AI-Powered Multimodal Diagnostic Assistant for Vehicle Fault Detection

Basil Vazhathottathil
Computer Science and Engineering
St. Joseph's College of Engineering and Technology
Palai, India
basilvazhathottathil2026@cs.sjcetpalai.ac.in

Diya Benny
Computer Science and Engineering
St. Joseph's College of Engineering and Technology
Palai, India
diyabenny2026@cs.sjcetpalai.ac.in

Jose Thomas
Computer Science and Engineering
St. Joseph's College of Engineering and Technology
Palai, India
josethomas2026@cs.sjcetpalai.ac.in

Prof. Sarju S
Computer Science and Engineering
St. Joseph's College of Engineering and Technology
Palai, India
sarju.s@sjcetpalai.ac.in

***Abstract*—Vehicle maintenance poses real challenges for regular drivers facing the growing complexity of today's cars, where OBD systems generate fault codes that demand expert knowledge to decipher, often resulting in avoidable trips to mechanics. This paper introduces a practical mobile solution—an AI-driven repair guide—that empowers non-experts by processing everyday inputs like spoken or typed problem descriptions, dashboard snapshots, and direct OBD-II data pulled over Bluetooth. Through targeted natural language analysis of symptoms alongside decoded diagnostic codes, the system assesses issue severity via a conversational chatbot, offering clear DIY repair steps complete with tool lists and safety tips for minor fixes, while directing users to local workshops for anything serious.**

It further tracks full service histories and pushes timely alerts for routines like fluid checks or tire rotations to prevent future headaches. Deployed as a React Native app with a robust FastAPI backend for quick, reliable performance across phones, initial real-vehicle tests confirm its potential to cut down on unnecessary service calls and boost owner confidence in handling basics.

***Index Terms*—Artificial Intelligence, Vehicle Diagnostics, Multimodal Input, Natural Language Processing, On-Board Diagnostics, Chatbot-Based Assistance, Preventive Maintenance**

I. Introduction

The rapid evolution of automotive technology has significantly increased the complexity of modern vehicles, making fault diagnosis and maintenance challenging for everyday users. While advanced electronic control units and sensors improve vehicle performance and safety, they also make it difficult for non-technical vehicle owners to understand and resolve common issues. As a result, even minor problems such as sensor faults, battery issues, or warning indicators often lead to unnecessary mechanic visits, increased maintenance costs, and loss of time.

On-Board Diagnostics (OBD) systems provide a standardized mechanism for detecting vehicle faults through diagnostic trouble codes. Although these codes are effective for identifying issues, interpreting them typically requires technical knowledge or professional tools. Existing mobile applications and diagnostic platforms mainly focus on retrieving fault codes or connecting users to service centers, offering limited guidance for self-diagnosis and basic repairs. Moreover, these systems rarely consider user-observed symptoms such as unusual behavior, warning messages, or contextual descriptions, which are often crucial for early fault identification.

Recent advancements in Artificial Intelligence (AI), particularly in Natural Language Processing (NLP) and intelligent conversational systems, have enabled the development of applications capable of understanding human-generated inputs and providing contextual assistance. AI-driven chatbots and decision-support systems offer an opportunity to simplify vehicle diagnostics by allowing users to describe problems in natural language and receive structured guidance. When combined with optional diagnostic data from OBD systems, such approaches can significantly improve accessibility and usability for non-technical users.

Motivated by these developments, this paper presents an AI-Powered Vehicle Repair Assistant designed to assist users in diagnosing and managing common vehicle issues through an intelligent, user-friendly platform. The proposed system accepts multimodal inputs, including textual descriptions, optional voice and image inputs, and OBD fault codes retrieved via Bluetooth. NLP techniques are used to extract key symptoms from user input, while decoded OBD data provides structured diagnostic insights. A chatbot-based decision engine evaluates fault severity and delivers step-by-step Do-It-Yourself (DIY) repair guidance for simple issues or recommends nearby professional workshops for complex or safety-critical problems.

In addition to fault diagnosis, the system supports preventive vehicle maintenance by maintaining service history and generating automated reminders for routine tasks such as oil changes and inspections. The solution is implemented as a cross-platform mobile application using React Native with a FastAPI-based backend to ensure scalability and real-time responsiveness. By combining multimodal input analysis, interactive chatbot guidance, and maintenance tracking, the proposed system aims to reduce unnecessary mechanic dependency and make vehicle diagnostics more accessible to everyday users.

