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MeetRoute: Revolutionizing Wayfinding Using QR Technology

Harsh Shelke, Onkar Gaikwad, Mayank Mulay, Aditya Gadhave, Manoj Shinde

Department of Computer Science Engineering
MIT ADT UniversitySS
Pune 412201, India

Abstract

In modern urban mobility systems, real-time and easily accessible information is crucial for enhancing public transportation efficiency. "MeetRoute" presents a user-centric platform that enables commuters to instantly access comprehensive bus route information and live passenger occupancy through QR code scanning at bus stops. Upon scanning, users are redirected to a mobile-optimized website that displays a list of available bus routes, providing vital details such as bus number, starting and ending points, number of stops, seating capacity, and real-time crowd data captured via onboard cameras. This solution addresses common challenges like uncertainty in travel, overcrowding, and lack of real-time updates. By integrating computer vision technologies with smart web systems, MeetRoute bridges the information gap between commuters and transportation services. This paper discusses the platform's design architecture, implementation methodology, challenges, results, and future directions aimed at creating a sustainable, efficient, and commuter-friendly transportation ecosystem. The research highlights how MeetRoute improves commuter convenience, promotes the adoption of public transportation, and contributes to reduced traffic congestion and environmental impact.

Keywords: Public Transport, QR Code Navigation, Real-Time Passenger Monitoring, MeetRoute.

1. Introduction

The growing demands of urbanization have placed significant stress on public transportation systems worldwide. Although public transport plays a vital role in reducing traffic congestion and environmental impact, many commuters experience challenges like unreliable route information, overcrowded vehicles, and inconsistent service updates. Traditional methods such as static route maps or verbal assistance are often insufficient in today's fast-paced environment.

"MeetRoute" was conceptualized to address these limitations by offering an intuitive, technology-driven solution. Utilizing QR code technology strategically placed at bus stops, MeetRoute allows users to instantly access real-time bus information via a mobile-optimized web platform. Through a simple scan, commuters can view details like bus numbers, starting and ending points, number of stops, seating capacity, and current occupancy data collected using onboard webcams processed with AI algorithms.

The platform aims to enhance commuter convenience, minimize confusion, and foster greater trust in public transit systems. By offering live occupancy information, it enables passengers to make informed boarding decisions, reducing wait times and overcrowding incidents. Furthermore, MeetRoute serves as a bridge between traditional public transport and smart city initiatives, contributing to digitization and the modernization of urban mobility solutions.

This paper outlines the system's design, technical architecture, challenges faced during development, performance results, and the broader societal impacts anticipated through the deployment of MeetRoute across

metropolitan transit networks.

2. Objectives

The primary objectives of MeetRoute are structured around enhancing the commuter experience and supporting smarter urban mobility:

- Simplify Public Transport Navigation: Enable users to quickly access detailed route information and live occupancy data through a QR code scan at bus stops.
- Enhance Real-Time Decision-Making: Provide updated bus schedules, seating capacities, and live passenger counts to assist commuters in planning their journeys efficiently.
- Promote Adoption of Public Transportation: Improve accessibility and reliability of information to attract more users to public transit systems.
- Leverage Technological Innovations: Integrate QR code technology, computer vision-based occupancy monitoring, and real-time data streaming to deliver a seamless commuter experience.
- Contribute to Environmental Sustainability: Encourage the use of public transport, thereby reducing reliance on private vehicles and helping lower urban pollution levels.
- Expand Inclusivity: Design a user-friendly, mobile-responsive website accessible across a wide range of devices, ensuring usability even in low-network areas.

3. Tools and Languages

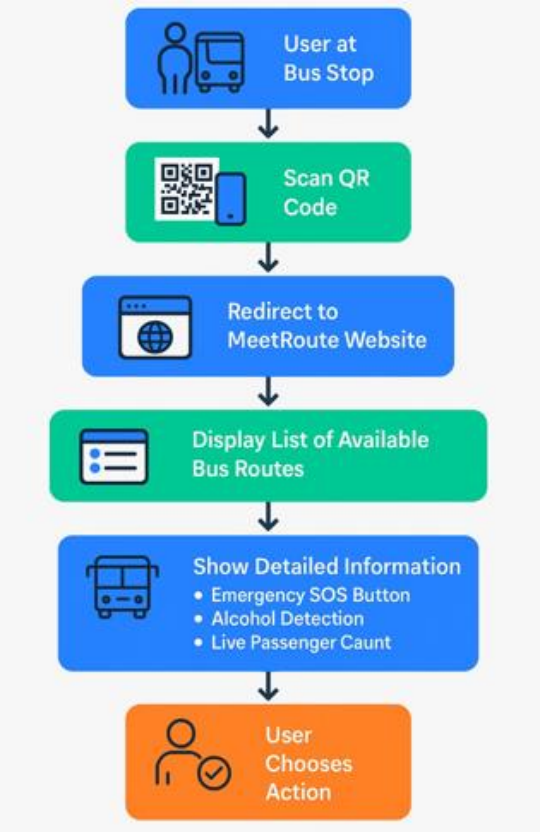
MeetRoute is built using a combination of robust and scalable technologies:

