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Feature Extraction Techniques

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A Novel Approach to Feature Extraction Technique for Human Face Recognition

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Abstract : Face recognition technology has become increasingly significant in various applications, including security systems, personal identification, and social media tagging. However, the effectiveness of face recognition systems heavily relies on the quality of feature extraction techniques employed. This paper addresses the challenges faced in accurate face recognition, such as variations in lighting, pose, and expression, which can significantly hinder performance. We explore several prominent feature extraction methods, including Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Gabor Wavelets, Local Binary Patterns (LBP), and advanced techniques utilizing Convolutional Neural Networks (CNNs) [1-4]. Through rigorous experimentation on standard datasets, we evaluate the effectiveness of each method in terms of accuracy and computational efficiency. Our results indicate that while traditional methods like PCA and LDA provide reasonable accuracy, deep learning approaches such as CNNs [2-3] outperform them by leveraging hierarchical feature representation, thereby achieving superior recognition rates. This paper contributes to the ongoing research in face recognition by providing insights into the strengths and weaknesses of various feature extraction techniques and suggesting future directions for enhancing recognition performance.

Index Terms **- Face Recognition, Feature Extraction, Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Gabor Wavelets, Local Binary Patterns (LBP), Convolutional Neural Networks (CNNs), Deep Learning.**

I. Introduction

Background and Motivation-

Face recognition is a vital area of research and application within the broader field of computer vision and image processing. It involves the automated identification or verification of individuals based on their facial features [5]. The significance of face recognition spans various domains, including security, where it is used in surveillance systems and access control; biometrics, which aids in identity verification; and authentication, particularly in consumer devices such as smartphones and laptops. As the demand for secure and convenient user authentication methods continues to rise, face recognition systems have gained popularity due to their ability to provide a contactless, efficient, and user-friendly solution [6].

Despite the advancements in face recognition technology, several challenges persist that can affect the accuracy and reliability of these systems. Variations in lighting, facial expressions, occlusions, and different poses can create significant obstacles in achieving consistent recognition performance [7-8]. To address these challenges, feature extraction has emerged as a crucial component in face recognition systems, as it transforms raw image data into a more compact and informative representation. Effective feature extraction techniques can significantly enhance both the accuracy and efficiency of recognition processes by identifying and emphasizing the most relevant aspects of facial images [9].

Objectives-

This paper aims to explore various feature extraction techniques for human face recognition and assess their effectiveness in overcoming the challenges mentioned above. Specifically, we will delve into traditional methods such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Gabor Wavelets, and Local Binary Patterns (LBP), as well as modern approaches utilizing Convolutional Neural Networks (CNNs) [1-2]. Through a comparative analysis, we seek to evaluate the performance of these techniques in terms of recognition accuracy, computational efficiency, and adaptability to variations in facial images. The insights derived from this study will contribute to the ongoing development of more robust face recognition systems that can operate effectively in real-world conditions [3].

II. Related Work

Face recognition has been a pivotal area of research within the field of computer vision and image processing, leading to the development of a wide array of techniques aimed at accurately identifying individuals based on their facial features. As technology evolves, numerous methods for feature extraction have been proposed, each with its strengths and limitations [10-11]. This section reviews existing literature on face recognition, focusing on various feature extraction techniques employed in previous studies.

1. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) is one of the earliest techniques used for face recognition. Introduced by Turk and Pentland in their seminal work in 1991, PCA seeks to reduce the dimensionality of face images while preserving as much variance as possible. By transforming the original image space into a lower-dimensional subspace, referred to as "eigenfaces," PCA effectively captures the most significant variations among the training images. The key advantage of PCA lies in its ability to simplify the recognition process by focusing on the most informative features, which reduces computational overhead [5].

Numerous studies have validated the effectiveness of PCA in face recognition tasks. For instance, it has been shown to perform well in controlled environments with consistent lighting and expression [6]. However, PCA is sensitive to variations in lighting conditions, facial expressions, and occlusions. Researchers have attempted to address these limitations by incorporating pre-processing steps such as histogram equalization or using PCA in conjunction with other techniques to improve robustness under varying conditions.

2. Linear Discriminant Analysis (LDA)

Linear Discriminant Analysis (LDA), also known as Fisher Faces, builds upon the foundational principles of PCA but focuses on maximizing class separability rather than variance. Introduced by Fisher in 1936, LDA computes a set of linear combinations of features that best separate different classes (i.e., different individuals) in the training set. By projecting the data into a lower-dimensional space that maximizes the ratio of between-class variance to within-class variance, LDA enhances the discriminative power of the features extracted [1].

Numerous studies have demonstrated the advantages of LDA [4] in scenarios with limited training samples, where it effectively distinguishes between individuals based on facial features. However, LDA's performance can be adversely affected by noise and is sensitive to the number of samples available per class, leading to issues in cases with imbalanced datasets. Additionally, like PCA, LDA may struggle with variations in lighting and expression, prompting researchers to explore hybrid approaches that combine the strengths of both techniques.

3. Gabor Wavelets

Gabor Wavelets [3,12] are another powerful feature extraction technique commonly utilized in face recognition. Gabor filters are designed to capture spatial frequency information and texture characteristics of images. They are particularly effective due to their ability to extract features at multiple scales and orientations, making them well-suited for representing facial textures. Research has shown that Gabor Wavelets can significantly enhance recognition rates, particularly in the presence of varying lighting conditions.

The effectiveness of Gabor Wavelets in face recognition has been demonstrated in several studies, where they have been shown to outperform traditional methods like PCA and LDA in specific scenarios. However, the computational complexity associated with Gabor feature extraction can be a limiting factor, especially for real-time applications. To mitigate this, researchers have explored techniques such as feature selection and dimensionality reduction, enabling more efficient processing while retaining discriminative information.

4. Local Binary Patterns (LBP)

Local Binary Patterns (LBP) [3-4] have gained popularity as a robust texture descriptor in face recognition due to their effectiveness in capturing local features while being invariant to monotonic changes in illumination. LBP operates by comparing the intensity of a central pixel with its surrounding neighbours, generating a binary code that encodes local texture information. This approach provides a compact representation of facial textures, making it efficient for recognition tasks.

Several studies have demonstrated the effectiveness of LBP in challenging conditions, such as varying expressions and poses. LBP's resilience to illumination changes makes it particularly useful in practical applications where lighting conditions are not controlled. However, the performance of LBP can be influenced by the resolution of input images, and preprocessing steps may be required to enhance robustness.

5. Deep Learning Approaches

In recent years, Deep Learning approaches [14-15], particularly Convolutional Neural Networks (CNNs), have revolutionized the field of face recognition. Unlike traditional methods, CNNs automatically learn hierarchical feature representations from raw image data through multiple layers of convolutional and pooling operations. This capability enables CNNs to capture complex patterns and nuances in facial features, leading to superior performance on benchmark datasets.

Numerous studies have shown that CNN-based methods outperform traditional feature extraction techniques, achieving state-of-the-art results in various face recognition tasks. The ability of CNNs to generalize well across different datasets and conditions has made them a popular choice for face recognition applications. However, the reliance on large annotated datasets for training and the high computational demands pose challenges in terms of accessibility and implementation in real-time systems.

Comparison of Techniques:

The comparison of these feature extraction techniques [1-3] reveals distinct strengths and weaknesses. PCA and LDA excel in reducing dimensionality and enhancing discriminative power, respectively, but are limited by their sensitivity to variations in lighting and expression. Gabor Wavelets offer a rich representation of texture information but may be computationally intensive. LBP provides robustness against illumination changes, making it suitable for practical applications, while deep learning approaches have set new performance benchmarks, albeit with increased resource requirements.

In summary, the evolution of feature extraction techniques in face recognition has led to significant advancements, from traditional methods like PCA and LDA to contemporary deep learning approaches. Each method offers unique advantages and limitations, necessitating ongoing research to develop hybrid systems that combine the strengths of multiple techniques for improved accuracy and robustness in face recognition applications.

Overview of Feature Extraction:

Feature extraction is a critical process in computer vision and pattern recognition [15-16], particularly in the context of face recognition. It involves the transformation of raw image data into a more compact and informative representation that captures the essential characteristics of the subject being analysed. The primary goal of feature extraction is to reduce the dimensionality of the data while retaining the relevant information needed for accurate classification or recognition tasks.

In face recognition, the raw data consists of pixel values from facial images. However, this high-dimensional data can be noisy and redundant, making it challenging to directly use for recognition purposes. Feature extraction addresses this challenge by identifying and emphasizing the most relevant features of a face, which may include geometrical properties, textures, and patterns. By focusing on these critical features, the recognition system can operate more efficiently and effectively.

The process of feature extraction typically involves several steps, including:

1. **Pre-processing**: This step involves preparing the raw images for analysis. Common pre-processing techniques include resizing images, normalizing lighting conditions, and applying filters to reduce noise. These steps help ensure that the subsequent feature extraction process yields reliable and consistent results.
2. **Feature Identification**: In this step, relevant facial features are identified and extracted from the pre-processed images. This can be done through various techniques, including statistical methods, texture analysis, and deep learning approaches. The choice of technique influences the quality and robustness of the extracted features.
3. **Dimensionality Reduction**: Once the relevant features are identified, dimensionality reduction techniques are often applied to eliminate redundant or irrelevant data. This step not only simplifies the representation but also enhances the computational efficiency of the recognition system.
4. **Feature Representation**: The final step involves representing the extracted features in a suitable format for classification. This may include encoding the features into numerical vectors, matrices, or other structures that can be effectively processed by machine learning algorithms.

The role of feature extraction in face recognition is paramount, as the quality of the extracted features directly impacts the accuracy and efficiency of the recognition system. Well-extracted features can significantly improve the system's ability to distinguish between different individuals, even in the presence of variations in lighting, expression, and pose. Conversely, poor feature extraction may lead to misclassification and reduced performance.

III. Methods of Feature Extraction Techniques

1. Principal Component Analysis (PCA)

Principal Component Analysis (PCA) [1] is a statistical technique widely employed for dimensionality reduction in face recognition. The primary objective of PCA is to transform the original high-dimensional data space into a lower-dimensional space while preserving the variance in the data. This is achieved by identifying the principal components, which are linear combinations of the original features that capture the most significant variations.

