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Implementation of the Linear Discriminant Analysis Algorithm for Feature Extraction in Face Pattern Recognition

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Abstract

In recent years, biometric technologies such as retina scanning, fingerprint recognition, voice recognition, and facial recognition have advanced rapidly and been widely implemented, particularly in security systems for identification and verification. Among these modalities, the human face possesses unique characteristics that make it highly suitable for recognition systems. However, facial recognition by computers remains a complex task that requires highly accurate algorithms. Deep learning has played a crucial role in improving the accuracy and speed of facial recognition systems, particularly in handling lighting variations and pose changes. This study focuses on the implementation of the Linear Discriminant Analysis (LDA) algorithm for feature extraction and facial classification. LDA has been proven to reduce data dimensionality without losing essential information and improve accuracy by maximizing inter-class differences while minimizing intra-class variations. Therefore, LDA offers an effective solution for developing structured, efficient, and accurate facial recognition systems.

Keywords: *facial recognition, biometrics, feature extraction, deep learning, Linear Discriminant Analysis (LDA)*

1. Introduction

In recent years, biometric technologies such as retina scanning, fingerprint recognition, voice recognition, and facial recognition have advanced rapidly and begun to be applied in various sectors, including security systems for identification and verification purposes. The human face has unique characteristics that can be utilized for identification and verification processes, for example in attendance systems, national ID card issuance, and security systems. For humans, recognizing another person's face is an easy task visually. However, for devices such as computers, this task is quite complex and requires precise and reliable programs [1].

Humans can identify individuals based on biological features of the face, but the ability of the human eye has limitations. Therefore, computerized methods are needed for face recognition in situations requiring greater accuracy and efficiency. Face recognition involves automatic detection operations followed by the verification of a person's face from an image or video [2]. The use of computerized methods for face recognition can overcome human limitations and provide more efficient and accurate solutions.

The implementation of efficient information systems is key in addressing the challenges of face recognition. Deep learning technology can improve recognition accuracy while maintaining optimal response speed. This approach is highly effective in overcoming issues such as lighting variations and changes in facial poses. This study also highlights the importance of protecting personal data in the use of face recognition technology and offers solutions to ensure compliance with privacy regulations [3]. Common challenges that arise in accuracy testing include differences in lighting levels between datasets and test subjects, as well as changes in facial attributes such as hairstyles or the presence of beards, which may affect results. Test results show that the eigenface PCA method achieves better accuracy performance compared to eigenface LDA, with the highest accuracy rate of 98.06% achieved through the PCA combination [4].

Given the need for a face recognition system, the application of the appropriate classification method can be a solution. The author is therefore interested in raising this issue as a final project entitled "Implementation of the Linear Discriminant Analysis Algorithm for Feature Extraction in Face Pattern Recognition." Ayu Anggrestianingsih, Agus Wahyu Widodo, and Muhammad Tanzil Furqon (2019) explained that the implementation of the Linear Discriminant Analysis (LDA) method for elective course classification can provide a systematic approach to data management. The LDA method allows for data classification by maximizing differences between categories, which in this context can be applied to classify and evaluate classic vehicles based on various features and criteria [5]. Rachmat Destriana (2021) also showed that LDA can be used in the classification of pineapple ripeness levels, highlighting the ability of this method to distinguish categories based on relevant features.

The application of the Linear Discriminant Analysis (LDA) method in face recognition systems is crucial because LDA can perform face classification more efficiently and accurately based on certain conditions and criteria. LDA works by reducing the dimensionality of facial data, which is usually very large, without losing important information, thus facilitating analysis and classification processes. In addition, LDA maximizes the distance between classes (i.e., different individuals) and minimizes variation within a class (i.e., variations in the same individual's face), making it ideal for identifying facial differences more accurately. In the context of face recognition information systems, the use of LDA produces a more structured, measurable, and efficient solution for handling face recognition, both in terms of evaluation and transactions, thereby improving the overall performance of the system [6]..

