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ELECTRODRIVE NAVIGATOR: AI-POWERED IOT SYSTEM FOR SMART ELECTRIC VEHICLE BATTERY MONITORING AND NAVIGATION

KOLLURU PAWAN KUMAR, Student, Department of Computer Science and Engineering Vikas College of Engineering and Technology

Mr. M ASHOK KUMAR, Associate Professor, Department of Computer Science and Engineering, Vikas College of Engineering and Technology

ABSTRACT

Electric Vehicles (EVs) are emerging as the cornerstone of sustainable transportation. However, issues such as limited range, inefficient battery usage, and inadequate charging infrastructure pose serious challenges to their widespread adoption. This paper presents the ElectroDrive Navigator, an innovative IoT- and AI-enabled system designed to monitor EV battery parameters in real-time and predict charging requirements. The system integrates sensors including INA219 for current and voltage, GPS for real-time location, and temperature sensors. Using a NodeMCU, data is transmitted to a cloud-based platform for analysis. A Random Forest AI model evaluates the data to forecast battery depletion and recommends nearby charging stations via a mobile app. This proactive system reduces range anxiety, ensures efficient energy use, and enhances the EV driving experience.

Keywords: Electric Vehicle, Battery Monitoring, Internet of Things (IoT), Artificial Intelligence (AI), Smart Navigation, Arduino, Predictive Analytics, Cloud Computing, Real-Time Monitoring.

1. INTRODUCTION

The adoption of electric vehicles is on the rise due to their environmental benefits and cost-effectiveness. Yet, one of the biggest challenges faced by EV users is range anxiety, which arises from the uncertainty of battery depletion and unavailability of nearby charging stations. Traditional battery management systems provide only basic data such as voltage and current, without predictive insights. The need for a system that monitors battery health in real-time and provides predictive and location-based solutions is critical. The ElectroDrive Navigator aims to fill this gap by combining

IoT, cloud computing, and machine learning to offer a comprehensive battery management and navigation solution. The project not only monitors battery parameters but also assists users by sending real-time alerts, thereby ensuring stress-free and reliable travel.

2. LITERATURE SURVEY

Amit Kumar et al. (2019) proposed a real-time battery monitoring system for EVs using IoT sensors. Although effective in capturing voltage and current data, it lacked predictive capabilities and mobile communication.

Deepak Patel and Priya Mehta (2020) developed an AI-based charging scheduler. While it optimized energy usage, it didn't include continuous real-time monitoring or GPS-based suggestions.

Rajesh Singh and Anil Verma (2021) integrated GPS with battery monitoring. Their system addressed location tracking but lacked advanced analytics and user alerts.

Jin Chen et al. (2022) built a cloud-based health management system using machine learning. However, it focused primarily on fleet vehicles, not individual users.

Soojin Lee and Hyun Park (2023) implemented a mobile alert system. While it helped user engagement, it lacked the depth of AI-based predictive monitoring.

3. EXISTING METHODS AND DRAWBACKS

3.1 **Basic Battery Monitoring Systems**:

These only track voltage and current without predictive analytics. Lack of AI results in inaccurate estimates, and no consideration is given to environmental conditions.

3.2 **Manual Charging Station Search**: Drivers use mobile apps or maps to find stations. This process is time-consuming and unreliable, especially if the data is outdated.

3.3 **Fixed Range Estimation Systems**: These estimations don't adapt to real-time changes in driving conditions, terrain, or battery health, causing errors in predicting available driving range.

4. PROPOSED SYSTEM AND ADVANTAGES

The ElectroDrive Navigator employs Arduino with INA219 for current and voltage sensing, a temperature sensor, and a GPS module. NodeMCU transmits this data via Wi-Fi to a cloud-based IoT platform (ThingSpeak). A Random Forest machine learning model is used for forecasting battery depletion.

Advantages:

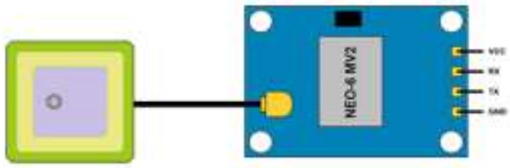
- Real-time monitoring of battery metrics.
- AI-based prediction improves charging planning.
- Mobile alerts minimize user intervention.
- GPS data enhances route planning and station accessibility.
- Promotes battery health and energy conservation.

