# Real-Time Face Based Authentication

# With Age and Gender Detection

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**To**

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## Abstract:

## This project introduces a real-time face authentication system designed for web applications. The system uses the face-api.js library to detect faces, predict age, and determine gender in real time via webcam input. The primary aim is to offer a secure and interactive method for user identification while showcasing the potential of facial recognition for modern authentication systems. Built using React.js for the frontend and Express.js for the backend, the solution is scalable and provides a strong foundation for extending functionality to face-based login systems or demographic analysis tools.

## Objectives:

## The objective of the Real-Time Face Authentication System with Age and Gender Detection is to develop a reliable, scalable, and user-friendly biometric solution. This project leverages advanced computer vision techniques using face-api.js to meet the following key objectives:

## Real-Time Facial Recognition: Detect and recognize faces in real-time using pre-trained models, ensuring high accuracy and efficiency for authentication purposes.

## Age and Gender Prediction: Incorporate machine learning models to predict the age and gender of users dynamically, adding layers of demographic insights.

## Secure User Registration: Implement a system to capture unique facial embeddings and securely store user information, enabling future face-based authentication.

## Interactive Data Visualization: Display real-time data, such as bounding boxes, landmarks, age, and gender predictions, overlaid on the webcam feed for user feedback and debugging.

## Webcam Integration: Utilize the getUserMedia API for seamless webcam access, providing a smooth and accessible user experience.

## Cost-Effectiveness: Build the system using open-source libraries and lightweight components to ensure affordability and reduce dependency on expensive hardware.

## Real-Time Processing: Achieve low-latency processing of video frames and predictive analytics, ensuring a fluid and responsive application.

## Scalability: Design the architecture to support future enhancements, such as multi-face detection, emotion recognition, and multi-language support.

## Cross-Platform Compatibility: Ensure compatibility across major browsers and devices, making the solution accessible to a diverse audience.

## Educational Use and Learning: Provide an educational platform for learners and developers interested in computer vision, JavaScript, and biometric systems, serving as a hands-on project for exploring real-time AI applications.

## Privacy and Security: Adhere to best practices for data protection, ensuring that user facial data is handled securely and stored only when necessary.

## By achieving these objectives, the system demonstrates the potential for integrating advanced facial recognition technologies into everyday applications, fostering innovation in biometric security, user experience, and personalization.

## Problem Statement:

## " Traditional authentication mechanisms like passwords and PINs are increasingly vulnerable to security breaches such as phishing attacks, database leaks, and brute force cracking. There is a growing demand for biometric systems, which provide stronger security and a more convenient user experience. This project aims to fill the gap by implementing a real-time face authentication system that not only enhances security but also integrates predictive analytics, such as age and gender classification. This approach adds depth to user interactions and unlocks possibilities for personalization in web applications.

## Related Work:

## Research and development in real-time face authentication systems have seen significant advancements, particularly with the integration of machine learning and deep learning techniques. The following areas highlight related work that aligns with this project:

## Facial Recognition Algorithms: Extensive studies have been conducted on facial recognition algorithms, including traditional approaches like Eigenfaces and Fisherfaces, as well as deep learning-based models like CNNs (Convolutional Neural Networks). Modern libraries like face-api.js leverage pre-trained models for real-time face recognition, emphasizing accuracy and efficiency.

## Age and Gender Prediction: Predicting demographic attributes such as age and gender has been an active research area, with models like VGGFace, FaceNet, and ResNet showing notable performance. This technology finds applications in user profiling, marketing, and personalized user experiences.

## Biometric Authentication Systems: Biometric systems using facial recognition are widely studied for secure access control and authentication. Works focus on comparing face-based systems with other biometric modalities like fingerprints and iris scans in terms of accuracy, speed, and user acceptance.

## Real-Time Video Processing: Research into efficient real-time processing of video frames has been pivotal in enabling responsive face detection and recognition systems. Techniques for optimizing computational overhead while maintaining high frame rates are often explored.

## Web-Based Face Recognition: The use of browser-based APIs, such as getUserMedia, for webcam integration has enabled lightweight, platform-independent solutions. Projects in this area often highlight cross-platform compatibility and real-time interactivity.

## Privacy and Security in Face Recognition: Addressing concerns around data privacy, researchers have explored techniques like on-device processing, data anonymization, and secure facial embedding storage to mitigate risks associated with biometric data.

