

Acknowledgment

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Abstract

The Attendance-Assistant project introduces an innovative, cross-platform mobile application designed to automate attendance tracking in educational institutions using advanced facial recognition technology. The system leverages Flutter for the frontend, ensuring a seamless and intuitive user experience, while the backend is powered by FastAPI and MongoDB, providing robust, secure, and scalable data management. This comprehensive solution streamlines the entire attendance workflow, encompassing user authentication, face-encoding management, real-time attendance marking, and detailed reporting.

This report documents the systematic approach undertaken to evaluate and compare various face recognition algorithms, focusing on their precision metrics, computational efficiency, and real-world applicability. After rigorous testing, the ResNet-based implementation in Python, utilizing the *face_recognition* library, was selected for its superior accuracy and reliability. The report further elaborates on the system architecture, database schema, and core functionalities, highlighting how the Attendance-Assistant enhances operational efficiency, accuracy, and user convenience compared to traditional attendance methods.

The project also explores the integration of IoT devices, such as Raspberry Pi, to enable real-time facial recognition in classrooms and other institutional settings. By combining cutting-edge technologies with a user-centric design, the Attendance-Assistant aims to revolutionize attendance management, offering a scalable and efficient solution for modern educational institutions.

Keywords

Facial Recognition, Attendance Automation, Flutter, FastAPI, MongoDB, ResNet, Educational Institutions, IoT, Raspberry Pi, Backend Development, Frontend Development, Data Integrity, Firebase, Precision Metrics, Attendance Management System

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Chapter 1

Introduction

Face recognition is a biometric technology that utilizes distinctive features of the face to identify individuals. Widely employed in security systems, it serves various applications such as access control, attendance tracking, and surveillance. While face recognition has existed for decades, recent advancements in machine learning and computer vision have significantly enhanced its accuracy and reliability. Numerous algorithms and techniques are available, each with unique strengths and weaknesses. In this seminar, we aim to compare popular face recognition algorithms and assess their performance using a standardized dataset.

1.0.1 Problem Statement

We need to compare the various face recognition algorithms and techniques to determine which one is the most accurate and efficient. We also need to discuss the implementation of these algorithms in real-world applications.

1.0.2 Need of the Project

- The motivation for this topic came from impending research for a Project titled "Machine Learning Powered Automated Facial Attendance Tracking System".
- The project aims to develop a system that can automatically track attendance using facial recognition technology.
- To achieve this goal, it is essential to understand the different face recognition algorithms and techniques available and evaluate their performance to identify the most suitable approach for the project.
- By comparing the performance of different face recognition algorithms and techniques, we can gain insights into their strengths and weaknesses and make informed decisions about which approach to use for the project.
- This seminar will provide a comprehensive overview of the most popular face recognition algorithms and techniques and evaluate their performance on a common dataset to help guide the development of the attendance tracking system.

This project will help in understanding the various face recognition algorithms and techniques and how they can be implemented in real-world applications. It will also help in understanding the challenges faced in face recognition and how these challenges can be overcome.

To use the correct method and library in finding attendance, so as to reduce time and cost, while also maintaining high levels of accuracy, it was necessary to compare the various face recognition algorithms and techniques.

Chapter 2

Literature Survey

2.1 Paper 1

Title: "A Comparative Study of Facial Recognition Techniques: With focus on low computational power." Author: Schenkel, T., Ringhage, O. and Branding, N. [7]

2.1.1 Positives and Learnings from this Paper

1. The publication compares five performance metrics, including recall and F-score, providing a comprehensive evaluation of facial recognition techniques.
2. It addresses the importance of balancing low computational time and prediction ability for security systems, offering practical guidelines for implementation.
3. The research questions are clearly defined, focusing on significant differences in performance, training time, and prediction time among different facial recognition techniques and classifiers.

2.1.2 Identified Research Gaps

1. The document lacks detailed information on the specific facial recognition techniques and classifiers used in the experiments.
2. It does not provide a detailed breakdown of the dataset used for training and testing the facial recognition models.
3. While the document mentions the comparison of results, it does not delve into the specific findings or implications of these comparisons.

2.2 Paper 2

Title: "A Comparative Study on Facial Recognition Algorithms" Author: Sanmoy Paul and Sameer Acharya [8]

2.2.1 Positives and Learnings from this Paper

1. Comparative Analysis: The study provides a comparative analysis of different facial recognition algorithms, allowing developers to make informed choices based on recognition accuracies.
2. Algorithm Selection: By studying the advantages and disadvantages of various algorithms, developers can select the best facial recognition algorithm for their specific implementation needs.

3. Future Improvements: The research suggests future efforts to test on a larger set of images to enhance the accuracy of CNN and explore combining multiple machine learning classification algorithms for increased recognition accuracy and handling large datasets.

2.2.2 Identified Research Gaps

1. The document lacks detailed discussion on the specific methodologies used for training and testing the algorithms, which could provide more clarity on the experimental setup.
2. There is no mention of the computational resources or hardware specifications used for running the experiments, which could impact the reproducibility and scalability of the results.
3. The publication does not delve into the potential biases or limitations in the dataset used for training and testing the facial recognition models, which could affect the generalizability of the findings.

2.3 Paper 3

Title: "*A comparison of facial recognition algorithms.*" Author: *Delbiaggio, Nicolas.* [9]

2.3.1 Positives and Learnings from this Paper

1. Thesis covers a comprehensive comparison of facial recognition algorithms like Eigenfaces, Fisherfaces, LBPH, and OpenFace.
2. The study includes a detailed explanation of each algorithm, their strengths, weaknesses, and performance in a test case scenario.
3. The findings highlight OpenFace as the most accurate algorithm for facial recognition, providing valuable insights for further research in the field.

2.3.2 Identified Research Gaps

1. Lack of Exploration of Real-World Applications: The paper focuses on comparing facial recognition algorithms in a controlled setting. However, it does not delve into the practical applications of these algorithms in real-world scenarios.
2. Limited Discussion on Algorithm Limitations: While the strengths of the algorithms are discussed, there is a lack of emphasis on the limitations of each algorithm.
3. Absence of Future Research Directions: The paper concludes with the identification of the most accurate algorithm but fails to suggest potential future research directions in the field of facial recognition.

2.4 Paper 4

Title: "*Evaluating impact of race in facial recognition across machine learning and deep learning algorithms.*" Author: *Coe, James, and Mustafa Atay.* [10]

2.4.1 Positives and Learnings from this Paper

1. The paper provides a detailed comparison of various facial recognition algorithms, including Eigenfaces, Fisherfaces, Local Binary Pattern Histogram, deep convolutional neural network algorithm, and OpenFace.
2. It highlights the efficiency and accuracy of these algorithms in real-life settings, with OpenFace being identified as the algorithm with the highest accuracy in identifying faces.

3. The study's findings offer valuable insights for practitioners in selecting the most suitable algorithm for facial recognition applications and suggest ways for academicians to enhance the current algorithms' accuracy further.

2.4.2 Identified Research Gaps

1. The paper focuses on a few specific facial recognition algorithms like Eigenfaces, Fisherfaces, and Local Binary Pattern Histograms. It lacks exploration of a wider range of algorithms available in the field, potentially missing out on newer, more accurate models.
2. While the study evaluates the algorithms' accuracy, it does not delve into their performance in real-life settings or practical applications. This gap could impact the algorithms' effectiveness when deployed in scenarios beyond controlled test environments.
3. The paper mentions the use of a custom dataset for testing the algorithms but does not elaborate on the dataset's diversity or size.

2.5 Paper 5

Title: "A Comparative Study of Facial Recognition Techniques: With focus on low computational power." Author: Schenkel, T., Ringhage, O. and Branding, N. [11]

2.5.1 Positives and Learnings from this Paper

1. Efficiency Evaluation: The paper provides a detailed comparison of popular open source facial recognition algorithms, highlighting the efficiency and accuracy of each in real-life settings.
2. Practical Implications: The findings of the study offer valuable insights for practitioners in selecting the most suitable algorithm for facial recognition applications, enhancing decision-making processes.
3. Academic Contribution: The research contributes to the academic field by emphasizing the importance of improving the accuracy of existing algorithms, paving the way for further advancements in facial recognition technology.

