INSIGHT VISION

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Introduction:

In today's highly competitive retail environment, understanding customer behavior is crucial for operational success and revenue growth. However, most retail stores still rely on outdated manual processes or basic footfall counters, which offer limited insights into visitor demographics or shopping patterns. This lack of real-time, detailed analytics limits a retailer's ability to personalize service, optimize staff allocation, and strategize marketing campaigns.

To bridge this gap, we propose Insight Vision, a smart camera system that leverages real-time computer vision to deliver actionable insights to store owners. This system goes beyond traditional counters by not only tracking footfall but also providing demographic breakdowns like age and gender and identifying peak business hours. It achieves this using advanced face detection and recognition models optimized for low-resource devices such as the Raspberry Pi 3 Model B+. The project demonstrates how AI, embedded systems, and intelligent data processing can come together to drive data-informed retail decisions.

Objectives:

1. To develop a smart video intelligence system capable of detecting and recognizing customer faces at retail store entrances.
2. To extract and store demographic information such as age and gender in real time.
3. To provide insights on visitor trends, peak hours, and customer frequency using a visual dashboard.
4. To implement the system on low-resource hardware like Raspberry Pi 3 B+ for cost-effective deployment.
5. To enable better business decisions through automated data collection and analysis.

Methodology:

The system architecture starts with a camera positioned at the store entrance, capturing live video at 1280x720 resolution and 30 FPS. OpenVINO's face-detection-retail-0005 model is used for detecting faces with low latency, outputting bounding box coordinates and confidence scores. Detected faces are then tracked across frames using a spatial and appearance-based tracking algorithm to minimize redundant recognition.

To ensure high-quality input, we apply a Head Pose Estimation filter that allows only front-facing faces (within ±30° yaw) and a Blur Detection filter based on Laplacian variance. Only high-quality face captures undergo embedding generation using OpenVINO's face-reidentification-retail-0095, which outputs a 256-dimensional face embedding vector optimized for real-time applications.

These embeddings are compared with previously stored entries using cosine similarity. If a match is found (similarity > 0.6), the system updates the visitor's data. If not, a new profile is created, generating a unique face ID, predicting age and gender, and storing all information in a PostgreSQL vector database.

The final stage involves visualizing the data in a user-friendly dashboard. This dashboard presents daily footfall, age and gender demographics, and peak visiting hours. The entire system runs efficiently on a Raspberry Pi 3 Model B+, making it suitable for budget-constrained retailers.

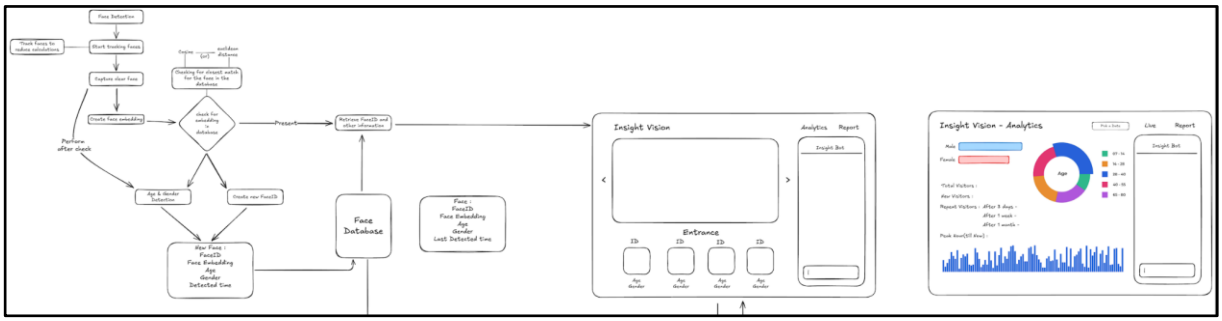

Figure 1 : Architecture of the Insight Vision

Result and Conclusion:

Our system successfully detects and recognizes customers in real time with high accuracy and speed. We evaluated two model combinations and chose the one offering optimal speed and acceptable accuracy (OpenVINO face detection + reidentification models). Key outcomes include:

- Stable performance on Raspberry Pi 3 Model B+
- Real-time detection and tracking
- Reliable demographic prediction
- Insights visualization via dashboard

The system delivers a daily footfall count, demographic charts, and peak hour reports. It provides a low-cost, automated alternative to traditional methods, enhancing the store's ability to understand and engage its visitors.

