**CHAPTER 1**

**INTRODUCTION**

**1.1 Introduction to the Project**

In the modern world, public safety and surveillance have become critical aspects of urban infrastructure. With the exponential growth of CCTV installations, there is a growing demand for intelligent systems that can automate the process of monitoring and analyzing video footage. Manual monitoring is not only time-consuming but also prone to human error. This project aims to develop an automated CCTV Footage Person Attribute Extraction System using deep learning and computer vision techniques. The system will allow users to manually upload surveillance videos, which will then be analyzed to extract vital person attributes.

The key objective of this project is to identify and classify multiple soft biometric attributes from video frames, such as age, weight, height, clothing type, and walking style (gait). These attributes are extremely useful in forensic investigations, crowd analysis, and missing person identification. By extracting such information directly from video, authorities can gain insights into suspects or individuals of interest without needing clear facial recognition or ID verification, especially when camera quality or conditions are suboptimal.

To accomplish this, the system utilizes a pipeline of deep learning models that work in stages: first detecting humans in the video, then segmenting their bodies and faces, and finally estimating different attributes. The architecture integrates state-of-the-art models for detection and classification, trained on publicly available datasets. Gait and posture are analyzed using motion-based patterns extracted over sequential frames, whereas visual features like clothing and body proportions are handled using frame-wise object recognition models.

This project not only contributes to the growing field of smart surveillance but also addresses real-world challenges such as occlusion, low resolution, varying lighting conditions, and crowded scenes. It is designed to be robust, extensible, and usable in multiple environments, including public spaces, transportation hubs, and secure facilities. By automating the process of attribute extraction from surveillance videos, the system enhances both the efficiency and accuracy of person tracking and identification.

**1.2 Introduction to Technology used**

Some of the core technologies used in this project is YOLO (You Only Look Once), Convolutional Neural Networks (CNNs) and temporal analysis models such as LSTM.

**1.2.1 YOLO (You Only Look Once )** :

YOLO (You Only Look Once) is utilized as the primary object detection model to accurately identify and locate human figures in the frames of manually uploaded CCTV footage. YOLO divides each video frame into a grid and simultaneously predicts bounding boxes and class probabilities for each region, enabling fast and precise detection of persons. This allows the system to efficiently extract the relevant regions of interest, significantly reducing the computational load for subsequent attribute analysis stages. By leveraging YOLO’s robust detection capability, the system ensures high accuracy in identifying individuals even in complex environments, such as crowded scenes or low-quality footage, which are common in surveillance videos.

**1.2.2 Convolutional Neural Networks (CNNs) :**

Convolutional Neural Networks (CNNs) are used as the core deep learning architecture for extracting and analyzing visual features from detected human regions in the uploaded CCTV video. After identifying and cropping the person from each frame using YOLO, CNNs process these regions to classify a variety of attributes such as age, clothing type, body shape, and facial features. CNNs are particularly well-suited for this task due to their ability to automatically learn hierarchical patterns in image data, such as textures, edges, and shapes, which are crucial for distinguishing subtle visual differences in human appearance. By leveraging CNNs, the system can perform robust and scalable attribute recognition even under variations in pose, lighting, and background clutter, making them essential for the success of person attribute extraction from surveillance footage.

**1.2.3 Long Short-Term Memory (LSTM) :**

Long Short-Term Memory (LSTM) networks are employed to recognize a person's gait or walking style from sequential video frames. Since gait is a temporal pattern that unfolds over time, LSTMs are well-suited for capturing such dynamic motion information. After detecting and tracking a person across multiple frames, relevant pose or body movement features are extracted and passed to an LSTM model. The LSTM processes these features in sequence, learning the temporal dependencies between body movements to identify unique gait characteristics. This enables the system to distinguish between different walking styles, which can serve as a soft biometric for person identification, even in cases where facial details are not clearly visible. LSTM’s ability to retain important motion cues over time makes it a critical component for gait recognition in surveillance-based attribute extraction

**1.3 unicodes**

Unicode is defined by Wikipedia as “a computing industry standard for the consistent encoding, representation, and handling of text expressed in most of the world's writing systems.” Unicode was developed when 8-bit encoding systems such as ASCII were still popular. Since ASCII could hold only 256 characters, only Roman characters were represented.