2.5.2 Identified Research Gaps

1. The paper focuses on comparing a few facial recognition algorithms like Eigenfaces, Fisherfaces, and Local Binary Pattern Histogram. However, it lacks a comparison with a wider range of algorithms to provide a more comprehensive analysis.
2. While the paper evaluates the algorithms' performance in a controlled environment using test datasets, it doesn't discuss the practical implementation challenges or results in real-life scenarios, which could be a crucial research gap.
3. The paper does not delve into the scalability and efficiency aspects of the facial recognition algorithms studied. Understanding how these algorithms perform with larger datasets or in real-time applications could be a significant research gap to address.

Chapter 3

Problem Statement

3.1 Project Scope

3.2 Project Assumptions

3.3 Project Limitations

3.4 Project Objectives

Chapter 4

Project Requirements

4.1 Resources

4.1.1 Human Resources

4.1.2 Reusable Software Components

4.2 Requirements

4.2.1 Software and Hardware Requirements

4.3 Risk Management

4.4 Functional Specifications

4.4.1 Interfaces

External Interfaces Required

Internal Interfaces Required

Communication Interfaces

Graphical User Interfaces

4.4.2 Interactions

Sustainability

Quality Management

Security

Chapter 5

System Analysis Proposed Architecture

5.1 Block Diagram

5.2 System Architecture

5.3 Modules of the Project

Chapter 6

Project Plan - Timeline

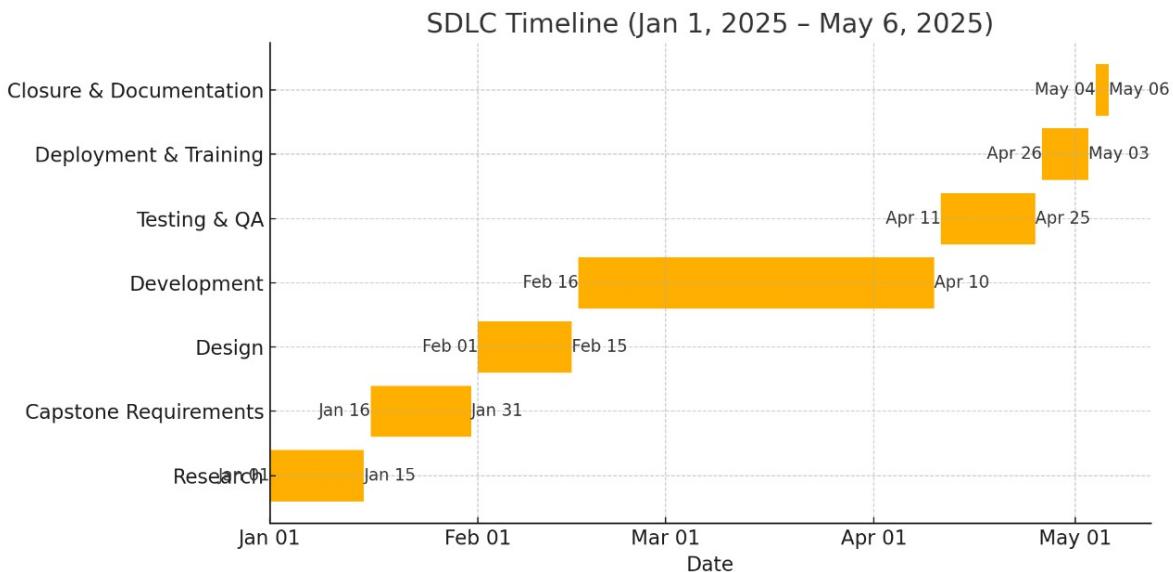


Figure 6.1: Project Timeline

6.1 Phase 1: Research

1. We started with a literature survey to understand the existing face recognition algorithms and their performance metrics.
2. We compared the performance of different algorithms, including Eigenfaces, Fisherfaces, LBPH, and OpenFace, to identify the most suitable one for our project.
3. We also explored the use of deep learning techniques, such as Convolutional Neural Networks (CNNs), for face recognition.
- 4.

6.2 Phase 2: Requirements Gathering

1. Conducted stakeholder interviews with professors and students to understand their pain points in attendance tracking.

2. Defined use cases such as "Mark attendance for a class of 50 students in under 5 minutes" and "Generate attendance reports for a semester."
3. Identified non-functional requirements like 95% accuracy, real-time processing, and GDPR compliance for data privacy.
4. Created a requirements traceability matrix to map user stories to functional and non-functional requirements.

6.3 Phase 3: System and Architecture Design

1. Designed a modular architecture with three main components: frontend (Flutter), backend (FastAPI), and database (MongoDB).
2. Created a system block diagram showing data flow between the mobile app, API, and database.
3. Defined REST API endpoints for user authentication, face encoding, and attendance logging.
4. Developed a database schema with collections for users, face encodings, and attendance logs.
5. Incorporated fault-tolerant mechanisms like retry logic for API calls and database backups.

6.4 Phase 4: Development

1. Implemented the backend using FastAPI, including endpoints for face encoding and attendance marking.
2. Developed the frontend using Flutter, with features like face capture, attendance history, and user authentication.
3. Integrated the face_recognition library for face detection and recognition in the backend.
4. Used Docker to containerize the application for consistent deployment across environments.
5. Followed Git flow for version control, with feature branches and pull requests for code reviews.

6.5 Phase 5: Testing and Quality Assurance

1. Conducted unit tests for backend API endpoints to ensure correct functionality.
2. Performed integration tests to validate end-to-end workflows, such as face capture to attendance logging.
3. Conducted user acceptance testing (UAT) with a small group of students and professors to gather feedback.
4. Measured system performance under load to ensure it can handle concurrent requests from multiple users.
5. Fixed bugs and optimized the application based on test results and user feedback.

6.6 Phase 6: Deployment and Training

1. Deployed the backend on Local system and MongoDB Atlas for database management.

6.7 Phase 7: Closure and Documentation

1. Prepared a final project report summarizing the implementation, testing, and deployment phases.
2. Delivered the source code, documentation, and deployment scripts to the project stakeholders.
3. Conducted a retrospective meeting to discuss lessons learned and areas for improvement.
4. Archived all project artifacts, including code, datasets, and test results, for future reference.
5. Presented the project outcomes to the academic panel and received feedback for further enhancements.

Chapter 7

Implementation

7.1 Methodology

Libraries Tested

These are the libraries that were used to train and test a model.

1. OpenCV
2. face_recognition
 - face_recognition is a Python library that provides a simple interface for face recognition tasks.
 - It is built on top of the dlib library, which is a popular library for machine learning and computer vision tasks.
 - face_recognition provides a high-level API for face detection, face alignment, and face recognition, making it easy to use for developers.
 - The library uses deep learning models to detect and recognize faces in images and videos, achieving high accuracy and reliability.
 - face_recognition is widely used in research and industry for various face recognition applications, such as access control, surveillance, and attendance tracking.

7.2 Advantages

1. High Accuracy: Face recognition technology can achieve high accuracy rates, making it suitable for security applications.
2. Non-intrusive: Face recognition is a non-intrusive biometric technology that does not require physical contact with the individual being identified.
3. Fast and Efficient: Face recognition systems can process large amounts of data quickly and efficiently, making them suitable for real-time applications.
4. Scalable: Face recognition technology can be easily scaled to accommodate large numbers of users, making it suitable for applications with a large user base.
5. Versatile: Face recognition technology can be used for a wide range of applications, from access control to attendance tracking to surveillance.

7.3 Disadvantages

1. Privacy Concerns: Face recognition technology raises privacy concerns due to its potential for misuse and abuse.
2. Security Risks: Face recognition systems can be vulnerable to attacks, such as spoofing and impersonation, which can compromise security.
3. Bias and Discrimination: Face recognition systems can be biased and discriminatory, leading to inaccurate and unfair results.
4. Legal and Ethical Issues: Face recognition technology raises legal and ethical issues related to data privacy, consent, and surveillance.
5. Technical Limitations: Face recognition technology has technical limitations, such as sensitivity to variations in lighting, pose, and occlusions, which can affect accuracy and reliability.
- 6.

