Mini Project Report

Entitled

Face Recognition Using Machine Learning

Submitted to the Department of Electronics Engineering in Partial Fulfilment for the Requirements for the Degree of

Bachelor of Technology
(Electronics and Communication)

: Presented & Submitted By :

Akshat Soni	U21EC091
Mahendra Choudhary	U21EC116
Yashkumar Sadhu	U21EC135

B. TECH. III (EC), 6th **Semester**

: Guided By :

Dr. Kishor Upla
Assistant Professor, SVNIT

(Year: 2023-24)

DEPARTMENT OF ELECTRONICS ENGINEERING
SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY
Surat-395007, Gujarat, INDIA.

Sardar Vallabhbhai National Institute Of Technology

Surat - 395 007, Gujarat, India

DEPARTMENT OF ELECTRONICS ENGINEERING

CERTIFICATE

This is to certify that the Mini-Project Report entitled "**Face Recognition Using Machine Learning**" is presented & submitted by Akshat Soni, Mahendra Choudhary, and Yashkumar Sadhu, bearing Roll No. U21EC091, U21EC116, and U21EC135, of B.Tech. VI, 6^{th} Semester in the partial fulfillment of the requirement for the award of B.Tech. Degree in Electronics & Communication Engineering for academic year 2023-24. They have successfully and satisfactorily completed their **Mini-Project** in all respects. We, certify that the work is comprehensive, complete and fit for evaluation.

Dr. Kishor Upla
Assistant Professor & Project Guide

Abstract

Facial recognition is an important application of computer vision and machine learning techniques. This ML project report explores using the OpenCV library and K-Nearest Neighbors (KNN) algorithm to build a real-time facial recognition system. After providing background on the history and motivation for facial recognition technology, the report outlines the overall process of face detection, data preparation, and face classification. Key methods are described including Haar feature-based cascade classifiers for face/eye detection and the KNN algorithm for face recognition from a dataset of labeled facial images. The implementation details cover the Python code using OpenCV to capture video frames, extract faces, generate training data, and build the KNN face classifier model. Experimental results are presented demonstrating the working face and eye detection followed by recognizing individuals' faces in real-time video. While highly capable, the limitations of current facial recognition technologies are discussed such as challenges with image quality, angles, and environmental factors. Potential future enhancements are also explored utilizing more advanced deep learning techniques and 3D facial modeling. Overall, this hands-on project provides insights into developing a facial recognition application by applying fundamental machine learning concepts.

Table of Contents

List of Figures

List of Abbreviations

AAM	Active Appearance Model
API	Application Programming Interface
CCTV	Closed-Circuit Television
CNN	Convolutional Neural Network
DARPA	Defense Advanced Research Project Agency
DL	Deep Learning
DMV	Department of Motor Vehicles
FPS	Frames Per Second
FRR	False Rejection Rate
FAR	False Acceptance Rate
HMM	Hidden Markov Model
HR	gh Resolution
ICP	Iterative Closest Point
IDE	Integrated Development Environment
IoT	Internet of Things
KNN	K-Nearest Neighbors
LDA	Linear Discriminant Analysis
LFA	Local Feature Analysis
LR	Low Resolution
MP	Megapixels
MPs	Megapixels
MSE	Mean Squared Error
NM	Nearest Mean
ORL	Olivetti Research Laboratory
OSH	Optimal Separating Hyperplane
OTP	One Time Password
PCA	Principal Component Analysis
PSNR	Peak Signal to Noise Ratio
SSD	Single Shot MultiBox Detector
SVM	Support Vector Machine
UUID	Universally Unique Identifier

Chapter 1
Face Detection and Recognition

1.1 Overview

Nowadays advancement of man-made brainpower is effectively creating; they open up tremendous potential outcomes before us. The investigation, gauging, and detection went to another level with the utilization of man-made reasoning advancements. As of late, an incredibly encouraging field of research is Computer vision. Face detection is a phase where identifying faces from images or video sources.[2] It may be very well utilized for remote distinguishing proof administrations for security in regions, for example, banking, transportation, law requirement, and electrical businesses.[1]