Many countries had developed their own versions of ASCII for their native languages. For example India developed ISCII. Alternatively, early Kannada writing software such as Baraha used customized ASCII fonts that merely rendered their own Kannada glyphs in place of the correct ASCII glyphs. While this solution is good for printing Kannada text on paper it is not suitable for applications such as transmitting Kannada text online or displaying Kannada text in web pages or on mobile devices. A universal encoding standard is needed. Unicode uses 16 bits (specifically UTF-16 uses 16 bits), which is way more than enough to represent characters in all of the world’s living languages, as well as historic scripts such as Brahmi.

UTF-16 assigns each of its characters with a unique 16-bit identification number known as a code point, and leaves the rendering of the character to the software. The code points for Kannada characters are in the range of 0x0C82 to 0x0CF2. This range of code points is reserved exclusively for Kannada characters, unlike in ISCII where the same character in different Indian languages is assigned the same code point.

**CHAPTER 2**

**LITERATURE SURVEY**

**2.1 Introduction**

In recent years, the integration of deep learning and computer vision in surveillance systems has transformed the way human identification and behaviour analysis are performed. Traditional CCTV systems rely heavily on manual monitoring, which is time-consuming and error-prone. With the advancements in artificial intelligence, especially convolutional neural networks (CNNs) and pose estimation techniques, it is now possible to automatically extract detailed person attributes from video footage, including age, gender, height, weight, clothing type, and gait.

Our system leverages deep learning models to analyze video input which are uploaded manually. The system processes each frame to detect individuals and estimate their soft biometrics and physical attributes using image and motions .This capability is especially valuable for smart surveillance, public safety, and forensic investigations. To build a robust and accurate model, it is essential to review existing literature on person attribute recognition, gait analysis, pose estimation, and multi-modal biometric systems. The literature survey provides insights into previously proposed models, datasets, methodologies, and real-world challenges, forming a foundation for designing and improving the system.

**2.2 Literature Survey**

Rohit Kumar Gupta et al. (2022), [1] proposed a CNN-based model for detecting age and gender from facial images, including real-time CCTV footage. The model uses convolutional, pooling, and fully connected layers with a softmax classifier to categorize gender (male or female) and age into specific groups. Trained on a Kaggle dataset with varied lighting and poses, the model treats age prediction as a classification task, enhancing accuracy in uncontrolled environments. This approach serves as a strong reference for our project, where we adapt their architecture and strategy for broader surveillance tasks like person identification and attribute-based filtering.

Sivachandiran et al. (2022), [2] developed an automated deep learning model named ADCNN-AGC for classifying age and gender from facial images in surveillance systems. The model uses MTCNN for detecting faces, EfficientNet for feature extraction, and 1D-CNN for classification. Tested on the UTKFace dataset, the model achieved 95.29% accuracy for gender and a mean absolute error of 2.89 in age prediction. Compared to other recent models like GRA-Net and RAN, ADCNN-AGC demonstrated superior results in both efficiency and accuracy. This research provides a robust and scalable solution for real-time demographic analysis and is highly relevant for CCTV-based systems where facial attributes need to be extracted quickly and accurately under uncontrolled conditions.

Nikouei et al. (2018), [3] proposed a real-time human detection system for edge computing environments using a Lightweight Convolutional Neural Network (L-CNN). Designed with resource constraints in mind, the model employs depthwise separable convolutions and is based on the SSD (Single Shot Multibox Detector) architecture, enabling efficient detection of human figures in surveillance footage. Tested on a Raspberry Pi 3, the L-CNN demonstrated competitive performance, achieving an average speed of 1.79 frames per second (FPS) and a false positive rate of 6.6%, while using significantly less memory than other standard models such as SSD-GoogleNet. This model is particularly relevant to edge-based smart surveillance systems, offering a viable approach for efficient person detection under limited hardware. Its application as a frontend human detector makes it a practical reference for projects like ours that require low-latency, high-accuracy person attribute extraction from CCTV footage.