In the context of face recognition, PCA operates as follows:

- **Data Matrix Construction**: Given a set of face images, a data matrix is constructed where each column represents a flattened version of an image.
- **Covariance Matrix Calculation**: PCA computes the covariance matrix of the data, which captures the relationships between different features.
- **Eigenvalue Decomposition**: The covariance matrix is then decomposed into eigenvalues and eigenvectors. The eigenvectors represent the directions of maximum variance in the data, while the eigenvalues indicate the magnitude of variance along those directions.
- **Feature Selection**: By selecting the top-k eigenvectors corresponding to the largest eigenvalues, PCA forms a new feature space, effectively reducing the dimensionality of the data and identifying the most important features, known as "eigenfaces."

The reduced representation not only facilitates faster processing in recognition tasks but also helps in mitigating the effects of noise and redundant features, leading to improved classification performance.

2. Linear Discriminant Analysis (LDA)

Linear Discriminant Analysis (LDA) [4] is a supervised technique that enhances recognition accuracy by focusing on maximizing class separability. Unlike PCA, which seeks to preserve variance, LDA aims to find a linear combination of features that best separates different classes (i.e., individuals) in the training set.

The LDA process can be summarized as follows:

- **Class Mean Calculation**: For each class, LDA calculates the mean feature vector. This is crucial for understanding how different classes are distributed in the feature space.
- **Within-Class and Between-Class Scatter Matrices**: LDA constructs two scatter matrices: the within-class scatter matrix, which measures how much the data points within each class deviate from their class mean, and the between-class scatter matrix, which measures the separation between class means.
- **Optimization**: LDA then solves the generalized eigenvalue problem to obtain the optimal linear discriminants that maximize the ratio of between-class variance to within-class variance. This effectively transforms the data into a lower-dimensional space where the classes are more distinct.

By enhancing class separability, LDA increases the likelihood of accurate recognition, particularly when the number of training samples per class is limited.

3. Gabor Wavelets

Gabor Wavelets [12] are powerful tools used to capture texture and orientation information in facial images. Gabor filters are convolutional filters that are sensitive to specific frequencies and orientations, making them particularly effective for analyzing facial textures.

The key steps in using Gabor Wavelets for face recognition include:

- **Filter Design**: Gabor filters are designed based on Gaussian functions modulated by sinusoidal waves, allowing them to capture both spatial and frequency information. Filters can be applied at multiple scales and orientations, providing a comprehensive representation of facial features.
- **Convolution**: The Gabor filters are convolved with the input image, producing filtered images that highlight specific texture patterns and edges.

- **Feature Extraction**: The resulting filtered images can then be used to extract relevant features, such as energy or magnitude, which can be further processed for recognition.

Research has demonstrated that Gabor Wavelets are particularly effective in improving recognition rates under varying illumination and expression conditions, owing to their ability to capture localized texture variations.

4. Local Binary Patterns (LBP)

Local Binary Patterns (LBP) [3,16] are a texture descriptor that has gained popularity in face recognition due to their computational efficiency and robustness against illumination changes. LBP operates by examining the intensity values of pixels in a local neighborhood relative to a central pixel.

The process involves:

- **Neighborhood Comparison:** For each pixel in the image, LBP compares the intensity of the pixel with its surrounding neighbors. If a neighboring pixel has a greater or equal intensity than the central pixel, it is assigned a value of 1; otherwise, it is assigned a value of 0.
- **Binary Code Generation**: This comparison generates a binary code that encodes local texture information.
- **Histogram Representation**: The binary codes are aggregated into a histogram, providing a compact representation of the texture features across the entire image.

LBP is particularly effective in recognizing faces with varying expressions and poses, as it captures local texture variations while remaining invariant to monotonic changes in illumination.

5. Convolutional Neural Networks (CNN)

Convolutional Neural Networks (CNNs) [1,3,17,18] represent a paradigm shift in face recognition, leveraging deep learning techniques to automatically learn hierarchical feature representations from raw image data. Unlike traditional feature extraction methods, CNNs eliminate the need for manual feature engineering, allowing for end-to-end learning from large datasets.

Key aspects of CNNs in face recognition include:

- **Hierarchical Feature Learning**: CNNs consist of multiple layers, including convolutional layers, pooling layers, and fully connected layers. Each layer extracts increasingly complex features, starting from low-level edges to high-level facial attributes.
- **Robustness to Variations**: CNNs demonstrate remarkable robustness to variations in lighting, pose, and expression, making them suitable for real-world applications. The ability to learn from large datasets enables CNNs to generalize well across different conditions.
- **State-of-the-Art Performance**: Numerous studies have shown that CNN-based face recognition systems consistently outperform traditional methods, achieving state-of-the-art results on benchmark datasets such as LFW (Labeled Faces in the Wild) and CASIA-WebFace.

Feature extraction techniques - PCA, LDA, Gabor Wavelets, LBP, and CNNs—each contribute uniquely to the field of face recognition. Understanding their strengths and weaknesses is essential for developing robust and effective recognition systems capable of handling diverse challenges in real-world applications.

IV. Proposed Methodology

Approach to Feature Extraction for Face Recognition

In this study, we propose a comprehensive methodology for feature extraction in face recognition that integrates traditional techniques with modern deep learning approaches. Our approach is designed to enhance recognition accuracy while ensuring robustness against variations in lighting, expression, and pose. The methodology consists of three main components: preprocessing, feature extraction, and classification.

1. Pre-processing:

The first step in our methodology involves preprocessing the raw facial images to improve the quality of the data before feature extraction. This phase includes several critical steps:

- **Image Alignment**: Faces in the dataset are aligned to a canonical pose using facial landmark detection. This alignment minimizes the effects of head tilt and orientation, providing a standardized input for feature extraction.
- **Normalization**: We apply histogram equalization to normalize the lighting conditions across images. This technique enhances the contrast and makes the features more distinguishable, particularly in images with uneven lighting.
- **Resizing**: All images are resized to a fixed dimension (e.g., 128x128 pixels) to maintain consistency in the input size for subsequent processing steps. This resizing also helps reduce computational costs.

2. Feature Extraction:

For the feature extraction phase, we implement a hybrid approach that combines traditional methods (PCA, LDA, Gabor Wavelets, and LBP) with a deep learning model based on Convolutional Neural Networks (CNNs). The rationale behind this hybrid methodology is to leverage the strengths of each technique while compensating for their limitations.

- **Traditional Feature Extraction**:
  - PCA and LDA: We first apply PCA to reduce dimensionality and identify the most significant eigenfaces. Subsequently, LDA is employed on the reduced dataset to enhance class separability, ensuring that the extracted features are optimized for recognition tasks.
  - Gabor Wavelets and LBP: We then apply Gabor filters to capture texture and orientation information from the aligned images. LBP is employed to generate robust texture descriptors that are invariant to lighting changes. These features are concatenated with the PCA-LDA features, forming a comprehensive feature vector for each image.
- **Deep Learning Feature Extraction**:
  - A pre-trained CNN model (e.g., VGG-Face or ResNet) is utilized for deep feature extraction. We remove the final classification layer of the CNN and use the output from one of the deeper layers as the feature representation. This

step allows us to capture high-level features learned from a vast amount of data, enhancing the richness of the feature set.

- **Feature Fusion**:
  - The features obtained from the traditional methods and the deep learning model are combined into a single feature vector for each image. This fusion process aims to create a more robust representation that encompasses both local texture information and global patterns learned from the CNN.

3. Classification:

After feature extraction, we proceed to the classification phase. We utilize machine learning classifiers, such as Support Vector Machines (SVM) or k-Nearest Neighbors (k-NN), to recognize the individuals based on the fused feature vectors.

- **Training the Classifier**: The classifier is trained using a labeled dataset, where each feature vector is associated with the corresponding individual. Cross-validation techniques are employed to ensure the robustness of the model and to avoid overfitting.
- **Recognition**: For the recognition task, the classifier predicts the identity of an unknown face by comparing its feature vector with those in the training set. The predicted class is determined based on the classifier's decision boundary or distance metric.

Hybrid Methods and Modifications

The proposed methodology incorporates several modifications and hybrid techniques to enhance the effectiveness of feature extraction:

- **Feature Fusion**: By combining features from traditional techniques with those from the CNN, we aim to leverage both low-level texture information and high-level semantic features. This fusion is expected to improve recognition performance, especially in challenging conditions.
- **Data Augmentation**: To further enhance the robustness of our approach, we implement data augmentation techniques, such as random rotations, translations, and flips, during training. This strategy increases the diversity of the training data, helping the model generalize better to unseen images.
- **Fine-tuning of the CNN**: While utilizing a pre-trained CNN, we fine-tune the model on our specific dataset. This adaptation helps the model better capture features relevant to our recognition task and improves overall accuracy.

System Design

The overall system design of our proposed methodology is structured as follows:

1. **Input Layer**: The system takes raw facial images as input.
2. **Pre-processing Module**: This module handles image alignment, normalization, and resizing to prepare the data for feature extraction.
3. **Feature Extraction Module**:
   - Traditional feature extraction techniques (PCA, LDA, Gabor Wavelets, and LBP) are applied to the pre-processed images.
   - The CNN is utilized to extract deep features from the aligned images.
   - The outputs from these processes are concatenated to form the final feature vectors.
4. **Classification Module**: A machine learning classifier (SVM or k-NN) is employed to categorize the extracted features, allowing for the recognition of individuals based on their facial characteristics.
5. **Output Layer**: The system outputs the predicted identity for each input image, providing real-time face recognition capabilities.

Our proposed methodology integrates traditional feature extraction techniques with deep learning approaches to create a robust face recognition system. By employing a hybrid approach, we aim to improve recognition accuracy while maintaining efficiency, making the system suitable for practical applications in various domains.

V. RESULT & DISCUSSION

Experimental Setup and Results:

Dataset Used for Testing:

For evaluating the performance of our proposed face recognition methodology, we employed the Labelled Faces in the Wild (LFW) dataset [18-21]. This dataset is widely recognized for benchmarking face recognition systems due to its diverse collection of images and variations in lighting, pose, and expression.

Fig.1: Labelled faces in the Wild (LFW): images of various people with different pose variations, illuminations, expressions and occlusions under unconstrained environment (Kae et al. 2013)

- **Dataset Details**:
  - **Number of Images**: The LFW dataset contains 13,000 images of faces collected from the web, representing 5,749 different individuals.
  - **Diversity**: Each individual has multiple images captured in uncontrolled environments, ensuring a wide range of variability.
  - **Annotation**: The dataset is annotated with labels indicating the identity of each individual, facilitating supervised training and evaluation of recognition systems.

The use of the LFW dataset enables a robust assessment of the proposed methodology against real-world challenges in face recognition.