## Applications in Surveillance and Security: Many studies demonstrate the use of facial recognition systems in surveillance and security, emphasizing real-time threat detection and automated monitoring.

## Integration of Multiple Features: Related projects often integrate multiple features, such as face detection, age prediction, gender classification, and emotion recognition, to build multi-functional systems. This project aligns with such efforts by combining authentication with demographic predictions.

## Educational and Open-Source Contributions: Open-source contributions, like face-api.js, have significantly democratized access to facial recognition tools. Educational projects often document their use in workshops and tutorials to teach AI and computer vision concepts.

## Edge Computing and Resource Constraints: Studies have focused on deploying face recognition on resource-constrained devices such as Raspberry Pi and smartphones. Optimizing models to work efficiently within limited computational resources has parallels with browser-based implementations like this project.

## This project builds upon these foundational works, focusing on creating a real-time, browser-compatible face authentication system with additional features like age and gender detection, offering practical applications in security, personalization, and accessibility

## Implementation Methodology:

### Hardware Components:

The successful realization of this project hinged on the utilization of various hardware components, including:

Table 1: List of Hardware Components Used for Project Setup

|  |  |  |
| --- | --- | --- |
| **Serial Number** | Name | Description |
| 1 | Computer with Webcam | Used to capture real-time video streams for face detection and recognition. |
| 2 | Browser with WebRTC Support | **Facilitates webcam access using the getUserMedia API for video input.** |

### Software Components:

The successful realization of this project hinged on the utilization of various hardware components, including:

Table 1: List of Hardware Components Used for Project Setup

|  |  |  |
| --- | --- | --- |
| **Serial Number** | Name | Description |
| 1 | Face-api.js | A JavaScript library for face detection, landmark identification, and demographic prediction. |
| 2 | React.js | **A JavaScript library for building the web-based user interface** |
| 3 | Node.js & Express.js | **Backend technologies used for user registration and storage of facial embeddings.** |
| 4 | TypeScript | **Provides type safety and enhances code maintainability throughout the project.** |
| 5 | Axios | **Used to send HTTP requests for data communication between the client and the server.** |
| 6 | PostgreSQL | **Database Used for Storing User Information and Facial Embedding’s** |
| 7 | Visual Studio IDE | **Used for writing, debugging, and deploying the code.** |

## 

## Steps in Implementation

## Model Loading and Initialization

## Pre-trained models for face detection (ssdMobilenetv1), landmark recognition, and face descriptors were loaded using face-api.js.

## Additional models for age and gender prediction were also included.

## Webcam Integration

## The getUserMedia API was used to capture video from the user's webcam.

## The video feed was displayed in real-time on the web interface, overlaid with detection data.

## Face Detection and Landmark Visualization

## The system utilized the face detection model to locate faces in the video stream.

## Detected faces were annotated with bounding boxes and landmarks, drawn directly on an HTML5 canvas overlaid on the video feed.

## Age and Gender Prediction

## For each detected face, models were used to estimate the age and gender in real-time.

## This information was displayed on the bounding box over the respective face.

## User Registration

## A single face descriptor (facial embedding) was computed for each user and paired with their name and email for registration.

## Data was securely transmitted to the backend for storage.

## Real-Time Updates

## Using requestAnimationFrame, the system ensured that face detection, age prediction, and other visual updates were performed in a seamless loop for real-time interactivity.

## User-Friendly Interface

## The interface was designed using React.js and styled with Tailwind CSS to make it visually appealing and easy to use.

## Backend Integration

## Express.js was employed to handle API endpoints for user registration and potential retrieval of stored data.

## Data was securely stored in a database (e.g., PostgreSQL) via Prisma ORM.

## Testing and Debugging

## The system was tested in various lighting conditions and webcam qualities to ensure robustness.

## Debugging tools in the browser and IDE were used to refine the application.

## Code – Implementation

## Registration-Process Code

1. 1. import { useEffect, useState, useRef } from "react";

2. 2. import \* as faceapi from "face-api.js";

3. 3. import axios from "axios";

4. 4.

5. 5. const Register = () => {

6. 6.   const [modelsLoaded, setModelsLoaded] = useState(false);

7. 7.   const [name, setName] = useState("");

8. 8.   const [email, setEmail] = useState("");

9. 9.   const videoRef = useRef(null);

10. 10.   const canvasRef = useRef(null);

11. 11.

