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Vigilant AI: Proactive Infrastructure Guardian

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Abstract-Infrastructure in both cities and rural areas often falls apart without anyone noticing, which can cause failures, service interruptions, and safety risks. Vigilant AI: Proactive Infrastructure Guardian is a smart, AI-powered system that uses computer vision, machine learning, and data from many sources to find early signs of cracks, blockages, damage, and wear on structures. By shifting from reactive maintenance to predictive monitoring, the system reduces costs, improves response time, and enhances the longevity of public infrastructure. With a scalable cloud edge architecture and real time dashboards, it empowers authorities to make faster, data-driven decisions. The solution is designed to be inclusive, efficient, and suitable for both smart cities and low-connectivity rural environments, ensuring safer and more sustainable infrastructure management.

Keywords: Predictive maintenance, AI-driven infrastructure monitoring, computer vision, structural health monitoring, real-time anomaly detection, deep learning, cloud edge architecture, crack detection, damage classification, structural degradation analysis, automated inspection, risk assessment, smart city infrastructure, rural infrastructure management, sustainable infrastructure systems.

I. INTRODUCTION

Infrastructure is a critical pillar of modern society, enabling essential services such as transportation, communication, energy, and water supply that support daily life and economic development. As infrastructure systems age and expand, traditional reactive maintenance approaches become inefficient, costly, and risky, often addressing problems only after failures occur. Vigilant AI responds to this challenge with a smart, AI-driven framework that enables continuous and real-time monitoring of infrastructure assets. By leveraging advanced technologies such as machine learning, deep learning, computer vision, and predictive analytics, the system identifies early indicators of damage, structural degradation, or abnormal behavior. This proactive strategy allows authorities to plan timely maintenance, reduce service disruptions, lower long-term costs, and improve public safety. Overall, Vigilant AI enhances the reliability, sustainability, and resilience of infrastructure systems across both urban and rural regions.

II. LITERATURE SURVEY

Artificial intelligence, Internet of Things (IoT), big data, and digital twin technologies have emerged as key enablers in the development of smart and sustainable urban infrastructure. Several studies report that the integration of AI and IoT supports real-time monitoring, predictive analytics, and intelligent decision-making in smart cities [1], [3], [7], [8]. Digital twin–based approaches further enhance infrastructure planning and sustainability by enabling virtual simulations and performance optimization of physical assets [1], [10]. Research also highlights the role of AI-driven models in improving infrastructure resilience and disaster preparedness by predicting failures and identifying vulnerabilities in advance [4], [6].Moreover, existing literature emphasizes the importance of ethical and responsible AI deployment in public infrastructure systems. Issues such as transparency, fairness, data privacy, and public trust are identified as critical challenges that must be addressed to ensure social acceptance of AI-driven solutions [2], [5]. Studies on AIoT-based frameworks demonstrate that combining AI with large-scale sensing infrastructures enables continuous condition monitoring, automated defect detection, and optimized maintenance scheduling [7], [12], [13], [14]. Overall, while prior research has extensively explored individual technologies, there remains a need for an integrated, scalable, and ethically aligned infrastructure monitoring system. This research gap provides strong motivation for solutions like Vigilant AI, which aim to deliver proactive, reliable, and sustainable infrastructure management across both urban and rural environments [1], [6], [15].

III. METHODOLOGY

The methodology outlines a systematic approach for designing, developing, and implementing Vigilant AI, an AI driven system aimed at providing proactive guidance for urban infrastructure. The approach emphasizes human centered design, predictive analysis, and ethical deployment to ensure the system is practical, reliable, and socially responsible. The development and implementation of Vigilant AI follows a systematic approach integrating human centered design, predictive analytics, and ethical AI practices. The system workflow combines user interaction, AI-based analysis, cloud storage, and real-time visualization to support proactive infrastructure monitoring.