2. Literature Study

The word "rancang" comes from the verb "merancang," which means to arrange or plan something. Meanwhile, the term "perancangan" is a noun form referring to that process. However, the term "rancang bangun" is also often used to describe the activity of designing [7].
In the context of technology, an application is a computer program based on data processing. The word "aplikasi" itself comes from the English word application, which means implementation or usage [7]. An application can be defined as a tool designed to help users achieve specific goals.

Applications are designed as programs that have been fully developed to carry out certain functions according to user needs. In a broader context, an information system is a collection of applications that support organizational operations, including hardware installation, software maintenance, and data management. Simply put, an application is software created to perform specific functions, either for individual or group users, depending on their needs or intended use [9].

A website, often referred to as a "site," is a URL-based platform that functions as a storage place for data and information on a particular topic. In general, all pages on the internet are hosted by web servers. These servers can be accessed through a local area network (LAN) or a specific internet address (URL) [14].

Websites have become an inseparable part of internet development. As a collection of pages containing various information, websites can be easily accessed by anyone, anytime, and anywhere via the internet. Moreover, the information provided can be accessed online 24 hours a day without being limited by space and time [15].

Computer vision is a technology that enables the detection of surrounding objects. This study discusses the optimization of computer vision technology in robots to move objects based on color. This robotic system is designed to recognize and move colored balls according to the detected color. Computer vision technology using the Pixy 2 camera is capable of detecting colored objects in real time, with an optimal detection time of 0.2 seconds per object. In testing, object recognition was carried out three times for each color, showing an accuracy rate of 100%. Optimizing computer vision helps robots recognize colored objects more efficiently [16].
Skin is an elastic layer that protects the body from various external environmental influences. In addition to being the largest and heaviest organ, the skin consists of three main layers: the epidermis, dermis or corium, and subcutaneous tissue or subcutis. Caring for facial skin to keep it healthy and fresh is an important investment for the future. Before treatment, it is essential to recognize each person's facial skin type.

Facial skin is more sensitive compared to the rest of the body's skin. Various factors, both external and internal, can affect the condition of facial skin. External factors include sun exposure, climate, pollution, air conditioning, skin trauma, as well as the use of inappropriate skincare or cosmetic products. Meanwhile, internal factors may include hormonal changes during puberty, menstruation, pregnancy, birth control pill usage, or suboptimal nutrition intake [18].

The face is also the part of the body most frequently seen by others and plays an important role in communication and emotional expression. Along with rapid technological development, image processing such as facial recognition systems has become an inseparable part of everyday life [19].

The face is one of the most common physiological parameters used to create biometric security systems. This is due to the uniqueness of each individual's face, which cannot be completely identical. Face recognition is one of the biometric identification methods that uses facial features as the main parameter. Research related to face recognition has been carried out for more than three decades and continues to be developed to this day [20].

A database is a collection of data organized to serve many applications simultaneously by storing and managing data so that it appears to be located in one place. A database is a structured storage of data/information. Application programs are programs/applications that users will use to interact with the database. An application program (or a set of interconnected programs) is used to carry out a series of database activities (create, read, update, and delete) on behalf of database users. The user interface is the layout/design that interacts with the user.

A use case diagram represents the behavior of an information system that will be built and modeled using use cases in the form of simple communication between actors and strategies that allow actors to achieve their goals. Use cases are used to determine what functions exist in the information system and who has permission to use them. Use case diagrams are classified into behavioral aspects, in which each aspect is described in detail. Each use case translates the behavior that the system must perform and its relationship between one or more actors [17].

3. Method

3.1. Analysis

In the system analysis, the author conducted an analysis of the current system, the method, and the proposed system. The diagram of the method steps is shown in Figure 3.1 below.

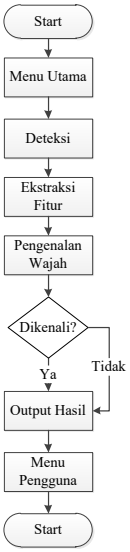

Fig 1: Steps of the Method

3.2. Current System Analysis

A facial recognition system is a technology used to identify or verify an individual's identity based on facial features. However, its implementation still faces several major challenges, such as sensitivity to pose variations, lighting conditions, and facial attributes like expressions or accessories. These challenges often cause a decrease in accuracy during the identification or verification process.