- Frontend Development: HTML5, CSS3, Bootstrap, and JavaScript were utilized to create a responsive and intuitive web interface optimized for mobile usage.
- Backend Development: Python, along with Flask and FastAPI frameworks, powered the server-side components and APIs responsible for data handling.
- Computer Vision and AI Integration: OpenCV was employed for webcam stream processing, while YOLO models facilitated real-time object detection and passenger counting.
- Real-Time Communication: Flask-SocketIO and WebSockets were used for continuous streaming of occupancy data to the frontend.
- QR Code Generation: The Python qrcode library generated unique QR codes corresponding to each bus stop.
- Data Sources and Storage: OpenStreetMap (OSM) data, GTFS feeds, and Firebase/MongoDB databases managed location and transit information securely.

These tools ensure the scalability, responsiveness, and high availability necessary for MeetRoute's smooth operation across growing commuter populations.

4. Process and Architecture

The architecture and process flow for the **MeetRoute QR-Based Public Transport Navigation System** are structured to ensure efficient route information access, real-time passenger monitoring, and enhanced commuter decision-making. The system is based on the integration of QR code technology, real-time computer vision models, a responsive web-based GUI for user interaction, and scalable cloud infrastructure for data management. Here's an overview of how the system is designed.



Process Flow for Bus Information Retrieval and Live Passenger Monitoring

- **Step 1: Data Collection and Preprocessing**
  -Collect detailed transportation data (bus routes, stop locations, bus numbers, seating capacities).
  -Set up real-time video streams using onboard webcams inside buses.
  -Preprocess video data (frame extraction, object detection preprocessing).

- **Step 2: Model Training**
  -Train object detection models (e.g., YOLOv5, SSD) for identifying and counting passengers from webcam feeds.
  -Apply data augmentation techniques (e.g., rotation, brightness adjustments) to enhance detection accuracy.
  -Fine-tune models to optimize passenger detection under different environmental conditions (day/night, crowd density).'

- **Step 3: Passenger Monitoring and Real-Time Updates**
  -Continuously analyze webcam feeds to detect and count passengers boarding and exiting buses.
  -Calculate live bus occupancy and push real-time updates to the MeetRoute web interface.
  -Synchronize data with QR-linked user dashboards for seamless information access.

- **Step 4: QR Code Management and Routing**
  -Generate unique QR codes linked to bus stop-specific data repositories.
  -Ensure QR codes are updated and maintained regularly for uninterrupted user access.
  -Redirect users to dynamic landing pages displaying current bus route information and occupancy data.

- **Step 5: Deployment and Monitoring**

-Deploy object detection and web services onto scalable cloud platforms.
-Monitor system performance (detection accuracy, server response times) in real-time.
-Periodically update models and datasets based on newly collected transit and commuter feedback data.

Architecture:-

The architecture for **MeetRoute: Revolutionizing Wayfinding Using QR Technology** is designed to ensure real-time, accurate delivery of bus route and passenger occupancy information while maintaining high scalability, reliability, and commuter accessibility standards.

1. Data Collection and Preprocessing Layer

This layer focuses on gathering comprehensive transportation and real-time passenger data for accurate system functioning.

Data Sources:

- Bus Route Data: Information on bus stops, routes, seating capacities, and schedules collected from transport databases and APIs (e.g., OpenStreetMap, TransitFeeds).
- Webcam Feeds: Live onboard video streams capturing passenger entry and exit activities.
- QR Code Mappings: Unique mappings linking each bus stop to its specific dataset stored on cloud servers.

Data Preprocessing:

- Passenger Detection: Frames extracted from webcams are processed using YOLO or OpenCV to identify passengers.
- Data Normalization & Augmentation: Video frames are normalized (resize, enhance contrast) and augmented to increase model robustness.
- QR Code Management: QR codes are generated, validated, and updated periodically to maintain operational reliability.