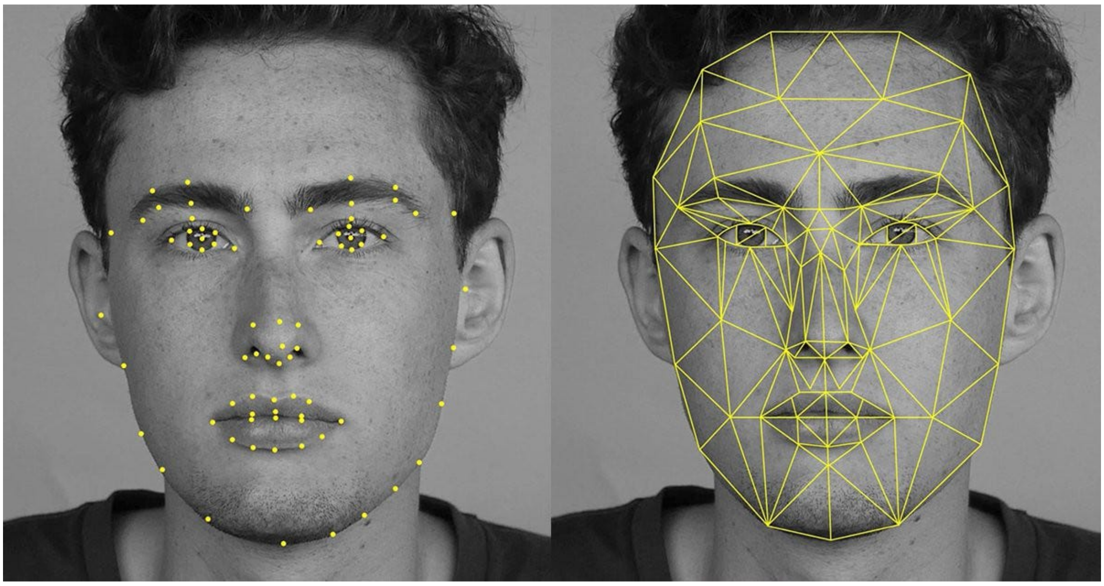

Figure 1.1: Basic parameter of a human face to be detected

Having huge varieties in visual upgrades because of evolving conditions, maturing, and interruptions like whiskers, glasses, and haircut changes, this capacity is extremely powerful. The objective here is to provide an easier human-machine interaction routine concern to face detection and recognition technology With the help of a regular web camera, a machine can detect and recognize a person's face from the previously stored database of faces.

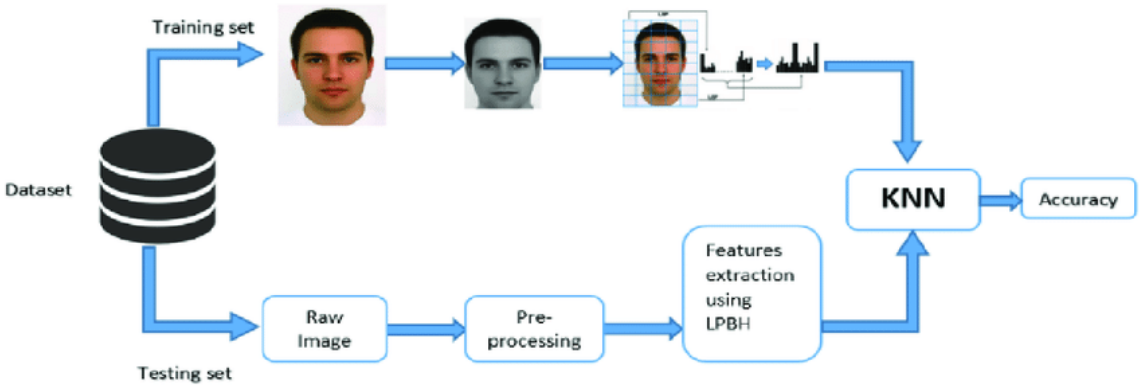

Figure 1.2: Face recognnition using KNN

1.2 Applications

Face recognition systems are useful in various expects such as security systems, biometric scans and voting purposes, and law enforcement or justice solution by always being one step ahead of the world's ever-advanced criminals.

The advantages of security and safety have prompted many industries to implement facial recognition technology into their daily operations[5].