Currently, many facial recognition systems rely on conventional feature extraction methods, which may be less optimal in handling facial data variability. As a result, facial recognition systems may experience reduced efficiency and accuracy, particularly when dealing with complex or unstructured facial data.

To overcome these obstacles, this research aims to apply the Linear Discriminant Analysis (LDA) algorithm as a feature extraction method. LDA is expected to enhance the system's ability to detect important facial patterns, thereby improving accuracy and efficiency in the recognition process. By designing an information system based on LDA technology, facial recognition can be performed more quickly, accurately, and reliably under various conditions.

3.3. Method Analysis

In this research, the Linear Discriminant Analysis (LDA) method is used as the main technique for feature extraction in facial pattern recognition. The following is the method analysis conducted:

1. Basic Principle of Linear Discriminant Analysis (LDA)
   LDA is a statistical technique aimed at maximizing class separation while minimizing within-class variability. It works by finding a feature space direction that maximizes the ratio between inter-class variance and intra-class variance. In the context of facial recognition, LDA helps identify important facial features that effectively distinguish individuals.
2. Advantages of LDA in Facial Feature Extraction
   a. Dimensionality Reduction: LDA reduces the dimensionality of facial data while retaining only the most relevant features for classification. This lowers computational costs without sacrificing important information.
   b. Efficient Classification: By utilizing the optimized feature space, LDA improves facial classification accuracy, especially in datasets with many classes.
   c. Robustness to Data Variability: LDA can handle some variability caused by differences in pose or lighting, as long as these variations are not extreme.
3. Limitations of the Method
   a. LDA is sensitive to the assumptions of normality and covariance among features. If the data does not meet these assumptions, its performance may decline.
   b. It is not optimal when the number of training samples per class is smaller than the initial feature dimensions, a condition known as the small sample size problem.
   c. Its effectiveness decreases when dealing with datasets containing very extreme pose or lighting variations.
4. Application of LDA in Facial Recognition Systems
   a. Preprocessing: Facial data undergoes preprocessing steps such as illumination normalization and cropping based on the facial area.
   b. Feature Extraction: LDA is applied to extract the most relevant facial features.

c. Classification: Extracted features are then used in classification algorithms, such as Nearest Neighbor or Support Vector Machine (SVM), to perform identification or verification.
d. Output Results: The system provides recognition results in the form of the identified individual's identity or an "unrecognized" status if the face does not exist in the database.

Through this analysis, LDA is expected to be implemented effectively to improve the performance of facial recognition systems in terms of both speed and accuracy.

3.4. Proposed System Analysis

Proposed System Analysis for LDA-Based Facial Recognition

1. Main Menu (Home)
   The main menu serves as the entry point to various application features. It includes a Start Detection button, which allows users to initiate the facial recognition process. Additionally, this menu may display basic information such as camera status or the number of successfully recognized faces.
2. Facial Recognition System
   a. Detection Process: The system automatically detects faces using face detection algorithms.
   b. Feature Extraction: Once a face is detected, facial features are extracted using LDA to obtain an optimal and compressed facial representation.
   c. Classification: Extracted feature data is matched with stored data in the database for identification or verification.
   d. Output Results: The system outputs recognition results, either the recognized individual's identity or an "unrecognized" status if the face is not in the database.
3. User Data Menu
   This menu displays user data recognized by the system, including:
   a. List of Individuals: Displays the names and data of registered individuals.
   b. Detection History: Provides information on detection time and location, including date and time records.
   c. Data Management: Allows administrators to add, edit, or delete user data in the database.
4. Advantages of the Proposed System
   a. Real-Time: Designed to operate in real-time, enabling direct facial recognition without significant delay.
   b. Accurate: With the application of LDA, the system improves recognition accuracy even under variations in pose or lighting.
   c. User-Friendly: The interface is designed to be simple, making it easy for users with minimal technical background.