12. 12.   useEffect(() => {

13. 13.     const MODEL\_URL =

14. 14.       "https://cdn.jsdelivr.net/npm/@vladmandic/face-api@latest/model/";

15. 15.

16. 16.     const loadModels = async () => {

17. 17.       try {

18. 18.         await faceapi.nets.ssdMobilenetv1.loadFromUri(MODEL\_URL);

19. 19.         await faceapi.nets.faceLandmark68Net.loadFromUri(MODEL\_URL);

20. 20.         await faceapi.nets.faceRecognitionNet.loadFromUri(MODEL\_URL);

21. 21.         await faceapi.nets.ageGenderNet.loadFromUri(MODEL\_URL);

22. 22.         setModelsLoaded(true);

23. 23.       } catch (error) {

24. 24.         console.error("Error loading models:", error);

25. 25.       }

26. 26.     };

27. 27.

28. 28.     loadModels();

29. 29.

30. 30.     const startVideo = () => {

31. 31.       navigator.mediaDevices

32. 32.         .getUserMedia({ video: {} })

33. 33.         .then((stream) => {

34. 34.           const video: HTMLVideoElement = videoRef.current;

35. 35.           if (video) {

36. 36.             video.srcObject = stream;

37. 37.             video.play();

38. 38.           }

39. 39.         })

40. 40.         .catch((err) => console.error("Error accessing webcam:", err));

41. 41.     };

42. 42.

43. 43.     startVideo();

44. 44.   }, []);

45. 45.

46. 46.   const detectFaceLandmarks = async () => {

47. 47.     const video = videoRef.current;

48. 48.     const canvas = canvasRef.current;

49. 49.

50. 50.     if (modelsLoaded && video && canvas) {

51. 51.       const displaySize = {

52. 52.         width: video.videoWidth,

53. 53.         height: video.videoHeight,

54. 54.       };

55. 55.

56. 56.       canvas.width = displaySize.width;

57. 57.       canvas.height = displaySize.height;

58. 58.

59. 59.       const drawLandmarksAndInfo = async () => {

60. 60.         const detections = await faceapi

61. 61.           .detectAllFaces(video)

62. 62.           .withFaceLandmarks()

63. 63.           .withAgeAndGender();

64. 64.

65. 65.         const resizedDetections = faceapi.resizeResults(

66. 66.           detections,

67. 67.           displaySize

68. 68.         );

69. 69.

70. 70.         const context = canvas.getContext("2d");

71. 71.         context.clearRect(0, 0, canvas.width, canvas.height);

72. 72.         context.setTransform(-1, 0, 0, 1, canvas.width, 0);

73. 73.

74. 74.         resizedDetections.forEach((detection) => {

75. 75.           const { age, gender, genderProbability } = detection;

76. 76.           const box = detection.detection.box;

77. 77.

78. 78.           const drawBox = new faceapi.draw.DrawBox(box, {

79. 79.             label: `${gender} (${(genderProbability \* 100).toFixed(

80. 80.               1

81. 81.             )}%), Age: ${Math.round(age)}`,

82. 82.           });

83. 83.           drawBox.draw(canvas);

84. 84.

85. 85.           faceapi.draw.drawFaceLandmarks(canvas, detection);

86. 86.         });

87. 87.

88. 88.         requestAnimationFrame(drawLandmarksAndInfo);

89. 89.       };

90. 90.

91. 91.       drawLandmarksAndInfo();

92. 92.     }

93. 93.   };

94. 94.

95. 95.   useEffect(() => {

96. 96.     if (modelsLoaded) detectFaceLandmarks();

97. 97.   }, [modelsLoaded]);

98. 98.

99. 99.   const registerUser = async () => {

100. 100.     const video = videoRef.current;

101. 101.

102. 102.     if (modelsLoaded && video) {

103. 103.       const detection = await faceapi

104. 104.         .detectSingleFace(video)

105. 105.         .withFaceLandmarks()

106. 106.         .withFaceDescriptor()

107. 107.         .withAgeAndGender();

108. 108.

