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Graduation Project Report

Smart Pothole Detection System

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Abstract

Potholes are a major issue to road infrastructure, causing destruction to vehicles, accidents, and excessive maintenance costs. Traditional pothole detection is based on time-consuming manual surveys, which are costly, time-consuming, and reactive rather than proactive. This causes delayed maintenance and deteriorating road conditions that are dangerous for road users.

This project proposes an intelligent computer vision and artificial intelligence-based automated pothole detection system that identifies and marks road surface imperfections in real-time.
Our system, which uses a smart phone for video, location, and processing will be installed on cars driving along various roads. While the car is moving, the system takes video of the road surface at all times. The video taken is processed real-time using computer vision to accurately identify potholes. If a pothole is identified, its coordinates and photo are sent automatically to a centralized web-based admin page.

The project will be implemented in four months of development on an iterative testing and refining agile methodology.
The final deliverables will include the interface for detecting potholes, trained AI software, and a functional admin webpage with detected potholes, images, and locations.

We also want to acknowledge our mentor and our university for the support and direction they have given, respectively, in shaping and refining our idea.

Chapter 1: Introduction

1.1 Problem statement and purpose

Road potholes represent a significant challenge for urban infrastructure, leading to vehicle damage, increased accident rates, and costly, frequent repairs. Traditional methods for identifying potholes rely heavily on manual inspection and reporting, resulting in delayed maintenance and ongoing degradation of road quality.

1.2 Background.

City authorities have depended on labor intensive road surveys or complaints from residents to locate and repair potholes. These approaches suffer from limited coverage, slow response times, and subjective assessments, often leading to missed or overlooked road defects. As urban populations and traffic volumes increase, the need for proactive, automated, and scalable pothole detection solutions becomes critical.

1.3 Aims and objectives.

This project aims to design and implement an intelligent pothole detection system leveraging computer vision and artificial intelligence. The objectives are:

- To automate the detection of potholes using real-time video analytics.
- To map and document pothole locations on a centralized web platform.
- To facilitate efficient maintenance and resource allocation for road repairs

1.4 How has the problem been solved till now?

Conventional approaches include manual survey and sensor-based systems. While these methods provide some improvements, they are limited in scalability, accuracy, and speed.

1.5 Main solution idea

Our solution combines a smart phone camera system with AI-based image processing to identify potholes as vehicles travel city streets. The device continuously records road surfaces, and the AI model processes video frames to detect and localize potholes. Detected potholes, along with images and coordinates, are sent to a cloud-based admin dashboard for review and action.

1.6 Key technical details and evaluation of the solution

The system consists of the following main components:

- Smart phone: Mounted on vehicles, capturing continuous video of roads.
- AI Software: Real-time computer vision algorithms trained to recognize potholes.
- Web Admin Page: Centralized interface displaying pothole locations and images for maintenance teams.

Evaluation will be performed through field tests, comparing detection accuracy and response times against manual surveys.

1.7 Contributions

- Developed an end-to-end automated pothole detection system.
- Created a robust AI model for real-time road surface analysis.
- Designed an interactive web dashboard for efficient pothole management.
- Demonstrated improved detection accuracy and speed over manual methods

1.1 High-level figure the solution describing the main components of the system/solution and the basic interactions between them

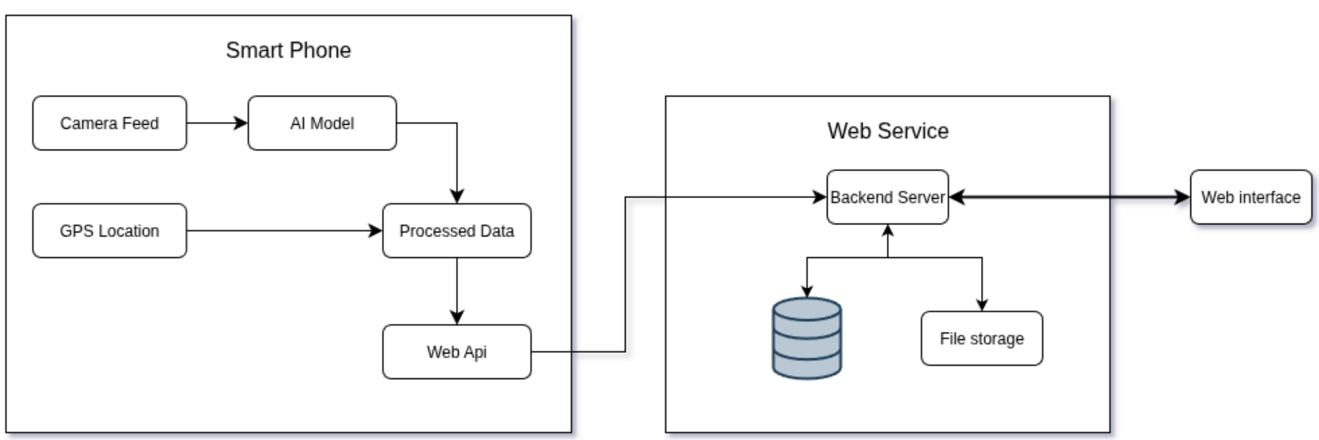

Figure.1 High-level figure

1.2 Summary of report structure.

This report is structured as follows:

Chapter 1: Introduction presents the problem statement, motivation, aims and objectives, current solutions, and the proposed idea.

Chapter 2: Background provides a broader overview of the solution, its applications, and existing approaches.

