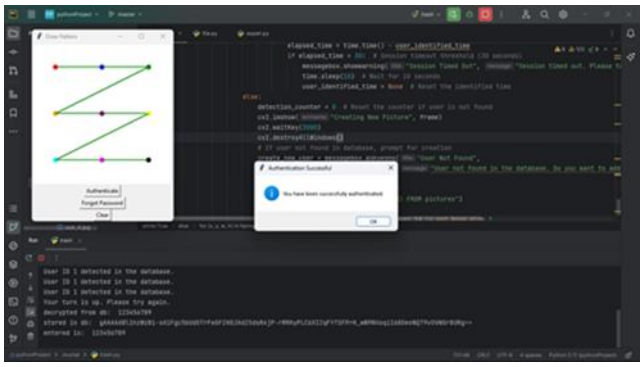

Fig. 21. Updated pattern is being authorized and also those clear and reset pattern functionalities will also work, those are user interests.

In the future, efforts to improve spoof detection algorithms to more precisely prejudice between real faces and spoof attempts could be the main focus to further improve the system. The accuracy and speed of object detection algorithms could be increased by optimization, providing dependable performance in a range of situations. To bolster security measures even more, multi-factor authentication and other features could be added. To improve scalability and resource efficiency, performance optimization efforts can also be made. To confirm the system's efficacy and direct future development efforts, extensive testing and assessment in real-world settings are essential.

4. Conclusion

To sum up, the system that has been built employs a thorough method of facial identification by utilizing advanced algorithms that enable the real-time detection and recognition of faces. It locates face features precisely and compares them to recorded data with extreme precision by utilizing computer vision. Integrating encryption techniques improves security by protecting private data, like user patterns. Furthermore, the graphical user interface simplifies the user experience by offering a user-friendly interface for fluid interaction. This all-encompassing

approach not only guarantees strong authentication but also promotes user confidence in the system's resiliency. It is a noteworthy development in the field of facial identification, providing a flexible and effective solution that can be used in a variety of contexts.

5. References and Author contributions

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5.2 Author contributions

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