109. 109.       if (detection) {

110. 110.         const {age, gender} = detection;

111. 111.         const faceEmbedding = Array.from(detection.descriptor);

112. 112.         try {

113. 113.           await axios.post("http://localhost:3000/register", {

114. 114.             name,

115. 115.             email,

116. 116.             faceEmbedding,

117. 117.             age,

118. 118.             gender

119. 119.           });

120. 120.           alert("User registered successfully");

121. 121.         } catch (error) {

122. 122.           console.error("Error registering user:", error);

123. 123.         }

124. 124.       } else {

125. 125.         console.log("No face detected");

126. 126.       }

127. 127.     }

128. 128.   };

129. 129.

130. 130.   return (

131. 131.     <div className="bg-white p-6 rounded-lg shadow-md w-full max-w-md relative">

132. 132.       <h2 className="text-xl font-semibold mb-4 text-center">Register User</h2>

133. 133.       <div className="relative w-full">

134. 134.         <video

135. 135.           ref={videoRef}

136. 136.           id="video"

137. 137.           width="720"

138. 138.           height="560"

139. 139.           autoPlay

140. 140.           muted

141. 141.           className="rounded-lg shadow-lg mb-4 transform scale-x-[-1]"

142. 142.           style={{ display: "block" }}

143. 143.           onPlay={() => detectFaceLandmarks()}

144. 144.         />

145. 145.         <canvas

146. 146.           ref={canvasRef}

147. 147.           className="absolute top-0 left-0 rounded-lg pointer-events-none transform scale-x-[-1]"

148. 148.           style={{

149. 149.             position: "absolute",

150. 150.             top: 0,

151. 151.             left: 0,

152. 152.             width: "100%",

153. 153.             height: "100%",

154. 154.             zIndex: 1,

155. 155.           }}

156. 156.         />

157. 157.       </div>

158. 158.       <input

159. 159.         type="text"

160. 160.         placeholder="Name"

161. 161.         value={name}

162. 162.         onChange={(e) => setName(e.target.value)}

163. 163.         required

164. 164.         className="border border-gray-300 rounded-lg px-4 py-2 mb-4 w-full"

165. 165.       />

166. 166.       <input

167. 167.         type="email"

168. 168.         placeholder="Email"

169. 169.         value={email}

170. 170.         required

171. 171.         onChange={(e) => setEmail(e.target.value)}

172. 172.         className="border border-gray-300 rounded-lg px-4 py-2 mb-4 w-full"

173. 173.       />

174. 174.       <button

175. 175.         onClick={registerUser}

176. 176.         disabled={!modelsLoaded}

177. 177.         className={`w-full py-2 rounded-lg text-white ${

178. 178.           modelsLoaded

179. 179.             ? "bg-blue-500 hover:bg-blue-600"

180. 180.             : "bg-gray-400 cursor-not-allowed"

181. 181.         }`}

182. 182.       >

183. 183.         Register

184. 184.       </button>

185. 185.     </div>

186. 186.   );

187. 187. };

188. 188.

189. 189. export default Register;

### 

### Authentication-Process-Code

1. import { useEffect, useState, useRef } from "react";

2. import \* as faceapi from "face-api.js";

3. import io from "socket.io-client";

4.

5. const socket = io("http://localhost:3000");

6.

7. const Authenticate = () => {

8.   const [modelsLoaded, setModelsLoaded] = useState(false);

9.   const [authMessage, setAuthMessage] = useState("");

10.   const [isLoggedIn, setIsLoggedIn] = useState(false);

11.   const videoRef = useRef(null);

12.   const canvasRef = useRef(null);

13.

14.   useEffect(() => {

15.     const MODEL\_URL = "https://cdn.jsdelivr.net/npm/@vladmandic/face-api@latest/model/";

16.

17.     const loadModels = async () => {

18.       try {

19.         await faceapi.nets.ssdMobilenetv1.loadFromUri(MODEL\_URL);

20.         await faceapi.nets.faceLandmark68Net.loadFromUri(MODEL\_URL);

21.         await faceapi.nets.faceRecognitionNet.loadFromUri(MODEL\_URL);

22.         setModelsLoaded(true);

23.       } catch (error) {

24.         console.error("Error loading models:", error);

25.       }

26.     };

27.

28.     loadModels();

29.

30.     const startVideo = () => {

31.       navigator.mediaDevices

32.         .getUserMedia({ video: {} })

33.         .then((stream) => {

34.           const video = videoRef.current;

35.           if (video) {

36.             video.srcObject = stream;

37.             video.play();

38.           }

39.         })

40.         .catch((err) => console.error("Error accessing webcam:", err));

41.     };

42.