The primary contributions of this work are summarized as follows:

- A multimodal vehicle diagnostic framework that integrates natural language symptom descriptions with structured OBD-II diagnostic data for improved fault identification.
- A conversational AI-based decision engine that evaluates diagnostic confidence and issue severity to provide either step-by-step Do-It-Yourself (DIY) repair guidance or professional workshop recommendations.
- A lightweight mobile implementation using a React Native frontend and FastAPI backend that enables real-time diagnostic assistance for everyday vehicle users.
- An evaluation across 21 diagnostic scenarios covering multiple DTC categories and vehicle manufacturers, demonstrating reliable diagnostic accuracy and action classification performance.

II. Related Work

Artificial Intelligence (AI) has been widely explored for vehicle fault diagnosis to overcome the limitations of traditional manual and rule-based diagnostic approaches. Early diagnostic systems relied on predefined rules or physics-based models, which required expert knowledge and specialized tools [1]. Recent research has applied Machine Learning (ML) and Deep Learning (DL) techniques to analyze vehicle sensor data, vibration signals, and acoustic patterns for fault detection [2], [4]. These methods demonstrate improved diagnostic accuracy by learning complex fault patterns automatically. However, their practical adoption is often limited by the need for large labeled datasets and limited validation under real-world conditions [3].

On-Board Diagnostics (OBD)-based solutions are commonly used in both commercial applications and research systems to detect faults through standardized Diagnostic Trouble Codes (DTCs) [9], [10]. Commercial tools such as OBD scanners and mobile diagnostic applications provide fault codes and basic explanations. However, these systems usually require additional hardware and technical expertise and do not consider user-observed symptoms, reducing their accessibility for non-technical users.

Natural Language Processing (NLP) and chatbot-based systems have also been investigated for automated vehicle diagnostics [5]. NLP-driven approaches extract fault-related information from textual descriptions, while chatbots improve user interaction [6]. Despite these advantages, most existing systems operate as standalone solutions and lack integration with structured diagnostic data and preventive maintenance support [3].

In contrast to existing approaches, the proposed AI-Powered Vehicle Repair Assistant integrates user-described symptoms with optional OBD fault codes in a unified AI framework. By combining NLP-based analysis, chatbot-guided interaction, and maintenance tracking, the system provides accessible and practical diagnostic assistance tailored to everyday vehicle owners.

III. Proposed System

The proposed AI-Powered Vehicle Repair Assistant is designed to assist everyday vehicle owners in diagnosing and managing common vehicle issues using an intelligent, user-friendly approach. The system focuses on reducing unnecessary dependence on professional mechanics by providing guided diagnostic support and basic repair recommendations for non-technical users.

The system accepts multimodal user inputs, including textual descriptions of vehicle problems and optional On-Board Diagnostics (OBD) fault codes retrieved via Bluetooth. Textual inputs allow users to describe symptoms in natural language, while OBD data provides structured diagnostic information directly from the vehicle's Electronic Control Unit (ECU). These inputs together enable more accurate and context-aware fault identification compared to standalone diagnostic tools. As shown in Fig. 1, the proposed system integrates multimodal user inputs with AI-based processing and backend services to deliver intelligent vehicle diagnostic assistance.

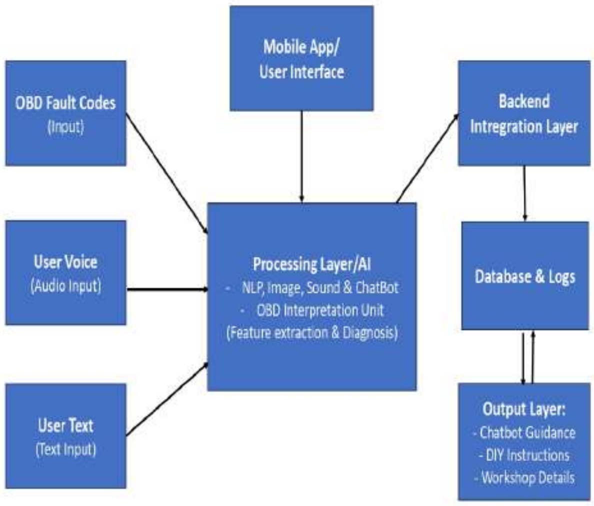

Fig. 1. System architecture of the AI-powered vehicle repair assistant.

The architecture consists of a mobile application interface that collects user inputs in the form of text, voice, and optional OBD fault codes. These inputs are processed by the AI layer, which performs symptom extraction, fault interpretation, and diagnosis. The backend integration layer manages data storage, user profiles, and communication with the database, while the output layer delivers chatbot guidance, DIY repair instructions, and workshop recommendations.

