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AI Based Smart Bus Passenger Counting and Alert System for Bus Capacity

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Abstract: Urban public transportation systems often face challenges related to overcrowding, passenger safety, and inefficient bus operations. This project proposes an AI- Based Smart Bus Passenger Counting and Alert System designed to monitor passenger load in real time. Using advanced computer vision techniques, the system detects and counts passengers entering and exiting the bus, maintaining an accurate record of occupancy. When the number of passengers approaches or exceeds the bus's maximum capacity, the system generates instant alerts for the driver and central control, ensuring safety and compliance with regulations. Additionally, the system collects passenger data to assist transport authorities in route optimization and operational planning. By automating passenger monitoring, this solution enhances safety, improves service efficiency, and provides valuable insights for intelligent urban mobility management.

I. INTRODUCTION

Public transportation is the backbone of urban mobility, offering a cost-effective and convenient mode of travel for millions of people every day. Buses, in particular, serve as a critical component of city transport systems, connecting residential, commercial, and industrial areas. However, one of the most significant challenges faced by bus transportation is overcrowding, which leads to discomfort for passengers, safety risks, and inefficiencies in transportation management. Overcrowded buses can increase the likelihood of accidents, reduce passenger satisfaction, and complicate traffic flow management. Traditionally, monitoring the number of passengers in a bus has relied on manual counting or basic ticketing systems. These methods are often inaccurate, labor- intensive, and unable to provide real-time data. Without precise passenger data, transportation authorities cannot optimize bus scheduling, route planning, or fleet management effectively. This gap emphasizes the need for an automated and intelligent system capable of monitoring bus occupancy accurately in real time. The proposed AI-Based Smart Bus Passenger Counting and Alert System addresses these challenges by integrating advanced technologies such as computer vision, artificial intelligence (AI), and edge computing. The system is designed to monitor passengers entering and exiting the bus using cameras installed at doors. Using AI algorithms, it can detect and count passengers in real time, maintaining an up-to-date record of bus occupancy. When the number of passengers approaches or exceeds the bus's maximum capacity, the system generates instant alerts for the driver and, optionally, the central control system. This feature ensures passenger safety, prevents overcrowding, and helps enforce capacity regulations. Furthermore, the system stores historical passenger data, which can be analyzed to optimize routes, improve bus scheduling, and predict passenger demand and Alert System offers a reliable, intelligent, and scalable

A. Problem Statement

Urban public transportation systems face persistent challenges related to overcrowding, passenger safety, and operational inefficiency. Buses often operate beyond their maximum capacity, leading to discomfort, safety hazards, and poor passenger experiences. Current methods for monitoring passenger loads—such as manual counting, ticket collection, or periodic inspections—are time- consuming, error-prone, and incapable of providing real-time insights..

B. Objectives of the Research

The primary goal of the AI-Based Smart Bus Passenger Counting and Alert System is to enhance passenger safety, comfort, and operational efficiency in public bus transportation by providing real-time monitoring of bus occupancy. The specific objectives of the system are as follows:

1) Real-Time Passenger Counting: Accurately detect and count passengers entering and exiting the bus using AI-based computer vision techniques, ensuring up-to- date occupancy data at all times.
2) Bus Capacity Monitoring: Continuously track the number of passengers onboard relative to the bus's maximum capacity to prevent overcrowding and maintain safety standards.
3) Instant Alerts and Notifications: Automatically generate visual and audio alerts for bus drivers and, if required, for central control systems when the bus reaches or exceeds its maximum capacity.
4) Data Collection and Analytics: Collect and store historical passenger data to analyze trends, optimize bus schedules, and improve route planning for transport authorities.

5) Automation and Efficiency: Reduce reliance on manual monitoring, minimize human error, and enable automated decision-making for better management of public transportation.
6) Scalability and Integration: Design a system that can be deployed across multiple buses and integrated with smart city infrastructure for broader urban mobility management.

By achieving these objectives, the system aims to improve passenger safety, enhance travel comfort, support data-driven operational planning, and contribute to the development of intelligent public transportation systems.