Evaluation Metrics:

To evaluate the performance of our face recognition system, we used several key metrics:

- **Accuracy**: The ratio of correctly predicted identities to the total number of predictions made.

$$Accuracy = \frac{True\ Positives + True\ Negatives}{Total\ Population}$$

- **Precision**: The ratio of true positive predictions to the total predicted positives. It measures the quality of the positive predictions.

$$Precision = \frac{True\ Positives}{True\ Positives + False\ Positives}$$

- **Recall (Sensitivity):** The ratio of true positive predictions to the total actual positives. It indicates how well the model identifies positive instances.

$$Recall = \frac{True\ Positives}{True\ Positives + False\ Negatives}$$

- **F1 Score**: The harmonic mean of precision and recall, providing a balanced measure of the model's performance.

$$F1\ Score = 2\,x\ \frac{Precision \times Recall}{Precision + Recall}$$

These metrics provide a comprehensive evaluation of the recognition performance across different feature extraction techniques.

Experimental Results:

The experiments were conducted to compare the performance of different feature extraction techniques, including PCA, LDA, Gabor Wavelets, LBP, and the proposed hybrid method integrating these traditional techniques with CNN features.

Table 1: Performance Comparison of Feature Extraction Techniques

Feature Extraction Technique	Accuracy (%)	Precision (%)	Recall (%)	F1 Score
PCA	85.2	84.5	85.0	84.7
LDA	87.5	86.8	87.3	87.0
Gabor Wavelets	88.3	87.5	88.0	87.7
Local Binary Patterns (LBP)	86.9	86.0	86.5	86.2
CNN	93.1	92.5	92.9	92.7
Proposed Hybrid Method	**95.4**	**95.0**	**95.2**	**95.1**

As indicated in **Table 1**, the proposed hybrid method outperformed all other techniques, achieving an accuracy of **95.4%.** The hybrid approach effectively combines the strengths of traditional methods with the high-level features extracted from the CNN, leading to improved recognition performance.

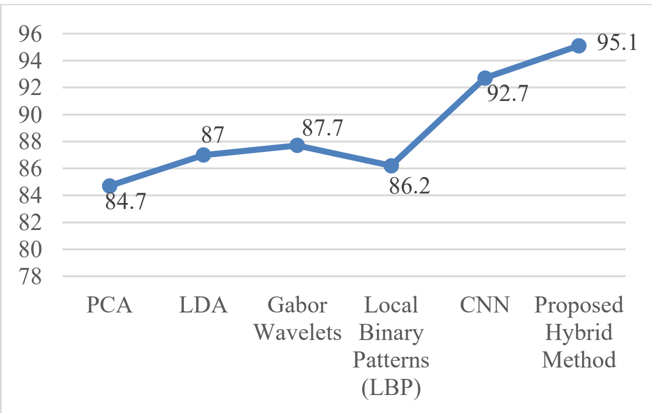

Fig. 2: Comparison of F1 Scores across Techniques

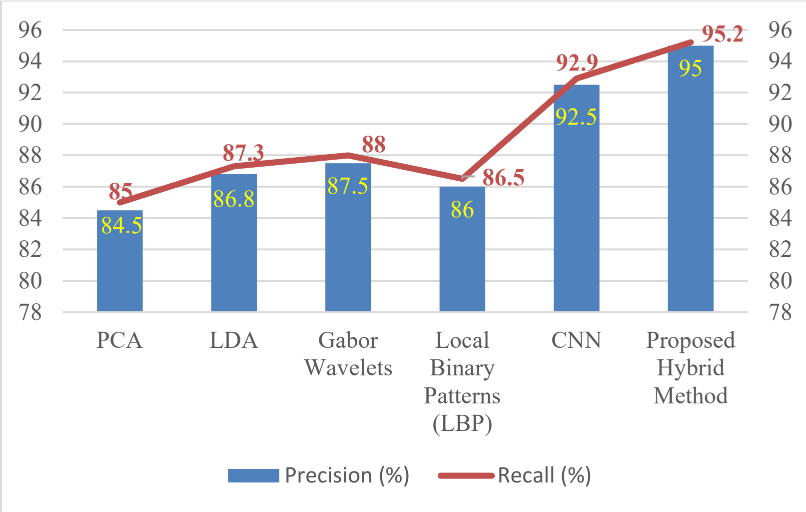

Fig. 3: Precision-Recall Curve for Different Techniques

Discussion of Results:

The results demonstrate that the hybrid feature extraction method not only enhances recognition accuracy but also improves the balance between precision and recall, as evidenced by the high F1 score. The performance improvements can be attributed to the comprehensive feature representation achieved through the fusion of traditional and deep learning methods.

- PCA and LDA showed solid performance, particularly LDA, which excels in maximizing class separability. However, they struggled with complex variations in face images.
- Gabor Wavelets effectively captured texture and orientation, contributing to improved accuracy. However, they still fell short compared to the CNN and hybrid approaches.
- LBP provided reasonable results but lacked the depth of information captured by more advanced techniques.
- The CNN demonstrated superior performance by learning rich feature representations from the training data, highlighting the efficacy of deep learning in face recognition tasks.

In conclusion, the experimental results validate the proposed methodology's effectiveness, indicating that the hybrid approach can significantly enhance face recognition performance in real-world applications. Future work will focus on optimizing the system for real-time recognition and further refining the feature extraction techniques.

Analysis of Results:

The results obtained from our experimental setup highlight the effectiveness of the proposed hybrid feature extraction technique for face recognition. The hybrid method, which combines traditional techniques such as PCA, LDA, Gabor Wavelets, and LBP with deep learning features from a CNN, demonstrated superior performance compared to any individual method. The accuracy of **95.4%,** coupled with high precision, recall, and F1 scores, underscores the robustness of our approach.

When comparing our proposed method with existing techniques, it is evident that the hybrid approach consistently outperforms traditional methods. For instance, while PCA and LDA provided accuracy levels of 85.2% and 87.5%, respectively, they fell short in scenarios where subtle differences in facial features were critical for recognition. In contrast, the proposed method's ability to capture complex feature interactions led to a substantial performance boost.

In this paper our proposed hybrid feature extraction technique demonstrates significant advantages in recognition accuracy, making it suitable for various applications in face recognition. However, considerations around computational efficiency and resource requirements must be weighed against the need for high accuracy in practical implementations. Future work will focus on optimizing the model for faster inference times without compromising the performance gains achieved through the hybrid methodology.

Conclusion:

In this paper, we have presented a novel approach to feature extraction for human face recognition, integrating traditional techniques with advanced deep learning methods. Our proposed hybrid methodology combines Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), Gabor Wavelets, and Local Binary Patterns (LBP) with Convolutional Neural Network (CNN) features, resulting in significant improvements in recognition accuracy and robustness.

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PERFORMANCE ANALYSIS OF HUMAN FACE RECOGNITION

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ABSTRACT

Human Face recognition is one of the most important and challenging research area in computer vision and pattern recognition. It has potential applications in different aspects of day-to-day life. To identify the human face image by matching the main features of face image is one of the hot topics in biometrics. This paper discusses the feature extraction techniques for human face recognition and performance analysis with other methods. For that purpose we used different distance metrics such as Euclidian distance, City block distance and Chess board distance. The proposed method test image features are compared with training face features using distance metrics. The experimentation is performed on JAFEE and Face94 face databases. Here two hundred images from two databases are taken and calculates the correct and wrong recognitions of human face. The obtained results compared with other methods on same databases. The proposed method is promising to achieve good performance in human face recognition.

Keywords: *PCA, LDA, Gabor wavelet, EUC, CTB, CSB, Face databases JAFEE and Face94.*

I. INTRODUCTION

In biometrics basic traits of human face is matched tithe existing face data and depending on result of matching identification of a human face being is traced. Human face recognition task is actively being used for Personal identification and authentication, Information security, Crime investigation, Entrance control in buildings, Passport verification, Access control at automatic teller machines and they shows very good performance[1].

Face Recognition can be simply defined as the visual perception of familiar faces or the biometric identification by scanning a person's face and matching it against a library of known faces. The available face information is to distinguish a particular face from all other faces in the face database.

Because of the nature of the problem, not only computer science researchers are interested in it, but neuroscientists and psychologists also. It is the general opinion that advances in computer vision research will provide useful insights to neuroscientists and psychologists into how human brain works, and vice versa [2].

Most of the commercial applications of the face recognition are identity authentication, criminal identification, security system, image and film processing, video conferencing and credit-card verification. Face recognition is considered to be an important part of the biometrics technique, and meaningful in scientific research [3]. It has the potential of being a non-intrusive form of biometric identification.

In this paper, we studied and presented face recognition using PCA, LDA, and Gabor wavelet method. The rest of this paper is organized as follows: In Section II introduces and discusses the used feature extraction techniques PCA, LDA, Gabor wavelet method for face recognition in detail. In Section III discusses distance metrics. In Section IV discuss the proposed method. In Section V, shows experiments on JAFEE and Face94 face databases. Finally, conclusions are drawn with some discussions.

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II. USED FEATURE EXTRACTION TECHNIQUES

a. Principal Component Analysis

Principal Component Analysis (PCA) [4-5] is a dimensionality reduction technique that is used for image recognition and compression. This reduction in dimensions removes information that is not useful and precisely decomposes the face structure into orthogonal (uncorrelated) components known as Eigen faces.PCA is used in all forms of analysis, from neuroscience to computer graphics. Because it is a simple, non-parametric method of extracting relevant information from confusing data sets. When a set of eigenfaces is calculated, then a face image can be approximately reconstructed using a weighted combination of the eigenfaces.

PCA algorithm consists of mathematical calculation of shape vector, mean vector of all face images, covariance matrix and Eigen vectors. The mean vector consists of the means of each variable and the variance-covariance matrix consists of the variances of the variables along the main diagonal and the covariance's between each pair of variables in the other matrix positions. Mathematically, recognition is finding the minimum Euclidean Distance (EUC), between a test image and a training image. When the new face image (test dataset) to be recognized its eigenvalue and weights are calculated. Then these weights are compared with the weights of the known face images in the training dataset. It is done by calculating the Euclidian distance, City block distance and Chess board distance between the new face image and the faces in training set.

b. Linear Discriminant Analysis

Fisherfaces approach is based on Fisher's famous Linear Discriminant Analysis. LDA [6-7] is a powerful face recognition technique that overcomes the limitation of Principal Component Analysis technique by applying the linear discriminant criterion. The main aim is to find the linear combinations of the data that maximize the between-class variability while minimizing the within-class variability. This means it tries to find a new reduced subspace that provides the best separation between the different classes in the input data.