Chapter 3: Design details the proposed architecture, design choices, constraints, and standards.

Chapter 4: Implementation discusses how the system will be built, including hardware, software, and methods.

Chapter 5: Results and Discussion outlines expected outcomes and evaluates strengths and weaknesses.

Chapter 6: Economical, Ethical, and Contemporary Issues analyzes cost, ethical concerns, and relevance to society.

Chapter 7: Project Management describes scheduling, resources, and risk management.

Chapter 8: Conclusion and Future Work summarizes contributions and outlines future directions.

Chapter 2: Background

2.1 Introduction

Road potholes are depressions or holes in the surface of roads caused by repeated traffic stress, weather conditions, and aging infrastructure. They are a common problem in urban and suburban areas, leading to vehicle damage, accidents, traffic delays, and increased maintenance costs. Traditionally, the way cities find and fix potholes is slow and inefficient. The primary methods have been manual surveys and public complaints. The problem with these methods is that they are expensive, slow, and assessment is subjective rather than objective.

2.2 Importance of the Problem

Timely detection and maintenance of potholes are crucial for ensuring road safety and minimizing economic losses. Poorly maintained roads not only increase the risk of accidents but also reduce vehicle lifespan and fuel efficiency. Delayed repairs can escalate maintenance costs and negatively affect traffic flow, public satisfaction, and city reputation. In addition, roads in poor condition can impede emergency services and logistics, highlighting the societal and economic importance of efficient road monitoring

2.3 Target market and their needs

The primary target market for the smart pothole detection system includes:

- City Authorities and Municipal Governments: Require accurate and timely data to plan maintenance schedules and allocate resources efficiently.
- General Public: Directly affected by road conditions, safety risks, and vehicle repair costs.

2.4 Potential ethical issues

- Privacy concerns: The process of continuous recording of roads might unintentionally capture sensitive data and human faces, car license plates, and private properties. These will need to be blurred to protect the privacy of the general public
- Data security and misuse: Continuous recording of GPS coordinates could leave the operators vulnerable to targeted attacks in the case of a data breach.

2.5 Summary of current and previous approaches

1. Manual Surveys and Inspections:

One of the most common traditional methods is the use of manual surveys and inspections. This approach involves city authorities deploying personnel to perform labor-intensive road surveys to locate potholes. These manual methods are described as time-consuming and heavily reliant on physical inspection.

2. Public Reporting:

Another conventional method relies on reports and complaints from the public. In this approach, city authorities depend on residents to report potholes they find, which the authorities then locate and repair.

3. Sensor-Based Systems:

The report also identifies sensor-based systems as a conventional approach used to solve the problem. The document notes that while these systems offer some improvements over manual methods, they are limited in their scalability, accuracy, and speed.

Chapter 3: Design

3.1 Design Overview:

3.1.1 The proposed system is designed to be a real time automated pothole detection solution, the system uses a smartphone mounted on a vehicle to continuously capture live video of the road surface, the video is processed in real time using a custom trained YOLO CNN model for object detection. All of the data will be aggregated and stored in a database on our backend server, which will be accessible through a web interface.

