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Intelligent Transit Management and Capacity Insights

T. H. Akshaya[1], S.S. Harini[2], K. Haripriya[3], C. S. Jeyakarthika[4], Dr. S. Parthasarathy[5], Dr. S. Miruna Joe Amali[6], Dr R. Karthick[7], R. Thangasankaran[8]

[1, 2, 3, 4]*Department of Computer Science Engineering,* [5]*Professor/EEE KLN.IRP Director,* [6]*Professor & Head Department of CSE,* [7]*Professor/CSE Department,* [8]*AP/EEE KLN.IRP Coordinator, College of Engineering, Pottapalayam, Sivagangai*

Abstract: The "Intelligent Transit Management and Capacity Insights" project offers a novel way to deal with the problems of crowding and discomfort among passengers on public transit. The technology offers real-time monitoring of seat occupancy on buses by utilizing cameras linked to a Raspberry Pi and machine learning techniques. The technology precisely counts the number of occupied seats by evaluating the images taken by the cameras. This information is then subtracted from the overall seating capacity to provide correct information about seat availability. This feature greatly improves passenger comfort while traveling in addition to helping to reduce congestion. Because of the system's compatibility with Raspberry Pi, existing bus infrastructures may be seamlessly integrated, guaranteeing dependable data processing. Additionally, the system's use of machine learning enables steady performance and accuracy improvements over time. By combining advanced technologies such as machine learning, cameras, and Raspberry Pi, this integrated solution represents a significant step forward in the enhancement of public transportation systems, ultimately leading to improved operational efficiency, safety measures, and passenger satisfaction.

Keywords: Seat Occupancy, Tracking System, Real-time Monitoring, Crowding Reduction, Passenger Comfort, Machine Learning, Raspberry Pi Integration, Public Transit Improvement, Congestion Reduction, Operational Efficiency, Passenger Satisfaction

I. INTRODUCTION

Public transit systems are the backbone of urban mobility, enabling the daily movement of millions. However, overcrowding, inefficient seat allocation, and a lack of real-time tracking hinder passenger comfort and efficiency. Innovative solutions leveraging advanced technologies are essential to improving bus transportation.

Automated seat monitoring systems, powered by computer vision and machine learning, provide real-time seat occupancy data, eliminating errors in manual counting. Camera-based monitoring analyzes onboard images with high accuracy, seamlessly integrating with existing infrastructure. Passengers can access seat availability through digital displays or mobile apps, enhancing their travel experience.

Real-time bus tracking further optimizes transit efficiency. GPS-based systems enable accurate location monitoring, improving fleet management, route planning, and schedule adherence. While these technologies enhance public transit, robust data protection measures must be in place to ensure privacy and security.

II. METHODOLOGY

The Intelligent Transit Management and Capacity Insights system was developed through a structured approach, starting with a detailed analysis of system requirements, including stakeholder feedback and literature reviews. To enhance real-time performance and integration, key hardware components such as cameras and Raspberry Pi microcontrollers were carefully selected and strategically positioned to optimize seat image capture.

Machine learning techniques, utilizing OpenCV and the Haar cascade algorithm for head detection, were implemented to accurately monitor seat occupancy. Rigorous testing under varying conditions—lighting, passenger density, and vehicle movement—ensured system accuracy. GPS modules were also integrated to enable precise real-time bus tracking, with software processing GPS data to determine bus position, speed, and direction.