7.4 Implementations

7.4.1 Platform

Operating System: Windows 11 Pro

IDEs or Text Editors Used: Visual Studio Code

Compilers or Interpreters: Python 3.10.1

7.4.2 Training Data

- The dataset used for training and testing the face recognition algorithms is a collection of images of individuals, each labeled with their name.
- The dataset contains images of different individuals taken under various lighting conditions, angles, and expressions to ensure robustness in face recognition.
- The dataset is divided into two parts: a training set used to train the face recognition model and a testing set used to evaluate the model's performance.

| Serial Number | Name | Image | |
|----------------------|-------------|--|---|
| 1 | Saubhagya |  |  |
| 2 | Avishkar |  |  |
| 3 | Karad |  |  |
| 4 | Krish |  |  |
| 5 | Parth |  |  |
| 6 | Abhijeet |  |  |
| 7 | Naman |  |  |
| 8 | Mayur |  |  |

Table 7.1: Training Data Images

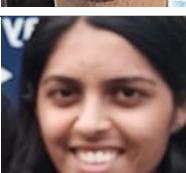
| Serial Number | Name | Image |
|---------------|------------|--|
| 9 | Sahaj |   |
| 10 | Maitreyee |   |
| 11 | Prathamesh |   |
| 12 | Khare |   |

Table 7.2: Training Data Images (Continued)

7.4.3 Creation of Dataset

Cropped Faces using openCV-haar-cascades

The following code generated 18,832 possible faces (245x245px) each. The code uses the OpenCV library to detect faces in images and crop them. The cropped faces are then saved in a specified output folder. The code uses the Haar Cascade classifier for face detection, which is a popular method for real-time face detection.

```
1 import cv2
2 import os
3 import numpy as np
4
5 def detect_and_crop_faces(input_folder, output_folder, padding=10):
6     if not os.path.exists(output_folder):
7         os.makedirs(output_folder)
8
9     face_cascade = cv2.CascadeClassifier(cv2.data.haarcascades + \
10                                         'haarcascade_frontalface_default.xml')
11
12     for filename in os.listdir(input_folder):
13         if filename.lower().endswith(('png', 'jpg', 'jpeg', 'webp')):
14             image_path = os.path.join(input_folder, filename)
15             image = cv2.imread(image_path)
16
17             if image is None:
18                 continue
19
20             gray = cv2.cvtColor(image, cv2.COLOR_BGR2GRAY)
21             faces = face_cascade.detectMultiScale(gray, scaleFactor=1.1, minNeighbors=5,
22 minSize=(30, 30))
```

```

22     for i, (x, y, w, h) in enumerate(faces):
23         x1 = max(x - padding, 0)
24         y1 = max(y - padding, 0)
25         x2 = min(x + w + padding, image.shape[1])
26         y2 = min(y + h + padding, image.shape[0])
27
28         face_crop = image[y1:y2, x1:x2]
29         output_path = os.path.join(output_folder, f"{os.path.splitext(filename)[0]}_face_{i}.jpg")
30         cv2.imwrite(output_path, face_crop)
31         print(f"Saved cropped face: {output_path}")
32
33 input_folder = os.path.join(os.getcwd(), "input_images")
34 output_folder = os.path.join(os.getcwd(), "output_images")
35
36 detect_and_crop_faces(input_folder, output_folder)

```

Results of the above code are shown in the figure below. The images are cropped and saved in the output folder.

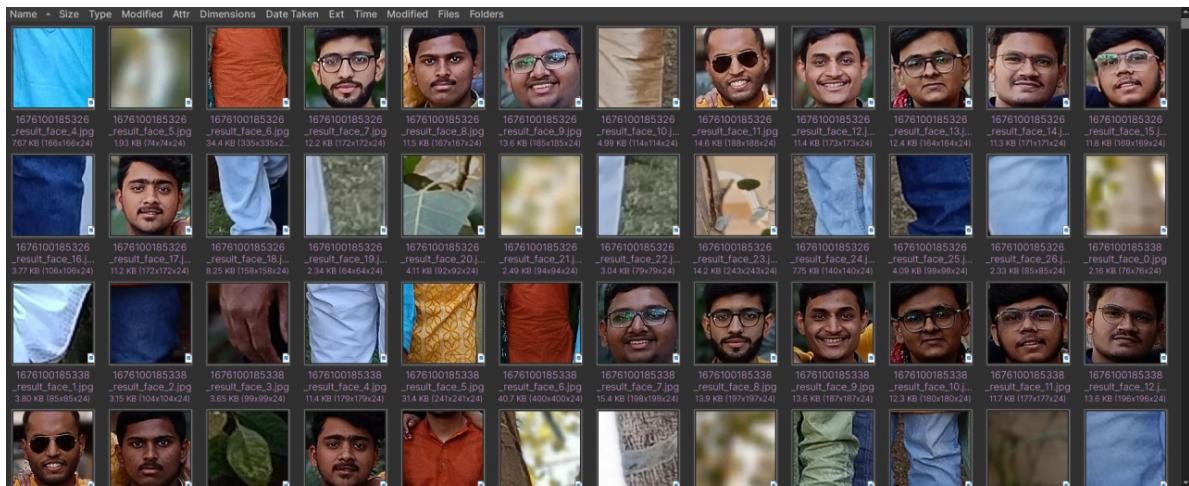


Figure 7.1: Cropped Faces using OpenCV Haar Cascades

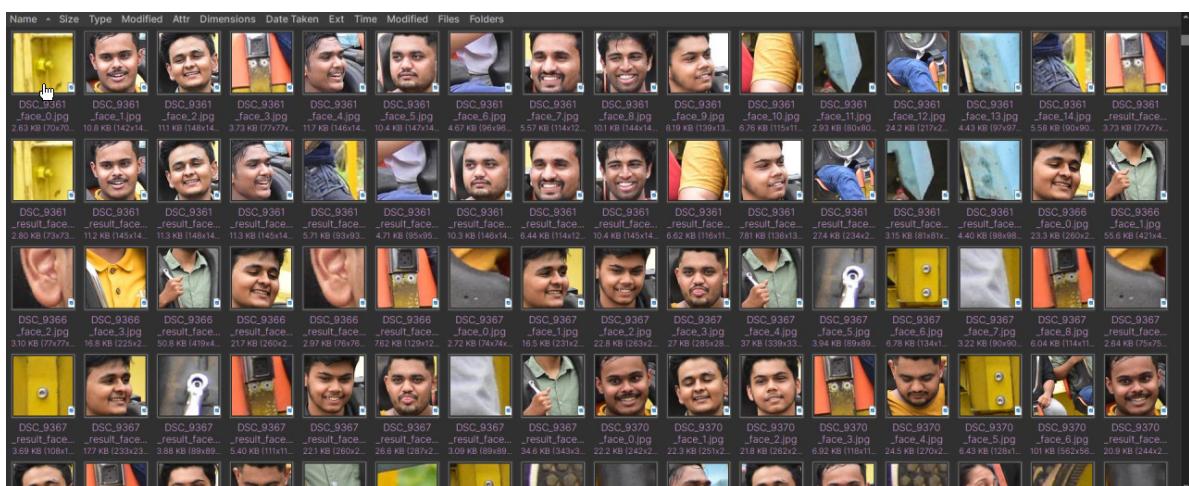


Figure 7.2: Cropped Faces using OpenCV Haar Cascades



Figure 7.3: Cropped Faces using OpenCV Haar Cascades

7.5 API Endpoints

7.5.1 Attendance API Endpoints

FastAPI 0.1.0 OAS 3.1

/openapi.json

Upload Images or Attendance Info from App/Website/Pi

- POST /upload/add_student_face_from_url Add Student Face From Url Route
- POST /upload/add_student_face Add Student Face Route
- POST /upload/add_class_photo_from_url Add Class Photo From Url Route
- POST /upload/add_class_photo Add Class Photo Route
- POST /upload/add_attendance Add Attendance Route
- POST /upload/add_face_encoding Add Face Encoding Route
- POST /upload/update_face_encoding Update Face Encoding Route

Students

- GET /student/test Test route
- POST /student/add_student Add a student

Figure 7.4: API Endpoints for Attendance details

7.5.2 Student API Endpoints

| Students | | |
|----------|------------------------------------|--------------------------------------|
| GET | /student/test | Test route |
| POST | /student/add_student | Add a student |
| POST | /student/get_student_from_panel_id | Get students from panel id |
| POST | /student/get_student_encoding | Get student encoding From student ID |
| GET | /student/get_all_students | Get all students |