II. PROPOSED SYSTEM & METHODOLOGY

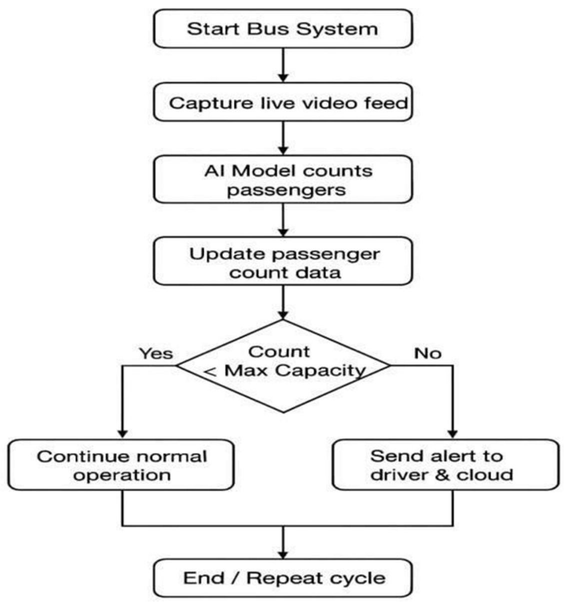

Fig. Activity Digram

The activity diagram for the AI-based smart bus passenger counting and alert system represents the workflow of monitoring and managing passenger occupancy in real time. The process begins when the system is powered on and the bus starts operating, triggering the cameras installed at the entry and exit points to continuously capture video streams of passengers boarding and alighting. Each video frame undergoes preprocessing, such as resizing, brightness adjustment, and background subtraction, to enhance detection accuracy. The preprocessed frames are then fed into an AI-based object detection model, typically a deep learning framework like YOLOv8, which identifies passengers and marks them using bounding boxes. Detected passengers are tracked across consecutive frames using tracking algorithms such as Deep SORT, enabling the system to update the real-time passenger count accurately. This count is continuously compared against the predefined maximum bus capacity. If the current count is below capacity, the system continues monitoring without interruption. However, if the count reaches or exceeds the threshold, the system triggers visual and audio alerts to notify the driver and may optionally send occupancy data to a central fleet management system for real-time monitoring and operational planning. The process operates in a continuous loop throughout the bus's journey, ensuring that passenger safety and capacity limits are maintained efficiently while providing actionable data for smart transportation management.

III. LITERATURE SURVEY

Automated Passenger Counting (APC) has become an important aspect of modern public transportation systems, aiming to improve operational efficiency, ensure passenger safety, and provide real- time occupancy information. Traditional APC methods relied on infrared sensors, pressure mats, or RFID systems, but these often suffered from limitations in accuracy, installation complexity, and inability to handle dynamic passenger flow. Recent advances in computer vision and artificial intelligence have enabled more accurate passenger counting using cameras and deep learning models. Studies employing convolutional neural networks (CNN) and object detection frameworks like YOLO (You Only Look Once) variants, including YOLOv3 and YOLOv8, have demonstrated the ability to detect and count passengers in real time even in crowded bus interiors.

These systems, however, face challenges such as occlusion, lighting variability, and camera placement constraints, which can reduce counting accuracy. Depth sensors or RGB-D cameras have been proposed to improve reliability by distinguishing passengers from the background and handling crowded entry points, but they add cost and processing requirements. Beyond vision-based methods, non-intrusive techniques such as Wi-Fi or Bluetooth probe detection and signal processing approaches have been explored, achieving reasonable accuracy in estimating passenger numbers without using cameras, though they depend on passengers carrying devices and may struggle in high-density scenarios. Hybrid methods combining sensor data with post-processing algorithms, including denoising using historical ticketing or flow information, have been shown to improve count reliability. Despite these advancements, a significant gap remains in integrating real- time passenger counting with capacity monitoring and alert systems. Many existing systems focus solely on counting passengers, without triggering alerts when buses approach or exceed maximum capacity, or providing actionable information to drivers and control centers. Furthermore, practical deployment challenges—including edge processing on buses, privacy preservation, cost-effective hardware implementation, and robustness in diverse operating conditions—are often underemphasized in literature. Therefore, developing an AI-based smart bus passenger counting system that not only accurately tracks boarding and alighting in real time but also generates automated capacity alerts addresses both operational needs and research gaps, offering a more comprehensive solution for modern urban transit management.