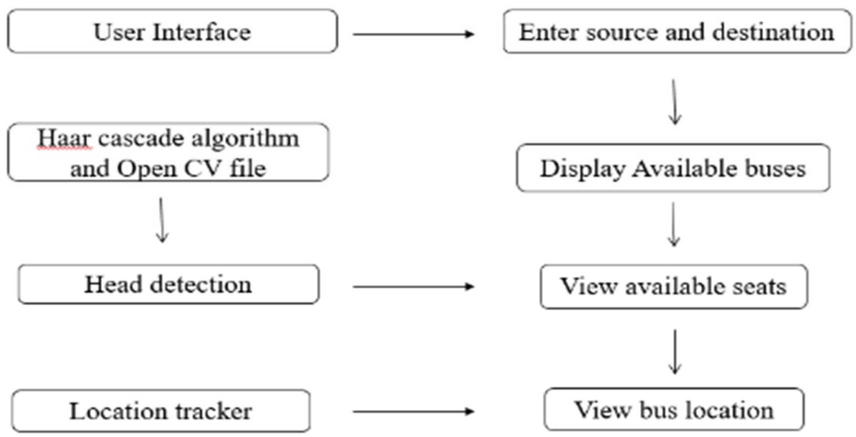

Fig: 1 Data flow diagram

The figure 1 illustrates the system's workflow, beginning with the User Interface, where passengers enter their source and destination to receive available bus options. Seat monitoring is achieved through Haar cascade and Open CV-based head detection, which processes onboard camera images to determine real-time seat availability. Additionally, a location tracker continuously monitors bus movement, providing passengers with live bus location updates through mobile applications or digital displays. This system enhances public transit by optimizing seat usage, improving route efficiency, and ensuring a seamless travel experience for passengers.

III. SEAMLESS WORKFLOW FOR INTELLIGENT TRANSIT MANAGEMENT AND CAPACITY INSIGHTS

The Intelligent Transit Management and Capacity Insights system ensures efficient real-time tracking of bus seat occupancy and location. Initially, the system captures interior images of the bus using an onboard camera. These images are processed using machine learning algorithms to detect and count passengers, determining the number of occupied seats. The total seat availability is then updated dynamically, providing passengers with accurate and real-time seating information.

To enhance accuracy, the system leverages the Haar Cascade algorithm, which efficiently detects passengers by identifying head positions within the captured images. This data is processed by the Raspberry Pi controller, which continuously updates the seat occupancy count. A user-friendly interface then displays the real-time seat availability, ensuring that passengers can make informed decisions before boarding. Additionally, the system incorporates a color-coded indicator, where green represents ample seating, yellow signals limited availability, and red warns of a full or nearly full bus. These intuitive visual cues enhance user experience and streamline passenger flow.

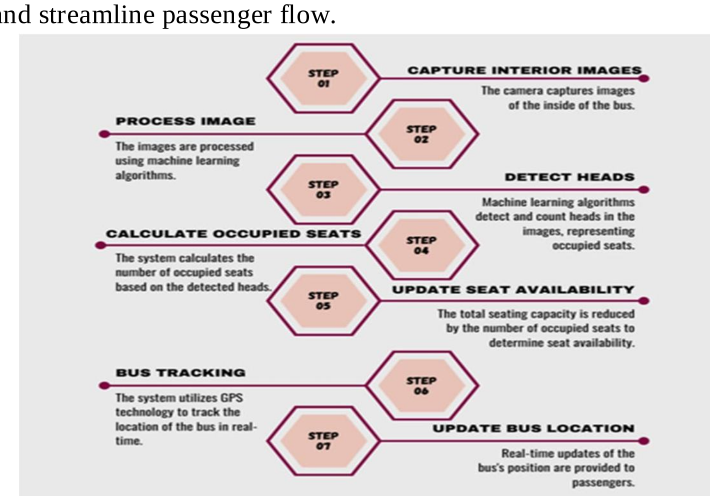

Fig: 2 Process flow diagram

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As shown in Figure 2, the system further enhances transit efficiency by integrating GPS-based bus tracking. Real-time location updates help passengers plan their journeys effectively while also assisting transit operators in optimizing fleet management. By combining image processing and GPS tracking, this system improves operational insights, enhances passenger convenience, and ensures smarter transit management.

IV. SYSTEM IMPLEMENTATION

The System Implementation process began with the precise installation of hardware components, ensuring seamless communication between GPS modules, Raspberry Pi, and automated seat monitoring cameras on buses. The hardware setup followed standardized procedures to optimize efficiency and maintain compatibility with the onboard computing system. System integration tests were conducted to verify hardware functionality and ensure smooth data exchange, establishing a solid foundation for further software deployment.