Guruh Fajar Shidik et al. (2019), [4] conducted a systematic literature review analyzing 220 journal publications on intelligent video surveillance systems from 2010 to 2019. The study categorizes research trends into three main areas: visual surveillance, intelligent surveillance integration, and system infrastructure design. It provides a detailed overview of machine learning techniques—especially deep learning, SVM, and fuzzy logic—used for surveillance tasks such as object detection, behavior analysis, and activity recognition. The review highlights key public datasets and evaluates five widely cited surveillance frameworks (e.g., SSF, RISE, and EDCAR), offering a valuable foundation for modular and scalable surveillance solutions. Although the paper lacks experimental validation, it serves as a rich knowledge base for developing advanced systems. For our CCTV-based person attribute extraction project, this review offers strategic insights into system design, suitable datasets, and integration frameworks, supporting the development of a robust, real-time surveillance solution focused on identifying multiple soft biometric traits.

Hitesh Panchal (2016), [5] The paper "CCTV Video Abstraction and Object Detection for Video Surveillance System" by Hitesh Panchal introduces an innovative algorithm for key frame extraction from CCTV footage, addressing the challenges of analyzing extensive video data. By employing video segmentation and automatic shot boundary detection, the algorithm efficiently summarizes video content, allowing for quick retrieval of relevant frames. This work highlights the importance of intelligent video management in surveillance systems, paving the way for further research in person attribute extraction. The findings emphasize the potential for enhancing video analysis techniques, which can be beneficial for developing advanced surveillance applications.

Joseph Redmon et al. (2018), [6] The paper "YOLOv3: An Incremental Improvement" by Joseph Redmon and Ali Farhadi presents significant enhancements to the YOLO object detection framework. The authors introduce a new classifier network that improves accuracy while maintaining high processing speed, achieving 28.2 mAP at 320x320 resolution. YOLOv3 employs multiscale predictions and a multilabel classification approach, allowing for effective detection of overlapping labels. This work highlights the advancements in real-time object detection, making it a crucial reference for projects focused on person attribute extraction from CCTV footage, where speed and accuracy are paramount for effective surveillance analysis.

Xiao Ke et al. (2020), [7] introduced a deep learning approach for extracting human attributes from surveillance images. It integrates SSD-based pose estimation and multi-feature fusion to effectively identify clothing attributes, addressing issues like pixel resolution and background interference. This approach is particularly relevant for CCTV attribute extraction systems, where accurate human region isolation is crucial for robust performance.

Prof. Nandhini N et al. (2019), [8] discussed a deep learning approach for identifying anomalies in surveillance footage. It leverages CNNs for feature extraction and anomaly detection, providing a robust framework for real-time analysis of high-dimensional data. This method can be adapted for person attribute extraction by focusing on specific human characteristics and movement patterns, making it a valuable reference for surveillance systems that require precise behavior monitoring.

Hiren Galiyawala et al. (2022), [9] presented a deep learning approach for person identification based on soft biometrics like age and clothing type. It uses Mask R-CNN for accurate person detection and attribute recognition, achieving high retrieval accuracy with fewer attributes. This method is highly relevant for CCTV-based person attribute extraction systems, providing a streamlined approach to identifying individuals in complex surveillance environments.

Fabbri et al. (2017), [10] proposed a tri-network approach (ResNet classifier + occlusion-resistant DCGAN + super-resolution DCGAN) for low-resolution surveillance video-based attribute classification, achieving a state-of-the-art benchmark on RAP under 80% occlusion/low resolution. It outperformed DeepMAR/ACN by >6% mAP by recovering classifiable features. The module-based architecture is stronger but limits real-time use.