5. RELATED WORK

Although previous works addressed components such as monitoring or navigation individually, they fall short in combining real-time data acquisition, cloud analytics, AI prediction, and mobile interfacing. The ElectroDrive Navigator unifies these to form a holistic and scalable solution.

NEO-6MV2 GPS Module

NEO-6MV2 GPS Module



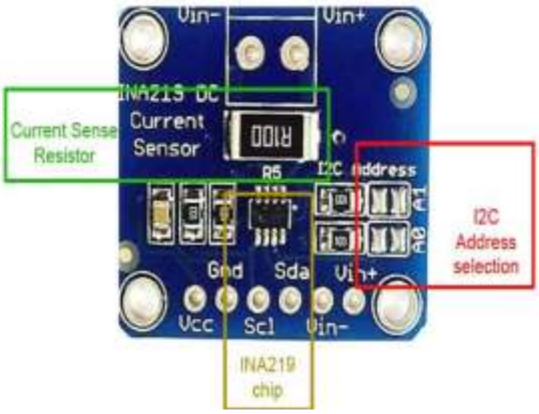
6. METHODOLOGY

1. **Data Acquisition**: Sensors capture live battery metrics.
2. **Data Transmission**: NodeMCU transmits data to ThingSpeak.
3. **Data Processing**: Cloud-based AI model predicts charging needs.
4. **Decision Making**: Based on trends and real-time usage.
5. **Notifications**: Alerts sent to user's smartphone with battery status and charging station locations.

7. SYSTEM MODULES

- **Sensor Module**: Collects voltage, current, temperature, and GPS data.
- **Microcontroller Module**: Arduino Uno as central control unit.

- **Wi-Fi Communication Module**: NodeMCU D1 Mini.
- **Cloud Analytics Module**: ThingSpeak IoT platform.
- **AI Prediction Module**: Random Forest algorithm.
- **User Interface Module**: Mobile app created using MIT App Inventor



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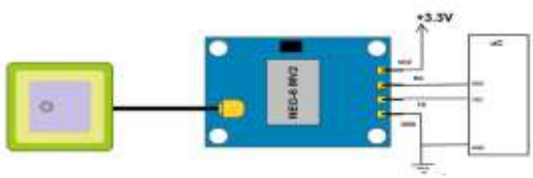
8. RESULTS

The prototype was successfully implemented and tested. The AI model achieved over 90% accuracy in predicting battery depletion times. Users received timely mobile notifications and location-aware charging recommendations. The overall user experience was significantly improved.



9. CONCLUSION

This paper presented the ElectroDrive Navigator, a smart EV battery monitoring and navigation solution. With real-time sensing, AI-based prediction, and mobile notifications, the system enhances user confidence and efficiency. It offers a comprehensive and scalable solution to improve electric vehicle operations and supports the broader goal of sustainable transportation.

10. Future Work

While the ElectroDrive Navigator has demonstrated significant promise in improving electric vehicle battery management and navigation, there is scope for future enhancements to make the system more robust, scalable, and commercially viable. Some potential areas for further research and development include:

- **Dataset Expansion**: The AI model's accuracy and generalization can be greatly improved by incorporating more diverse datasets. Future efforts should focus on collecting real-time battery and usage data from a broader range of electric vehicles, environmental conditions, and driving behaviors to better represent real-world diversity.
- **Integration with Public Infrastructure**: The system can be enhanced by integrating with public and private EV charging networks to access live availability data, charging costs, and expected wait times. This dynamic integration would allow users to make more informed decisions and optimize route planning further.
- **Edge AI Deployment**: Presently, the AI model runs on a laptop for testing and development. Future versions could transition the predictive analytics engine to an edge computing device, such as the NVIDIA Jetson Nano or Raspberry Pi 4, allowing for real-time, offline predictions without relying on constant cloud connectivity. This would reduce latency and enhance system independence.
- **Battery Health Prediction**: Beyond charge level prediction, future models can assess battery degradation and estimate remaining lifespan. This will assist in long-term EV maintenance and reduce unexpected battery failures.

By pursuing these future developments, the ElectroDrive Navigator can evolve into a comprehensive and intelligent EV management solution suitable for commercial deployment.

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