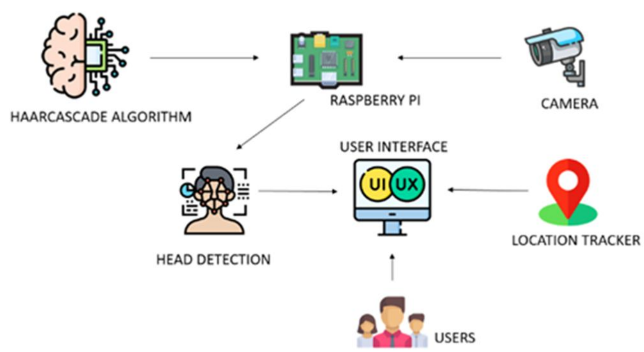

Fig: 3 System Implementation

As depicted in Figure 3, software integration aimed to consolidate tracking and seat monitoring functionalities into a unified system architecture. The Haar Cascade algorithm, running on Raspberry Pi, processed camera feeds for head detection, while the location tracker provided real-time bus positioning. A user-friendly interface facilitated seamless interaction, allowing passengers to access accurate seat availability and bus tracking information, ultimately enhancing the overall transit experience.

V. OUTPUT

Figure 4 shows the homepage of the bus seat availability system with a simple, user-friendly design. It features a navigation bar and a bold heading, "Stay ahead of the crowd!!," with a button to check seat availability.

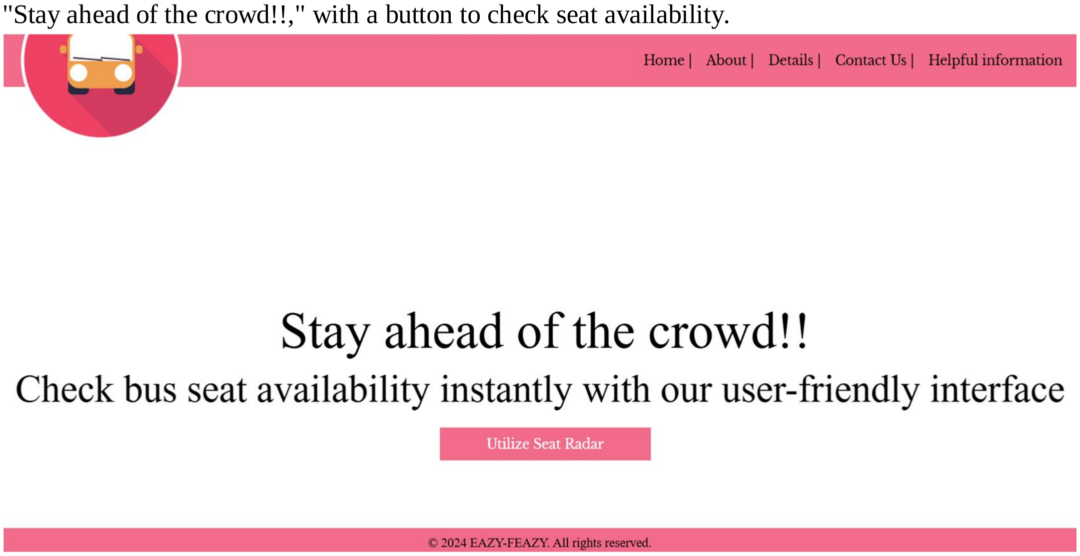

Fig: 4 Homepage of the website

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Figure 5 shows the Bus Search page, allowing users to find available buses based on journey details. It features a structured form with dropdowns for source, destination, and schedule. Users can search buses with a prominent black button for easy access.

Fig: 5 Input data feed page

Figure 6 displays the Bus Details page, showing key information like Bus ID, source, and destination. Users can check real-time status or view the route using interactive buttons. The clean pink and white design ensures clarity and ease of use.