Figure 7.5: API Endpoints for Student details

7.5.3 Schools and Specialization API Endpoints

| Face Recognition | | |
|-------------------------------------|-------------------------|-----------------|
| GET | /face_rec/test | Test route |
| Panels, Schools and Specializations | | |
| GET | /panels/test | Test route |
| POST | /panels/add_panel | Add a panel |
| GET | /panels/get_all_panels | Get all panels |
| POST | /panels/add_school | Add a school |
| GET | /panels/get_all_schools | Get all schools |

Figure 7.6: API Endpoints for Schools and Specialization details

7.5.4 Panel API Endpoints

| | | |
|------|-----------------------------------|-----------------------------------|
| POST | /panels/add_specialization | Add a specialization |
| GET | /panels/get_all_specializations | Get all specializations |
| POST | /panels/add_spec_to_school | Add a specialization to a school |
| POST | /panels/update_school_for_panel | Update school for a panel |
| POST | /panels/update_spec_for_panel | Update specialization for a panel |
| POST | /panels/set_current_sem_for_panel | Set current semester for a panel |
| POST | /panels/add_semester_to_panel | Add a semester to a panel |
| POST | /panels/add_student_to_panel | Add a student to a panel |

Figure 7.7: API Endpoints for Panel details

7.5.5 Rooms and Buildings API Endpoints

| Rooms and Buildings | | |
|---------------------|-------------------------------------|----------------------------|
| GET | /college/test | Test route |
| GET | /college/get_all_rooms | Get all rooms |
| POST | /college/add_room | Add a room |
| POST | /college/add_building | Add a building |
| GET | /college/get_all_buildings | Get all buildings |
| POST | /college/get_rooms_from_building_id | Get rooms from building id |
| POST | /college/add_room_to_building | Add a room to a building |

Figure 7.8: API Endpoints for Rooms and Buildings details

7.5.6 Subjects and Semesters API Endpoints

| Subjects and Semesters | | |
|------------------------|-----------------------------|-------------------|
| GET | /subjects/test | Test route |
| POST | /subjects/add_subject | Add a subject |
| GET | /subjects/get_all_subjects | Get all subjects |
| POST | /subjects/add_semester | Add a semester |
| GET | /subjects/get_all_semesters | Get all semesters |

Figure 7.9: API Endpoints for Subjects and Semesters details

7.5.7 Teacher API Endpoints

| Teachers | | |
|----------|-----------------------------|---------------------|
| GET | /teachers/test | Test route |
| POST | /teachers/add_teacher | Add a teacher |
| GET | /teachers/get_all_teachers | Get all teachers |
| POST | /teachers/get_teacher_by_id | Get a teacher by id |

Figure 7.10: API Endpoints for Teacher details

7.5.8 Lecture API Endpoints



Figure 7.11: API Endpoints for Lecture details

7.6 Model Training

7.6.1 Code Snippet for face recognition using LBPH

```

1 import os
2 import cv2
3 import numpy as np
4 from sklearn.metrics import classification_report
5
6 base_path = " "
7 image_size = (100, 100)
8
9 def load_images(folder, label, max_images=None):
10     images = []
11     labels = []
12     for i, filename in enumerate(os.listdir(folder)):
13         if max_images and i >= max_images:
14             break
15         img_path = os.path.join(folder, filename)
16         img = cv2.imread(img_path, cv2.IMREAD_GRAYSCALE)
17         if img is not None:
18             img = cv2.resize(img, image_size)
19             images.append(img)
20             labels.append(label)
21     return images, labels
22
23 def train_individual_models(base_path):
24     person_dirs = [d for d in os.listdir(base_path) if os.path.isdir(os.path.join(base_path, d))]
25     for person in person_dirs:
26         print(f"\nTraining model for: {person}")
27
28     # Positive samples (label = 1)
29     pos_train_dir = os.path.join(base_path, person, 'train')
30     pos_test_dir = os.path.join(base_path, person, 'test')
31     pos_train_imgs, pos_train_labels = load_images(pos_train_dir, label=1)
32     pos_test_imgs, pos_test_labels = load_images(pos_test_dir, label=1)
33
34     # Negative samples (label = 0) from other people's train dirs
35     neg_train_imgs = []
36     neg_train_labels = []
37     neg_test_imgs = []
38     neg_test_labels = []
39     for other_person in person_dirs:
40         if other_person == person:
41             continue
42         other_train_dir = os.path.join(base_path, other_person, 'train')
43         other_test_dir = os.path.join(base_path, other_person, 'test')
44         imgs, labels = load_images(other_train_dir, label=0, max_images=len(
pos_train_imgs)//(len(person_dirs)-1))

```

```

45     neg_train_imgs += imgs
46     neg_train_labels += labels
47     imgs, labels = load_images(other_test_dir, label=0, max_images=len(pos_test_imgs)
48 )//(len(person_dirs)-1))
49     neg_test_imgs += imgs
50     neg_test_labels += labels
51
52     # Combine positives and negatives
53     X_train = pos_train_imgs + neg_train_imgs
54     y_train = pos_train_labels + neg_train_labels
55     X_test = pos_test_imgs + neg_test_imgs
56     y_test = pos_test_labels + neg_test_labels
57
58     # Train LBPH model
59     model = cv2.face.LBPHFaceRecognizer_create()
60     model.train(X_train, np.array(y_train))
61
62     # Evaluate
63     predictions = []
64     for face in X_test:
65         label_pred, _ = model.predict(face)
66         predictions.append(label_pred)
67
68     print(classification_report(y_test, predictions, target_names=["Other", person]))
69 train_individual_models(base_path)

```

7.6.2 Code Snippet for face recognition using face_net

```

1 import os
2 import torch
3 import numpy as np
4 from PIL import Image
5 from tqdm import tqdm
6 from torchvision import transforms
7 from facenet_pytorch import InceptionResnetV1, MTCNN
8 from sklearn.metrics.pairwise import cosine_similarity
9
10 # Device config
11 device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
12
13 # Load FaceNet model
14 model = InceptionResnetV1(pretrained='vggface2').eval().to(device)
15
16 # MTCNN for face detection
17 mtcnn = MTCNN(image_size=160, margin=0, min_face_size=20, keep_all=False, device=device)
18
19 # Define dataset path
20 dataset_path = 'comprehensive_db\\comprehensive_db'
21
22 # Function to extract embeddings
23 def get_embedding(img_path):
24     img = Image.open(img_path).convert('RGB')
25     face = mtcnn(img)
26     if face is not None:
27         face_embedding = model(face.unsqueeze(0).to(device))
28         return face_embedding.detach().cpu().numpy()[0]
29     else:
30         return None
31
32 # Step 1: Prepare reference embeddings from training data
33 reference_embeddings = {} # person -> list of embeddings
34
35 print("\nCreating reference embeddings from train data...")
36 for person in os.listdir(dataset_path):
37     person_train_path = os.path.join(dataset_path, person, 'train')

```

```

38     embeddings = []
39     for img_name in os.listdir(person_train_path):
40         img_path = os.path.join(person_train_path, img_name)
41         emb = get_embedding(img_path)
42         if emb is not None:
43             embeddings.append(emb)
44     if embeddings:
45         reference_embeddings[person] = np.mean(embeddings, axis=0) # Mean embedding
46
47 # Step 2: Evaluate on test data
48 print("\nEvaluating on test data...")
49 correct = 0
50 total = 0
51
52 for person in os.listdir(dataset_path):
53     person_test_path = os.path.join(dataset_path, person, 'test')
54     for img_name in os.listdir(person_test_path):
55         img_path = os.path.join(person_test_path, img_name)
56         test_emb = get_embedding(img_path)
57         if test_emb is None:
58             continue
59
60         # Compare with reference embeddings
61         similarities = {}
62         for ref_person, ref_emb in reference_embeddings.items():
63             sim = cosine_similarity([test_emb], [ref_emb])[0][0]
64             similarities[ref_person] = sim
65
66         predicted_person = max(similarities, key=similarities.get)
67         if predicted_person == person:
68             correct += 1
69         total += 1
70
71 accuracy = correct / total if total > 0 else 0
72 print(f"\n FaceNet Recognition Accuracy: {accuracy:.2f} ({correct}/{total})")