Natural Language Processing (NLP) techniques are used to analyze user-provided text and extract key symptoms, affected vehicle components, and intent. When OBD fault codes are available, the system decodes and maps them to standardized fault descriptions. The processed information is passed to a decision and recommendation engine, which evaluates the severity of the detected issue using predefined rules and confidence thresholds.

Based on the severity assessment, the system classifies vehicle issues into simple or complex categories. For simple issues, the system provides step-by-step Do-It-Yourself (DIY) repair guidance using commonly available tools, along with safety precautions. For complex or safety-critical problems, the system escalates the diagnosis and recommends nearby professional workshops using location-based data.

In addition to diagnostic assistance, the proposed system supports preventive vehicle maintenance by maintaining a service history for each user. The system stores past issues and service activities and generates automated reminders for routine maintenance tasks such as oil changes and inspections. This feature encourages proactive vehicle care and helps reduce unexpected breakdowns.

The solution is implemented as a cross-platform mobile application developed using React Native, with a FastAPI-based backend handling AI processing, user authentication, and data management. Lightweight AI models are used to ensure real-time responsiveness and scalability. By integrating multimodal input analysis, chatbot-guided interaction, and maintenance tracking within a single framework, the proposed system offers a practical and accessible solution for intelligent vehicle repair assistance.

IV. Methodology

The methodology of the proposed AI-Powered Vehicle Repair Assistant follows a modular and systematic approach to enable accurate vehicle fault diagnosis and user-friendly guidance. The system integrates user inputs with AI-based analysis and decision logic to provide practical repair assistance and maintenance support. Each module operates independently while contributing to a unified diagnostic workflow.

A. User Input Acquisition

The system collects diagnostic information directly from the user through a mobile application interface. Users describe vehicle issues using natural language text input, which allows them to report symptoms without requiring technical knowledge. In addition, optional On-Board Diagnostics (OBD) fault codes are retrieved from the vehicle via Bluetooth when an OBD scanner is available. This combination of unstructured user input and structured diagnostic data forms the basis for analysis.

B. Data Preprocessing and Interpretation

The system preprocesses textual inputs using the moonshotai/kimi-k2-instruct-0905 large language model, which is based on transformer architectures [11]. The model is accessed through the Groq API and orchestrated using the LangChain framework [12]. The model employs a Byte-Pair Encoding (BPE) tokenizer (Tiktoken-compatible) to tokenize user input before inference.

The LLM performs symptom extraction, fault component identification, and intent classification through structured prompting, using a low temperature setting ($T = 0.2$) to maximise diagnostic consistency.

OBD fault codes are validated and decoded using a curated database of over 21,000 standardized Diagnostic Trouble Code (DTC) mappings covering Powertrain (P), Chassis (C), Body (B), and Network (U) categories based on ISO and SAE diagnostic specifications [13], [14]. Decoded codes are combined with extracted NLP symptoms to form a unified diagnostic context, enabling multimodal fault identification.This multimodal fusion of structured OBD data and natural language symptom descriptions improves diagnostic reliability compared to standalone diagnostic tools.

C. Fault Analysis and Severity Classification

The processed inputs are forwarded to the decision and recommendation engine. The engine analyzes extracted symptoms and decoded fault information to assess the nature and severity of the detected issue.

The engine assigns a confidence score $c \in [0, 1]$ to each diagnosis turn. To prevent erratic shifts across multi-turn conversations, the system computes a cumulative confidence score using:

$$C_{new} = 0.6 \cdot C_{prev} + 0.4 \cdot c_{current}$$

The engine applies the following decision thresholds:

TABLE I
DECISION ENGINE CONDITIONS AND ACTIONS

Condition	Action
$C_{new} \geq 0.7$ and issue is user-fixable	**DIY** — Provide step-by-step repair guidance
$C_{new} < 0.7$	**ASK** — Request additional clarification from user
$C_{new} < 0.7$ (LLM confidence)	Trigger web search verification using Retrieval-Augmented Generation (RAG)
Severity ≥ 0.75 or safety-critical condition	**ESCALATE** $\rightarrow$ Recommend professional workshop
Emergency input (fire, brake failure)	Force severity = 1.0, action = **ESCALATE**

D. Recommendation and User Guidance

Based on the severity classification, the system generates appropriate recommendations. For simple faults, the system provides step-by-step Do-It-Yourself (DIY) repair instructions, including basic safety precautions and commonly required tools. For complex or safety-critical issues, the system escalates the diagnosis and recommends nearby professional workshops using location-based information. This approach ensures user safety while minimizing unnecessary mechanic visits.