Shoitan et al. (2023 ), [11] proposed a spatio-temporal person retrieval method in video surveillance using a combination of ByteTrack for robust tracking and two attribute recognition models—APR and ALM—to provide higher accuracy. Unlike conventional methods, their method relates the bounding boxes from frames to reduce detection errors and enhance attribute recognition. Evaluated on the SoftBioSearch dataset, the system achieved a 93.21% true positive, 14% better than state-of-the-art. While it performs well in occlusion and low visibility, its reliance on advanced tracking can be an issue for real-time applications. However, it addresses a significant loophole in attribute-based person retrieval.

Yaghoubi et al. (2020), [12] provided an exhaustive survey of Human Attribute Recognition (HAR), condensing state-of-the-art contributions in terms of most significant challenges such as data imbalance, occlusion, and attribute correlation. Different from previous surveys, they formulated a challenge-oriented taxonomy and critically examined deep learning methods, datasets, and measures, including sub-areas such as pedestrian and clothing attribute recognition. The survey recognizes gaps in the literature including the absence of integrated data, occlusion, and model explainability. It recognizes the use of CNNs, GCNs, and RNNs in filling the gaps, providing insightful information in the design of more trustworthy and interpretable HAR systems.

Amirgaliyev et al. (2025), [13] gave a comprehensive overview of ML and DL methods for person detection, tracking, identification, and face recognition, focusing on the shift from traditional features to deep CNNs like YOLO and FaceNet. Using the PRISMA method, they evaluated over 140 articles and encountered issues of occlusion, night vision, and ethical concerns. The research points to efficient, privacy-sensitive models and rich data sets as crucial, with directions for future research in smart surveillance systems suggested.

Haritha et al. (2025), [14] developed an AI-powered surveillance framework using YOLOv8 for object detection and LSTM for anomaly detection to promote public safety through automated crowd monitoring and prevention of crime. The system can operate in real-time using CCTV footage to monitor crowd density and spotting suspicious activity so that alerts can be given when an anomaly or over-crowding occurs. The authors report high detection results (95.4%) and anomaly detection recognition (92.7%) along with a 30% computation overhead; allowing the framework to be built on existing CCTV hardwares. The model uses contextual filtering and low latency processing to assist secure alterations, and scalability or operational effectiveness in workplace environments, public areas and industrial locations. While the framework showed a successful proof of concept, the system's ability to be optimized to other environments, along with the ambiguity of privacy implications will require future evaluation.

Amirgaliyev et al. (2025), [15] presented a systematic review of over 140 studies focused on machine learning and deep learning techniques for person detection, tracking, identification, and face recognition. They analyze classical approaches like HOG and Kalman filters alongside modern deep models such as YOLO, ArcFace, and DeepSORT. The paper highlights real-world applications in surveillance, transportation, and smart cities while addressing challenges such as occlusion, real-time constraints, and ethical concerns. This review serves as a valuable reference for developing intelligent video surveillance systems, especially for projects involving CCTV-based person attribute extraction using deep learning.

Iyshwarya Ratthi et al. (2024), [16] introduced an AI-based human height estimation model for surveillance, leveraging monocular cameras and YOLOv7 with a hybrid attention mechanism (HAM). Designed to aid in missing child retrieval, the system uses camera calibration and a new dataset (“Sense-Height”) featuring adults and children. Unlike traditional models, this approach handles occlusion, diverse lighting, and motion conditions with high accuracy (error as low as 0.02 cm). The paper provides strong empirical validation and proposes a field-of-view (FOV) zoning strategy. This work is significant for integrating height as a soft biometric in intelligent video surveillance.

Taha et al. (2024), [17] proposed a gait recognition model using IMU data instead of conventional video. Their system collects gait features from shoe-embedded sensors and processes them using stacked sparse autoencoders. The high-level features are then clustered to identify physical characteristics like age, gender, and body size. The model shows greater robustness to occlusion and environmental variation than visual gait recognition systems. While it is not directly usable for CCTV-based projects, its deep learning approach and gait-based soft biometric extraction provide a strong conceptual base for designing attribute recognition models using motion cues in surveillance footage.