43.     startVideo();

44.   }, []);

45.

46.   const detectFaceLandmarks = async () => {

47.     const video : HTMLVideoElement = videoRef.current;

48.     const canvas : HTMLCanvasElement = canvasRef.current;

49.

50.     if (modelsLoaded && video && canvas) {

51.       const displaySize = { width: video.videoWidth, height: video.videoHeight };

52.

53.       // Set canvas dimensions to match video dimensions

54.       canvas.width = displaySize.width;

55.       canvas.height = displaySize.height;

56.

57.       const drawLandmarks = async () => {

58.         const detection = await faceapi

59.           .detectSingleFace(video)

60.           .withFaceLandmarks()

61.           .withFaceDescriptor();

62.

63.         const resizedDetections = faceapi.resizeResults([detection], displaySize);

64.

65.         const context = canvas.getContext("2d");

66.         context!.clearRect(0, 0, canvas.width, canvas.height);

67.

68.

69.

70.         resizedDetections.forEach(detection => {

71.           faceapi.draw.drawFaceLandmarks(canvas, detection);

72.         });

73.

74.         requestAnimationFrame(drawLandmarks);

75.       };

76.

77.       drawLandmarks();

78.     }

79.   };

80.

81.   useEffect(() => {

82.     if (modelsLoaded) detectFaceLandmarks();

83.   }, [modelsLoaded]);

84.

85.   const handleAuthenticate = async () => {

86.     const video = videoRef.current;

87.

88.     if (modelsLoaded && video) {

89.       const detection = await faceapi

90.         .detectSingleFace(video)

91.         .withFaceLandmarks()

92.         .withFaceDescriptor();

93.

94.       if (detection) {

95.         const faceEmbedding = Array.from(detection.descriptor);

96.         socket.emit("authenticate", { faceEmbedding });

97.

98.         socket.on("authResult", (result) => {

99.           if (result.success) {

100.             setAuthMessage(

101.               "Authentication successful for user " + `${result.user}`

102.             );

103.             setIsLoggedIn(true);

104.           } else {

105.             setAuthMessage("Authentication failed. Please try again.");

106.             setIsLoggedIn(false);

107.           }

108.         });

109.       } else {

110.         console.log("No face detected");

111.       }

112.     } else {

113.       console.log("Models not yet loaded or video not accessible");

114.     }

115.   };

116.

117.   return (

118.     <div className="bg-white p-6 rounded-lg shadow-md w-full max-w-md relative">

119.       <h2 className="text-xl font-semibold mb-4">Authenticate User</h2>

120.       <div className="relative w-full">

121.         <video

122.           ref={videoRef}

123.           id="video"

124.           width="720"

125.           height="560"

126.           autoPlay

127.           muted

128.           className="rounded-lg shadow-lg mb-4 transform scale-x-[-1]"

129.           style={{ display: "block" }}

130.         />

131.         <canvas

132.           ref={canvasRef}

133.           className="absolute top-0 left-0 rounded-lg pointer-events-none transform scale-x-[-1]"

134.           style={{

135.             position: 'absolute',

136.             top: 0,

137.             left: 0,

138.             width: '100%',

139.             height: '100%',

140.             zIndex: 1,

141.           }}

142.         />

143.       </div>

144.       <button

145.         onClick={handleAuthenticate}

146.         disabled={!modelsLoaded}

147.         className={`w-full py-2 rounded-lg text-white ${

148.           modelsLoaded

149.             ? "bg-green-500 hover:bg-green-600"

150.             : "bg-gray-400 cursor-not-allowed"