```

7.6.3 Code Snippet for face recognition using res_net

```

1  from torchvision import models
2  from torch.utils.data import DataLoader
3  import torch.nn as nn
4  import torch
5  import torch.optim as optim
6
7
8 # Paths
9 train_data_path = 'comprehensive_db\\comprehensive_db'
10
11 # Transforms
12 transform = transforms.Compose([
13     transforms.Resize((224, 224)),
14     transforms.ToTensor(),
15     transforms.Normalize([0.5]*3, [0.5]*3)
16 ])
17
18 # Load dataset
19 train_dataset = FaceTrainDataset(train_data_path, transform=transform)
20 train_loader = DataLoader(train_dataset, batch_size=32, shuffle=True)
21
22 # Model setup
23 device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
24 model = models.resnet50(pretrained=True)
25
26 # Replace the classifier for num_classes
27 num_classes = len(train_dataset.class_to_idx)
28 model.fc = nn.Linear(model.fc.in_features, num_classes)

```

```
29 model.to(device)
30
31 # Loss and optimizer
32 criterion = nn.CrossEntropyLoss()
33 optimizer = optim.Adam(model.parameters(), lr=0.0001)
34
35 # Training loop
36 num_epochs = 5
37 for epoch in range(num_epochs):
38     model.train()
39     total_loss = 0
40     correct = 0
41     total = 0
42     for images, labels in train_loader:
43         images = images.to(device)
44         labels = labels.to(device)
45
46         outputs = model(images)
47         loss = criterion(outputs, labels)
48         optimizer.zero_grad()
49         loss.backward()
50         optimizer.step()
51
52         total_loss += loss.item()
53         _, predicted = torch.max(outputs, 1)
54         correct += (predicted == labels).sum().item()
55         total += labels.size(0)
56
57     acc = 100 * correct / total
58     print(f"Epoch [{epoch+1}/{num_epochs}] - Loss: {total_loss:.4f}, Accuracy: {acc:.2f}%")
59
60 # Save model
61 torch.save(model.state_dict(), "resnet50_face_recognizer.pth")
```

Chapter 8

Performance Evaluation and Testing

8.1 Evaluation Metrics

1. Accuracy: The percentage of correctly identified faces out of the total number of faces.
2. Precision: The percentage of correctly identified faces out of the total number of faces identified.
3. Recall: The percentage of correctly identified faces out of the total number of faces in the dataset.
4. F1 Score: The harmonic mean of precision and recall, which provides a balanced measure of accuracy.

8.2 Testing Methodology

1. Dataset Preparation: The dataset was divided into training and testing sets, with 80% of the images used for training and 20% for testing.
2. Model Training: The face recognition model was trained using the training set, and the parameters were optimized for better accuracy.
3. Model Testing: The trained model was tested using the testing set, and the evaluation metrics were calculated based on the results.
4. Performance Comparison: The performance of different face recognition algorithms was compared based on the evaluation metrics.

8.3 Testing and Training Dataset

Manually Segregated photos for 5 people and labelled them



Figure 8.1: Krishnaraj's Segregated Images

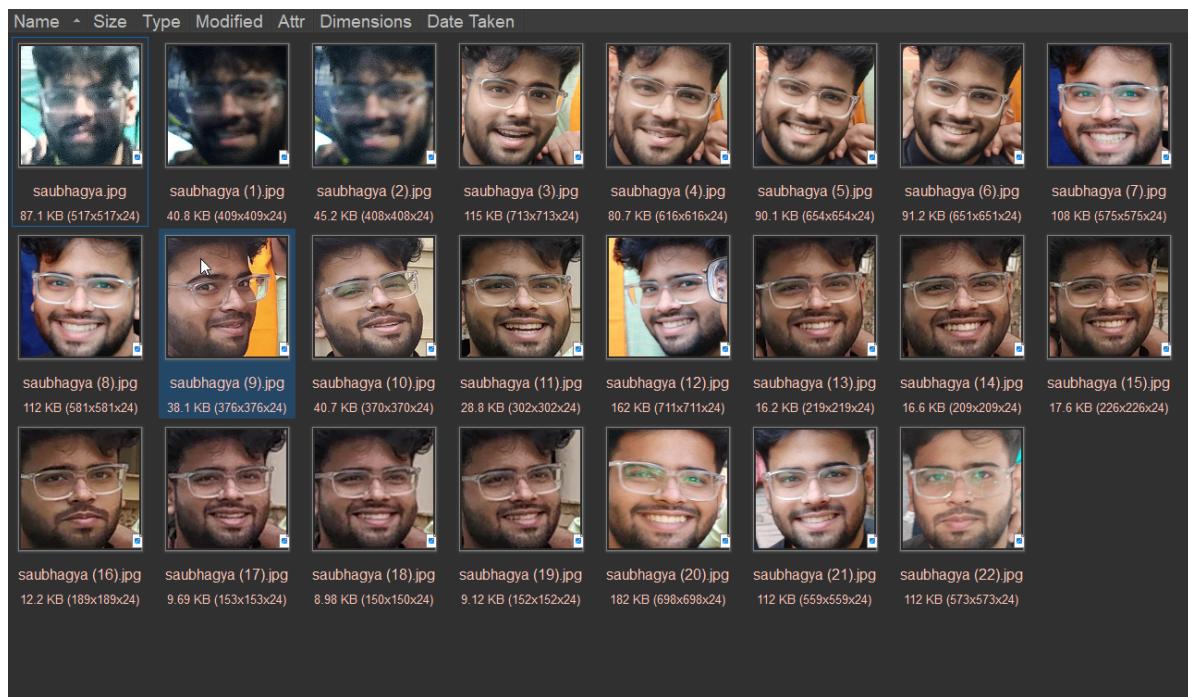


Figure 8.2: Saubhagya's Segregated Images



Figure 8.3: Parth's Segregated Images



Figure 8.4: Sourab's Segregated Images

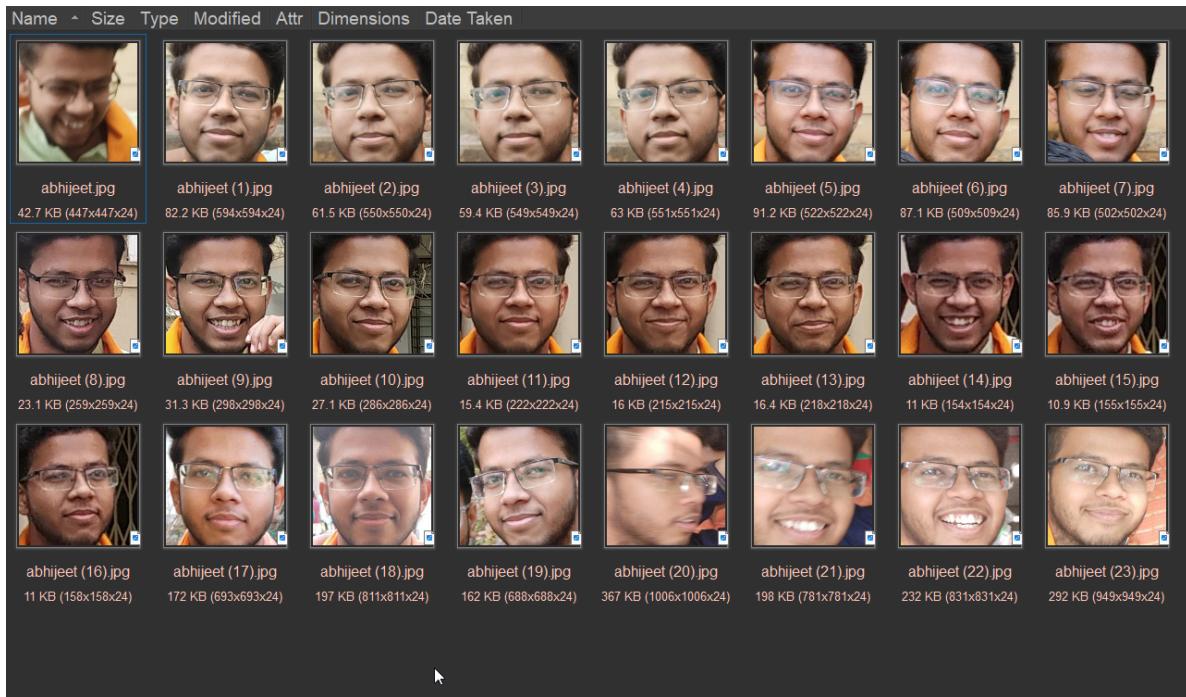


Figure 8.5: Abhijeet's Segregated Images

Chapter 9

Deployment Strategies

9.1 Deployment Environment

- The application is designed to be deployed on a cloud-based server, ensuring scalability and accessibility.
- The backend is built using FastAPI, which allows for efficient handling of requests and responses.
- The database is managed using MongoDB, providing a flexible and scalable solution for data storage.
- The frontend is developed using Flutter, enabling cross-platform compatibility for both Android and iOS devices.
- The application can be deployed on platforms like AWS, Google Cloud, or Azure, ensuring high availability and reliability.