Gururaj et al. (2024), [18] presented a detailed review of face recognition (FR) systems, covering traditional techniques like PCA and LDA, and advanced deep learning methods including CNN-based hybrid models. The paper explores FR challenges such as pose variation, occlusion, and aging, while classifying existing approaches into appearance-based, landmark-based, and hybrid methods. It also discusses video-based FR systems, dataset availability, and future directions. Although it does not introduce new models, this survey offers valuable insights into the selection of algorithms and datasets that can aid in developing accurate and real-time person attribute recognition from CCTV surveillance footage.

**2.3 Summary of Literature Survey**

Table 2.1 shows the summary of literature survey done.

**Table 2.1: Observations of Literature Survey**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Author Name** | **Title of Paper** | **Methodology used** | **Advantages** | **Future Work** |
| Rohit Kumar Gupta, Shivaprasad M B, Dr. S. Srividhya | Age & GenderDetection using Convolutional Neural Network | Multi-Branch Deep Neural Network | Simple CNN architecture. Utilizes Keras, TensorFlow, OpenCV.Classifies into defined age/gender classes. | Improve accuracy under challenging conditions. Expand attributes beyond age/gender. Real-time multi-person detection. |
|  |  |  |  |  |
|  |  |  |  |  |

**2.4 Comparison with Existing Systems**

System offers a significant advancement over traditional methods by integrating advanced image analysis and a user-friendly digital interface. Unlike existing systems that rely primarily on user-provided data such as footwear size, brand preferences, and historical purchases our approach leverages foot photo analysis to assess actual physical characteristics like foot length, width, shape, arch type, and potentially gait patterns. This shift from subjective input to objective measurement allows for far more accurate and personalized recommendations.

In contrast to conventional systems that often require users to manually select sizes or navigate style filters, our application simplifies the process. Users can either take a photo of their foot or upload an existing one, and the system will automatically detect and display the foot's length in centimeters using image processing techniques. This eliminates guesswork and ensures sizing precision. Following this, users are prompted to select their gender, which helps further refine the recommendation logic based on gender-specific sizing and fit parameters.

Another key differentiator is the app's integration with online shopping platforms. After foot analysis and gender selection, users are presented with curated options from selected e- commerce websites, allowing them to seamlessly proceed to purchase footwear that best suits their anatomical profile. This creates a unified experience from measurement to purchase. Privacy and data security are addressed through robust anonymization protocols and secure data handling practices, which are essential when dealing with biometric imagery. Unlike existing systems that analyze shopping history or collect potentially intrusive user input, our system focuses purely on physical foot attribute ensuring data relevance and minimal privacy concerns.

Finally, in a competitive market where many footwear recommendation tools rely on brand affiliations or customer reviews, our solution stands out by offering scientifically grounded, anatomically accurate recommendations. It not only improves user satisfaction through better fit and comfort but also redefines how consumers interact with footwear e-commerce by offering a tailored, intuitive, and efficient experience.

**2.5 Proposed System**

The proposed system for our footwear recommendation application leverages cutting-edge image processing and user-centric design to deliver a highly personalized, efficient, and secure user experience. The core component of the system is the Image Processing Module, which plays a crucial role in analyzing foot photos uploaded or captured by the user. This module will employ advanced image analysis techniques to extract precise measurements and characteristics such as foot length, width, shape, and arch type. These features are essential in determining the accurate footwear size and the ideal footwear fit, which varies based on individual foot structure. By ensuring accurate measurement and foot profiling, the system aims to significantly reduce the likelihood of sizing issues and improve overall customer satisfaction.

To make the process simple and accessible for users, the application will feature a user-friendly interface that guides them through each step. Users will be able to either take a photo of their foot in real time or upload one from their device gallery. After submitting the photo, they will be prompted to select their gender, which helps in narrowing down the footwear catalog, as sizes and styles often differ between male and female categories. Additionally, the user will be asked to choose their preferred e-commerce platform such as Amazon, Flipkart, or Zappos from which they would like to purchase footwears. Based on this selection, the system will recommend suitable products directly from the chosen platform, along with purchase links for a smooth and seamless shopping experience. Security and privacy are key priorities in our system. All uploaded photos and user data will be handled with strong encryption methods and securely stored to prevent unauthorized access. User consent will be a requirement for data usage, and data retention policies will comply with modern privacy standards. These measures are essential to protect sensitive biometric data and build user trust in the system.