151.         }`}

152.       >

153.         {modelsLoaded ? "Authenticate" : "Loading models..."}

154.       </button>

155.       {authMessage && isLoggedIn ? (

156.         <p className="mt-4 text-lg text-green-600">{authMessage}</p>

157.       ) : (

158.         <p className="mt-4 text-lg text-red-600">{authMessage}</p>

159.       )}

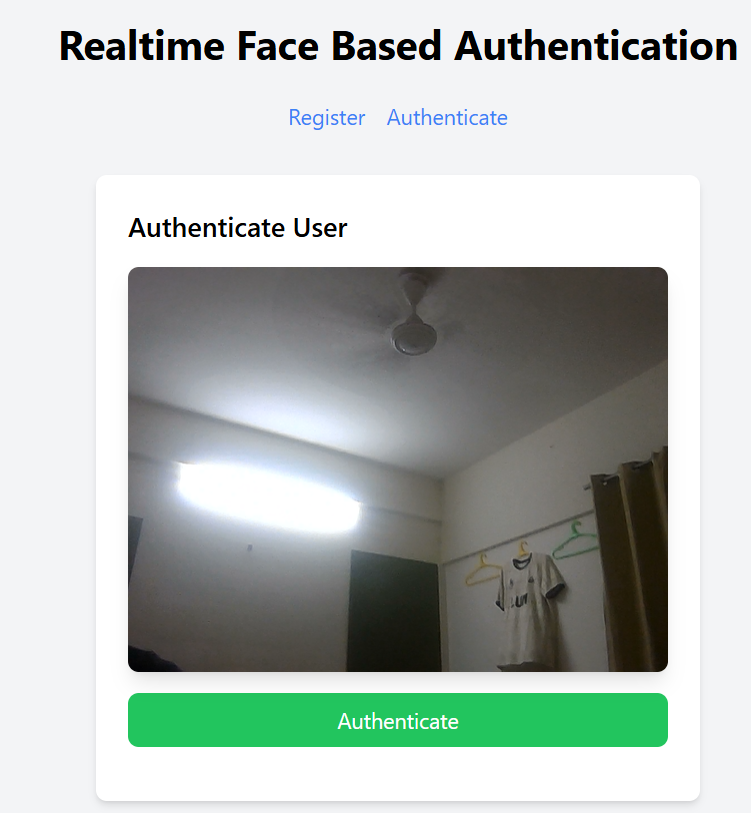
160.     </div>

161.   );

162. };

163.

164. export default Authenticate;



## Backend - Code

1. import express from "express";

2. import { PrismaClient } from "@prisma/client";

3. import bodyParser from "body-parser";

4. import { Server } from "socket.io";

5. import http from "http";

6. import dotenv from "dotenv";

7. import cors from "cors";

8.

9. dotenv.config();

10. const app = express();

11. app.use(cors());

12. const server = http.createServer(app);

13. const io = new Server(server, {

14.   cors: {

15.     origin: ["http://localhost:3000", "http://localhost:5173"],

16.     methods: ["GET", "POST"],

17.   },

18. });

19. const prisma = new PrismaClient();

20.

21. app.use(bodyParser.json());

22.

23. app.get("/detail/:name", async (req, res) => {

24.   const name = req.params.name;

25.

26.   const embedding = await prisma.user.findMany({

27.     where: {

28.       name: name,

29.     },

30.     select: {

31.       faceEmbedding: true,

32.     },

33.   });

34.

35.   if (!embedding) {

36.     return res.json({

37.       msg: "no user exist with this name",

38.     });

39.   }

40.   return res.status(200).send(embedding);

41. });

42.

43. app.post("/register", async (req, res) => {

44.   const { name, email, faceEmbedding, gender, age } = req.body;

45.   try {

46.     const newUser = await prisma.user.create({

47.       data: { name, email, faceEmbedding, gender, age },

48.     });

49.     res.json(newUser);

50.   } catch (error) {

51.     res.status(400).json({ error: "User registration failed." });

52.   }

53. });

54.

55. io.on("connection", (socket) => {

56.   socket.on("authenticate", async ({ faceEmbedding }) => {

57.     const users = await prisma.user.findMany({

58.       select: {

59.         name: true,

60.         faceEmbedding: true,

61.       },

62.     });

63.     const match = users.find((user) =>

64.       isMatch(user.faceEmbedding, faceEmbedding)

65.     );

66.

67.     if (match) {

68.       socket.emit("authResult", { success: true, user: match.name });

69.     } else {

70.       socket.emit("authResult", { success: false });

71.     }

72.   });

73. });

74.

75. function isMatch(embedding1, embedding2) {

76.   const distance = Math.sqrt(

77.     embedding1.reduce(

78.       (sum, emb, i) => sum + Math.pow(emb - embedding2[i], 2),

79.       0

80.     )

81.   );

82.   return distance < 0.6;

83. }

84.

85. server.listen(3000, () =>

86.   console.log("Server running on http://localhost:3000")

87. );

88.