1.2.1 Automobile Security

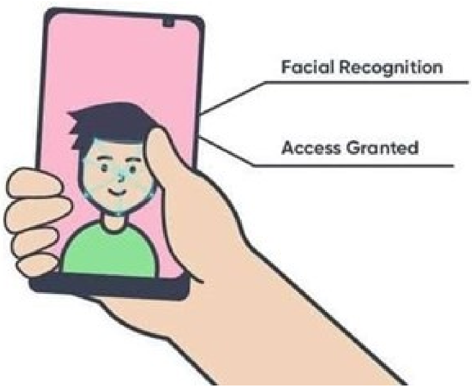

Figure 1.3: Showcasing Automobile Security

Facial recognition technology has become increasingly prevalent in various aspects of our daily lives, sometimes without us even realizing it. While we may not consciously ponder the intricacies of this technology regularly, it is essential to understand its diverse applications.[4]

One familiar context in which facial recognition is utilized is in the security and transportation industry. Armored trucks, as you mentioned, are prime examples of this. These vehicles are responsible for safeguarding high-value items, whether it's classified information or a substantial amount of cash. In these situations, facial recognition technology, depicted in Figure 1.3, plays a critical role in enhancing security measures. It helps ensure that only authorized personnel have access to the contents of the truck. Moreover, it can be employed to monitor the driver's attention, ensuring they are focused on the road and maintaining a high level of alertness to prevent potential security breaches.[5]

In addition to the security sector, ride-sharing applications have also harnessed the power of facial recognition. These apps employ facial recognition technology to confirm the identity of both passengers and drivers. For passengers, this means they can be certain that they are getting into the correct vehicle and not falling victim to imposters. For drivers, it provides an extra layer of safety, as they can be sure that they are picking up the right passenger. This verification process enhances the overall security and trustworthiness of ride-sharing services, fostering a safer and more reliable transportation experience.

The versatility of facial recognition technology is not limited to these specific applications. It has found its way into various other domains, including access control systems, payment authentication, and even the healthcare sector for patient identification. As technology continues to advance, we can expect facial recognition to become an even more integral part of our lives, contributing to both security and convenience in various contexts.

1.2.2 Access Control

Facial recognition technology is expanding its presence beyond cars and smartphones, with applications emerging in home security and access control. Homeowners can now utilize facial recognition to grant access to their IoT devices and even their homes, replacing traditional keys with a more secure and convenient alternative.[3] Smart door locks and surveillance cameras equipped with facial recognition help ensure that only authorized individuals can enter the premises, offering protection against unauthorized access and potential home invasions. As this technology continues to advance, it has the potential to make homeowners feel more secure within their living spaces, bolstering both security and convenience.

However, it's important to carefully address privacy and security concerns associated with facial recognition in the home. Striking the right balance between the benefits of this technology and potential risks is essential to ensure that it's deployed responsibly and ethically, preserving the privacy and security of residents.

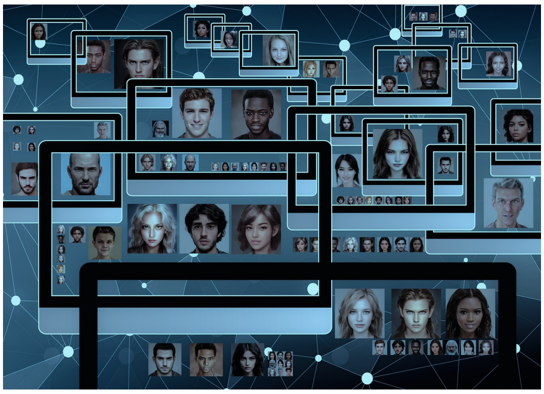

Figure 1.4: Showcasing Automobile Security

1.2.3 Education

Other than federal and local security, facial recognition applications may exist most prominently in the education sector. A growing number of schools already use cameras that utilize facial recognition software to identify students, staff, unauthorized individuals, and even behavior that could present a threat to safety. This is one of many new tech trends that are transforming education. For schools using this technology, the main benefit they see is tracking student attendance as well as maintaining the security of their campus. Unfortunately, technology can be very biased and studies have shown evidence for the software to be banned.

1.2.4 Immigration

Immigration offices exist as an extension to more well-known government segments. Facial recognition technology is used to enforce stricter border control, particularly when it comes to criminals and persons of interest who attempt to cross the border.