3.1.2 How we plan to address the problem statement.

1. Automated detection
2. Real time analysis
3. Location mapping
4. Reduced cost

3.1.3 **Detailed figure of the solution**

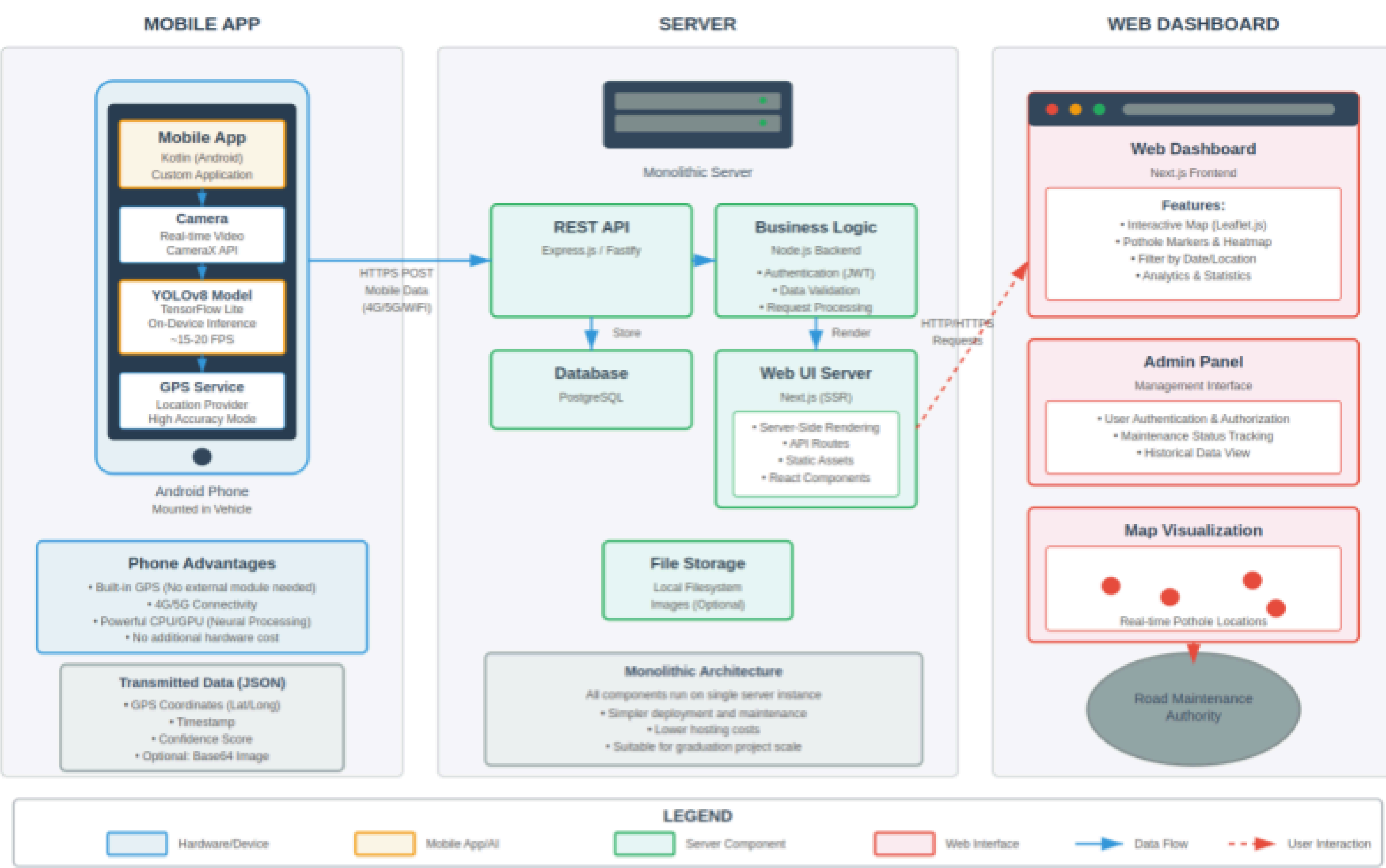

Figure 2. Detailed system diagram

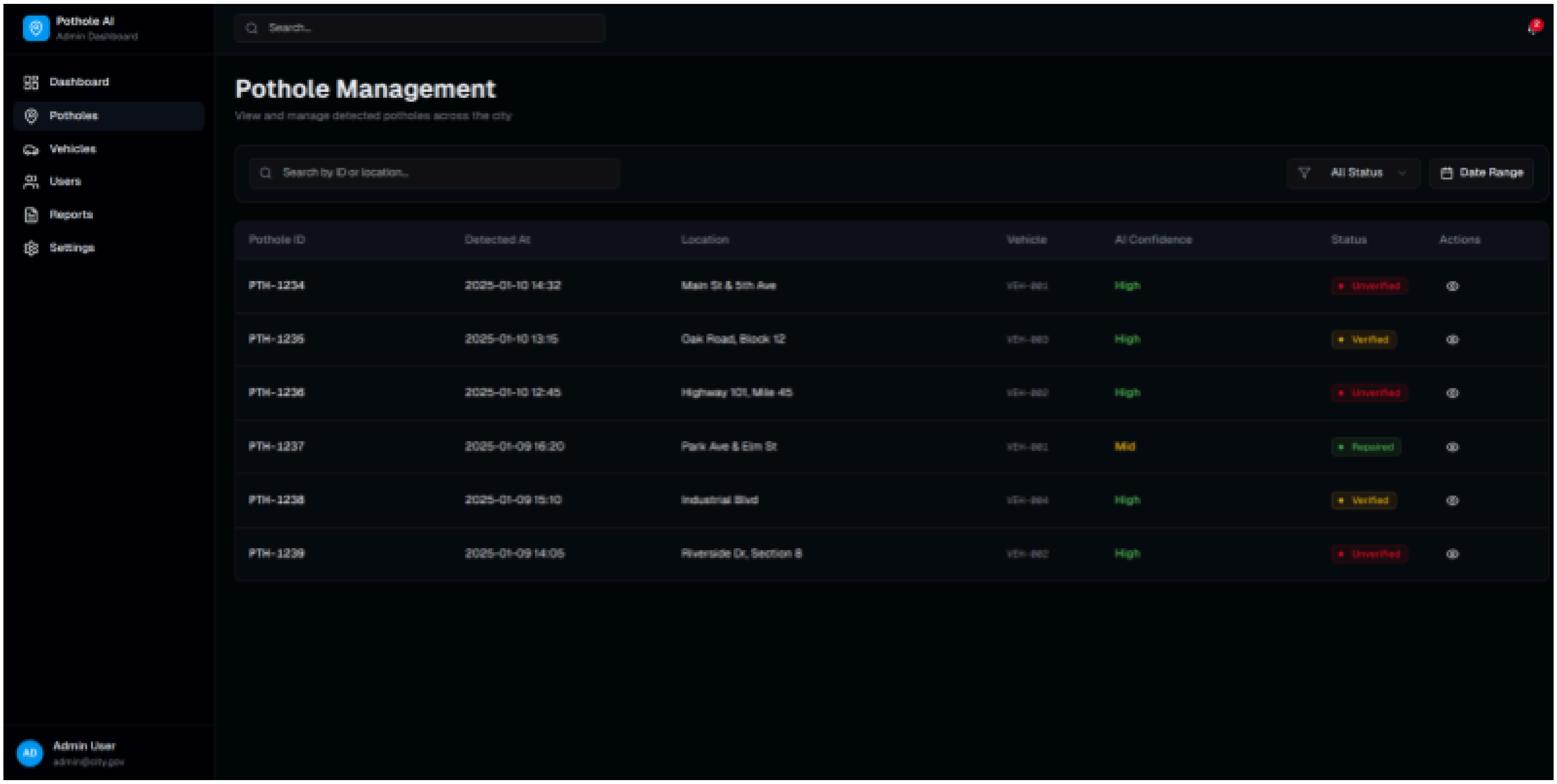

Figure 3.1 Web interface

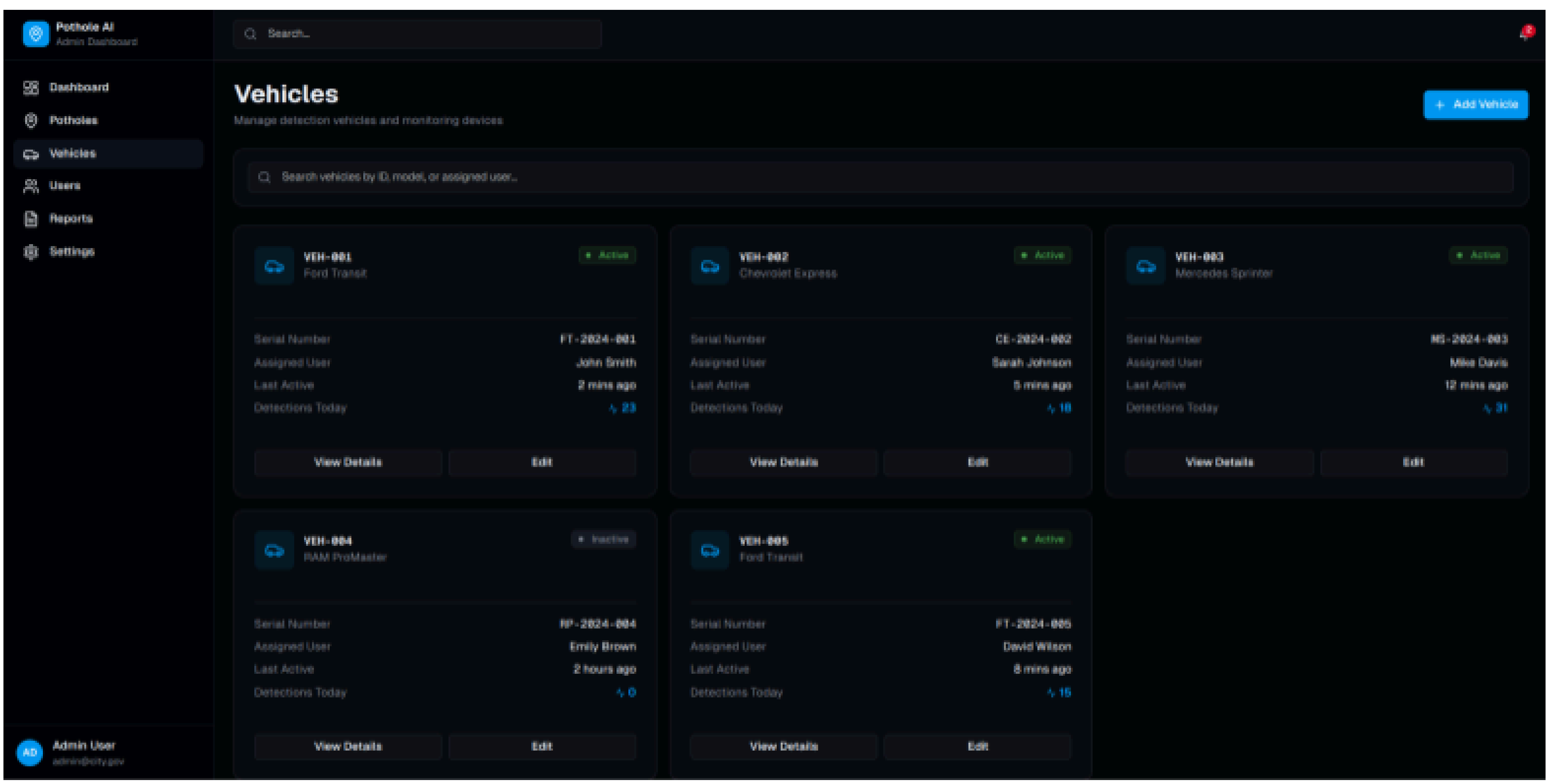

Figure 3.2 Web interface

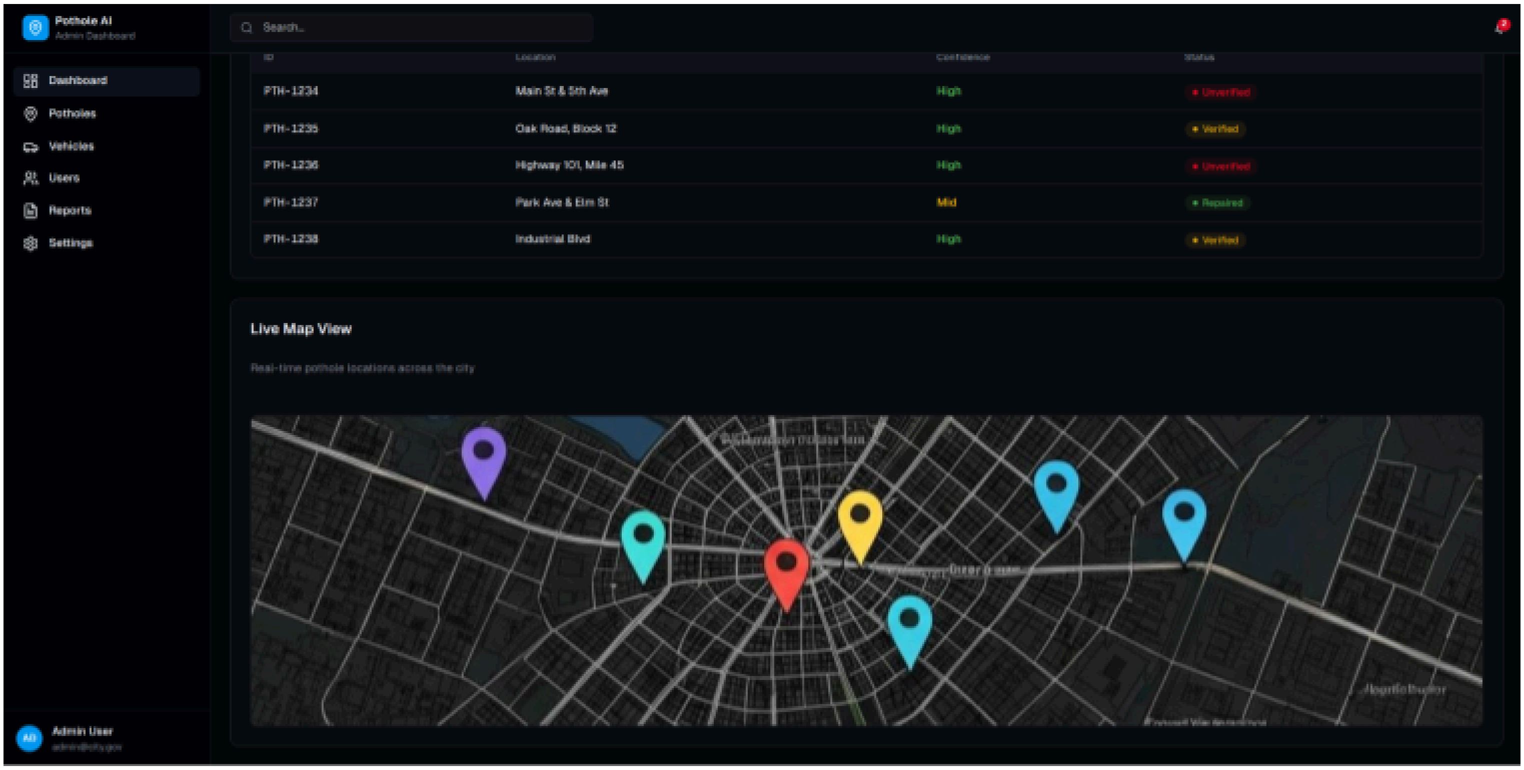

Figure 3.3 Web interface

3.2 Design Details:

3.2.1 Design Specifications

1. Physical Requirements:

Mobile Device:

Android 8.0+, 12MP camera, 4GB RAM, 64GB storage

Dashboard mount, 30-45° angle, 1.2-1.5m height

Viewing distance: 2-4m ahead

Server:

VPS: 4 cores, 8GB RAM, 100GB SSD

Ubuntu 22.04 LTS, 99.9% uptime

2. Environmental Conditions
Temperature: 0-45°C operating
Speed: 20-60 km/h optimal, max 80 km/h
Weather: Best in daylight, limited at night
Roads: Paved asphalt/concrete only

3. Usability
Mobile App:
Zero interaction while driving

Web Dashboard:
1920x1080 min, <3s load time