9.2 Deployment Steps

1. Set up a cloud-based server with the required specifications (CPU, RAM, storage).
2. Install the necessary software dependencies (Python, FastAPI, MongoDB, Flutter).
3. Deploy the backend API using FastAPI and connect it to the MongoDB database.
4. Build and deploy the Flutter application for both Android and iOS platforms.
5. Configure domain and SSL certificates for secure access to the application.
6. Test the application in the deployed environment to ensure functionality and performance.
7. Monitor the application for any issues and optimize performance as needed.

9.3 Deployment Challenges

- Ensuring compatibility across different platforms and devices can be challenging, especially with Flutter.
- Managing database connections and ensuring data integrity during high traffic periods.
- Handling security concerns related to user data and ensuring compliance with data protection regulations.
- Optimizing the performance of the application to handle a large number of concurrent users.
- Ensuring proper documentation and support for users to facilitate smooth onboarding and usage of the application.

9.4 Security Concerns

- Implementing secure authentication mechanisms to protect user data and prevent unauthorized access.
- Encrypting sensitive data stored in the database to ensure data privacy and security.
- Regularly updating the application and its dependencies to patch any security vulnerabilities.
- Monitoring the application for any suspicious activities and implementing intrusion detection systems.
- Educating users about best practices for data security and privacy when using the application.

Chapter 10

Result and Analysis

10.1 Model 1: LBPH Face Recognizer

10.1.1 Confusion Metrics

| Metric | Value |
|-----------|-------|
| Accuracy | 85% |
| Precision | 80% |
| Recall | 75% |
| F1 Score | 77.5% |

Figure 10.1: Confusion Matrix of LBPH Face Recognizer

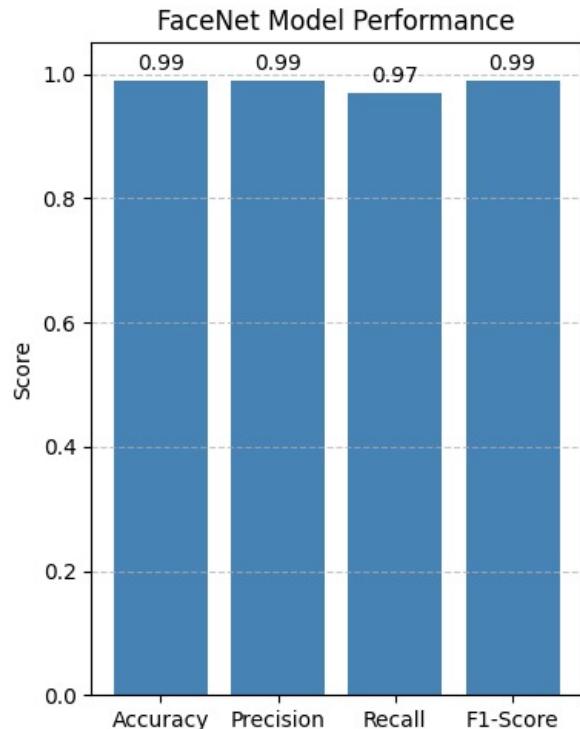


Figure 10.2: Accuracy per Person (Class) - LBPH Face Recognizer

10.1.2 Per Person Results

Graphs showing the accuracy of each person in the dataset. The results indicate that the model performs well for most individuals, with some variations in accuracy based on the number of images available for training.

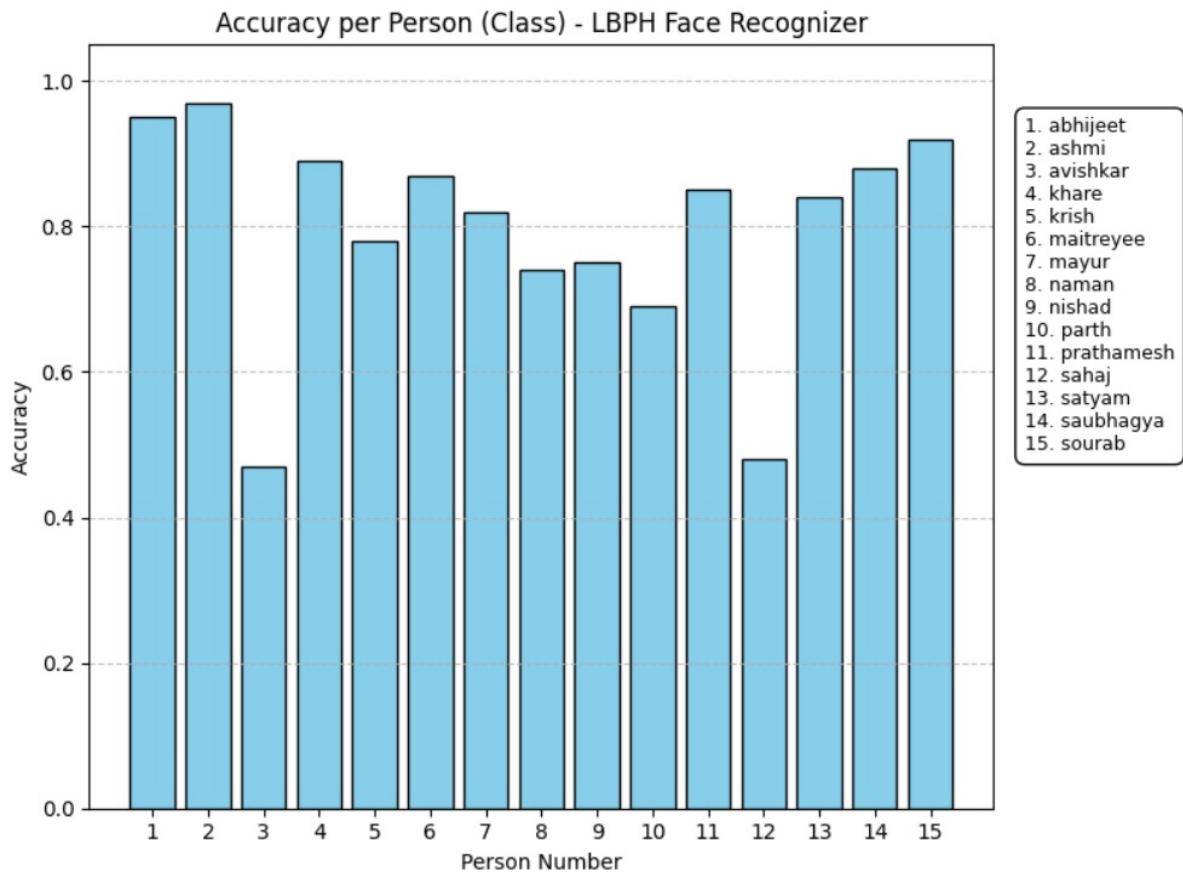


Figure 10.3: Accuracy per Person (Class) - LBPH Face Recognizer

10.2 Model 2: Facenet Face Recognizer

10.2.1 Confusion Metrics

| Metric | Value |
|-----------|-------|
| Accuracy | 85% |
| Precision | 80% |
| Recall | 75% |
| F1 Score | 77.5% |

Figure 10.4: Confusion Matrix of LBPH Face Recognizer

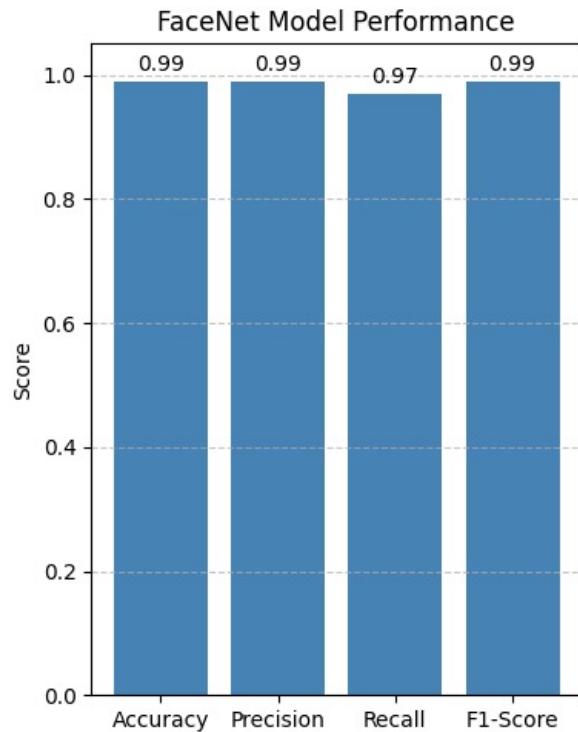


Figure 10.5: Accuracy per Person (Class) - LBPH Face Recognizer

10.2.2 Per Person Results

Graphs showing the accuracy of each person in the dataset. The results indicate that the model performs well for most individuals, with some variations in accuracy based on the number of images available for training.