Chapter 2
Face Recognition using OpenCV and KNN

Face recognition is a crucial security application. Through this project, a very basic form of face recognition has been implemented using the Haar Cascades Classifier, openCV and K-Nearest Neighbors Algorithm.

Face recognition is an easy task for humans but it's an entirely different task for a computer. Very little is known about human recognition to date on How do we analyze an image and how does the brain encode it are inner features (eyes, nose, mouth) or outer features (head shape, hairline) used for successful face recognition?[10] Neurophysiologist David Hubel and Torsten Wiesel have shown that our brain has specialized nerve cells responding to specific local features of a scene, such as lines, edges, angles or movement. Since we dont see the world as scattered pieces, our visual cortex must somehow combine the different sources of information into useful patterns. Automatic face recognition is all about extracting those meaningful features from an image, putting them into a useful representation and performing some classifications on them.

The whole process can be divided into three major steps where the first step is to find a good database of faces with multiple images for each individual. The next step is to detect faces in the database images and use them to train the face recognizer and the last step is to test the face recognizer to recognize the faces it was trained for.

2.1 Brief on KNN

KNN stands for K-Nearest Neighbors, which is a simple yet effective algorithm used for both regression and classification tasks in machine learning. It is a non-parametric and instance-based learning algorithm[9]. In KNN, the input consists of the k closest training examples in the feature space.

The output depends on whether KNN is used for classification or regression as following:

KNN for Classification: For classification tasks, the KNN algorithm assigns a class to an unlabeled data point based on the majority class among its k-nearest neighbors. The class is determined by the mode of the classes of the k-nearest data points.

KNN for Regression: For regression tasks, the KNN algorithm predicts the value of a target variable for an unlabeled data point based on the average or weighted average of the values of its k-nearest neighbors. The predicted value is the mean of the values of the k-nearest data points.

KNN is based on the assumption that similar data points exist in close proximity to each other. It doesn't involve any training process but relies on the stored labeled training data to make predictions or estimations. One of the key decisions in using the KNN algorithm is choosing the appropriate value of k, the number of neighbors to consider when making a prediction.

2.2 Technology Stack

Python - Thw whole code has been written in Python

cv2 - cv2 is the OpenCV module and is used here for reading writing images also to input a video stream

Algorithm — KNN
Classifier — Haar Cascades **Working/Implementation**

2.3 Generating Training Data

The following steps are followed to generate training data

- Write a Python Script that captures images from your webcam video stream.
- Extracts all Faces from the image frame (using haar cascades).
- Stores the Face information into NumPy arrays.
- Read and show video stream, capture images.
- Detect Faces and show bounding box (haar cascade).
- Flatten the largest face image(gray scale) and save it in a NumPy array.
- Repeat the above for multiple people to generate training data.

```
import cv2
import numpy as np

cap = cv2.VideoCapture(1)
face_cascade = cv2.CascadeClassifier("
   haarcascade_frontalface_alt.xml")

skip = 0
```

```
face_data = []
dataset_path = "./face_dataset/"

file_name = input("Enter the name of person : ")


while True:
    ret,frame = cap.read()

    gray_frame = cv2.cvtColor(frame,cv2.COLOR_BGR2GRAY)

    if ret == False:
        continue

    faces = face_cascade.detectMultiScale(gray_frame,1.3,5)
    if len(faces) == 0:
        continue

    k = 1

    faces = sorted(faces, key = lambda x : x[2]*x[3] , reverse = True)

    skip += 1

    for face in faces[:1]:
        x,y,w,h = face

        offset = 5
        face_offset = frame[y-offset:y+h+offset,x-offset:x+w+offset]
        face_selection = cv2.resize(face_offset,(100,100))

        if skip % 10 == 0:
            face_data.append(face_selection)
            print (len(face_data))


        cv2.imshow(str(k), face_selection)
        k += 1

        cv2.rectangle(frame,(x,y),(x+w,y+h),(0,255,0),2)

    cv2.imshow("faces",frame)
```

```python

    key_pressed = cv2.waitKey(1) & 0xFF
    if key_pressed == ord('q'):
        break

face_data = np.array(face_data)
face_data = face_data.reshape((face_data.shape[0], -1))
print (face_data.shape)


np.save(dataset_path + file_name, face_data)
print ("Dataset saved at : {}".format(dataset_path + file_name
    + '.npy'))

cap.release()
cv2.destroyAllWindows()
```

2.4 Building the face classifier

Recognise Faces using the classification algorithm — KNN.