The proposed system is expected to address major challenges in facial recognition, such as accuracy and efficiency, while also providing a better user experience. With this analysis, the system development process will be more focused, and the resulting system will be better aligned with user needs..

4. Result

The results of the research conducted by the author are presented as follows:

4.1. Main Menu Display

Fig 2: Website Display

This website provides various menus designed to make it easier for users to extract faces from images through an intuitive process. The functions of each button available are:

a. Face List
   This button is used to add a new face to the database. It is useful when saving someone's face for reference or for training the face detection model.
b. Edit Face
   This feature allows users to edit or update previously registered face information, such as changing the name or replacing the image used.
c. Delete Face
   Used to remove face data from the system if it is no longer needed for detection.
d. Choose File

This menu allows users to manually select an image from their device, which will then be used for the face detection process.

e. Upload & Detect
After selecting a file, users can click this button to upload the image and automatically run the face detection process on the selected image.

f. Clear Screen
This button clears the previous detection results from the screen, allowing the user to start a new process without interference from past data.

g. About Application
This menu opens an information modal containing the technical explanation and concepts behind the application, such as the use of the Linear Discriminant Analysis (LDA) method in the face identification process.

4.2. New Face List Display

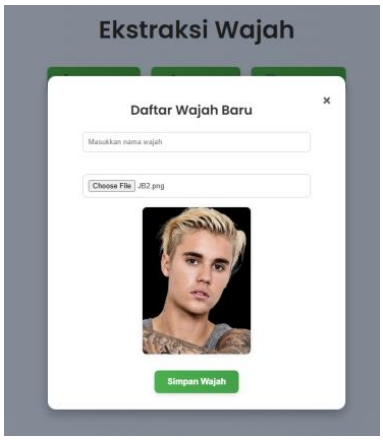

Fig 3: New Face List

This form is used to add new faces into the system or the application's face database. This feature is important as the basis for future face recognition and comparison processes.
Form Components:

a. Enter Face Name
A text input field to provide a label or identity name for the face being registered. The name will be used as a reference when the system performs face matching.

b. Choose File
Allows the user to select a face image from a local device. The selected image will be processed and stored along with the entered name.

c. New Image Preview
Once a new image is selected, it is displayed below immediately, helping the user verify the correct file before saving.

d. Save Face
Submits the name and image file to the server/application system. After pressing, the face will be saved and can be used for future detection and comparison.

e. Close Button (X)
Located at the top right corner to close the form if the user does not wish to continue adding a new face.

4.3. Edit Face Display

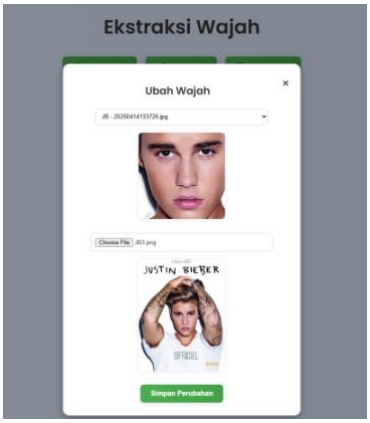

Fig 4: Edit Face

This feature allows users to update face images that were previously registered in the system. It is very useful when there is a clearer, newer, or different expression image to improve detection accuracy.
Form Components:

a. Face Selection Dropdown
Users can choose which face to update from a list of saved file names. Each entry typically has a unique identity (e.g., name + timestamp).
b. Old Face Image
Displayed automatically after the user selects a face from the dropdown. Helps identify the selected face for updating.
c. Choose File (New Image)
Button to select a new face image from the local device. This image will replace the old one in the selected entry.
d. New Image Preview
Shows the new image once selected, ensuring it is correct before saving.
e. Save Changes
Confirms and saves the face update into the system. The old image will be replaced by the new one.
f. Close Button (X)
Located at the top right to close the edit form if the user decides not to continue with the update.