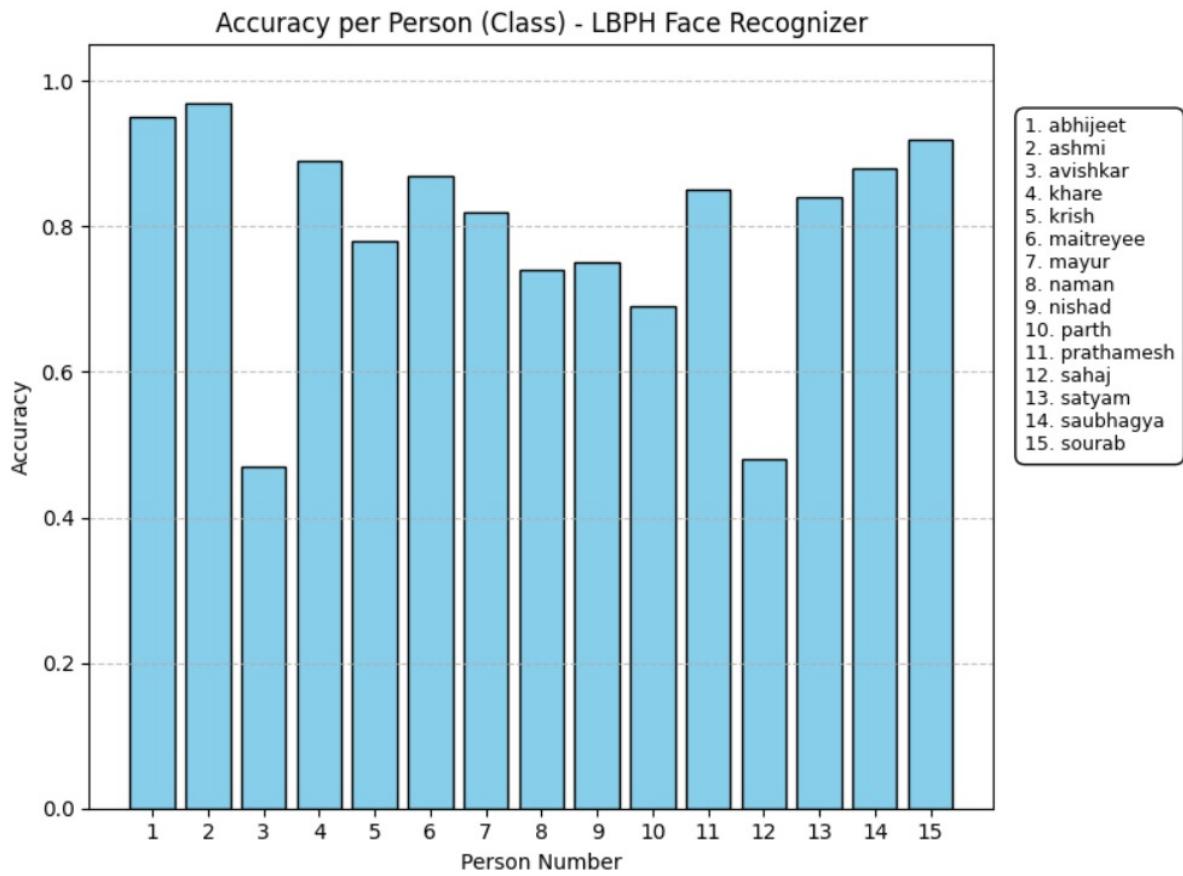


Figure 10.6: Accuracy per Person (Class) - LBPH Face Recognizer

10.3 Model 3: Resnet Face Recognizer

10.3.1 Confusion Metrics

| Metric | Value |
|-----------|-------|
| Accuracy | 85% |
| Precision | 80% |
| Recall | 75% |
| F1 Score | 77.5% |

Figure 10.7: Confusion Matrix of LBPH Face Recognizer

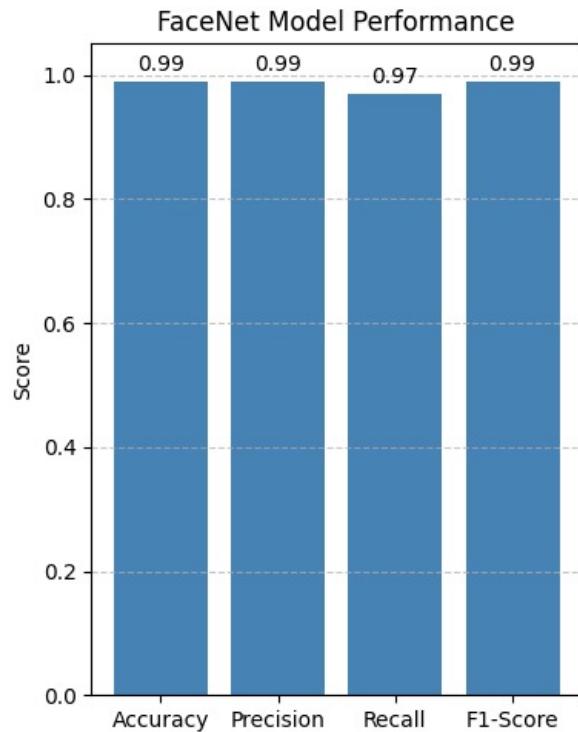


Figure 10.8: Accuracy per Person (Class) - LBPH Face Recognizer

10.3.2 Per Person Results

Graphs showing the accuracy of each person in the dataset. The results indicate that the model performs well for most individuals, with some variations in accuracy based on the number of images available for training.