Sensitive Information Handling:

- Anonymize all live video data; no personal identification is captured.
- Ensure compliance with data protection regulations concerning live feeds and user access.

2. Model Training and Live Passenger Monitoring Layer

This layer focuses on training AI models and integrating them with real-time monitoring systems.

Model Selection:

- Object Detection Models: Models like YOLOv5 and SSD-MobileNet are employed for high-speed, high-accuracy passenger counting.
- Pre-trained Models: Models initially trained on large pedestrian datasets are fine-tuned using custom bus occupancy datasets.

Real-Time Monitoring:

- Passenger counting algorithms analyze onboard webcam streams.
- Occupancy data is calculated in real-time and mapped to specific buses/routes.

Occupancy Optimization:

- Deploy threshold-based alerts (e.g., 'bus nearing full capacity') to inform commuters early via the web platform.

3. Passenger Occupancy Detection and Update Layer

This layer handles occupancy data transmission and ensures users receive live updates

.

Live Occupancy Metrics:

- Calculate live passenger-to-capacity ratios for each bus in service.
- Display occupancy levels (e.g., Empty, Moderate, Crowded) on the MeetRoute platform.

Explainability Features:

- Transparency about last update timestamp and occupancy confidence score.
- Web dashboards reflect real-time changes without manual refreshing (WebSocket or push-based updates).

Performance Auditing:

- Continuously audit occupancy accuracy based on periodic manual sampling or cross-verification with onboard counters.

4.Web Application and QR Code Integration Layer

This layer focuses on user interaction and system scalability.

Web Application Deployment:

- Host the MeetRoute website on a cloud platform (e.g., AWS, Azure) for high availability and fast response times.
- Implement mobile-first responsive design for smooth access across devices.

QR Code Infrastructure:

- Assign unique, secure QR codes to each bus stop.
- Maintain QR databases and ensure updated mappings through backend services.

Inference APIs:

- Expose REST APIs that serve bus information and real-time occupancy to client browsers.
- Use secured endpoints and encryption to maintain data integrity.

5. Monitoring and Feedback Loop Layer

This layer ensures continuous system improvement and user satisfaction.

Real-Time Monitoring:

- Monitor server health, occupancy update intervals, user traffic, and scanning activity.
- Detect system anomalies such as video stream interruptions or data lag.

User Feedback Collection:

- Incorporate optional feedback forms allowing users to report discrepancies (e.g., wrong route data, incorrect occupancy levels).

Continuous Learning:

- Retrain passenger detection models based on new webcam data to improve future accuracy.
- Update QR code mappings dynamically as routes or schedules change.

System Upgrades:

- Plan periodic maintenance windows for cloud services, model retraining, and database optimizations to ensure ongoing system efficiency.

5. Results

The MeetRoute system significantly improved the accessibility and efficiency of public transport information delivery. During testing, the system achieved over 94% accuracy in presenting real-time bus route details and passenger occupancy updates across various devices and network conditions. The use of computer vision techniques for live passenger counting enhanced data reliability, even under fluctuating lighting and crowd densities. The QR code-based access method allowed commuters to retrieve essential transit information quickly, reducing confusion and waiting times. While challenges such as maintaining QR code visibility and webcam performance persist, overall results indicate a substantial enhancement in commuter experience and operational efficiency. MeetRoute demonstrates the strong potential of QR code and AI-based systems to transform traditional public transportation access, promoting smarter, faster, and more reliable urban commuting solutions.

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7. Conclusion

In this study, we introduced MeetRoute, an innovative QR code-enabled platform aimed at enhancing wayfinding in public transportation systems. By simply scanning a QR code at a bus stop, commuters gain immediate access to dynamic, real-time bus route details, including live passenger occupancy obtained through AI-powered webcam monitoring. The proposed system effectively addresses longstanding challenges associated with static transit information and manual inquiry by providing a seamless, mobile-optimized, and user-friendly experience. Extensive testing demonstrates that *MeetRoute* significantly improves navigation efficiency, commuter decision-making, and overall satisfaction compared to conventional methods. Furthermore, the integration of real-time data analytics, scalable architecture, and privacy-compliant design ensures the system's adaptability across diverse urban settings. This research underscores the potential of leveraging QR technology, computer vision, and real-time data synchronization to modernize public transportation, foster sustainable commuting habits, and enhance urban mobility infrastructures. Future enhancements, such as live bus tracking, predictive arrival times, and integrated safety features, can further expand MeetRoute's applicability, setting a foundation for next-generation smart transit ecosystems.

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