Dr. ASTAN: Data Report - Advanced Shopper Tracking and Analysis Network

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Abstract - This research article introduces Dr. ASTAN, an innovative system that uses multi-camera inputs to follow and evaluate shopper movements in a retail environment. Dr. ASTAN uses deep learning models, especially YOLOv5mu for object recognition and DeepSORT for real-time multi-object tracking in several zones. The objective of the system is to map consumer behavior, generate actionable insights, and visualize trends using Pandas and Power BI. The results offer retailers a comprehensive view of foot traffic, zone engagement, and consumer behavior patterns, enabling data-driven decision-making to enhance sales and customer experience.

***Key Words*:** Dr. ASTAN, deep learning, YOLOv5mu, DeepSORT, consumer behavior, retail analytics

1.INTRODUCTION

Understanding customer movement and behavior in retail settings is critical for optimizing shop layouts, increasing customer engagement, and driving sales. In response to this demand, Dr. ASTAN provides a complex solution that incorporates powerful computer vision algorithms. Using YOLOv5mu for shopper detection and DeepSORT for real-time multi-camera tracking, the system effectively monitors customer interactions in the retail setting. Dr. ASTAN analyzes client movement patterns by splitting the store into three critical zones, resulting in actionable knowledge that may be used to make strategic decisions. The processed data is visualized with tools like Pandas and Power BI, giving store managers a complete picture of shopper dispersion, traffic hotspots, and dwell times. This project not only improves understanding of consumer behavior but also empowers businesses to generate more engaging shopping experiences.

2. Body of Paper

2.1 Literature Review

2.1.1 Customer Tracking and Behavior Analysis in Retail

Understanding customer behavior in retail environments has been a subject of interest for many researchers, as it plays a significant role in optimizing store layouts, marketing strategies, and enhancing customer experiences. Traditional methods of tracking customer behavior often relied on technologies such as **RFID (Radio Frequency Identification)** and **Beacon-based systems** for gathering movement data. These systems, while useful, have limitations in terms of accuracy and scalability.

For example, **Zhao et al. (2017)** demonstrated the use of RFID tags to track customers in a retail environment, which allowed for insights into customer dwell time but lacked precise localization capabilities. Similarly, **Bluetooth beacon-based solutions Koo et al. (2018)** have been employed to track mobile devices inside stores, providing data on customer paths and hot zones. However, these approaches are limited by the need for customer devices and tags, which often miss out on anonymous customer behaviors.

2.1.2 Computer Vision in Retail Analytics

More recently, advancements in **computer vision (CV)** have led to the deployment of camera-based tracking systems, which provide a non-intrusive way to gather detailed customer movement data. Computer vision enables the identification, tracking, and analysis of customer activities in real-time without the need for external devices. One notable solution in this space is the use of **YOLO (You Only Look Once)**, an object detection algorithm that operates efficiently in real-time. YOLO has been widely used in retail for detecting and counting objects, including people, from camera feeds.

Redmon et al. (2016) introduced YOLO, which was a breakthrough in the field of object detection because of its speed and accuracy. YOLO divides the input image into grids and predicts bounding boxes and class probabilities directly from the image, making it suitable for real-time applications in dynamic environments like retail stores.

In parallel, **DeepSORT (Simple Online and Realtime Tracking with a Deep Association Metric)**, proposed by **Wojke et al. (2017)**, enhanced tracking by associating detected objects over multiple frames. DeepSORT integrates a **Kalman filter** for predicting the trajectory of objects and the **Hungarian algorithm** for data association, making it highly effective in maintaining consistent tracking over time.

2.1.3 Integrated Detection and Tracking Systems

Several systems have attempted to integrate object detection with tracking algorithms to improve the accuracy and robustness of customer movement analysis in stores. For instance, **Zhang et al. (2020)** combined YOLO with a **CSRT (Channel and Spatial Reliability Tracking)** algorithm to monitor customer movements and understand interaction zones within a store. However, their approach faced limitations in environments with crowded scenes, where maintaining the identity of multiple customers was challenging.

ASTAN builds upon this body of work by integrating YOLO with DeepSORT, which offers a more scalable and accurate solution for tracking customer movement across various zones in real time. The key innovation in ASTAN lies in the **zone-based analysis** it provides, which allows for finer-grained insights into customer behavior, such as how long they spend in particular sections and their movement patterns across different areas of the store.