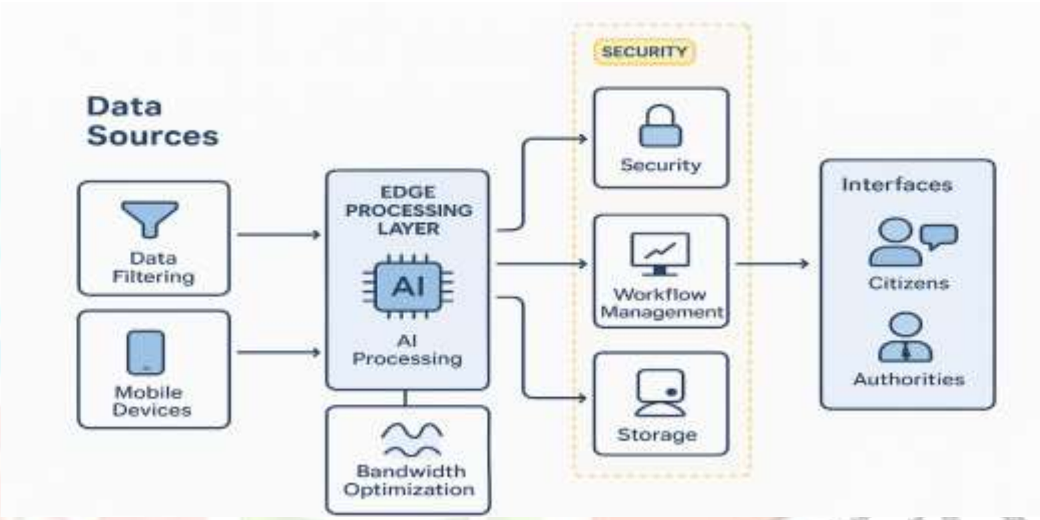

Figure 1: System Architecture

1. **User Interaction & Frontend:** Citizens, authorities, and admins interact with a React.js web interface to report infrastructure issues, view complaint status, and track maintenance progress. The frontend communicates with the backend using API-based HTTP requests for uploading images, registering complaints, and generating reports.

2. **Backend Processing & Data Management:** The backend receives and processes user requests, triggers machine learning workflows, and manages scalable cloud storage for images, predictions, reports, and user inputs, enabling real-time access and analytics.

3. **AI/ML Prediction & Processing:** Deep learning and ML models like ResNet50, Mobile Net, and XG Boost detect infrastructure damages, classify complaints, predict severity levels, identify anomalies, and support predictive maintenance for efficient issue resolution.

4. **Edge Data Acquisition & Communication:** Real-time images and videos are captured from cameras and inspection devices. Gateway communication layers filter, preprocess, and securely transmit data to ensure reliable and optimized flow to the AI/ML processing engine.

5. **Data Visualization, Dashboards & Alerts:** Interactive dashboards (Plotly/Dash) provide visual insights into damage trends, complaint statistics, and maintenance performance. The system triggers automated alerts for authorities to enable timely interventions and efficient resource allocation.

6. **Integration, Security & Continuous Feedback:** APIs integrate edge devices, AI modules, dashboards, and external systems. Encryption, authentication, and controlled access ensure secure operations. Verified field inspections and resolved cases are fed back into the system to retrain models, improving prediction accuracy and overall system efficiency.

IV. RESULTS

The Vigilant AI system produced highly effective results in detecting and predicting infrastructure issues using machine learning and deep learning models. Models such as Mobile Net, Res Net, and accurately identified damages like cracks, blockages, and garbage accumulation in images with high precision. The XG Boost model efficiently prioritized complaints based on severity and urgency, helping authorities respond faster. The system's user dashboards for citizens, authorities, and administrators provided real-time insights, issue tracking, and visual analytics. Testing showed that the system achieved high accuracy, reduced response time, and improved resource management. Overall, the results confirm that Vigilant AI is a reliable, scalable, and cost-effective solution for proactive infrastructure maintenance in both smart cities and rural areas.

Figure 2: Create Account Page

The above Figure 2 shows the Create Account page of the Vigilant AI system, providing input fields for name, email, phone number, and password, along with a role selector for Citizen, Authority, or Admin. This interface supports role-based access and ensures that users are registered according to their functional responsibilities within the platform.