4.4. Delete Face Display

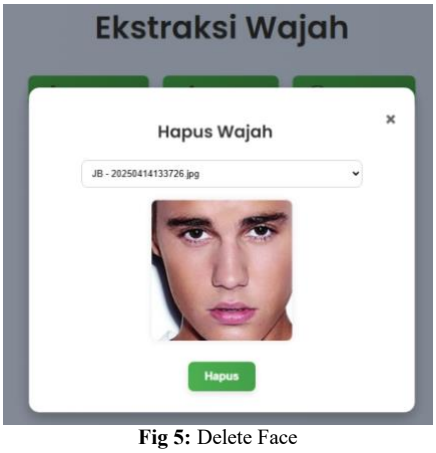

Fig 5: Delete Face

This feature is used to delete previously stored face data from the system. It is useful when a face entry is no longer needed or to keep data management organized.
Form Components:
a. Title "Delete Face"
Indicates that this interface is for removing stored face data.
b. Face Selection Dropdown
Allows users to choose which face to delete, based on stored name or label.
c. Face Image Preview
After selection, the system displays the face preview to confirm the correct face is being deleted.
d. “Delete” Button
A green button used to confirm the deletion of the selected face from the system. Once pressed, the data will be permanently removed from the database or storage folder.
e. “X” (Close) Button
Located at the top right corner to close the form without deleting.

4.5. Upload and Detect Display

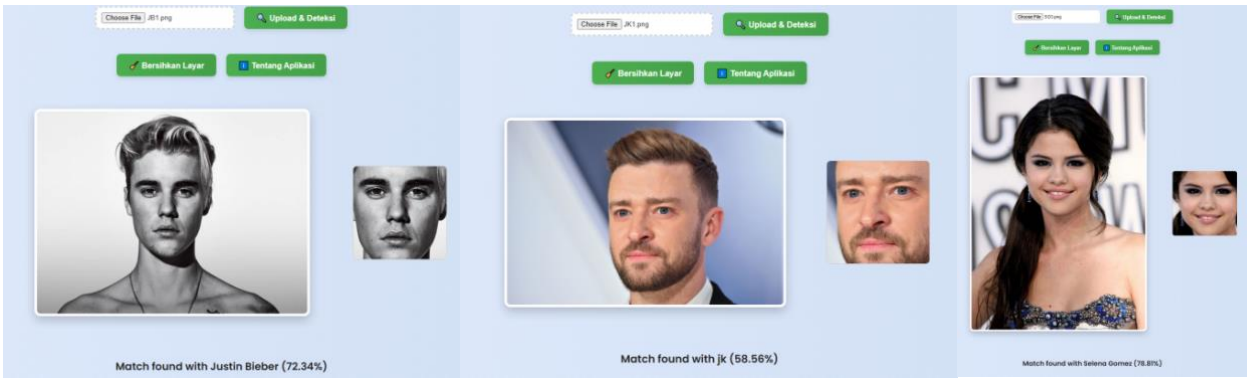

Fig 7: Upload & Detect

This feature allows users to upload a face image, after which the system performs face detection and recognition to identify whether the face is already known in the system, along with its similarity level.
Form Components:
a. Input File (Choose File)
For selecting an image from the local computer.

Example file: JB1.png

b. "Upload & Detect" Button
Once an image is selected, pressing this button will:
Upload the image to the server

c. Detect faces in the image
Match the detected face against faces stored in the database

d. Detection Results – After processing, the display will show:
The uploaded image (large, on the left)
Matching face(s) from the database (on the right)
The similarity percentage between the uploaded face and the database face(s).
Example: Match found with Justin Bieber (72.34%)

4.6. About Display

Fig 8: About Display

This section shows information about the application.

5. Conclusion

The conclusions of the research are as follows: High Efficiency and Accuracy in Face Verification The system is capable of verifying identities quickly and accurately by utilizing advanced face recognition algorithms, making it highly suitable for various security and real-time identification applications. Flexible and Ready for Further Development — With an intuitive design and the ability to integrate with other technologies such as IoT and machine learning, this system has the potential to be continuously developed on a large scale and in dynamic environments.

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