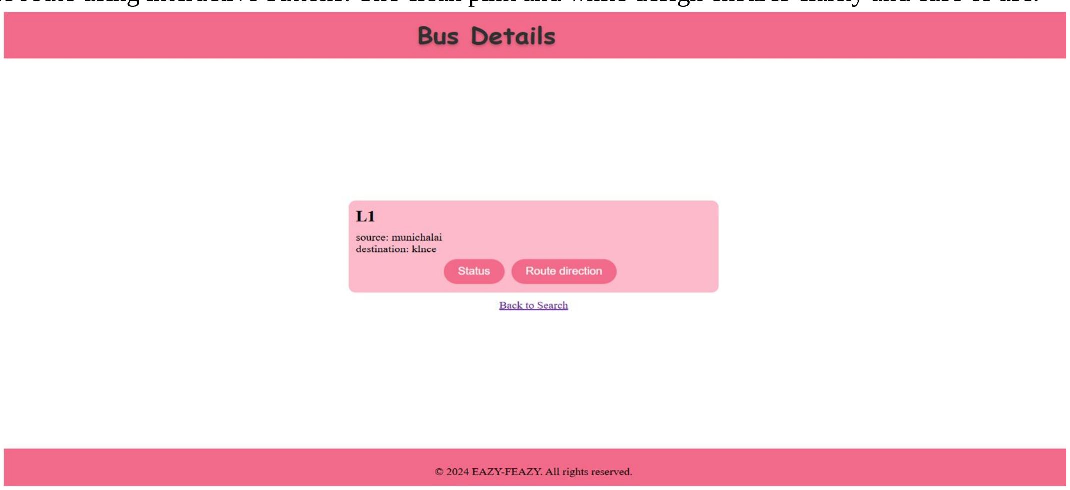

Fig: 6 Available buses

Figure 7,8,9 shows the Vehicle Seat Monitoring page, updating seat availability in real-time using OpenCV. A live camera feed detects occupied and vacant seats, dynamically adjusting the count. A visual indicator changes color based on availability.

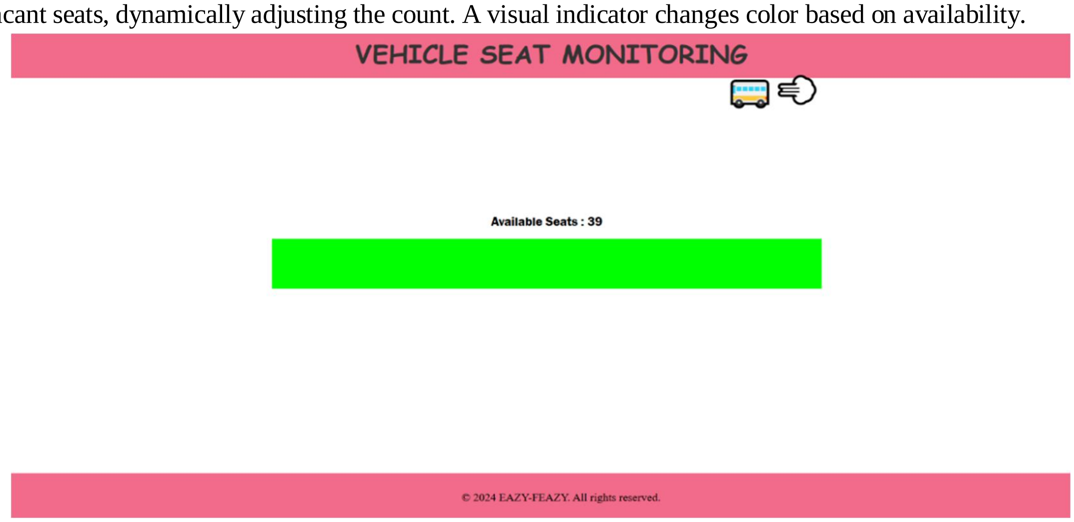

Fig: 7 Real-time Seat Availability - Green Status

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Figure 7 represents a seat availability page with a green indicator, showing that many seats are available, ensuring ample seating options for passengers.