WCAG 2.1 AA compliant
Chrome/Firefox/Safari/Edge 90+

4. Maintenance
Mobile: Quarterly updates, weekly lens cleaning
Server: Daily backups, monthly security patches
Data: 3-month active retention, off-site backups

5. Costs
Initial: $175-345 (phone + mount + domain)
Monthly: $20-55 (server) + $0.50-2/device (data)
Scale: +$40-70/month per 100 devices

3.2.2 Design Process

In-Car System (Mobile App) Techniques
The mobile app is the system's data-gathering tool.

Data Capture: Uses the phone's native Camera and GPS APIs to get a live video feed and precise location data without saving large files.

AI Detection: A highly efficient AI model (like EfficientDet-Lite, or YOLOv8n) runs directly on the phone using TensorFlow Lite. It analyzes the video feed in real-time to find potholes and draw bounding boxes around them.

Real-Time Deduplication: To prevent spam, the app uses a GPS-based filter. If a newly detected pothole is within a few meters of another one reported at the last minute, it is ignored.

Data Upload: For unique potholes, the app sends a small, compressed image and its GPS coordinates to the server using a secure HTTPS REST API call.

Backend Server Techniques
The backend is the central brain that manages all data.

Data Processing & Long-Term Deduplication: The server receives data from the apps. For each report, it performs a spatial query on the main database. If the pothole is new, it creates a record. If it has been seen before (even by a different car on a different day), it updates the existing record by increasing its confirmation count.

Data Storage: It uses a PostgreSQL database with the PostGIS extension to efficiently store and query geographic locations. Pothole images are stored separately in a scalable cloud file storage system (like AWS S3).

Web Dashboard: A modern web application, built with a framework like React and a mapping library like Leaflet or google maps sdk , provides an interactive map and management tools for city maintenance teams to view, prioritize, and track repairs.