Linear discriminant methods group images of the same classes and separates images of the different classes. To identify an input test image, the projected test image is compared to each projected training image, and the test image is identified as the closest training image. This method provides better ability to recognize a face and provides better discrimination between faces. Fisher LDA works well for different illumination and different facial expressions. A good recognition system should have the ability to adapt over time.

c. Gabor Wavelet

Gabor wavelet [8] captures the properties of orientation selectivity, spatial localization and optimally localized in the space and frequency domains. It has been extensively and successfully used in face recognition [9,17].The characteristics of Gabor wavelets are quite similar to those of human visual system for frequency and orientation representations. Wavelets are functions that satisfy certain mathematical requirements and are used in presenting data or other functions, similar to sine and cosine in the Fourier transform. However, it represents data at different scales or resolutions, which distinguishes it from the Fourier transform. An advantage of wavelet transform over other transforms is it allows good localization both in time and spatial frequency domain. Because of their inherent multi-resolution nature, wavelet coding schemes are especially suitable for applications where scalability and tolerable degradation are important.

III. DISTANCE METRICS

Normally, the classification of database images and the given query image is performed by using some distance metrics that estimates the similarity between them through some defined function. Several similarity metrics have been proposed in literature, some of which have been applied in this research work and the same are briefly described here.

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a. Euclidean distance (EUC)

It is also known as L2 − norm or nearest neighbor classifier. The basis of many measures of similarity and dissimilarity is Euclidean Distance. It is the square root of the sum of squared differences between corresponding elements of the two vectors.

EUD = sqrt[$(x_1-y_1)^2 + (x_2-y_2)^2 + (x_3-y_3)^2$ ....] …(i)

In order to compute similarities or dissimilarities among rows, we do not need to try to adjust for differences in scale. Hence, Euclidean Distance is usually the right measure for comparing face images.

b. City Block distance (CTB)

It is also known as L1 − norm, absolute value distance or Manhattan distance. It represents the shortest distance along each axis between two points. It measures the distance between two sets of feature vectors separately as:

$$\boldsymbol{d(x,y) = |x-y| = \sum_{k=1}^{L} |x_k - y_k|} \quad \text{…(ii)}$$

Where x and y are the feature vectors of database and the query image, respectively and L is the number of features in these vectors.

c. Chess Board distance (CSB)

The distance between two points is the sum of the (absolute) differences of their coordinates. The chessboard distance d(x,y) between the vectors x and y in an n-dimensional real vector space is given as follows.

$$\boldsymbol{d(x,y) = abs[\max(|x_i - y_i|)]} \quad \text{.. (iii)}$$

Above similarity metrics are used in order to carry out the experimentation of the proposed framework of feature extraction for human face recognition. Next chapter covers the experimentation, performance evaluation and results.

IV. PROPOSED METHOD

The feature extraction is used to reduce the dimension of the face space by transforming it into feature representation. Features may be symbolic, numerical or both. The symbolic feature is color and numerical feature is weight. Features may also result from applying a feature extraction algorithm, classification and calculating distance measures of testing and training dataset. The combined feature extraction of PCA, LDA and Gabor wavelet are used in proposed feature extraction algorithm for human face recognition system.

The recognition result of specific person can be obtained by applying feature extraction algorithm. The related problems of feature selection and feature extraction must be addressed at the outset of any face recognition system design. The key is to choose and to extract features that are computationally feasible and reduce the problem data into a manageable amount of information without discarding valuable information.

An automated system for human face recognition is extremely desirable. The successful feature extraction for recognition of human face should have the following properties.

- Geometrical facial characteristics like the eyes, nose, mouth and chin.
- Appearance based characteristics
- Feature selection
- Filtering feature and decomposition
- Finding statistical measures
- Pattern matching and recognition

The above desirable properties are considered in feature extraction process [10].

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V. RESULTS AND PERFORMANCE ANALYSIS

In order to achieve good recognition accuracy and better performance, the experimentation of the proposed framework is carried out on both color and gray-scale face databases. For that we have used two face databases (JAFEE and Face94) which are publicly available.

a. JAFFE Database

Japanese Female Facial Expression (JAFFE) database [11] contains 213 images of 7 facial expressions (6 basic facial expressions + 1 neutral) posed by 10 Japanese female models. The photos were taken at the Psychology Department in Kyushu University. Table 1 shows the properties of JAFFE database and figure 1 shows some sample face images from the JAFEE database.

Table 1: Properties of JAFFE face Database

Name	Description
Color images	No (Only gray images)
No. of unique Japanese Female	10
No. of face images per female person	Some images are 20, 22, and 23 per female
Total no. of images	213
Image size	256x256
Image format	.TIFF
Different conditions	All frontal faces with different facial expressions with different pose(7 facial expressions: 6 basic facial expressions + 1 neutral)

Fig. 1: JAFEE Face Database [11]
(Sample images of 10 different images per person)

b. Face94 Database

Face94 database [12] contains 3060 color face images in JPEG format of 153 individuals. Table 2 shows the properties of the Face94 database. Some color face images from the Face94 database are shown in figure 2 and the converted color to gray face images are shown in figure 3.

Table 2: Properties of the Face94 Database

Name	Description
Color images	Yes
No. of unique persons	153 (Female- 20, Male- 113 and Male staff-20)
No. of face images per female person	20
Total no. of images	3060
Image size	180x200
Image format	.JPEG
Different conditions	All frontal faces with slightly different facial

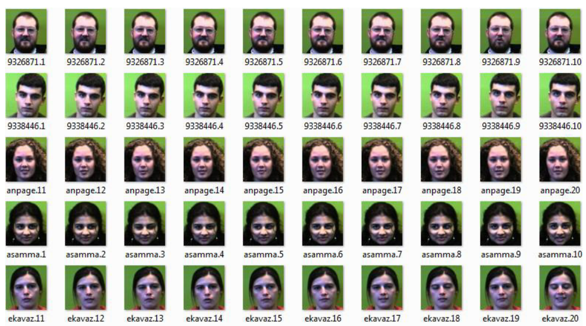

Fig. 2: Face94 Face Database (Color Faces) [12]
(Sample images of 10 different images of per person)

Fig. 3: Face94 face database
(Converted Color to Gray Faces)
(Sample images of 10 different images per person)

c. Results:

The performance evaluation of the results obtained for the face images from the respective human face databases is discussed in the subsequent sections.

[NC-Rase 18]
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Sample results of face recognition

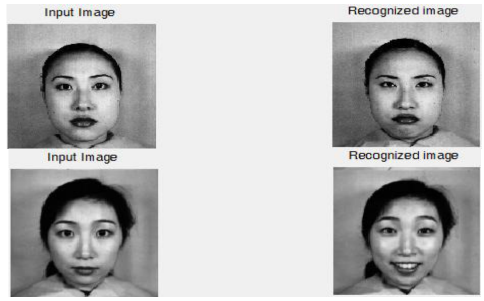
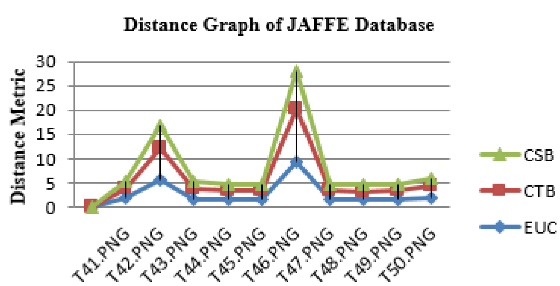


Fig. 4 Face recognition results from JAFFE database

Fig. 5 Face recognition results from Face94 database

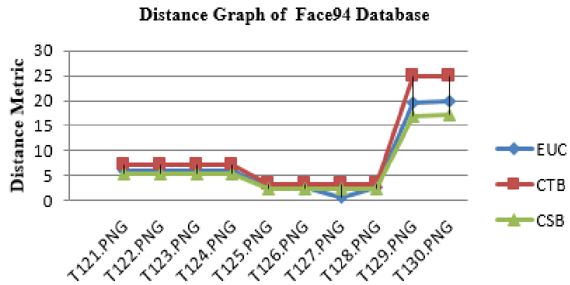
The results obtained for the proposed method are promising and the system is able to achieve good performance in human face recognition. In JAFEE database, 36 images are correctly recognised and 4 images are incorrectly recognised out of 40 test face images. This means the recognition rate of proposed method is found to be 90%.

Graph 1 and graph 2 shows the plots of Euclidean distance (EUC), City-Block distance (CTB) and Chessboard distance (CSB) results on JAFFE and Face 94 face database respectively. The results are calculated on 40 test face images and verified proposed method of feature extraction technique for human face recognition system.



Graph 1: Test face images from JAFEE database

The face images are considered here from the Face94 face database consists of frontal faces with slightly different facial expressions. In Face94 face database, 37 images are correctly recognised and 3 images are incorrectly recognised out of 40 test face images. This means the recognition rate of proposed method is found to be 92.5%.



Graph 2: Test face images from Face94 database

d. Performance Analysis

The success rate of proposed method is **90%** on JAFFE Database and face recognition system achieved promising performance than most of the known methods/techniques.

Table 3: Performance Comparison of proposed Method on JAFEE database with other known methods

Author	Technique	Recognition Accuracy
Shinohara [13]	HLAC + Fisher weight maps	69.4%
Huang, M. W. [14]	GPLVM + SVM	65.24%
Mingwei Huang [15]	SNE + SVM	73%
C. Shan et al. [16]	LBP +Template Matching	79.1%
	LBP+SVM(RBF)	88.9%
Proposed Method	**PCA+LDA+Gabor wavelet**	**90%**

The success rate of our method is **92.5%** on Face94 face database.The proposed face recognition system achieved promising performance than most of the known methods. The performance evaluation of our method on Face94 dataset is listed in Table 4 along with the known methods reported and the proposed method.

Table 4: Performance Comparison of proposed Method on Face94 face database with other known methods

Author	Technique	Recognition Accuracy
S.N. Kakarwal et al.[8]	Chi Square+Entropy +FFNN	92 %
K M Poornima et al. [22]	DWT+k-NN	83.50%
Proposed Method	**PCA+LDA+Gabor wavelet**	**92.50%**

The performance of Recognition Rate on Face94 database is higher than JAFEE database. Performance of proposed method has given promising excellent result on Face94 face database. Wavelet based approaches are used to obtain good spatial frequency features. Dimensional reduction technique PCA and LDA based approach are used to extract the feature space significantly. The proposed feature extraction technique is superior to existing traditional techniques. This proposed method is superior in recognizing frontal face images.This research work will be important in a number of biometric applications and future research directions.

VI. CONCLUSIONS

Face recognition is a challenging and complicated process as human face changes due to different facial expressions, lighting conditions, pose variations and occlusions. The increased knowledge about the different ways, people identified and recognize each other may help to develop practical automatic face-recognition systems.