2.1.4 Zone-Based Customer Analytics

In addition to tracking, **zone-based customer analytics** has emerged as a critical component in retail optimization. **Kim et al. (2019)** studied customer heatmaps to identify high-traffic areas within stores, which enabled retailers to rearrange products more strategically. Similarly, **Huang et al. (2021)** used motion sensors combined with camera feeds to monitor customer flow and optimize product placement.

ASTAN extends these approaches by using advanced **deep learning models** for real-time tracking and detection, allowing retailers to monitor customer paths and interactions in more detail than was possible with previous technologies. The use of **zone-based analysis** in ASTAN helps in generating dynamic heatmaps, which provide actionable insights for better store management and personalized marketing.

2.1.5 Challenges in Existing Systems

Several challenges persist in existing systems for customer tracking, particularly in the areas of scalability, accuracy, and privacy. For instance, RFID and beacon systems often require customer compliance (e.g., carrying a tagged device), and camera-based systems struggle with occlusion and identity maintenance in crowded environments. **Ding et al. (2020)** pointed out that occlusion and crowding are major problems in computer vision systems used in retail, as they can cause the system to lose track of individuals.

In ASTAN, the combination of YOLO's fast detection and DeepSORT's robust tracking algorithm addresses many of these challenges. By focusing on detecting and tracking individuals within defined store zones, ASTAN provides accurate, real-time analysis without requiring customers to carry any external devices. Furthermore, ASTAN employs ethical practices in data collection, ensuring that customer identities remain anonymous while still providing retailers with actionable insights.

2.2 Problem Statement:

In the highly competitive retail industry, understanding customer behavior is critical for optimizing store layouts, improving marketing strategies, and enhancing the overall shopping experience. Traditional methods of gathering customer insights, such as surveys or manual observations, are often time-consuming, error-prone, and fail to provide real-time data. Retailers need a more efficient and accurate solution to track and analyze customer movements within their stores, enabling data-driven decisions to increase sales and customer satisfaction.

The ASTAN (DATA Report Advanced Shoppers Tracker and Analysis Network) project addresses this challenge by utilizing advanced computer vision and deep learning techniques to automatically detect, track, and analyze customer behavior in real-time. Through intelligent zone-based monitoring and heatmap generation, ASTAN helps retailers understand foot traffic patterns, popular product zones, and customer engagement, ultimately leading to better store management and marketing optimization.

2.3 Methodology

2.3.1 Data Acquisition

Dr. ASTAN relies on multiple video feeds from strategically placed cameras across a retail store. These cameras are positioned to capture different areas of the store, ensuring complete coverage and minimizing blind spots. The video streams serve as the primary input for the system, allowing for real-time monitoring of customer movement.

- Camera Placement: Cameras are installed in the Entry Zone, Main Shopping Zone, and Checkout Zone to capture shopper interactions in each of these key areas.
- Frame Processing: The video feeds are broken down into frames, which are then processed in real-time for object detection and tracking.

2.3.2 Object Detection using YOLOv5mu

The YOLOv8 (You Only Look Once) model is used for object detection. YOLO is known for its real-time performance and high accuracy, making it suitable for dynamic environments like retail stores.

- Detection Model: YOLOv8 is a modified version of the YOLO object detection model, optimized for identifying people within retail environments.
- Gridding: The model divides the video frames into grids and predicts bounding boxes for each grid cell. It detects customers and provides their precise locations in the video feed.
- Inference: The object detection model is run in real-time, with inference speeds optimized for low latency to ensure smooth tracking.

2.3.3 Multi-Object Tracking using DeepSORT

For tracking multiple customers across different zones of the store, the DeepSORT (Simple Online and Realtime Tracking) algorithm is employed. DeepSORT maintains the identities of detected objects (i.e., customers) across frames, allowing the system to track individual customers as they move through the store.

- Tracking Algorithm: DeepSORT uses a Kalman filter to predict the future position of objects and the Hungarian algorithm for data association, ensuring accurate tracking even in crowded scenes.
- Re-ID Feature: DeepSORT also incorporates re-identification (Re-ID) features, which help maintain the consistency of tracking when a person is temporarily occluded or leaves and re-enters the camera's field of view.
- ID Assignment: Each detected customer is assigned a unique ID that is maintained throughout their journey within the store, enabling the system to track movements and interactions across different zones.