- load the training data (NumPy arrays of all the persons)
- x- values are stored in the NumPy arrays
- y-values we need to assign for each person
- Read a video stream using OpenCV
- extract faces out of it
- use knn to find the prediction of face (int)
- map the predicted id to name of the user
- Display the predictions on the screen — bounding box and name

```python
import numpy as np
import cv2
import os

#KNN Algothithm Code

def distance(v1, v2):
```

```python
#Eucledian Distance
    return np.sqrt(((v1-v2)**2).sum())

def knn(train, test, k=5):
    dist = []

    for i in range(train.shape[0]):
        # Get the vector and label
        ix = train[i, :-1]
        iy = train[i, -1]
        # Compute the distance from test point
        d = distance(test, ix)
        dist.append([d, iy])
    # Sort based on distance and get top k
    dk = sorted(dist, key=lambda x: x[0])[:k]
    # Retrieve only the labels
    labels = np.array(dk)[:, -1]

    # Get frequencies of each label
    output = np.unique(labels, return_counts=True)
    # Find max frequency and corresponding label
    index = np.argmax(output[1])
    return output[0][index]


cap = cv2.VideoCapture(1)
face_cascade = cv2.CascadeClassifier("haarcascade_frontalface_alt.xml")

dataset_path = "./face_dataset/"

face_data = []
labels = []
class_id = 0
names = {}


# Preparing Dataset
for fx in os.listdir(dataset_path):
    if fx.endswith('.npy'):
        names[class_id] = fx[:-4]
        data_item = np.load(dataset_path + fx)
        face_data.append(data_item)

```

```python
        target = class_id * np.ones((data_item.shape[0],))
        class_id += 1
        labels.append(target)

face_dataset = np.concatenate(face_data, axis=0)
face_labels = np.concatenate(labels, axis=0).reshape((-1, 1))
print(face_labels.shape)
print(face_dataset.shape)

trainset = np.concatenate((face_dataset, face_labels), axis=1)
print(trainset.shape)

font = cv2.FONT_HERSHEY_SIMPLEX

while True:
    ret, frame = cap.read()
    if ret == False:
        continue
# Converting frame to grayscale
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)

# To Detect multiple faces in the image
    faces = face_cascade.detectMultiScale(gray, 1.3, 5)

    for face in faces:
        x, y, w, h = face

        # Get the face ROI
        offset = 5
        face_section = frame[y-offset:y+h+offset, x-offset:x+w+offset]
        face_section = cv2.resize(face_section, (100, 100))
        out = knn(trainset, face_section.flatten())

        # Draw rectangle in the original image
        cv2.putText(frame, names[int(out)],(x,y-10), cv2.FONT_HERSHEY_SIMPLEX, 1,(255,0,0),2,cv2.LINE_AA)
        cv2.rectangle(frame, (x,y), (x+w,y+h), (255,255,255), 2)
    cv2.imshow("Faces", frame)
    if cv2.waitKey(1) & 0xFF == ord('q'):
        break
cap.release()
cv2.destroyAllWindows()
```