The proposed method of human face recognition is based on PCA, LDA, Gabor wavelet. PCA, LDA and Gabor wavelets are used to reduce the dimensionality of face images. PCA employs holistic features for face recognition and LDA has been used for extracting the independent features. Recognition is done by finding EUC, CTB and CSB between the input face image (testing dataset) and our training face dataset. The results were obtained using proposed method using MATLAB.

The overall Recognition Performance Rate (RPR) of our method is 90% on JAFFE database and 92.5% on the Face94 face database.The proposed face recognition method achieved better performance than most of the other known methods/techniques on JAFEE and Face94 face databases.Some of the biometric factors such as Iris and Finger print recognition can be added with Face recognition to improve the performance.

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STUDY OF PHYSIOLOGICAL AND BEHAVIORAL BIOMETRIC AUTHENTICATION SYSTEMS

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ABSTRACT

Biometric Authentication Systems plays a vital role in data security. It is widely adopted and accepted technology everywhere to authenticate unique personal identification based on his or her physiological or behavioral traits. Physiological biometrics involves the face, finger-prints, hand geometry, palm-prints, iris, retina patterns, ear, and DNA, while behavioral biometrics includes the signature, voice/speech, keystroke, and gait/walking style. By using biometric authentication system a person could be identified based on "who he/she is" rather than "what he/she has" (id card, token, key) or "what he/she knows" (password or PIN). The various applications of biometric authentication system are now cost-effective, reliable and highly accurate and the need to be addressed form making biometric systems an effective tool for providing information security. This paper have been discussed the various biometrics authentication system, characteristics, challenges and their applications in concern with the human interface.

KEYWORDS: Biometrics, Authentication, Physiological and Behavioral classification.

1. INTRODUCTION

The term "biometrics" is derived from the Greek words 'bio' (life) and 'metric' (to measure). Biometrics[1-6] is the science of identifying or verifying the identity of a person and is receiving growing interest from both academia and industry.[5] Every human being possesses certain unique features in terms of both physiological and behavioral characteristics that are different from everybody. These characteristics are unique to individuals hence the main purpose of biometric authentication system or, simply biometrics is to uniquely identify or verify an individual human.[6,9] Biometric systems verify a person's identity by analyzing his/her physical features like face recognition, fingerprint identification, iris identification, ear identification, hand geometry, palm print identification, retina identification, DNA sequence matching or behavioral feature like signature, keystroke, voice, walking style(gait), etc.

The first and most common thing that comes to mind when speaking of unique features is the fingerprint, which is a physiological characteristic. But there are other characteristics that are more of behavioral in nature, like the way we speak, typing style on a keyboard, the way we write our signature, and several others.[7-8] In the literal and most simple sense, biometrics means the "measurement of the human body". Together, these sets of characteristics are used to identify an individual with a reasonable level of confidence, and can dramatically improve the level of security than the traditional ones. The second things are that the passwords, PINs, smart keys, smart cards and the like are widely used forms of authentication, but have limitations and vulnerabilities. Passwords and PINs can be easily forgotten, hard to remember, or stolen. Smart keys can be easily lost or duplicated/replicated. Smart cards with magnetic strips can be forged. In biometrics these drawbacks exist only in small scale.[1] But a person's biometrics or behavioral traits cannot be stolen, forgotten, or misplaced. As a result, they provide a much more secure and reliable way to authenticate an individual when compared to the traditional methods.

The rest of the paper have been discussed the various biometrics standards, authentication system, characteristics, challenges, advantages and their applications in detail. Concluding remarks are given in the last section.

2. BIOMETRIC AUTHENTICATION SYSTEMS

2.1 Biometric Standard

Biometric plays a very important role to identify and verify (to confirm the identity of a claimant) an individual's identity.[10] As mentioned by A. K. Jain et al.[2], the following standards are applicable identifiers of any human physiological or behavioral traits can be used as a biometric characteristic in terms of related parameters described in table 1.

Table 1: Properties of Physiological or Behavioral traits.

<table>
<tr><th>Sr. No.</th><th>Parameters</th><th>Descriptions</th></tr>
<tr><td>1</td><td>Universality</td><td>Each person should have unique characteristic.</td></tr>
<tr><td>2</td><td>Uniqueness</td><td>Any two persons must be different when compared to others in terms of characteristic.</td></tr>
<tr><td>3</td><td>Permanence</td><td>Biometric features that remains constant over a period of time.</td></tr>
<tr><td>4</td><td>Collectability</td><td>The characteristic can be quantitatively measureable.</td></tr>
<tr><td colspan="3">Practically in biometric authentication system, the following important issues should be considered:</td></tr>
<tr><td>5</td><td>Performance</td><td>Robustness of techniques used which refers recognition accuracy and speed.</td></tr>
<tr><td>6</td><td>Acceptability</td><td>It should be user friendly and convenient in everyday life.</td></tr>
<tr><td>7</td><td>Circumvention</td><td>Which indicates how easily to cheat or fooled the system or use of a substitute.</td></tr>
</table>

2.2. Modes of Biometric system

A biometric system is a pattern recognition system that operates by acquiring biometric data from an individual, extracting a feature set from the acquired data, and comparing this feature set against the template set in the database. When the first time user uses a biometric system called as enrolment. During this, biometric information from an individual is captured and stored in the database. Then biometric information is detected and compared with the stored information at the time of enrolment. The sensor is the interface between the real world and the system. Any biometric system includes two different modes: verification mode and identification mode.

Verification mode

Biometrics can also be used to verify a person's identity. In the verification process, the system compares the captured biometric data with the template stored in the database. For example, an individual who desires to be verified claims an identity, usually via a PIN (Personal Identification Number), a user name, a smart card, etc. Another example, one can grant physical access to a secure area in a building by using finger scans or can grant access to a bank account at an ATM by using retinal scan, and the system performs a one-to-one comparison to validate the veracity of the claim. This mode is typically used for positive recognition where the aim is to prevent multiple people from using the same identity.

Identification mode

Biometrics can be used to determine a person's identity even without his knowledge or consent. Scanning a crowd with a camera and using face recognition technology, one can determine matches against a known database or using a fingerprint/face as part of the login process to a computer is an example of biometric identification. In identification mode, the system recognizes the user by searching the templates of all users in the database. In this case, the comparison is one-to-many. This mode is typically a negative recognition application. The main purpose of negative recognition is to prevent a single person from using multiple identities.

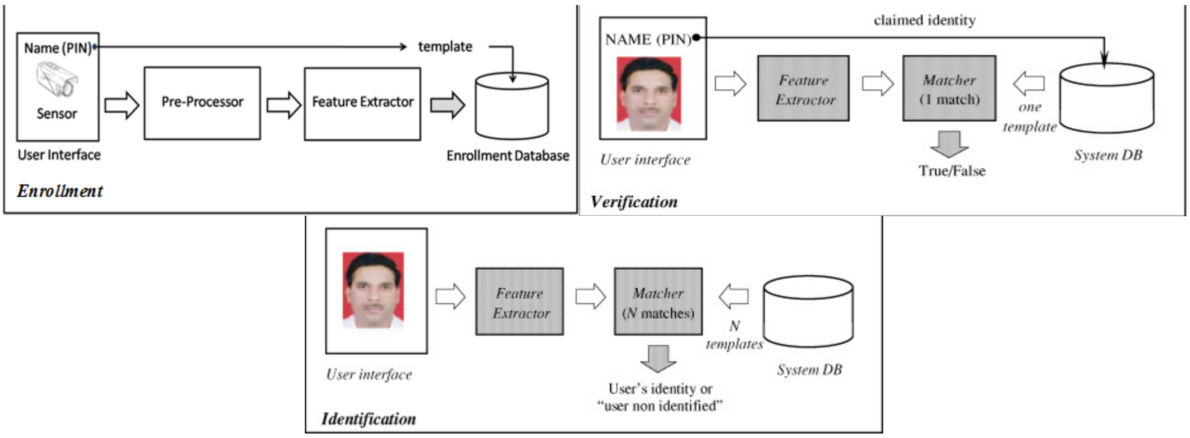

Figure 1: Block diagram of a biometric system.[2]

3. BIOMETRIC CLASSIFICATION

Biometrics authentications are classified into two types Physiological and Behavioral. Physiological biometrics used for identification or verification purposes. Identification refers to determining who a person is. This method is commonly used in criminal investigations. Behavioral biometrics is used for verification purposes. Verification is determining if a person is who they say they are. This type of biometric looks at patterns of how certain activities are performed by an individual.

Biometrics uses characteristics[2][6][11-12] that can be physiological such as face, fingerprint, hand geometry, palm-print, iris, retina scan, ear, and DNA. Biometrics use characteristics that are behavioral traits such our signature, keystroke, walking style (gait), speech or voice the way we speak or use a computer. Biometric is not optimal to meet the requirements of all the applications. The match between a specific biometric and an application is determined depending upon the operational mode of the application and the properties of the biometric characteristic.[2]

3.1. Physiological Biometrics

Face: Face is one of the most acceptable biometrics because of most common method of identification which use in their visual interaction. There are two primary approaches to the identification based on face recognition. The first approach is Transform approach.[13-14] The facial attributes like eyes, eyebrows, nose, mouth, shape of the face, shape of the mouth, etc are extracted from the face images for the identity of a person. The invariance of geometric properties among the face features is used for recognizing the face. The various face databases such as ORL, JAFFE, Yale, Face94, FERET database etc., are used to obtain the recognition rates. As mentioned by Anil K. Jain et al., the two most popular recognition approaches are[2]:

- Measuring the location and shape of facial attributes;
- Analyzing the overall face image as "a weighted combination of a number of canonical faces".