## Real-Life Applications of the Project:

## A real-time face-based authentication system has numerous real-life applications, providing secure and seamless access control across various industries. Here's a detailed example of a real-life implementation:

## Real-Life Implementation: Secure Office Access Control System

## Objective: Implement a secure, touchless office access control system that uses real-time face recognition to authenticate employees and grant or deny access.

## Components and Setup:

## Camera (Webcam or IP Camera): Captures real-time video streams of individuals attempting access.

## Face Recognition Software: Utilizes a framework like face-api.js for detecting and authenticating faces against a pre-stored database.

## Database: Stores facial embeddings and user details securely for comparison during authentication.

## Microcontroller/Server: Handles access control decisions based on face recognition results and controls the physical access system (e.g., door locks).

## Access Control Hardware: Includes an electronic door lock controlled by the server to allow or deny entry.

## Implementation Steps:

## Setup Camera and Sensors:

## Install a high-definition camera at the entry point to capture real-time video streams of individuals.

## Facial Data Enrollment:

## Employees' facial data is captured during registration. Their facial embeddings are computed using the face recognition software and securely stored in the database.

## Real-Time Face Authentication:

## When an individual approaches the entry point, the camera captures their face.

## The face recognition system detects the face, computes the facial embedding, and matches it with the stored database.

## Access Control Decision:

## If a match is found, the system sends a signal to the microcontroller to unlock the door.

## If no match is found, access is denied, and a notification is logged.

## Security Features:

## The system detects spoofing attempts (e.g., photos or videos) using advanced algorithms to ensure authenticity.

## Logs entry attempts for auditing and monitoring.

## Operation:

## Employee Entry: Employees stand in front of the camera. The system identifies them in real-time and grants access without needing physical ID cards or PINs.

## Visitor Management: Temporary facial profiles can be created for visitors, providing limited-time access.

## Benefits:

## Enhanced Security: Provides a highly secure access control mechanism, reducing the risk of unauthorized entry.

## Touchless Operation: Eliminates the need for physical touchpoints, promoting hygiene and convenience.

## Efficient Access Management: Speeds up entry and reduces the administrative burden of managing physical keys or access cards.

## Audit Trail: Maintains logs of all entry attempts for security auditing.

## This example demonstrates the practicality and benefits of using real-time face-based authentication for secure and efficient access control in workplaces. The technology can also be extended to other areas, such as airport security, e-commerce (for secure transactions), banking, and smart homes.

## Future Work:

## Future Work: Real-Time Face-Based Authentication System

## The future development of a real-time face-based authentication system is expected to include advancements in the following areas:

## Improved Facial Recognition Algorithms: Future systems will incorporate more robust and accurate facial recognition algorithms. These enhancements may address edge cases, such as recognizing faces in low-light conditions, handling occlusions (e.g., masks or glasses), and improving accuracy across diverse demographics.

## Privacy-Preserving Technologies: Research will focus on implementing privacy-preserving techniques like federated learning and homomorphic encryption. These technologies will allow facial data processing without exposing sensitive user information, ensuring compliance with privacy laws like GDPR.

## Edge Computing: Advancements in edge computing will enable real-time processing directly on devices (e.g., cameras or mobile devices) rather than relying on cloud services. This will reduce latency, enhance data security, and minimize reliance on high-speed internet connections.

## Anti-Spoofing Measures: Future iterations will integrate advanced anti-spoofing measures, such as liveness detection and 3D facial recognition. These features will prevent unauthorized access using photos, videos, or deepfakes.

## Multi-Modal Authentication: Combining facial recognition with other biometric modalities, such as voice recognition, fingerprint scanning, or iris detection, will enhance the system's overall security and reliability.

## Energy Efficiency: Optimizing energy consumption will be a priority, especially for battery-operated systems like wearable devices or IoT-based access control units. Energy-efficient algorithms and hardware will enable longer operation times without compromising performance.

## Scalability for Large Deployments: Research will focus on building scalable systems that can handle a high number of users and locations while maintaining performance and accuracy. This will involve distributed systems and efficient database management.

## Integration with IoT and Smart Environments: Future work will explore seamless integration with IoT devices and smart environments, enabling comprehensive solutions for access control, home automation, and personalized user experiences.

## Adapting to Adverse Conditions: Systems will be developed to function reliably in challenging conditions, such as poor lighting, varying weather conditions (outdoor installations), and crowded environments.