To ensure scalability and performance, the backend system will be optimized to handle a high volume of user requests and data processing operations without delays. This ensures that the app remains responsive and efficient even during peak usage times. The system will also support cloud-based architecture to scale resources dynamically based on demand.

Finally, the application will incorporate a continuous feedback mechanism, where users can rate the footwear recommendations, leave reviews, and provide additional preferences. This feedback will be fed into a machine learning-based recommendation engine that continuously adapts and improves its suggestions based on user behavior and trends. Over time, this will enable the app to offer increasingly accurate and relevant recommendations, enhancing the overall user experience and keeping the system aligned with evolving user needs and preferences.

**2.6 Objectives**

* To develop a cross-platform mobile application using React Native that runs on Expo Go for foot size prediction.
* To enable users to capture or upload an image of their foot and receive accurate foot size estimations using image processing techniques and a clustering-based algorithm.
* To build a Flask-based backend server to process images, compute foot measurements, and communicate results back to the mobile client.
* To implement a secure user authentication system (registration, login, and profile editing) with PostgreSQL as the user database.
* To integrate the backend with CSV-based URL mapping for major platforms like Amazon, Flipkart, and Zappos, providing product links based on foot size, gender, and category.
* To ensure a user-friendly and responsive UI in the mobile app that allows seamless interaction with the prediction and recommendation system.
* To facilitate easy deployment and testing via Expo Go, allowing quick access and feedback during development and demonstration.
* To ensure the system is modular, scalable, and ready for future enhancements, such as local prediction or multi-brand filtering.

**CHAPTER 3**

**REQUIREMENT SPECIFICATION AND ANALYSIS**

**3.1 Introduction**

Our footwear recommendation project leverages sophisticated foot image analysis to accurately determine measurements such as foot length, width, and girth. These measurements are then matched with footwear specifications from popular platforms like Zappos, Amazon, and Flipkart to provide personalized recommendations. The application features an intuitive interface that enables easy photo uploads, gender selection, and direct purchasing, with a strong focus on user privacy, precision, and high performance.

**3.2 Functional Requirements**

* **Image Processing Module**

Develop a robust image processing module capable of analyzing foot photos to accurately extract key measurements. These include foot length, width at the ball and bridge, and overall girth. This module will serve as the foundation for precise footwear size detection and fit analysis.

* **Footwear Recommendation Algorithm**

Implement an intelligent matching algorithm that utilizes the extracted foot measurements along with the user’s selected gender to recommend suitable footwear. This algorithm will compare the user's measurements with a curated database of footwear specifications to ensure personalized and accurate suggestions.

* **E-Commerce Platform Integration**

Integrate the system with major online retail platforms such as Zappos, Amazon, and Flipkart. This will allow real-time fetching of relevant footwear options that match the user’s profile and preferences, enabling a seamless experience from measurement to purchase.

* **User Interface and Experience**

Design and deploy a user-friendly front-end interface using React and Expo Go, allowing users to effortlessly upload foot images, choose gender, and view recommended products. The interface will emphasize ease of use, speed, and responsiveness.

* **Back-End and Data Management**

Use Node.js to handle server-side logic and API communication, ensuring secure processing of data and efficient handling of user interactions. Implement PostgreSQL as the primary database to store user data, foot measurements, recommendation logs, and product listings from integrated platforms.

* **Cross-Platform Mobile Support**

Utilize Expo Go to enable quick testing and deployment of the mobile app on both Android and iOS platforms, ensuring broad accessibility and consistent performance across devices.

**3.3 User Interface Requirements**

* Users should be able to upload a foot photo either by taking a new picture or selecting one from their gallery.
* Users must select their gender to receive accurate and relevant footwear recommendations.
* The system should provide precise foot measurements such as length, width, and girth based on the uploaded image.
* Users should receive personalized footwear suggestions that match their foot dimensions and selected gender.
* Users must have the option to choose their preferred e-commerce platform like Amazon, Flipkart, or Zappos to view and purchase recommended footwears.
* The application should ensure secure handling of foot images and personal data, while offering smooth and consistent performance across mobile devices.