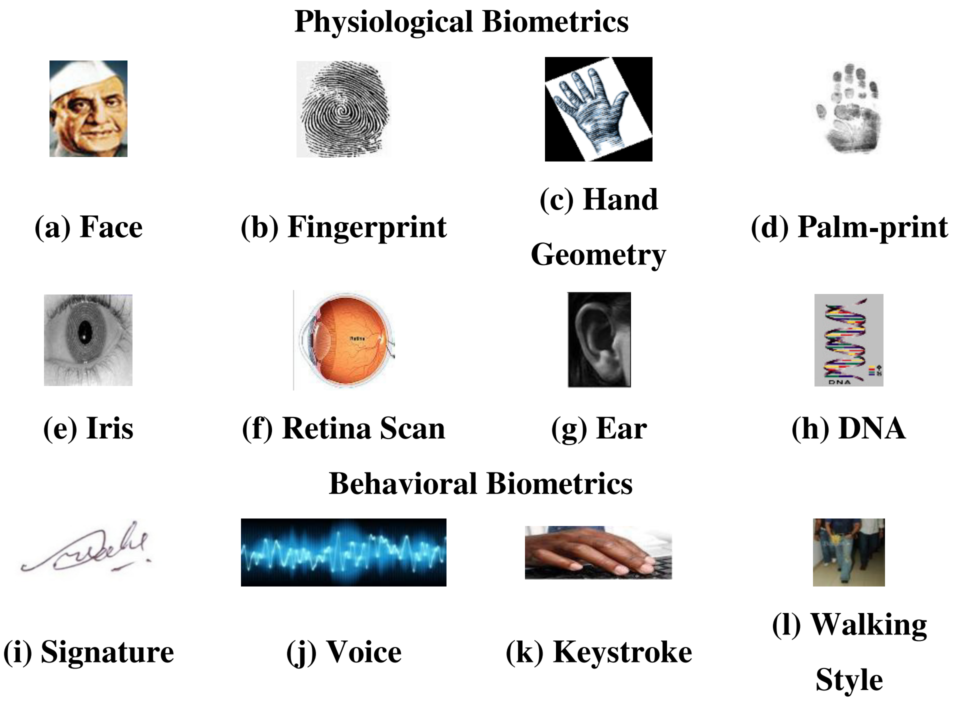

Figure 2: Biometric Classification.

Fingerprint: Fingerprint identification is well established and a mature science. It has also been extensively tested in various legal systems and is accepted as an international standard for identification. The law enforcement agencies are principle users of fingerprints; various electronic readers are now commonly available and are used for authentication purposes, mainly in access control applications. No two individuals have been found to have identical fingerprints. Smooth and clean surfaces record better quality fingerprints but fingerprints can also be found on irregular surfaces such as paper. There are three basic categories of fingerprint:[15]

- Visible prints or patent made in oil, ink or blood
- Latent prints which are invisible under normal viewing conditions; and
- Plastic prints which are left in soft surfaces such as new paint.

Hand Geometry: The recognition of human hand based on the many measurements including its shape, size of palm, and length and width of the fingers.[16] The actual shape and dimensions of your hand are sometimes used for access control and time-and-attendance operations in the workplace. That shape of a person's hand (after a certain age) does not significantly change its shape. As compared to some other biometric identification (fingerprints), hand geometry does not produce a large data set. The physical size of a hand geometry-based system is large, and it cannot be embedded in certain devices like laptops.[17] Therefore a large number of records, hand geometry biometrics may not be able to distinguish one individual from another who has similar hand characteristics.

Palm-print: The palm is a pattern of ridges and valleys as like the fingerprints. The study of palm print is an ancient practice to know the personal details of a person and also for the astrologers. Palm features[18] are unique for an individual with rich information on it like principal lines and wrinkles, textures and ridges are used for identifying a person. Palm features are extracted using high or low resolution cameras. The features of the palm such as geometry of hand, ridge and valley features, principal lines, and wrinkles may be combined to build a highly accurate biometric system. Latent palm print is of growing importance in forensic applications.

Iris: Iris biometrics is the unique feature characteristics of human iris because it remains unchanged individuals lifetime. The iris is the annular region of the eye bounded by the pupil and the sclera (white of the eye). The complex iris texture carries very distinctive information useful for personal recognition.[19-20] Early iris-based recognition technique required considerable user participation and were expensive. The newer systems have become more users friendly and cost effective. While iris system have a very low false Accept Rate (FAR) compared to other biometrics traits, the False Reject Rate (FRR) of these systems can be rather high.[21]

Retina Scan: Retinal scan is the example of secure biometrics because it is not easy to change or replicate the retinal vasculature.[22] Basically the retina is a thin nerve on the back of the eye. It is a part of eye which senses light and transmits impulses through the optic nerve to the brain. Blood vessels used for identification which are located along the neural retina. This technique involves using a low-intensity infrared light source through an optical coupler to scan the unique patterns of retina. The reflection of vascular information is being recorded. Retina scanning works for identification as well as verification. The additional advantages include the small template size and good operational speed.

Ear: The shape of an ear is different from person to person. An ear biometric is based on matching the distance of salient points on the pinna from a landmark location on the ear. The features of ear are very distinctive in establishing the identity of an individual user.[23] A sensor such as a camera collects a side profile image of the user's head, from which the system automatically locates the ear and isolates it from the surrounding hair, regions of the face, and the user's clothes. A combination of color and depth analysis algorithm is used to localize the ear pit and then generates an outline of the visible ear region.

DNA: DNA (Deoxyribonucleic Acid) provides the most reliable form of identification of all the biometric identification systems. It is powerful digital and unchangeable during a human's life and even after death. Deoxyribonucleic acid (DNA) can be collected from various sources such as blood, finger nails, hair, mouth swabs, saliva, straws, etc., that has been attached to the human body. DNA is currently used mostly in forensics applications for identifying people. DNA biometrics differs from standard biometrics in several ways[24]:

- DNA requires a tangible physical sample as opposed to an impression, image, or recording.
- DNA matching is not done in real-time, and currently not all stages of comparison are automated.
- DNA matching does not employ templates or feature extraction, but rather represents the comparison of actual samples.

DNA matching has become a popular use in criminal trials. There are many complexities surrounding the issue of biometrics of DNA, such as biometrics and health issues, private information, access to DNA and data. The process of DNA is slowly and costly.[25-26]

3.2. Behavioral Biometrics

Signature: Signature verification uses behavioral biometrics of a hand written signature to confirm the identity of a person. A person does not make a signature in a fixed manner; hence the data obtained from any one signature from an individual has to allow for a range of possibilities. Signature recognition is based on the dynamics of making the signature like acceleration rates, directions, pen pressure, stroke length, etc., rather than a direct comparison of the signature after it has been written.[27] The major difficulty with this technology is to differentiate between the consistent parts of a signature. These are the characteristics of the static image and the behavioral parts of a signature which vary with each signing.

Voice: Our voices are uniquely different to each person, and cannot be exactly replicated. Voice is a combination of physiological and behavioral characteristics of a person. Speech or voice recognition systems can discriminate between two very similar voices, including twins. The features of individual's voice are based on the shape and size of vocal tracts, mouth, nasal cavities and lips that are used in the synthesis of sound.

The benefits of voice biometric systems are mostly used for telephone-based applications.[28] It can be automated and used with speech recognition. The weakness of the system is a high false non-matching rate. Speaker/voice verification focuses on the vocal characteristics that produce speech and not on the sound or the pronunciation of the speech itself. Voice verification is used for call centres, healthcare, government, electronic commerce, financial services, and customer authentication for service calls.

Keystroke: Keystroke biometrics or typing dynamics is the detailed timing information that describes exactly when each key was pressed and when it was released as a person is typing at a computer keyboard.[29] The behavioral biometric of keystroke dynamics uses the manner and rhythm in which an individual types characters on a keyboard or keypad. The keystroke rhythms of a user are measured to develop a unique biometric template of the users typing pattern for future authentication. Such type of technique is classified into two types like static and dynamic verification techniques. The static verification uses a neural network approach while the dynamic verification is using statistics.

Walking style (Gait): The walking style of a person is also known as the Gait of the person. Gait is a behavioral biometric and may not remain invariant, especially over a long period of time, due to fluctuations in body weight, major injuries involving joints or brain. It is more specific as a study of human motion, using the eye and the brain of observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles.[30] Gait is not supposed to be very distinctive, but is sufficiently discriminatory to allow verification in some low-security applications.

Table 2: Comparison of Biometrics based on Physiological & Behavioral parameters[31-32]

Biometrics	Circumvention	Permanence	Acceptability	Uniqueness	Universality	Collectability	Measurability
Face	Low	Medium	High	High	High	High	High
Fingerprint	High	Medium	Medium	High	Medium	Medium	High
Hand	Medium	Low	Medium	Medium	High	Medium	Medium
Palm Print	Medium	Medium	Medium	Medium	Medium	Medium	High
Ear	Low	High	High	High	Medium	High	High
Iris	Low	Medium	Low	High	Medium	Low	High
Retina	Low	Medium	Low	High	Medium	Low	High
DNA	Low	Medium	High	High	Medium	Low	Low
Signature	High	Medium	Medium	High	Low	Medium	High
Voice	High	Medium	High	Medium	High	High	High
Keystroke	Medium	Medium	High	Medium	Medium	Medium	Medium
Gait	Low	Medium	High	Medium	High	High	Medium

4. CHALLENGES, ADVANTAGES AND APPLICATIONS

4.1 Challenges

Some of the possible challenges/difficulties in Physiological and Behavioral Authentication for a machine are listed below.

- Face recognition is an eminent biometric trait offers several challenging tasks. Some of them are pose variation; illumination-different lighting conditions; persons wearing collusions such as hat, scrap, eye glasses, etc.; aging effect; various facial expressions degrades the performance of the system.
- The recognition rate of biometric profile degrades when the finger is wet and wrinkled. Research needs to be focused to address when the finger is wet and wrinkled towards development of system.
- The research should be advanced to reduce the hardware requirements.
- The recognition rate degrades, when the human eyes are covered by some occlusions and if the face images with various facial expressions are captured from the device.
- Research in this area needs to be more improved to assure its reliability against important factors namely contact lenses, eye glasses, watery eyes etc.
- In retinal scan, it has to be developed to distinguish and identify individual wearing glasses or lens.
- DNA approach is not automatic and the method of acquisition of samples needs to be developed.
- Keystroke technology has to be developed more to increase the accuracy.
- Long term reliability and lack of accuracy are the main issues to be focused in signature approach.
- In speech recognition, the technology needs to be advanced to store the unique digital code by decreasing the space. And also, the accuracy degrades, when the person's voice changes.

4.2 Advantages & Applications

The advantages of adopting biometrics for authentication of an individual are listed below.

- **Security:** The biometric systems offer a higher degree of security than conventional methods. Security is a primary concern at airports, harbor, ATM machines, border checkpoints, network security, control accesses to buildings, and e-mail authentication on multimedia workstations. Face recognition technology have been implemented at many airports around the world as a security purpose.

- **Accountability:** The biometric-based authentication systems are able to keep track of the user's activities. Better alternate of saving time and resources.
- **Scalability:** The biometric-based authentication systems are easily scalable. No remembering of passwords or login ID's is required. Elimination of need of carrying authorized documents.