Below is the flowchart for facial recognition

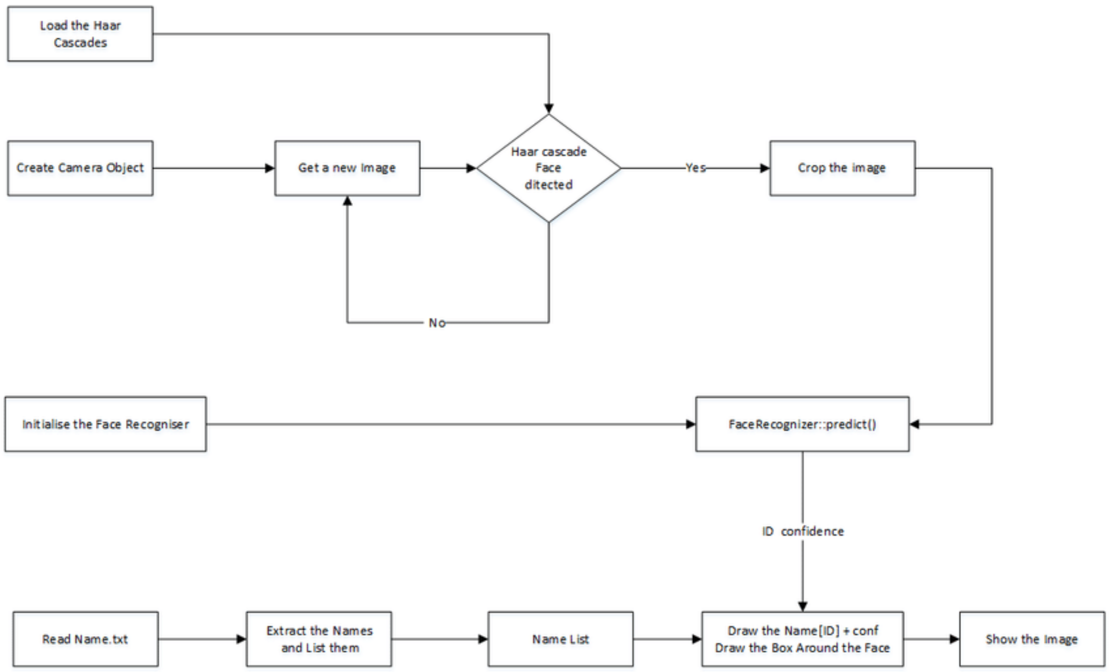

Figure 2.1: Flowchart to show process

2.5 Testing Face Recognition

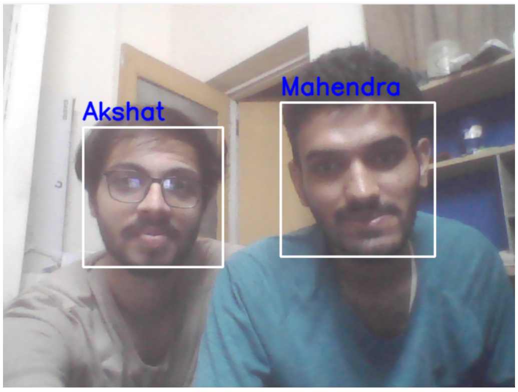

Figure 2.2: Face Recognition

Chapter 3
Conclusion

3.1 Summary

This ML project report showed the development of a real-time facial recognition system using computer vision and machine learning techniques. The key technologies employed included OpenCV (Open Source Computer Vision Library) for image and video processing, Haar feature-based cascade classifiers for face and eye detection, and the K-Nearest Neighbors (KNN) algorithm for facial recognition and classification.

The Haar cascades, though relatively simple compared to modern deep learning methods, demonstrated the ability to effectively detect faces and facial features like eyes in real-time video streams. This approach leverages hand-crafted features and a cascaded classifier structure to rapidly scan images and locate regions of interest.[9]

To build the facial recognition component, the KNN algorithm was utilized. This involved first generating a training dataset by capturing multiple images of individuals' faces, extracting the face regions, and storing them as labeled data. The KNN model was then trained on this dataset, enabling it to classify new face images by finding the nearest neighbors in the feature space and predicting the corresponding identity.

The implementation in Python combined these techniques, integrating OpenCV for video input, Haar cascades for face/eye detection, and KNN for recognition[13]. Experimental results demonstrated the system's capability to detect and recognize faces accurately in real-time video feeds.

Overall, this project provided insights into the practical implementation of facial recognition systems, combining established computer vision methods with machine learning algorithms to achieve real-time performance and laying the groundwork for further advancements in this rapidly evolving field.

3.2 Limitations of Facial Recognition Technology

Despite the promising potential of facial recognition systems, they currently face several key limitations. One major challenge is the impact of varying image quality, lighting conditions, and camera angles on the system's performance. Low-resolution or poorly lit images, as well as faces captured at non-frontal angles, can significantly reduce the accuracy of facial detection and recognition algorithms. Additionally, occlusions such as glasses, facial hair, or other obstructions can further hinder the system's ability to reliably identify individuals. These factors highlight the need for more robust and adaptable algorithms that can handle diverse real-world scenarios effectively.