2.3.4 Zone-Based Customer Analysis

The store is divided into three key zones: Entry Zone, Main Shopping Zone, and Checkout Zone. Each zone is equipped with cameras and monitored individually to gain insights into customer behavior and interactions within these areas.

- Zone Definition: Virtual boundaries are defined for each zone, and customer movements are

tracked as they pass through or linger in specific zones.

- Dwell Time and Interaction Analysis: The system captures the amount of time each customer spends in a zone and logs their interactions with products or store displays. This information is used to create zone-specific heatmaps that highlight areas of high and low customer engagement.
- Heatmap Generation: Using real-time tracking data, heatmaps are generated for each zone to identify high-traffic areas and optimize store layout and product placement based on customer behavior.

2.3.5 Data Processing and Visualization

The final stage of the methodology involves processing the collected data and visualizing the results using Pandas for data manipulation and Power BI for creating dashboards and reports.

- Data Handling: Customer movement data, including entry and exit times, dwell times in specific zones, and paths taken through the store, are stored and processed using the Pandas library. This allows for efficient data manipulation and preparation for analysis.
- Visualization in Power BI: The processed data is then fed into Power BI, where it is visualized in the form of dynamic heatmaps, customer movement paths, and zone engagement metrics. Store managers can access these visualizations through a user-friendly interface, enabling real-time monitoring and analysis of customer behavior.
- Actionable Insights: The visualizations help store managers make data-driven decisions, such as rearranging product placements, optimizing store layouts, or creating personalized marketing strategies based on observed customer preferences.

2.3.6 Ethical Considerations and Privacy Protection

Dr. ASTAN adheres to strict privacy standards to ensure that customer identities remain anonymous throughout the tracking process. While the system tracks movement and behavior, it does not collect any personally identifiable information (PII), such as facial features or demographic data.

- Anonymity: All tracking data is anonymized, ensuring that the customers' identities are protected. Only non-identifiable behavioral data is used for analysis and visualization.
- Compliance: The system complies with relevant data protection regulations, such as GDPR (General Data Protection Regulation), ensuring that customer privacy is respected throughout the process.

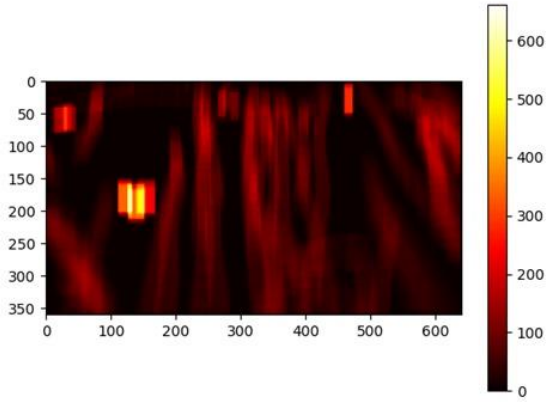

Fig -1: Heatmap of Customer Movements

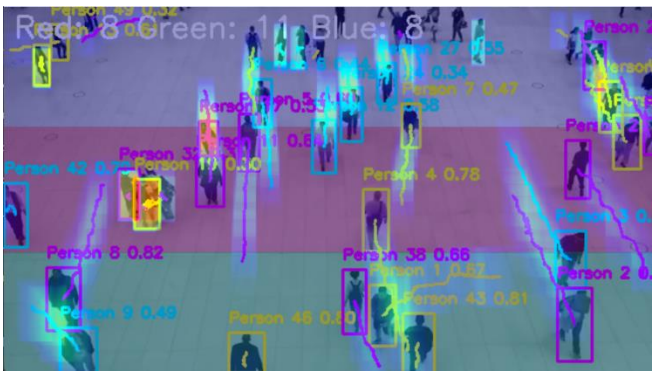

Fig-2 : **Human Detection and Path Tracking**

3. CONCLUSIONS

Dr. ASTAN offers a reliable way to track and analyze consumer behavior in a retail environment by combining DeepSORT for precise multi-object tracking with the YOLOv5mu model for real-time object detection. By dividing the store into different zones and collecting detailed data on customer movements, the system

provides retailers with valuable insights into shopper behavior. With Pandas handling data processing and Power BI enabling visualization, store managers have a user-friendly platform to monitor key performance metrics effectively.

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