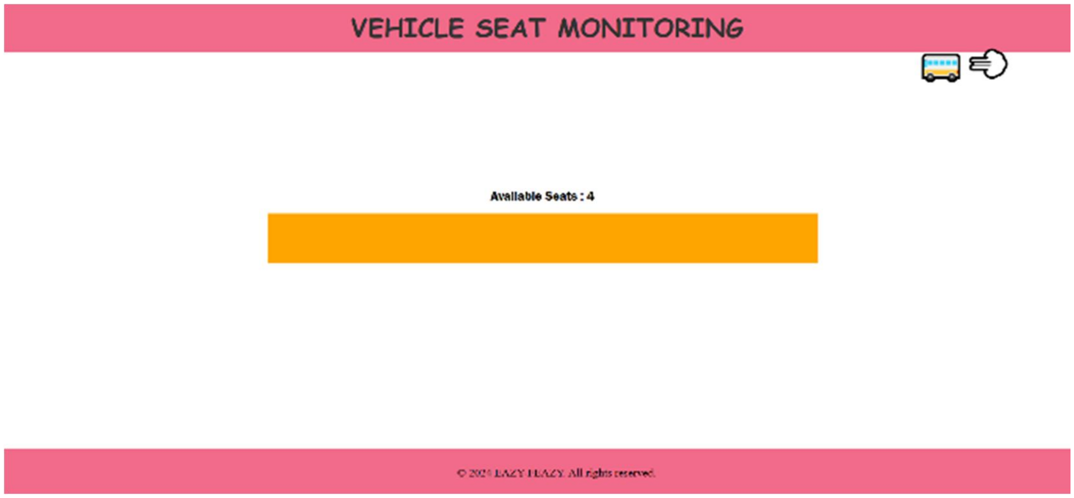

Fig: 8 Real-time Seat Availability - Orange Status.

Figure 8 represents a seat availability page with a orange indicator, warning that only a few seats are left, indicating limited availability.

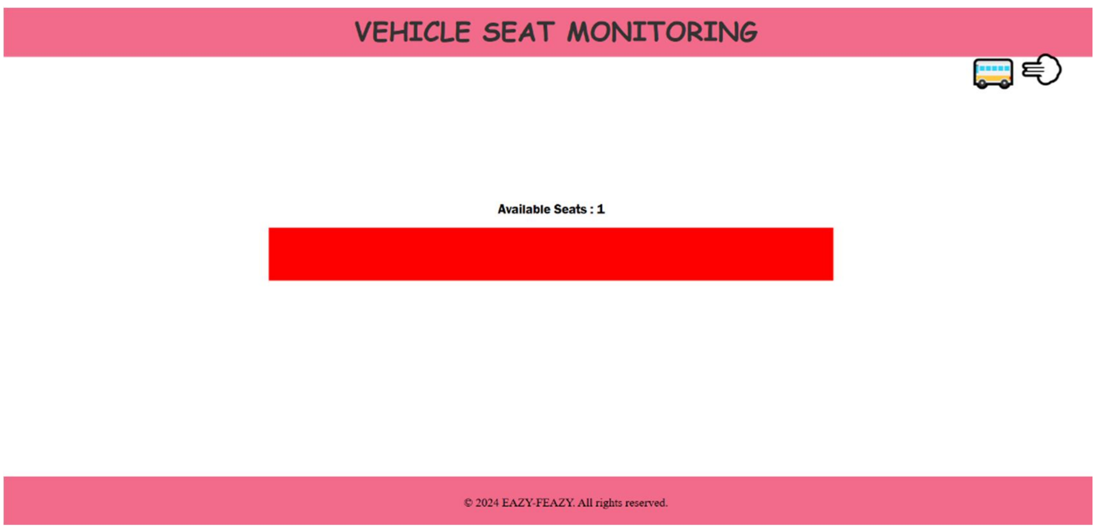

Fig: 9 Real-time Seat Availability - Red Status.

Figure 9 represents a seat availability page with a red indicator, signaling that no seats or only one seat is available, indicating full or nearly full occupancy.

VI. THERMAL STUDY OF THE PROPOSED SYSTEM

Analyzing the Raspberry Pi controller's heat performance was crucial for the Vehicle Tracker project's reliability and durability. Due to continuous operation in vehicles, the controllers were prone to overheating, risking hardware failure. Using the FLUKE Thermal Analyzer, in-depth thermal studies identified hotspots under various conditions, such as high ambient temperatures and computational loads.