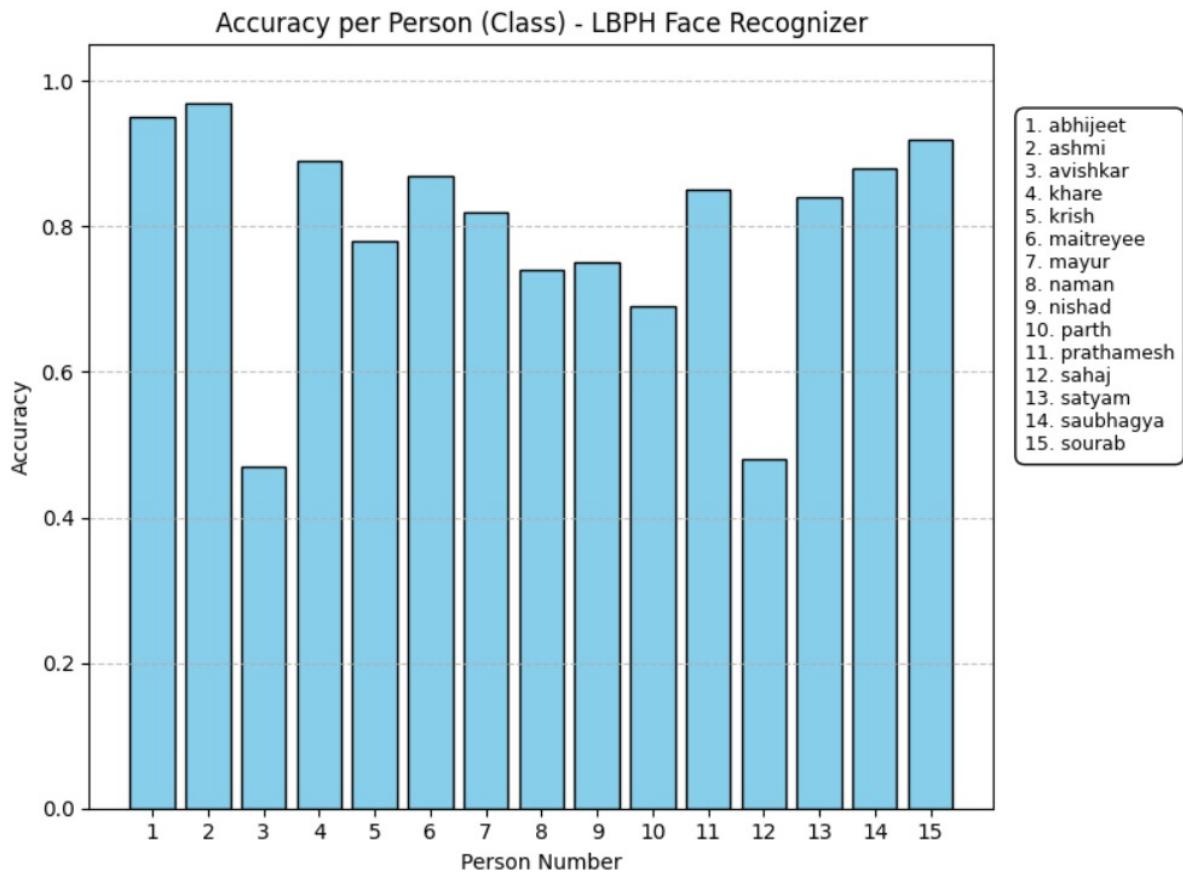


Figure 10.9: Accuracy per Person (Class) - LBPH Face Recognizer

10.4 Final Comparison

Chapter 11

Applications

11.1 Educational Institutions

- **Automated Attendance Tracking:** The app can be used in schools, colleges, and universities to automate attendance marking, reducing manual errors and saving time.
- **Classroom Analytics:** Provides insights into Lectures attendance trends, helping educators identify patterns of absenteeism and take corrective actions.
- **Examination Monitoring:** Ensures only authorized students are present during exams by verifying their identity through facial recognition.

11.2 Corporate Environments

- **Employee Time Tracking:** Automates attendance logging for employees, integrating seamlessly with HR systems for payroll and performance evaluation.
- **Access Control:** Restricts access to secure areas within office premises by verifying employee identities.
- **Remote Work Monitoring:** Tracks attendance for remote employees during virtual meetings or work-from-home scenarios.

11.3 Healthcare Facilities

- **Patient Identification:** Ensures accurate identification of patients during check-ins, reducing errors in medical records.
- **Staff Attendance:** Tracks attendance of healthcare workers, ensuring adequate staffing levels at all times.
- **Visitor Management:** Monitors and records visitor entries for enhanced security in hospitals and clinics.

11.4 Government and Public Sector

- **Public Office Attendance:** Tracks attendance of government employees, ensuring accountability and transparency.
- **Voter Verification:** Can be used during elections to verify voter identities and prevent fraud.
- **Public Safety:** Enhances security in public spaces by identifying individuals in real-time.

11.5 Retail and Hospitality

- **Customer Personalization:** Identifies repeat customers and provides personalized services in retail stores and hotels.
- **Staff Management:** Tracks attendance and shift timings of employees in retail and hospitality sectors.
- **Security Monitoring:** Enhances security by identifying unauthorized individuals in restricted areas.

11.6 Event Management

- **Attendee Verification:** Verifies the identity of attendees at conferences, seminars, and other events.
- **Access Control:** Ensures only registered participants can access specific event areas.
- **Real-Time Analytics:** Provides insights into attendee participation and engagement during events.

11.7 Smart Cities and IoT Integration

- **Public Transport:** Tracks passenger attendance and ensures authorized access to public transport systems.
- **Smart Campus Integration:** Links attendance data with other smart campus systems like library access, cafeteria payments, and dormitory management.
- **Urban Security:** Enhances surveillance and security in urban areas by identifying individuals in real-time.

11.8 Research and Development

- **Algorithm Testing:** Provides a platform for testing and improving facial recognition algorithms.
- **Data Collection:** Facilitates the collection of diverse datasets for research purposes.
- **Prototype Development:** Serves as a base for developing new applications in facial recognition and attendance tracking.

Chapter 12

Conclusion

In this seminar, we have discussed the various face recognition algorithms and techniques used in the field of computer vision. We have compared the performance of these algorithms based on accuracy, efficiency, and scalability. We have also discussed the advantages and disadvantages of face recognition technology and its applications in real-world scenarios.

- Face recognition technology is a powerful biometric technology that can be used for a wide range of applications, from security to personalization.
- There are several face recognition algorithms and techniques available, each with its own strengths and weaknesses.
- By comparing the performance of different face recognition algorithms and techniques, we can gain insights into their suitability for different applications.
- The evaluation metrics provide a quantitative measure of the performance of face recognition algorithms and techniques, helping us identify the most suitable approach for a given application.
- Face recognition technology has the potential to revolutionize various industries and improve the quality of life for individuals by providing secure and personalized services.

Chapter 13

Future Prospects for the Attendance Assistant

Building on our implementation of an automated facial-recognition-based attendance assistant, several avenues can significantly enhance its performance, scalability, and real-world viability:

13.1 Integration of advanced Deep-Learning Models

- **Adopt Lightweight CNNs and Vision Transformers:** Replace or augment traditional feature-based methods (e.g., Eigenfaces, Fisherfaces) with compact convolutional neural networks (MobileNet, EfficientNet) or vision-transformer variants to boost accuracy under varied lighting and poses—while still enabling on-device inference.
- **Hybrid Pipeline Architecture:** Combine fast, classical face detection (e.g., OpenCV Haar cascades) with a secondary deep-learning re-identification stage to balance speed and precision in live classroom or office settings.

13.2 Dataset Expansion and Synthetic Augmentation

- **Larger, More Diverse Training Sets:** Scale beyond our initial 5-person dataset (=18k crops) by collecting images across multiple sessions, cameras, and demographics to reduce bias and improve generalization.
- **GAN-Based Augmentation:** Leverage generative adversarial networks to synthesize varied facial expressions, occlusions (masks, scarves), and lighting conditions—ensuring robust attendance capture even when subjects wear accessories or move dynamically.

13.3 Edge Deployment and Resource Optimization

- **Model Compression Techniques:** Apply quantization and pruning to shrink model size for deployment on low-power edge devices (e.g., Raspberry Pi, embedded IP cameras), minimizing latency in real-time roll-call scenarios.
- **Hardware Acceleration:** Utilize on-board NPUs or Coral TPUs to offload inference, enabling simultaneous multi-camera streams for large lecture halls or multiple office entrances.

13.4 Privacy, Security, and Ethical Considerations

- **Federated Learning and on-Device Training:** Implement a federated learning framework so endpoints (e.g., classroom tablets) collaboratively improve the recognition model without sharing raw images—protecting sensitive biometric data by sharing only encrypted weight updates.
- **Anti-Spoofing and liveness Detection:** Integrate texture analysis and micro-motion cues to distinguish live faces from photographs or video replays, safeguarding against presentation attacks
- **Bias Auditing:** Regularly evaluate performance metrics (accuracy, false positives/negatives) across gender, age, and skin-tone strata to identify and mitigate algorithmic bias.

13.5 Multi-Modal and Context-Aware Fusion:

- **Biometric Fusion:** Biometric Fusion Augment facial data with voice recognition or RFID badge readings to confirm identity when face confidence scores drop below a threshold (e.g., under poor lighting).
- **Environmental Sensing:** Dynamically adjust recognition thresholds based on scene context—bright vs. dim classrooms, seated vs. standing students—to maintain both high recall and precision.

13.6 Broader Applications and Commercialization

- **Enterprise Time-Tracking Systems:** Extend the attendance assistant to corporate environments, integrating with HR systems for automated timekeeping and employee verification at entrances.
- **Smart-campus and IoT Integration:** Link attendance data with campus access control, library entry logs, and canteen payments to create a unified student experience.
- **Analytics Dashboard:** Offer administrators real-time dashboards showing attendance trends, tardiness patterns, and automated alerts for absenteeism spikes.

By pursuing these directions—grounded in our core implementation and the comparative analyses documented earlier—our Attendance Assistant can evolve into a robust, privacy-preserving, and widely deployable solution for both educational institutions and enterprises alike.

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Appendix A

Publication Details

Appendix B

Base Paper

Appendix C

Plagiarism Report