Surprisingly, people outperform technology when it comes to facial recognition. However, while watching a source video, people can only look for a few persons at a time. A computer can compare a large number of people against a database of thousands. As technology improves, higher-definition cameras will become available. Computer networks will be able to move more data, and processors will work faster.Facial recognition algorithms will be better able to pick out faces from an image and recognize them in a database of enrolled individuals.[14] The simple mechanisms that defeat today's algorithms, such as obscuring parts of the face with sunglasses and masks or changing one's hairstyle, will be easily overcome. An immediate way to overcome many of these limitations is to change how images are captured. Using checkpoints, for example, requires subjects to line up and funnel through a single point. Cameras can then focus on each person closely, yielding far more useful frontal, higher-resolution probe images. However, wide- scale implementation increases the number of cameras required. Bio-metric applications that are evolving are promising. They include movements, expressions, gait, and vascular patterns, as well as iris, retina, palm print, ear print, speech recognition, and smell signatures. A mix of modalities is preferable since it increases a system's ability to deliver findings with more certainty.

3.3 Future Work

Facial recognition has shown immense potential as a bio-metric identification technology with wide-ranging applications in security, surveillance, law enforcement, and various other industries. Despite its current limitations, the future of this technology appears promising as researchers continue to advance the underlying algorithms and hardware capabilities.

One promising direction is the integration of deep learning models, particularly convolutional neural networks (CNNs), which have shown superior performance in various computer vision tasks. These advanced models can learn more robust and discriminative features from facial images, improving recognition accuracy and generalization to diverse scenarios. Additionally, the incorporation of 3D facial modeling techniques could enhance the system's ability to handle varying head poses and facial expressions, providing a more comprehensive and robust solution. Furthermore, research into privacy-preserving facial recognition algorithms and ethical guidelines for deployment will be crucial as this technology becomes more widespread across various industries.

References

[1] Takeo Kanade, *Computer recognition of human faces*, Birkhäuser Basel, 1977.

[2] Woodrow Bledsoe, *Originates of Automated Facial Recognition 1964 to 1966*.

[3] Takeo Kanade, *Picture Processing System by Computer Complex and Recognition of Human Faces*, *Proceedings*, 1973.

[4] Wikipedia, *History of Face recognition technology*.

[5] Cordenne Brewster, *Application of facial recognition technology*, Blog Post.

[6] Ahmad Tolba, Ali El-Baz, Ahmed A El-Harby, *Face recognition: A Literature review*, *International Journal on Image Processing*, 2005.

[7] Nawaz Hawiz Barnouti, Sinan Sameer Ahmed, Waem Esam Matti, *Face recognition: A Literature Review*, *International Journal of Applied Information Systems (IJAIS)*, 2015.

[8] Matthew Turk, Alex Pentland, *Eigenfaces for recognition*, *Journal of cognitive neuroscience*, vol. 3, no. 1, pp. 71–86, MIT Press, 1991.

[9] Idenfy, *What is facial recognition?*, https://www.idenfy.com/blog/what-is-facial-recognition/, 2023.

[10] Balaji Sridharan, K Muneeswaran, Malathy Ramalingam, *Facial image recognition for biometric authentication systems using a combination of geometrical feature points and low-level visual features*, *Journal of King Saud University-Computer and Information Sciences*, vol. 34, no. 7, pp. 4109–4121, Elsevier, 2022.

[11] Wikipedia, *Face recognition technology*.

[12] Aditya Prasad, Asif Shaik, Abbu Vinay Babu, *Evaluation of Haar Cascade Classifiers for Face Detection*, *ICDIP: International Conference on Digital Image Processing*, 2012.

[13] Marrin Marry Solomo, Mahendra Singh Meena, Jagandeep Kaur, *Face Identification Based on K-Nearest Neighbor*, *Scientific Journal of Informatics*, vol. 6, no. 2, pp. 150–159, 2019.

[14] Marrin Marry Solomo, Mahendra Singh Meena, Jagandeep Kaur, *Challenges in Face Recognition Systems*, *International Journal of Student Research*, 2023, Seminar Report from provided PDF.