Preventive cooling measures reduced overheating risks, ensuring system stability and longevity. Maintaining optimal temperatures improved performance, contributing to efficient transport management. Prioritizing thermal management enhanced passenger convenience and operational efficiency, ensuring a smooth and reliable travel experience.

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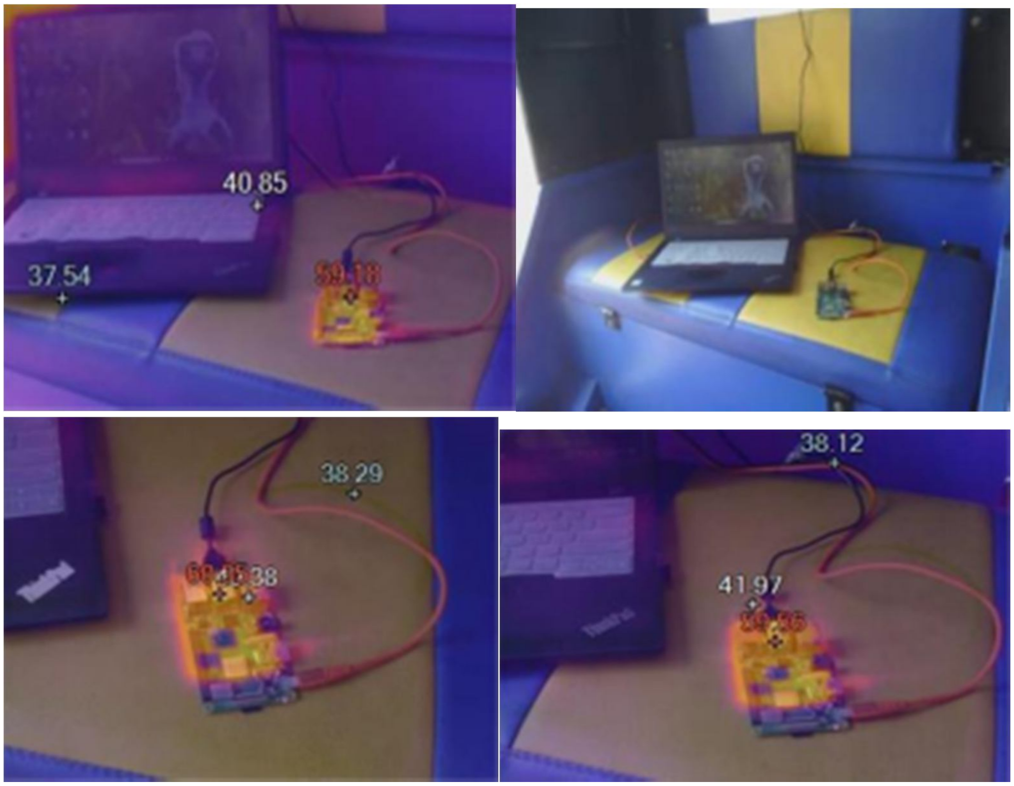

Fig: 10 Thermal IR Images of Raspberry Pi Controller.

VII. CONCLUSION

In conclusion, the Intelligent Transit Management and Capacity Insights system successfully demonstrated how integrating real-time seat monitoring and vehicle tracking can enhance transport efficiency, improve passenger experience, and optimize resource allocation. By combining advanced hardware installations, such as cameras and GPS modules, with machine learning-based software, the system provided accurate seat availability updates and precise vehicle tracking. These capabilities not only enhanced passenger convenience but also contributed to reducing congestion and improving overall service quality by enabling dynamic service adjustments based on real-time demand.

Future advancements can further refine the system's capabilities by incorporating predictive analytics to anticipate passenger demand and optimize route planning proactively. Enhanced sensor technology and improved machine learning algorithms can increase the accuracy and reliability of seat occupancy detection, while deeper integration with digital displays and mobile applications can provide seamless real-time updates to passengers. These enhancements will elevate the system’s efficiency, ensuring a more responsive and passenger-friendly public transit experience. While the current implementation marks a significant step forward in transport management, continued innovation will drive even greater operational effectiveness and passenger satisfaction in the future.

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