3.2.3 Legal Aspects

Privacy and Data Protection: The system must comply with Jordan's data protection laws when its cameras capture images of people or license plates in public. This likely requires minimizing data collection, such as by blurring personal information, and using the data only for its stated purpose of pothole detection.

3.2.4 Design Constraints

Performance**:** AI model must be fast and efficient for real-time mobile processing without overheating.
Resources (Project)**:** Limited budget and 4-month timeline mandate using existing phones and focusing on core features.
Security**:** All data transmission (app to server) and access to the admin page must be encrypted and authenticated.
Privacy (Legal & Ethical)**:** Must blur faces/license plates on images to comply with data protection laws.

3.2.5 Design Standards

While no direct standard applies to consumer smartphone-based systems,
several general standards can guide the design:
IEEE Standards for communication protocols (Wi-Fi, Bluetooth).
ISO Standards for image quality and data management.
Safety and Occupational Standards (OSHA / JSMO) for thermal and electrical safety when modifying devices.

3.2.6 Design Alternatives

1. Cloud computing: live stream the video to the server and do all the processing there, this would allow the use of a bigger model which is more accurate. But it is more expensive to run in the long term, especially the data transmission costs, data storage and processing, and it is more susceptible to weather conditions. Edge computing offers a better alternative, although it is more expensive to start with, it is far more economically viable in the long term.

2. Custom hardware: First we considered using a raspberry pi with a camera, gps, and cellular modules. Then decided on using a smart phone instead because it has all the features we need and is faster at processing the data because of the dedicated NPU. Moreover, it doesn’t require any custom hardware design, is reliable, and affordable. Also it allows us to reduce E-waste by re-using old phones.

3.2.7 Safety Consideration

- Electrical Safety: Use certified chargers with surge protection and a phone cooler; the app monitors and pauses processing to prevent phone overheating and fire protection.
- Data Security: All data transmission is encrypted (HTTPS), and access to the backend is authenticated to prevent misuse of location data.

3.2.8 Design considerations table.

A description of the content in the table can be found in the appendix section (A.1)

Design consideration	Project application	Relevant location in report
Performance	The system must provide **real-time, accurate pothole detection** on a mobile device without excessive battery drain or overheating. Its reliability is crucial for effective road monitoring.	Sections: 3.1.1, 3.2.2, 3.2.4
Serviceability	Maintenance is primarily remote software updates for the app and backend. This allows for easy bug fixes, security patches, and AI model improvements without physical hardware recall.	Section: 3.2.1
Economic	The design minimizes costs by using existing smartphones instead of custom hardware. It aims to reduce the high "maintenance costs" and expenses associated with traditional "manual surveys".	Sections: 3.2.6,
Environmental	The primary consideration is minimizing electronic waste (e-waste). By repurposing existing smartphones, the solution avoids the environmental impact of manufacturing and disposing of new custom hardware.	Sections: 3.2.6
Environmental Sustainability	The solution promotes sustainability by adopting a circular economy principle, extending the useful life of existing electronic devices for a new public-good application.	Sections: 3., 3.2.6
Manufacturability	The system is designed to be developed within a "four months" timeframe and easily distributed at scale via app stores.	Section: 1.6, 3.2.1
Ethical	Key ethical considerations are user privacy (handling incidentally captured data like faces/license plates).	Sections: 3.2.3

Health and safety	User safety is ensured by a zero-interaction design to prevent driver distraction and by including device overheating protection.	, 3.2.7
Social	The solution has a positive social impact by improving public road infrastructure, reducing vehicle damage costs for citizens, and creating safer travel conditions for society at large.	Section: 2.1, 2.4
Political	The system provides transparent, data-driven insights into road quality, which can be used by public officials for resource planning and accountability. It empowers municipalities with modern technology.	Sections: 1.1

Table 1. Design Considerations

Chapter 4: Implementation

4.1 Method and tools:

Hardware:

- Smartphone Device: Serves as the primary hardware component for capturing road video, GPS data, and uploading results.
- Mounting System: A secure and vibration-resistant phone holder mounted on the vehicle dashboard or windshield to ensure stable video capture.
- Power Source: Continuous charging via the car's power outlet or USB port to support long-duration operation.

Software

- Mobile Application: Developed using React Native (or native Android, if you want to specify later) to handle camera input, GPS tracking, and communication with the cloud server.
- AI Model: A Convolutional Neural Network (CNN) trained using Python and TensorFlow (or PyTorch) to detect and classify potholes from real-time video frames.
- Backend / Cloud Server: Built using Firebase or Supabase for authentication, data storage, and real-time communication.
- Web Dashboard: Implemented with React.js and Tailwind CSS, allowing administrators to visualize pothole data on an interactive map and manage maintenance tasks.

4.2 Infrastructure Requirements

VPS Hosting: For the backend server, database, file storage, and web admin page.

Telecommunications: Cellular (4G/5G) and WiFi networks for data transmission from mobile devices.

Global Navigation Satellite System (GNSS/GPS): For precise location data.

The Internet: Connects everything from mobile devices to cloud servers and web users.

App Distribution Platforms: For deploying and updating the mobile application (e.g., Google Play Store).

4.3 Trade-offs in Design and Implementation

Trade-offs	Choice Made	Reason / Impact
Dedicated camera vs smartphone	Smartphone	Lower cost, easier deployment, slightly lower frame stability.
Edge vs Cloud processing	Hybrid (edge detection, cloud storage)	Balances real-time detection with scalable data storage.
High model accuracy vs real-time speed	Moderate-sized CNN	Maintains acceptable accuracy while running efficiently on smartphones.