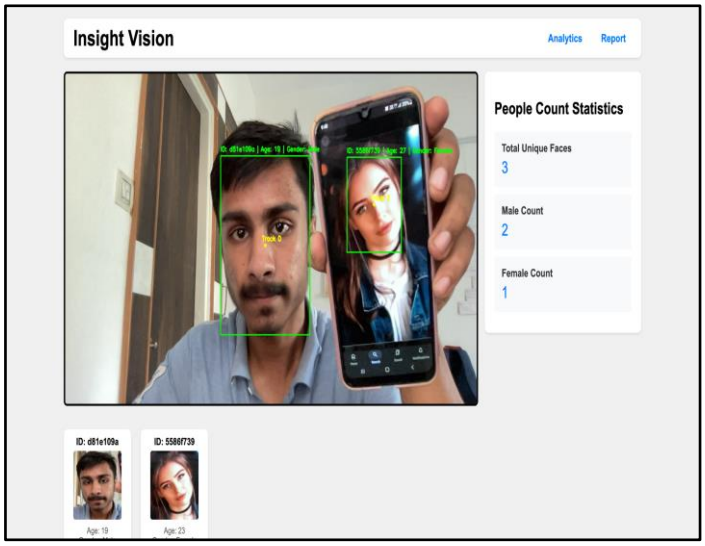

Figure 2 : Live Detection

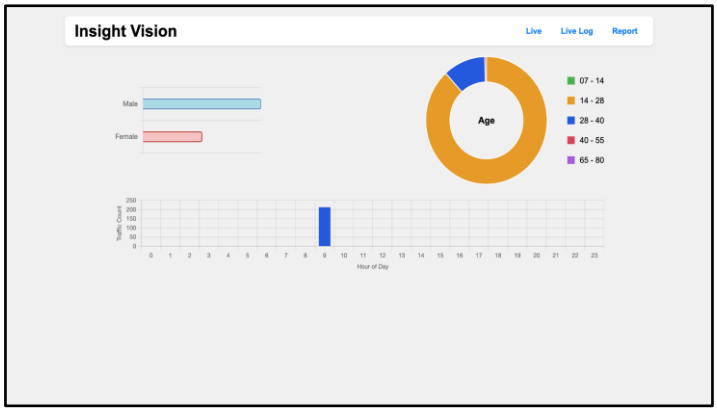

Figure 3: Analytics

Project Outcome & Industry Relevance:

Insight Vision offers a robust, affordable analytics solution tailored for retail environments. It automates the process of tracking customer visits, analyzing demographics, and identifying trends—without manual effort. The system can be deployed in small and mid-sized retail stores to improve marketing strategies, staffing decisions, and customer service.

In the broader industry, this project showcases how edge computing and AI can solve real-world challenges. The system's low resource footprint and high efficiency make it relevant for retail chains, malls, exhibitions, and public spaces where understanding crowd behavior is critical.

Working Model vs. Simulation/Study:

The project involves the development and testing of a fully working physical model implemented on Raspberry Pi 3 Model B+ using real-time video feed, embedded AI models, and a PostgreSQL database.

Project Outcomes and Learnings:

We learned how to integrate computer vision models on low-power devices, apply quality filters for improved accuracy, and manage vector-based face matching using cosine similarity. Key outcomes:

- Real-time insight generation
- Smooth performance on low hardware

- Deep understanding of OpenVINO optimization and facial recognition workflows

Future Scope:

The system can be extended with multiple cameras to track movement across various store sections. Integration with point-of-sale data can allow correlation between visit frequency and purchases, enabling conversion tracking. The dashboard can include predictive analytics and customer segmentation tools for even deeper insights. Additional improvements could include:

- Masked face recognition
- Emotion detection
- Cloud-based analytics dashboard
- Mobile app for real-time alerts
- Cross-store face tracking for retail chains

In future iterations, the model can also support multilingual speech-based interaction for customer queries or integrate with smart signage for personalized marketing in real time.