E. Chatbot-Based Interaction

A chatbot interface facilitates continuous interaction between the user and the system. The chatbot presents diagnostic explanations, asks follow-up questions when additional clarification is required, and delivers repair guidance in a conversational manner. Maintaining context across interactions allows the system to refine diagnoses and improve user experience without overwhelming the user with technical details.

F. Maintenance Tracking and Reminder Generation

The system maintains a record of diagnosed issues, repair actions, and service history for each vehicle. Based on stored data and predefined maintenance rules, automated reminders are generated for routine servicing tasks such as oil changes and periodic inspections. This module supports preventive maintenance and helps users manage long-term vehicle health.

G. System Deployment

The complete system is deployed as a cross-platform mobile application developed using React Native. A FastAPI-based backend manages AI model execution, data storage, authentication, and API communication. Lightweight AI models are used to ensure real-time response and scalability across devices.

V. Results and Discussion

The AI-Powered Vehicle Repair Assistant was evaluated on its functionality, reliability, and diagnostic accuracy. The evaluation covered text-based diagnosis, chatbot interaction, OBD fault interpretation, and maintenance tracking.

The system processes user-provided textual descriptions using the NLP pipeline described in Section IV.B. The decision engine generates follow-up questions and diagnostic responses through the chatbot interface, enabling users to describe problems in natural language and receive structured guidance.

TABLE II
OBD-Based Findings

Vehicle	Year	OBD DTC	Decoded Result
Hyundai Eon	2011	P0501	Vehicle Speed Sensor Fault
Jeep Compass	2023	—	No Active Fault

Real-world testing using an OBD-II sensor validated fault code retrieval and decoding. The system established stable communication with vehicle ECUs and accurately decoded DTCs to human-readable descriptions. In vehicles without active issues, the system returned a normal diagnostic status, confirming reliable OBD connectivity.

The system was evaluated against 21 ground-truth diagnostic scenarios spanning Powertrain (P), Chassis (C), Body (B), and Network (U) fault codes as well as symptom-only descriptions across eight vehicle manufacturers (Honda, Toyota, Ford, BMW, Kia, Nissan, Mercedes, and Hyundai). The results demonstrate strong diagnostic performance with a macro F1-score of 85.7%. The 0.0% false positive escalation rate indicates that the system does not incorrectly refer user-fixable issues to professional workshops, ensuring reliable DIY guidance.

TABLE III
AI Diagnostic Evaluation Across 21 Scenarios

Metric	Value
Diagnostic Accuracy	76.2%
Action Precision	85.7%
Action Recall	85.7%
Macro F1-Score	85.7%
False Positive Rate (escalation on DIY faults)	0.0%
Average LLM Confidence	75.1%

The FastAPI backend reliably handles user authentication, chat history storage, vehicle profile management, and issue summaries.

VI. Conclusion and Future Work

This paper presented an AI-Powered Vehicle Repair Assistant designed to support non-technical vehicle owners in diagnosing and managing common vehicle issues through an intelligent and user-friendly system. By integrating Natural Language Processing (NLP), chatbot-based interaction, and optional On-Board Diagnostics (OBD) fault interpretation, the proposed system enables users to understand vehicle problems and receive guided assistance without immediate reliance on professional mechanics. The system successfully demonstrated text-based diagnosis, chatbot-guided recommendations, OBD fault decoding, and maintenance tracking during Phase II evaluation, validating its practical feasibility in real-world scenarios.

Experimental results showed reliable retrieval and interpretation of OBD fault codes from real vehicles, along with meaningful diagnostic explanations presented through an interactive chatbot interface. The backend implementation using FastAPI and PostgreSQL ensured stable data handling, while the modular system architecture allowed partial implementation of features without affecting core functionality. Overall, the proposed solution provides an accessible and cost-effective approach to vehicle diagnostics and preventive maintenance, with the potential to reduce unnecessary service visits and improve user awareness of vehicle health.

Despite its effectiveness, the current system has certain limitations. Voice-based input, image-based diagnostics, and real-time predictive maintenance using continuous OBD sensor streams were not implemented in the current phase. These limitations define clear directions for future work. Planned enhancements include the integration of speech-to-text modules for voice interaction, computer vision techniques for analyzing dashboard warning indicators, and predictive maintenance models using real-time OBD data to anticipate faults before failure occurs. Additional future improvements include multilingual support, expanded vehicle compatibility, and enhanced workshop recommendation mechanisms.

By addressing these future extensions, the proposed system can evolve into a comprehensive intelligent vehicle assistance platform that further improves accessibility, reliability, and user experience in automotive maintenance.

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