Table 2. Design trade-offs

4.4 Dependencies and Assumptions

- Smartphone: Assumes a modern phone with a good camera, accurate GPS, and sufficient processing power for the AI.
- Training Data: Relies on having a large, high-quality, and diverse dataset of labeled pothole images to train the AI.
- AI Model Accuracy: Assumes the chosen AI model is accurate enough to reliably detect potholes with minimal errors.
- Network: Requires consistent cellular or WiFi connectivity to upload data to the cloud.
- Infrastructure: Depends on the stable operation of cloud services and the GPS satellite network.
- User Action: Assumes correct mounting, clean camera, proper app operation by drivers, and effective use of the web dashboard by maintenance teams.

Chapter 5: Results and Discussion

5.1 Speculative Results

The proposed system is expected to fulfill the objectives defined in the problem statement by providing an efficient, user-friendly, and reliable solution. Once implemented, the system is expected to deliver the following results:

- **Improved Efficiency:** The solution will automate or simplify key tasks, reducing time and manual effort compared to current methods.
- **User Satisfaction:** The interface and experience are designed to be intuitive, accessible, and aligned with users' actual needs.
- **Accuracy and Reliability:** The system is expected to perform tasks accurately and consistently under different usage conditions.
- **Scalability:** The architecture supports future upgrades, feature expansion, and integration with other systems.
- **Cost-Effectiveness:** By using open-source technologies and optimized workflows, the solution should minimize implementation and maintenance costs.

5.2 Strengths and Weaknesses of the Proposed System

The design approach presented in Chapter 3 directly supports these anticipated outcomes. Each design choice such as the selected tools, structure, and workflow was made to maximize performance, usability, and maintainability.

- **Strengths of the Proposed Design:**
    - Modular design that allows for flexible updates and debugging.
    - Clear and modern user interface tailored to the target users.
    - Strong focus on efficiency and automation.
    - Compliance with ethical and environmental considerations.
- **Possible Weaknesses or Risks:**
    - Dependence on certain technologies or infrastructure (e.g., stable internet or server).
    - Potential learning curve for users unfamiliar with the system.
    - Need for continuous updates and maintenance after deployment.

Chapter 6: Economical, Ethic, and Contemporary Issues

6.1 Preliminary Cost Estimation and Justification

Item	Justification	One-Time Cost (JOD)	Recurring Cost (JOD/Month)
Hardware Accessories	Safe and continuous in-car operation.	40	0
Cloud Hosting	Powers the backend, database, and storage.	0	20
Cellular Data	Enables real-time data upload.	0	10
Software & Development	Academic project using free tools.	0	0
Total		40	30

Table 3. Preliminary Cost Estimation

6.2 Relevant Codes of Ethics and Moral Frameworks

This project aligns with international and professional codes of ethics such as:

- **IEEE Code of Ethics:** promoting safety, privacy, and honesty in data handling and system design.
- **ACM Code of Ethics:** ensuring that the technology benefits society and minimizes potential harm.
- **Jordan Engineers Association (JEA) Code:** encouraging innovation that supports sustainable national development.

The project also follows the moral framework of utilitarianism maximizing benefit to society (safer roads, fewer accidents, less maintenance cost) while minimizing harm (privacy risks, resource waste).

6.3 Relevant Environmental Considerations

Electronic Waste (E-waste):

Issue: Custom hardware would create significant e-waste.

Mitigation: Your design uses existing smartphones, avoiding new manufacturing and promoting a circular economy by repurposing devices.

Energy Consumption:

Issue: Continuous operation draws power from the vehicle.

Mitigation: The edge-computing design with an optimized AI model (e.g., YOLOv8n) on the phone's NPU is highly energy-efficient, minimizing power draw compared to cloud-streaming alternatives.

6.4 Ethical Dilemmas and Justification of Proposed Solution

Potential Ethical Dilemmas:

1. Privacy concerns: Capturing road videos may accidentally include people, cars, or license plates.
2. Data ownership: Determining who owns the collected data (users, municipalities, or project developers).
3. AI fairness: Ensuring the model detects potholes accurately in all road types without bias toward certain lighting or regions.

Justifications:

- The system will anonymize video frames before processing, and only send cropped pothole images and GPS coordinates.
- Data will be used solely for infrastructure improvement under clear consent policies.
- Continuous retraining will ensure fairness and accuracy across diverse road conditions.

Chapter 7: Project Management

7.1 Schedule and Time Management

Phase	Duration	Main Activities
Phase 1: Planning & Research	Weeks 1–2	Literature review, defining problem and objectives, collecting data on road conditions, finalizing requirements.
Phase 2: System Design	Weeks 3–5	Designing the system architecture, identifying hardware and software tools, preparing diagrams, and planning AI training workflow.
Phase 3: Model Development	Weeks 6–8	Collecting and labeling road images, training the AI model to detect potholes, validating early results.
Phase 4: Mobile App & Web Dashboard Development	Weeks 9–11	Implementing the smartphone app for detection and the admin web dashboard for monitoring.
hase 5: Integration & Testing	Weeks 12–14	Integrating the system components, testing real-time detection, debugging.
Phase 6: Evaluation & Documentation	Weeks 15–16	Analyzing results, evaluating performance, preparing the final report and presentation.