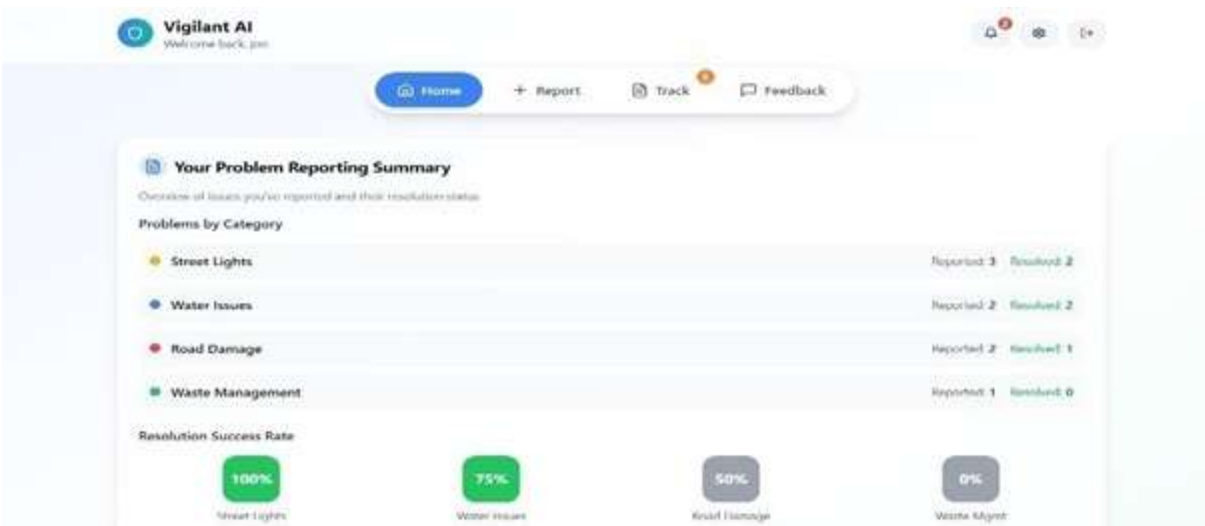

Figure 3: User/Citizen Dashboard

The above Figure 3 shows the Users/Citizens Dashboard of the Vigilant AI application, summarizing the infrastructure issues reported by the user across categories such as Street Lights, Water Issues, Road Damage, and Waste Management. For each category, the dashboard displays the number of issues reported, the number resolved, and the corresponding resolution success rate. A simple navigation bar with options like Home, Report, Track, and Feedback enables users to easily access different system features and monitor the status of their submissions.

Figure 4: Media Capture Interface

The above Figure 4 shows the Media Capture screen, where users upload or capture photos of damaged infrastructure. It allows taking images through the camera or uploading files, and the uploaded photos appear in the preview section. This step helps ensure the AI receives clear visuals for accurate issue detection.

Figure 5: Final Review and Submission Screen

The above Figure 5 shows the final step of the infrastructure issue reporting process, where the user reviews all detected details before submitting the complaint. The interface displays key information such as issue type, department, priority level, number of media files, detected location, AI confidence score, and user details. After verifying the information, the user can provide a short description and submit the complaint for processing.

Figure 6: Authority Dashboard

The above Figure 6 shows the "Authority Dashboard" for the Vigilant AI application, designed for officials to "Manage complaints and track municipal services". It provides a high-level summary at the top, displaying key metrics like "Total Complaints" (247), "Resolved Today" (23), "In Progress" (45), and "Citizens Served" (892). Below this, a "Recent Complaints" feed shows as a "Broken street light" and "Water supply disruption,".

Figure 7: Map View Live Complaint Visualization

The above Figure 7 shows the Map View interface, which allows authorities to monitor real-time complaint locations. The panel includes filters for complaint status (All, Pending, In Progress, Resolved) and map modes such as Normal View and Heatmap. Each coloured marker on the map represents a complaint with its respective status, helping authorities track active issues and navigate directly to their locations using zoom and navigation controls.

Figure 8: Admin Dashboard

The above Figure 8 shows the Admin Command Center of Vigilant AI, providing real-time system monitoring. It displays live technical status (active users, system load, uptime) along with key service metrics such as total complaints, resolved cases, average resolution time, and AI validation rate. A left-side navigation panel allows administrators to manage complaints, authorities, and citizen records efficiently.

Figure 9: AI Intelligence Monitor Dashboard

The above Figure 9 shows the AI Intelligence Monitor, providing a quick overview of AI model performance. It highlights overall accuracy, validation count, average confidence, and model uptime. The dashboard also lists active models with their accuracy and validations, along with a live feed showing recent AI validation events and system activities.

V. CONCLUSION

The Vigilant AI project leverages AI and advanced ML/DL models like Mobile Net, Res Net, and XG Boost to transform infrastructure monitoring from reactive to predictive. It efficiently detects structural defects, classifies anomalies, and prioritizes maintenance tasks, reducing downtime and costs. The platform is scalable and inclusive, functioning effectively in both urban and rural areas through edge computing, lightweight models, real-time alerts, and user-friendly dashboards. By enhancing transparency, accessibility, and citizen engagement, it improves service delivery and public trust. Vigilant AI also supports SDGs 9, 11, and 13, promoting safer, resilient, and environmentally optimized infrastructure.

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