**3.4 Integration with Social Platforms**

* Integrate the application with popular social media platforms and footwear focused communities to utilize user-generated content for improving recommendation accuracy.
* Leverage social trends, reviews, and fashion insights from these platforms to enhance the personalization of footwear suggestions.
* Allow users to share their recommended footwears, feedback, or purchase experiences directly on social media to encourage engagement.
* Promote community interaction and brand visibility by fostering a social environment where users can explore, discuss, and support footwear choices.

**3.5 Software Requirements**

The project requires the following software to run:

**3.5.1 ReactJS**

React JS is used for developing the front-end interface of the application. It allows the creation of dynamic and reusable components, which enhance user interaction and responsiveness. React’s virtual DOM helps improve performance by minimizing direct manipulation of the actual DOM. This ensures a smooth and efficient user experience across devices.

**3.5.2 Expo Go**

Expo Go is a framework and platform for universal React applications. It enables developers to preview their React Native app instantly on a mobile device by scanning a QR code, eliminating the need to build the app every time. This significantly accelerates the testing and development cycle. Expo also provides various built-in tools and libraries to simplify app deployment.

**3.5.3 Node.js**

Node.js is used to manage the back-end operations of the app. It handles server- side logic, API requests, and real-time data processing efficiently. Being event-driven and non-blocking, Node.js supports scalability and fast response times. It ensures seamless communication between the client interface and the database.

**3.5.4 PostgreSQL**

PostgreSQL is the relational database used to store and manage structured data such as user profiles, foot measurements, and footwear product details. It supports complex queries and ensures data integrity and security. With its open-source nature and advanced performance features, it is ideal for handling large-scale data efficiently. It integrates smoothly with Node.js back-end frameworks.

**3.5.5 Visual Studio Code (VS Code)**

VS Code is the chosen integrated development environment (IDE) for writing and organizing the project’s source code. It provides intelligent code completion, syntax highlighting, debugging tools, and extensions tailored for JavaScript, React.

**3.5.6 npm (Node Package Manager)**

npm is used to install and manage the various dependencies and libraries required by the application. It ensures that packages like React, Express, and image processing tools are consistently installed and maintained across development environments. npm scripts can also automate tasks such as starting servers or building production versions of the app. This tool is essential for efficient project setup and management.

**3.5.7 Image Processing Libraries**

Image processing libraries like OpenCV.js are essential for analyzing foot images and extracting accurate measurements such as length, width, and girth. These libraries provide functions for image filtering, edge detection, scaling, and measurement calculations. They help automate the analysis process with high precision. Integration with the front-end ensures real-time feedback to the user based on the processed image.

**3.5.8 Python Programming language**

Python programming language is essential for our footwear recommendation project due to its versatility, rich ecosystem of libraries, and ease of integration with various technologies. Python's extensive libraries such as OpenCV for image processing, NumPy for numerical computations, and Flask for web development make it ideal for implementing the image analysis module and backend services. Its simplicity and readability enhance development efficiency, allowing rapid prototyping and iterative improvements.

**3.6 Hardware Requirements**

**3.6.1 Processor (CPU)**

The hardware requirements for our footwear recommendation project include a minimum Intel Core i5 or equivalent processor, with a recommended upgrade to an Intel Core i7 or higher for optimal performance in processing image analysis and recommendation algorithms.

**3.6.2 Memory (RAM)**

For memory (RAM), a minimum of 8 GB is sufficient, though 16 GB or more is recommended to manage large datasets and concurrent user requests effectively. Storage should ideally start at a minimum of 256 GB SSD (Solid State Drive) for faster data access, with a recommended upgrade to 512 GB SSD or higher to accommodate user data, footwear information, and system logs

**3.6.3 Network Connectivity**

Stable internet connection for accessing e-commerce APIs, deploying updates, and ensuring seamless user experience.

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