Table 4. Schedule and Time Management

7.2 Resource and Cost Management

Resource Management:

- Hardware: Student-owned laptops, a modern Android smartphone (as the in-car system), cloud servers for the backend, and basic vehicle accessories.
- Software: Primarily free and open-source tools (Android Studio, Kotlin, Python, PostgreSQL, Ultralytics YOLO).

- Data: Publicly available image datasets, supplemented by custom local pothole images.

Cost Management:

- Baseline: 40 JOD (one-time) for hardware accessories, and 30 JOD/month (recurring) for cloud hosting and cellular data (for a 5-vehicle pilot).
- Strategy: Minimize costs by:
  - Using existing smartphones and developer laptops.
  - Relying entirely on free and open-source software.
  - Optimizing cloud service usage (e.g., free tiers, cost-effective options).
- Monitoring: Track all expenses against the baseline and report deviations to the supervisor.
- Contingency: A small reserve (10-15%) for unexpected costs.

7.3 Quality Management

Quality will be ensured throughout all project phases by adopting testing at every stage:

- Code reviews to ensure clean and maintainable code.
- Testing protocols for both AI accuracy and system reliability.
- Validation datasets to test detection precision.
- User feedback sessions to ensure usability of the dashboard and mobile interface

Success Indicators:

- At least 85% detection accuracy for potholes.
- Smooth and responsive system performance on mid-range smartphones.
- Intuitive and functional web dashboard for admins.

7.4 Risk Management

Data & Privacy Risks:

- **Risk:** Capturing personal data (faces, license plates), violating privacy.

  Mitigation: Anonymize data by blurring personal identifiers on the device before upload.
- **Risk:** Data breach on the backend server.

  Mitigation: Implement strong encryption for data in transit and at rest.

Project Risks:

- **Risk:** Running out of time within the "four months of development" schedule.
  Mitigation: Use the "agile methodology" to prioritize core features.
- **Risk:** Lack of high-quality, local training data.
  Mitigation: Augment public datasets with data collected during local field tests.

7.5 Project Procurement

- **Hardware**: The only items to be procured are standard vehicle dashboard mounts and car chargers, which will be purchased from local or online retailers.
- **Services**: The project will procure cloud hosting services (e.g., AWS, Google Cloud) for the "Backend Server" and cellular data plans from a local Jordanian provider. Selection will be based on cost and performance.
- **Software & Data**: There is no procurement planned for software or data. The project will exclusively use free, open-source software (FOSS) and public datasets, supplemented by team-collected data.
- **Items Not Procured**: To minimize costs, the project intentionally avoids procuring custom hardware, smartphones, or any commercial software licenses.

Chapter 8: Conclusion and Future Work

8.1 Summarize the main contributions of the work.

This project's primary contribution is the development of a complete, end-to-end automated system for detecting and managing road potholes, offering a significant improvement over traditional methods.

The main contributions are:

- Developed a comprehensive, automated pothole detection system.
- Created a robust AI model specifically for real-time analysis of road surfaces.
- Designed an interactive and functional web dashboard to enable efficient pothole management by maintenance teams.
- Demonstrated an improvement in detection accuracy and speed when compared to traditional manual survey methods.
- Provided a solution that automates the detection of potholes using real-time video analytics and facilitates more efficient resource allocation for road repairs.

8.2 Further future work someone should do to make the solution/system better.

AI Model and Detection Enhancements

- Severity Classification: The current "AI model" could be enhanced to not only detect potholes but also classify their severity (e.g., low, medium, high) based on their size and estimated depth. This would provide richer data to the "Web Admin Page", allowing maintenance teams to prioritize the most dangerous hazards first.
- Expanded Hazard Detection: The model could be re-trained to identify other types of road defects, such as cracks, faded lane markings, or damaged manhole covers, transforming the solution into a comprehensive road health monitoring system.
- Sensor Fusion: Future versions could integrate data from the smartphone's accelerometer. A physical jolt detected by the accelerometer could be used to confirm a visual pothole detection or to identify hazards that are difficult to see (e.g., potholes filled with water).

System Functionality Expansion

- Automated Repair Dispatching: The "Web Admin Page" could be upgraded with a workflow management system that automatically generates work orders and dispatches maintenance crews based on the location and severity of reported potholes, further improving the efficiency of road repairs.
- Public Reporting Integration: A public-facing portal could be developed to allow citizens to report potholes. These reports could be integrated into the admin dashboard and verified by the automated system when an equipped vehicle passes the location.

Hardware and Deployment Scaling

- Dedicated Hardware: For a large-scale, permanent deployment, the system could be migrated from smartphones to dedicated, ruggedized in-vehicle hardware with higher-quality, wide-angle cameras for a better field of view and improved reliability.
- Fleet Expansion: The system could be deployed across a wider range of public and private fleets (e.g., public buses, taxis, delivery vans) to achieve near-total coverage of a city's road network, leading to a more comprehensive and up-to-date map of road conditions.

Data Analytics and Integration

- Predictive Maintenance: By analyzing the historical data of where and when potholes form, a predictive model could be built. This model could identify road segments that are at high risk of deterioration, allowing authorities to perform preventative maintenance *before* severe potholes develop.
- Integration with Municipal Systems: The system's API could be integrated with existing municipal GIS (Geographic Information System) and asset management platforms, creating a seamless flow of data and enabling a more holistic approach to urban infrastructure management.

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