IoT-Enabled Smart Walking Stick for the Visually Impaired with KNN Path Prediction

Abstract

Visually impaired individuals face significant challenges in safe navigation and independent mobility. Traditional walking sticks provide only basic tactile feedback and cannot predict path safety. This paper proposes an IoT-enabled smart walking stick equipped with ultrasonic and infrared sensors, GPS, and vibration feedback integrated with a K-Nearest Neighbors (KNN) classifier to predict safe versus unsafe paths. Data collected from sensors is processed to classify environments in real time, offering predictive guidance to users. The system also provides IoT-based caregiver alerts for emergencies. This approach enhances mobility, safety, and independence for visually impaired individuals, combining IoT with machine learning for a socially impactful assistive technology.

Keywords: IoT, Smart Walking Stick, KNN, Path Prediction, Assistive Technology

1. Introduction

Globally, over 285 million people suffer from some form of visual impairment, with a large portion requiring assistive devices for daily mobility. Existing smart canes typically provide obstacle detection using ultrasonic sensors but fail to predict the safety of upcoming paths. A solution that integrates IoT for monitoring and machine learning for intelligent prediction is needed. This research addresses this gap by proposing an IoT-enabled smart walking stick that not only detects obstacles but also predicts safe and unsafe paths using the KNN algorithm, while also allowing caregivers to monitor and respond in emergencies.

2. Literature Review

Several smart cane systems have been proposed in past studies. Most approaches rely solely on ultrasonic sensors for obstacle detection or GPS for navigation. Recent works have introduced camera-based vision systems, LiDAR, and IoT integration for improved functionality. However, these solutions often lack lightweight, real-time machine learning techniques for path prediction. The novelty of this work lies in applying the KNN algorithm on multimodal sensor data to classify paths as safe, risky, or unsafe, which has not been fully explored in previous research.

3. Proposed System

The proposed system consists of an IoT-enabled walking stick equipped with ultrasonic and infrared sensors, a GPS module, vibration motors, and an ESP32 microcontroller. The sensors collect real-time data on obstacles, terrain changes, and location. This data is processed and classified by a KNN algorithm into safe or unsafe paths. Alerts are given to the user through vibrations or audio feedback, while GPS and emergency alerts are sent to caregivers through an IoT platform. The design emphasizes affordability, portability, and low-power consumption.

4. Methodology

1. Data Collection: Sensor data (distance, slope, GPS coordinates) is gathered in various environments. 2. Preprocessing: Noise is removed, and data is normalized for consistency. 3. Training: The dataset is labeled as 'Safe' or 'Unsafe' and used to train the KNN model. 4. Prediction: Live sensor readings are classified by the KNN model to predict path safety. 5. IoT Integration: The ESP32 transmits alerts and GPS data to a cloud platform, accessible to caregivers. 6. Feedback: The user receives vibration/audio signals for navigation assistance.

5. Results & Discussion

Preliminary testing demonstrates that the system can achieve high accuracy in obstacle detection and path classification using KNN with optimized parameters (k=3 or k=5). Response times remain suitable for real-time use, and IoT connectivity allows effective caregiver monitoring. Field tests show that the smart stick improves safety, reduces accidents, and increases confidence for visually impaired users compared to traditional canes.

6. Conclusion & Future Work

This research presents a novel IoT-enabled smart walking stick that combines lightweight machine learning (KNN) with IoT integration for enhanced navigation assistance. The system provides predictive safe-path classification and real-time caregiver alerts, offering a practical and impactful assistive technology. Future enhancements may include integrating camera-based vision with deep learning, voice-based assistance, and solar-powered energy solutions for extended usability.

References

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