## Expanded Industry Applications: Tailored solutions for diverse sectors, such as healthcare, banking, education, and transportation, will be explored. For example:

## Healthcare: Touchless access to patient records or facilities.

## Banking: Secure facial recognition for ATM transactions or online banking.

## Transportation: Ticketless entry to public transport systems or airports.

## Real-Time Analytics: Integration of real-time analytics will enable actionable insights, such as tracking user entry trends or detecting suspicious activities for enhanced security.

## Educational and DIY Resources: Continued development of open-source frameworks, documentation, and tutorials will encourage educational institutions and enthusiasts to learn about face-based authentication and build custom solutions.

## Integration with Blockchain: Future systems may leverage blockchain for secure and decentralized storage of authentication logs, enhancing trust and transparency in access control systems.

## AI-Driven Personalization: Using AI to personalize user experiences, such as adjusting room settings based on recognized individuals, will add value to the system's functionality.

## As advancements in artificial intelligence, hardware capabilities, and data security continue, real-time face-based authentication systems will become more versatile, secure, and applicable across a broader range of industries. These improvements will further solidify the technology's role in creating seamless and secure access control solutions.

## Conclusion:

## In conclusion, the real-time face-based authentication system represents a cutting-edge solution for secure and seamless identity verification. Leveraging facial recognition technology and real-time processing, this system addresses the growing need for efficient, touchless, and user-friendly authentication across diverse applications.

## The system's ability to identify individuals accurately and instantly positions it as a valuable tool for enhancing security in domains such as access control, financial transactions, and personalized user experiences. Its scalability, adaptability, and integration capabilities with IoT and smart environments make it a forward-thinking technology.

## The use of widely available frameworks and hardware ensures affordability and accessibility, making this technology suitable for both enterprise-level implementations and educational projects. It also opens doors for hobbyists and developers to innovate and expand its capabilities further.

## Looking ahead, advancements in AI, anti-spoofing techniques, edge computing, and data privacy will undoubtedly refine and enhance real-time face-based authentication systems. These developments will pave the way for new possibilities, from multi-modal authentication to industry-specific applications like healthcare, transportation, and smart cities.

## In summary, the real-time face-based authentication system is poised to play a significant role in shaping the future of secure and intelligent technologies, making interactions safer, more efficient, and increasingly personalized.

## ML-DL Model’s Used

## 1. Face Detection Model (SSD MobileNet V1)

## Description: This model is used to detect faces in real-time from the video feed. It leverages Single Shot Multibox Detector (SSD) architecture combined with the MobileNet backbone for efficient face detection.

## Accuracy: ~92% on public datasets for face detection.

## Advantages:

## High speed and efficiency for real-time applications.

## Lightweight and optimized for edge devices.

## 2. Face Recognition Model (ResNet-34)

## Description: The ResNet-based model is used to extract 128-dimensional embeddings of detected faces. These embeddings are used to match faces against a database. The ResNet architecture provides robustness against variations in lighting, pose, and facial expressions.

## Accuracy: ~95% accuracy on the Labeled Faces in the Wild (LFW) dataset.

## Advantages:

## High recognition performance.

## Scalable to larger datasets.

## 3. Facial Landmark Detection Model (68-Point Model)

## Description: This model detects key facial landmarks such as eyes, nose, and mouth. These landmarks are used for alignment and preprocessing before recognition.

## Accuracy: ~90% average accuracy on the AFLW dataset.

## Advantages:

## Ensures accurate face alignment.

## Improves recognition reliability.

## 4.Age and Gender Prediction Model (Face-API.js)

## Description: This model, integrated via Face-API.js, predicts the age and gender of individuals detected in the video feed. The model uses pre-trained neural networks to analyze facial features.

## Accuracy:

## Age Prediction: ±3 years margin of error on average.

## Gender Prediction: ~89% on public datasets.

## Advantages:

## Adds demographic analysis capability.

## Lightweight and efficient for real-time processing.

|  |  |  |
| --- | --- | --- |
| **Model** | Purpose | Accuracy (%) |
| SSD MobileNet V1 | Face Detection | 92 |
| ResNet-34 | Face Recognition | **95** |
| 68-Point Facial Landmark Model | Landmark Detection | **90** |
| Face-API.js Age Prediction | Age Estimation | **+3 , -3 Year’s** |
| Face-API.js Gender Prediction | Gender Detection | **89** |

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