Computer vision applications are universally used in digital camera, mobile phones, security areas, cars, toys, hospitals, airports. The primary applications of biometric authentication systems are person verification (matching) and person identification (one-to-many comparison). Some of the applications of biometric systems are[33-34] access control application can achieve high accuracy, surveillance, image database investigations, general identity verification, smart card applications, criminal analysis systems, automatic attendance and time monitoring in classes, banking systems, boarding pass for personal authentication, home security systems, electronic voting and ATM machine to secure an individual, military force to authenticate refugee; also schools, colleges, companies, government offices, and other private sectors to authenticate employees, Entry to high security places such as parliamentary house and defense zone.

5. CONCLUSION

Biometric Authentication System is widely adopted and accepted technology everywhere to authenticate an individual's human identity. This paper makes a review study of the existing Physiological and Behavioral biometric methodologies, advantages, comparisons of various biometrics traits and applications. The advantages of adopting biometrics for authentication of an individual are meaningful for the society. The research needs to be more focused to address above challenges in order to implement reliable biometric recognition system. The biometric features can be easily acquired and measured for the processing only in the presence of a person. The biometric recognition systems have been proved to be accurate and very effective in different applications. The use of biometrics raises several privacy questions such as in case of face recognition privacy will be wiped out. In spite of all these, it is quite sure that in future biometric based recognition will have a great influence on our day-to-day life. Scientific work is very important for future applications and progress in the biometrics.

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FACE RECOGNITION USING FEATURE EXTRACTION TECHNIQUE

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ABSTRACT:
Face Recognition is a type of biometric software application. It is an active and alive research field spread over the several areas, machine learning, image analysis, image processing, pattern matching-recognition and neural networks. It is hand-free and non-intrusive method of identifying individual human faces by the feature extraction technique and classification of faces. Feature extraction is one of the most important researches in computer vision. This paper compares the different feature extraction approaches such as Gabor Filter, Singular Value Decomposition (SVD), Discrete Cosine Transform, Discrete Wavelet Transform, and Dimensional Reduction techniques such as eigen-face approach (PCA), fisher-face approach (LDA) are used to extract the useful features for human face recognition. The main focus of this paper is to improve the robustness of Automatic Face Recognition Systems.

Keywords :- Face recognition, Feature extraction. Gabor Filter, DCT, SVD, PCA, LDA.

INTRODUCTION :

A biometric system is a pattern recognition system that operates by acquiring biometric data from an individual, extracting a feature set from the acquired data, and comparing this feature set against the template set in the database. When the first time user uses a biometric system called as enrolment. During this, biometric information from an individual is captured and stored in the database. Then biometric information is detected and compared with the stored information at the time of enrolment. The sensor is the interface between the real world and the system. Any biometric system[1] includes two different modes: verification mode and identification mode.

FACE RECOGNITION

Face is one of the most acceptable biometrics because of most common method of identification which use in their visual interaction. There are two primary approaches to the identification based on face recognition. The first approach is Transform approach [2-3] and the most popular vectors are eigenfaces. Each eigenface is derived from covariance analysis of face image, two faces are considered to be identical if they are nearly close in eigenface feature space. Another approach is Attribute-based [4]. The facial attributes like eyes, eyebrows, nose, mouth, shape of the face, shape of the mouth, etc are extracted from the face images for the identity of a person. The invariance of geometric properties among the face features is used for recognizing the face.

The main advantages of face biometrics is that this method is hands-free and non-intrusive (identification can continuously be performed from a distance). It has high accuracy in recognition in environment and highly approved by the majority of users. Face recognition is an active and live research area as face verification is used in applications like face tracking, CCTV,

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criminal detection, forensic evidence etc. to enable this biometric technology we require a PC camera or video camera. As mentioned by Anil K. Jain et al., the two most popular recognition approaches are [1]:

- Measuring the location and shape of facial attributes (e.g. distances between pupils or from nose to lip or chin);
- Analyzing the overall face image as "a weighted combination of a number of canonical faces".

Detecting faces in a given image and recognizing persons based on their face images are classical object recognition problem that have received extensive attention. Because of advances in information technology and demand for high security and surveillance, human face recognition is one of the most important biometrics. This work is motivated to develop a feature extraction technique for recognising human face.

FEATURE EXTRACTION TECHNIQUES

Face recognition commonly includes feature extraction, feature reduction and recognition or classification. Many researchers have tried to develop various feature extraction[5-8] techniques for human face recognition. They specify various existing techniques of feature extraction for human face recognition process. Feature extraction is to find the most representative description of the faces, making them can be most easily distinguished from others.

The usage of a mixture of techniques makes it difficult to classify these systems based purely on what types of techniques they use for feature representation or classification [5]. Recognition or classification is to choose the best available measure method such as Euclidean distance, which is used to classify the feature of face images present in the database and test image. Features may be symbolic, numerical or both. The various feature extraction techniques for human face recognition are divided into Geometric and Photometric approaches. Geometric approaches consider individual features such as eyes, nose, mouth and a shape of the head and then develop a face model based on the size and the position of these characteristics. In photometric approaches the statistical values are extracted, subsequently, these values are compared with the related templates.

Gabor Filter:

The Gabor filter [9-13] is an image processing tool which is applied for feature extraction that stores the information about the digital images [9]. Gabor functions first proposed by Dennis Gabor as a tool for signal detection in noise. Denis Gabor [10] showed that there exists a "quantum principle" for information. The time-frequency domain for 1D signal must necessarily be quantized so that no signal or filter can occupy less than certain minimal area in it. A large number of researches have been devoted to feature extraction based on Gabor filter [11-12,14].

The characteristics of Gabor wavelets are quite similar to those of human visual system for frequency and orientation representations. This Gabor-wavelet based extraction of features directly from the gray-level images is successful and widely been applied to texture segmentation and fingerprint recognition. Gabor Wavelet filter works as a band pass filter for the local spatial frequency distribution, achieving an optimal resolution in both spatial and frequency domains.

A face image is convolved with Gabor filter of five spatial frequencies and eight orientations, The Gabor filters with the different frequencies and orientations, which form the Gabor filter bank, have been used to extract features of face images. Following figure shows a family of Gabor wavelets on ORL face image.

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Singular Value Decomposition:

The basic idea behind SVD[17] is taking high variable set of data points and reducing it to a lower dimension set that better exposes the substructure of the original data more clearly by ordering the lower dimensional data from most variance to the least. It is a powerful linear algebra technique for solving linear-equations in the least-square sense, and works even for singular matrices or matrices numerically close to singular.

The SVD are known to be more robust than usual eigen vectors of covariance matrix. This is because, the robustness are determined by the directional vectors rather than mere scalar quantity like magnitudes (Singular value stored in S). SVD can be used to find a solution of a set of linear equations corresponding to a singular matrix that has no exact solution it locates the closest possible solution in a least-square sense [18]. The advantage of SVD over eigen decomposition that for a prescribed accuracy of computation SVD requires half the numerical precision of eigen decomposition [19].

Discrete Cosine Transform:

The Discrete Cosine Transform (DCT) [20-21] captures both frequency and location information (location in time). DCT is similar to the Discrete Fourier Transform (DFT) in the sense that they transform a signal or image from the spatial domain to the frequency domain, use sinusoidal base functions, and exhibit good de-correlation and energy compaction characteristics. Discrete Cosine Transform (DCT) of an N*M image has used for feature extraction. In this matrix high frequency components are located at the top left corner of the matrix and the low frequency components are located at the bottom right corner of the matrix. The selection static coefficient selection approach is used for the coefficient. In this approach the most prominent coefficients are selected from a DC coefficient [19,20,22] using zigzag manner diagonally as Figure 5.

Above figure 5 shows two components AC (Alternate Current) and DC (Direct Current) [23]. The AC components represent individual pixel value while DC component represents the whole image. Discrete Cosine Transform has the properties of decorrelation, energy compaction, orthogonality and separability. The advantages of DCT [20] feature extraction is a better job of concentrating energy in to lower order coefficients. The disadvantage of the DCT feature extraction technique is that the DCT features are sensitive to changes in the illumination direction. Only spatial co-relation of pixel inside the single 2D-block is considered and co-relation from pixel of neighboring block is neglected and the magnitude of the DCT coefficients is not spatially invariant. The output array of Discrete Coefficient Transform coefficients contains integers. DCT is easier to implement computationally and also efficient to consider a set of basic functions which given a known input array size 8×8 [24].

Principal Component Analysis:

Principal Component Analysis (PCA) [25-31] is a dimensionality reduction technique that is used for image recognition and compression. This reduction in dimensions removes information that is not useful and precisely decomposes the face structure into orthogonal (uncorrelated) components known as Eigen faces. In PCA, Eigenfaces recognition derives its name from the German prefix 'eigen', meaning 'own' or 'individual'. The basic idea of using the eigenfaces was first proposed by Kirby and Sirovich [26] using Karhunen-Loeve(KL) transform to represent human faces. This approach was very successful in representing faces using the above mentioned analysis. It is also known as Karhunen-Loeve transformation (KLT) or eigenspace projection [25-26]. In this method, faces are represented by a linear

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combination of weighted eigenvector, known as eigenfaces. PCA can be applied to the task of face recognition by converting the pixels of an image into a number of eigenface feature vectors, which can then be compared to measure the similarity of two face images.

The PCA algorithm is as follows:

1. Acquire an initial set of face images (the training set and testing set) and form its feature vector representation.
2. Calculate the covariance matrix.
3. Form the Eigen-faces according to the highest Eigen value of the covariance matrix.
4. Classify the given face image, according to the Euclidean distance and threshold values.

Linear Discriminant Analysis (LDA):

Linear Discriminant Analysis (LDA) [32-35] is a powerful face recognition technique that overcomes the limitation of Principal Component Analysis technique by applying the linear discriminant criterion. LDA is a dimensionality reduction technique which is used only for classification problem not for regression. The main aim is to find the linear combinations of the data that maximize the ***between-class*** variability while minimizing the ***within-class*** variability. This means it tries to find a new reduced subspace that provides the best separation between the different classes in the input data. Each face image is considered in higher dimensional space. After applying LDA to the data to get new vectors called as Fisher faces. The face image is then projected from two dimensional spaces to C dimensional space, where C is the number of classes of the images. The LDA method tries to find the subspace that discriminates different face classes.

The LDA algorithm is applied to all face images as below:

1. Acquire the training set and test set of face images and form its feature vector representation.
2. Calculate the within class and between-class covariance matrices S_W and S_B matrices.
3. Classify the given face image, according to the Euclidean distance and threshold values.