IV. IMPLEMENTATION

The implementation of this system involves combining hardware, software, and artificial intelligence to monitor bus occupancy in real-time and provide alerts when capacity is reached. The main components include cameras, edge computing devices, AI models, passenger counting algorithms, and an alert mechanism.

A. Hardware Setup

1) Cameras:
- High-resolution RGB or RGB-D cameras are installed at bus entry and exit points.
- The placement is critical: cameras are positioned at a top-down or angled view to capture passengers as they board or alight.
- RGB-D cameras can capture depth information, which helps in crowded conditions or when passengers overlap.

2) Edge Computing Device:
- A local computing unit like NVIDIA Jetson Nano/TX2, Raspberry Pi with AI accelerators, or similar is installed on the bus.
- This device runs AI models in real-time and processes video data without relying on a central server, which ensures low latency and immediate alerts.

3) Driver Alert System
- Visual indicators (LED screens, dashboard display) and audio alerts notify the driver when bus capacity is reached or exceeded.
- Optional: Connectivity to a central monitoring system for real-time fleet management and reporting.

B. Data Acquisition

1) Video Data Capture:
1. Continuous video streams are captured from the cameras as passengers enter and exit the bus.
2. The data is processed frame by frame to detect and count passengers.

2) Training Data Collection:
1. Annotated images/videos of passengers boarding and alighting are used to train the AI model.
2. Annotations mark individual passengers to allow the model to recognize people under different lighting, poses, and occlusion scenarios.

C. AI Model Development

1) Passenger Detection:
- A deep learning object detection model, such as YOLOv8, is used to detect passengers in real-time video frames.
- The model identifies passengers accurately, even when they are partially occluded or in crowded scenarios.

2) Tracking and Counting:
- A tracking algorithm (like Deep SORT) follows each detected passenger across consecutive frames to determine whether they are entering or exiting the bus.
- This enables accurate real-time counting and prevents double counting.

3) Optimization:
- Techniques such as background subtraction, frame differencing, and multi-frame validation reduce false detections due to lighting changes, reflections, or movement of objects inside the bus.

D. Real-Time Processing
1) The edge device continuously processes video frames to detect and track passengers.
2) Each time a passenger crosses a predefined zone near the bus door (entry or exit), the onboard count is updated.
3) The system maintains a real-time passenger count, which is critical for accurate capacity monitoring.

E. Capacity Monitoring and Alert System
1) Threshold Detection:
- The bus has a predefined maximum capacity limit based on safety and regulations.
- The system constantly compares the current passenger count against this limit.

2) Driver Alerts:
- When passenger count reaches or exceeds the threshold, visual and audio alerts notify the driver immediately.
- Alerts can include LED indicators, dashboard messages, or warning sounds.

3) Central Monitoring (Optional):
- Real-time data can be transmitted to a central server for fleet management.
- Fleet operators can monitor bus occupancy across routes, optimize schedules, and prevent overcrowding.

F. Software and Integration
1) Programming Environment: Python is commonly used with libraries such as OpenCV for image processing and PyTorch/TensorFlow for AI models.
2) User Interface: A simple display on the bus shows the current passenger count and triggers alerts when thresholds are met.
3) Testing and Validation: The system is tested under real-world conditions including varying lighting, crowded buses, multiple bus types, and different passenger behaviors to ensure robustness and reliability.

V. CONCLUSION
The AI-Based Smart Bus Passenger Counting and Alert System provides an efficient and reliable solution for monitoring bus occupancy in real time. By integrating advanced computer vision techniques and AI-based detection models, the system accurately counts passengers boarding and alighting, overcoming limitations of traditional methods such as infrared sensors or manual counting. The real-time processing capability ensures that bus drivers receive immediate alerts when the vehicle approaches or exceeds its maximum capacity, enhancing passenger safety and compliance with transportation regulations. Additionally, the system offers the potential for central monitoring, enabling fleet operators to optimize routes, prevent overcrowding, and improve overall operational efficiency.

Overall, this project demonstrates the practical application of AI and edge computing in public transportation, addressing challenges like overcrowding, inaccurate passenger counts, and delayed response to capacity limits. The implementation of such intelligent systems contributes to smarter urban mobility, safer travel, and a more efficient public transit ecosystem. With further enhancements—such as integration with ticketing systems, predictive analytics for passenger flow, and multi-camera tracking—the system can evolve into a fully autonomous solution for modern smart cities.

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