Discrete Wavelet Transform (DWT):

Discrete Wavelet Transform (DWT) [36] is used in image and signal analysis. It decomposes an image into a set of basic functions called wavelets and the decomposition is defined as the resolution of an image. Wavelets are functions that satisfy certain mathematical requirements and are used in presenting data or other functions, similar to sine and cosine in the Fourier transform. However, it represents data at different scales or resolutions, which distinguishes it from the Fourier transform. Two-dimensional DWT is implemented as a set of filter banks, comprising of a cascaded scheme of high-pass and low-pass filters. 2D-DWT decomposes an image into 4 “sub-bands” that are localized in frequency and orientation, by LL, HL, LH, HH [37].

Discrete Wavelet Transform (DWT) [38-40] is obtained by filtering the signal through a series of digital filters at different scales. The scaling operation is done by changing the resolution of the signal by the process of subsampling. In DWT, the input sequence is decomposed into low-pass and high-pass sub-bands, each consisting of half the number of samples in the original sequence. The band LL is a closer approximation to the original image. The bands LH and HL record the changes of the image along horizontal and vertical directions, respectively. The HH band shows the high frequency component of the image. Second level decomposition can then be conducted on the LL sub band. The various wavelet transforms like Daubechies wavelets, Coiflets, Biorthogonal wavelets, and Symlets are different in mathematical properties such as symmetry, number of vanishing moments and orthogonality.

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Classification Technique:

After extracting the face features, the next step is to classify the face image using classification [41]. Classification techniques [42-44] such as supervised or unsupervised learning will then be selected on the basis of the training data sets. Various classification techniques will be compared with the training data, so that an appropriate decision rule is selected for subsequent classification. The classified results should be checked and verified for the recognition accuracy and reliability.

Appearance-based face recognition algorithms use a wide variety of classification methods. Sometimes two or more classifiers are combined to achieve better results. According to Jain, Duin and Mao [43], there are three concepts that are the key in building a classifier - similarity, probability and decision boundaries.

The goal of achieving correct classification rate according to the characteristics required has been always desired. Feature extraction greatly affects the design, development and performance of the classifier, and it is one of the core issues of face recognition research.

CONCLUSION:

As an important component of pattern recognition, feature extraction has been paid close attention by many scholars, and currently has become one of the research hot spots in the field of pattern recognition. This paper deals with feature extraction techniques for human face recognition. We have presented different approaches to automatic face recognition using concepts of different feature extraction techniques with classifications. The main focus was to improve the robustness of Automatic Face Recognition Systems taking into consideration different variations of face images of each individual.

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Table 1: Similarity based Classifiers

Method	Description
Template Matching	Assign sample to most similar template
Nearest Mean	Assign pattern to nearest class mean
1-Nearest Neighbor (1-NN)	Assign pattern to nearest pattern's class
k-Nearest Neighbor (k-NN)	Like 1-NN, but assign to the majority of k-nearest pattern
Subspace Method	Assign pattern to nearest class subspace

Table 2: Probability based Classifiers

Method	Description
Neural Network Classifier	Classifier which maps any input pattern to a number of classifications.
Bayes Classifier	Assign pattern to the class with the highest estimated posterior probability
Logistic Classifier	Predicates probability using logistic curve method
Parzen Classifier	Bayesian classifier with Parzen density estimates

Table 3: Decision boundary based Classifiers

Method	Description
Minimum Distance Classifier	Identity covariance matrix. Euclidean distance
Fisher Linear Discriminant (FLD)	Linear classifier. Can use MSE optimization.
Binary Decision Tree (BDT)	Nodes are features. Can use FLD.
Perceptron	Iterative optimization of a classifier (e.g. FLD)
Multi-layer Perceptron	Two or more layers. Uses sigmoid transfer functions.
Radial Basis Network (RBN)	Optimization of a Multi-layer perceptron. One layer at least uses Gaussian transfer functions.
Support Vector Machines (SVM)	Maximizes margin between two classes.

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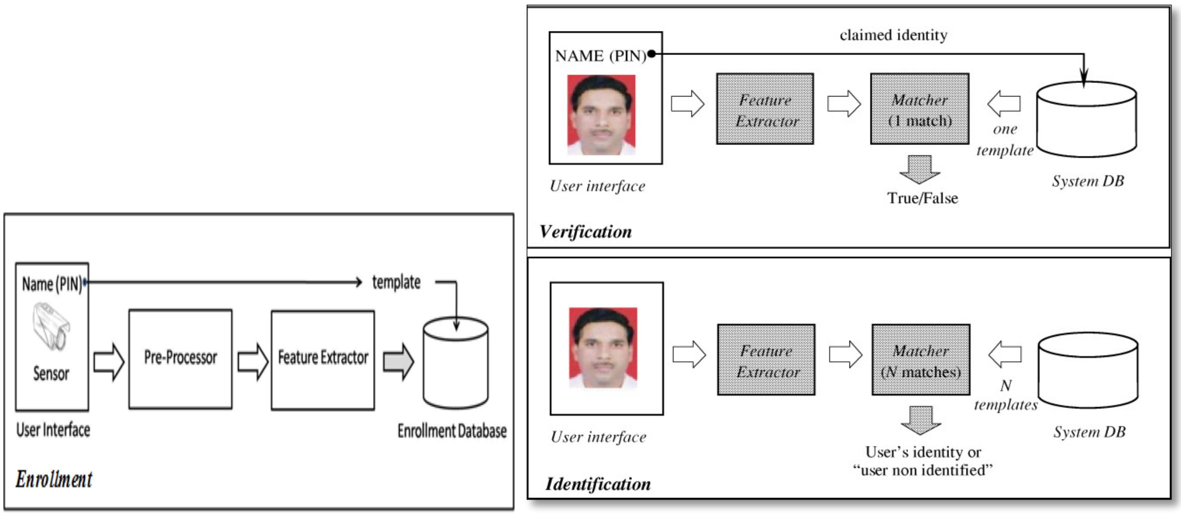
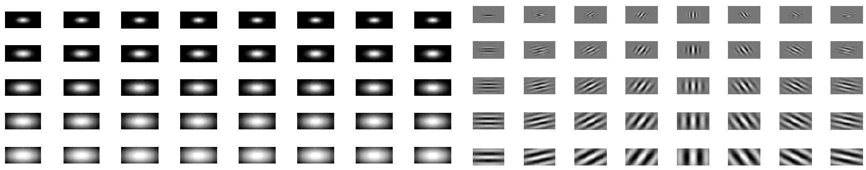


Fig. 1: Block diagram of a biometric system [1].



(a) (b)

Fig. 2: (a) Magnitude of Gabor Filter, and (b) Real part of Gabor Filter with 5 different scales and 8 different orientations

Fig. 3 Original face image from ORL database

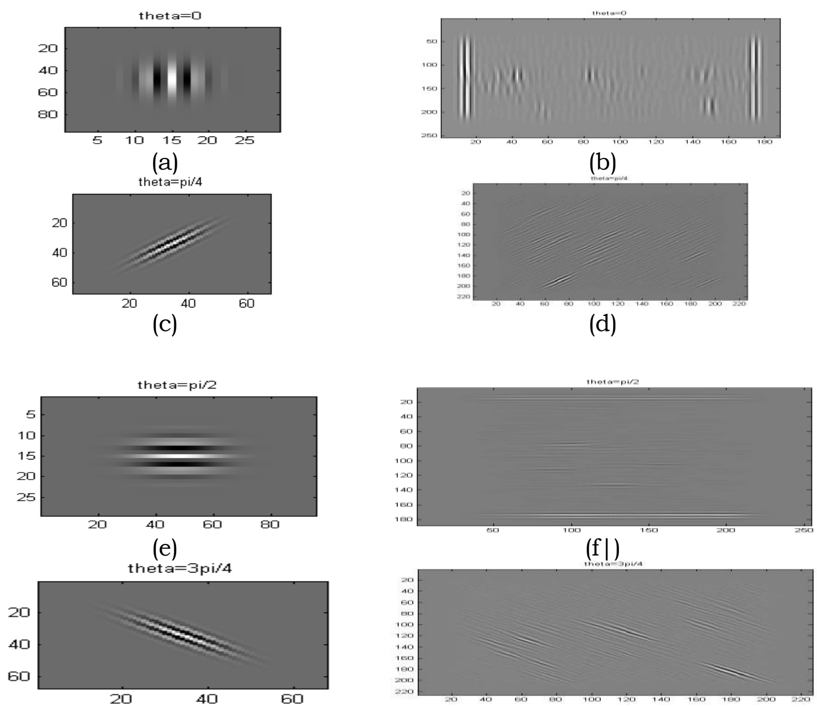


Fig.4: Gabor Wavelets (a), (c), (e), (g) and its filters (b), (d), (f), (h) on different values of theta (θ=0, π/4, π/2, 3π/4) from figure 3 [15-16]

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I J R B A T, Issue (XI) Vol (II) May 2023 : 126-136
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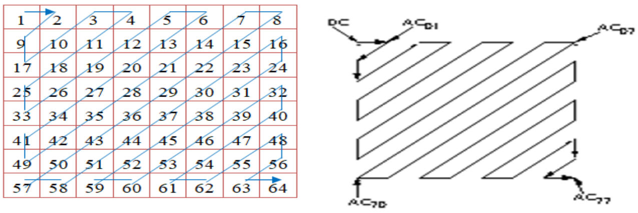
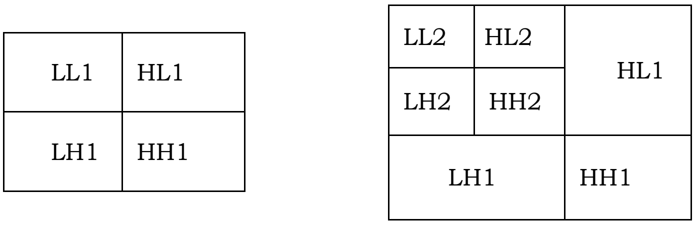


Fig. 5: Zigzag Scanning of DCT coefficients of 8x8 pixel image for Feature Vector



(a) (b)
Fig.6: Discrete Wavelet Transform: a) 1-D DWT b) 2 level 2-D DWT

Fig. 7: Original face image from ORL and its 2D-Decomposition at level 1

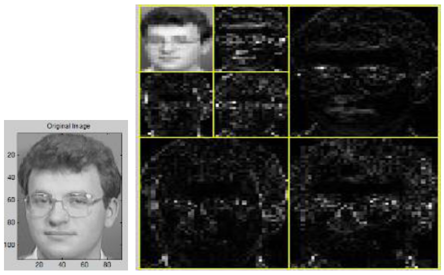


Fig. 8: Original face image from ORL and its 2D-Decomposition at level 2

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