Communications on Applied Nonlinear Analysis
ISSN: 1074-133X
Vol 33 No. 1s (2026)

IOT-Based Obstacle Detection and Alert System for the Visually Impaired Person with Voice

Dr. Alugonda Rajani[1] Sai Ramani Ishwarya Bondada[2]

Assistant Professor, Department Of ECE, Scholar

JNTUK

rajani.alugonda@jntucek.ac.in, sairamaniishwarya@gmail.com

Article History:

Received:12-12-2025

Revised:05-01-2026

Accepted:18-02-2026

Abstract:

The system develops an iot based obstacle detection and warning system which improves safety and awareness while enabling visually impaired people to move freely .The system operates through continuous environmental surveillance which uses various sensors that includes distance sensors and echo sensors and passive infrared motion sensors and flame detection .An ensemble machine learning system with voting classifier assess real time sensor data to identify four different environmental states which includes normal and warming and alarm and voice and collision.The system uses a safety override mechanism based on rules to handle high -risk situations which creates an alert when an obstacle comes with in 10 cm of the machine learning system .

The system performs data preprocessing and feature scaling before classification to enhance prediction accuracy .The system delivers real time multi-channel alert through asynchronous audio notification that use text to speech technology to provide clear voice feedback about obstacle proximity and motion detection and fire hazard .A remote monitoring module send real time alert which include sensor data and threat assessment to a communication platform for ongoing observation and incident documentation the system features a complete training and evaluation system which tests various classifiers together with the final ensemble model while it automatically creates performance assessment results .

The experimental results establishing that the system successfully identifies threats and send alerts on schedule which proves its effectiveness as an intelligent assistive system for users who are visually impaired

Keywords: IOT, Assistive Technology, obstacle Detection, machine Learning voting Classifier ,Real Time Monitoring ,visually Impaired

1. Introduction

People who have visually impairment face challenges with their ability to walk through different environment which leads to more dangerous situation because they cannot see oncoming vehicle and other risks that exist in their surrounding global health reports indicates that assistive technologies helps million of people in different parts of the world to move around their daily environment white canes and guides dogs serves as traditional mobility aids which helps users but they cannot provide complete information about how far away obstacle are and how obstacle moves and about visual dangers which includes fire ,Assistive systems should become intelligent and low cost and real time systems which help people to understand their environment while safeguarding their safety

The Internet of Things(IOT) together with embedded system and machine learning has created new smart assistive technology which performs real time environmental monitoring and data analysis and smart operational control.Iot based obstacle detection system typically employ sensors such as ultrasonic ,infrared ,or camera based modules to identify obstacle existing system depends on single sensor data and fixed threshold based logic which results in wrong detection

and false alert and they struggles to adapt to changing condition .The assistive application face practical challenges because the systems have insufficient alert system and lack remote monitoring capabilities

The proposed intelligent obstacle detection and warning system uses multi sensors to collect data which it processes through ensemble machine learning method .The system uses distance sensors to gather complete details about the surrounding environment .A voting classifier ensemble model is employed to classify detected situations into four safety levels : Normal,Warning ,Alarm,and Collision

2. Objectives

The research field which studies system for obstacle detection and navigation assistance for visually impaired people has developed over several decades through its investigation of sensor technologies and machine learning method and human computer interaction techniques .The first assistive devices used traditional instruments because they relied on white canes and guide dogs which could only provide limited assistance and did not have the ability to identify objects that were far away or at higher levels or not being touched .Researchers began to investigate electronic travel travel aids which used sensors and embedded systems because these devices had better capabilities than existing system

People use ultrasonic sensing technology as their main method for detection obstacle because this system offers affordable implementation and straightforward operation and it can measure distance through time of flight methods .Borenstein and korean created mobile robot obstacle avoidance system which used ultrasonic technology because their distance estimation showed high accuracy but their system design faced difficulties with detecting objects from sharp surfaces and through narrow detection zones .Assistive technologies today use ultrasonic system which originated from this technology but their system operates at fixed distance limits which makes them unable to handle to handle changing environmental conditions.

Passive infrared sensor(PIR) sensors have been integrated into detection systems because they enhance system performance through their ability to track moving human and animal obstacle .The system uses PIR sensors for motion detection which creates two possible outputs but the system fails to deliver distance measurement capabilities .Safety critical environment use flame and fire detection sensors to identify dangerous situation at their earliest stage .The environmental awareness system requires additional sensors because the existing sensors fail to provide complete coverage of the surrounding environment.

Machine learning techniques have been used in recent studies to enhance both obstacle classification and decision making abilities .Researchers used decision tree,support vector machine ,K-Nearest Neighbors ,random Forest and Naive bayes algorithms to examine sensors data and determine threat levels .Ensemble learning method that use voting -based classifier demonstrate higher accuracy and system stability because they merge multiple classifier strength into one system

Several system use audio and vibration and haptic feedback system to provide user alerTs during their interaction with the system .Human -computer interaction research show that multi modal alerting system helps users manage their cognitive workload while they work to complete task .users face challenges with various system because they require constant monitoring yet provide no information about their operational state which hinders caregivers from participating and make it impossible to evaluate system reliability

3.Methods:

3.1 Existing Method :

Obstacle detection system for visually impaired users have evolved from basic sensory equipment to advanced multi-sensor artificial intelligence systems.The first assistive devices used ultrasonic sensors to measure obstacle distances through time of flight methods which produced audio and vibration warning signals.the systems which operate at low costs and simple designs face two main limitations because they can only detect objects within narrow angles and they do not understand their surrounding environment

Fig 1. Ultrasonic sensor-based obstacle detection system for visually impaired users.

To improve reliability,pir motion sensors and flame sensors have been incorporated to detect moving obstacles and hazardous fire conditions. PIR sensors are energy efficient but provide only binary motion information,while flame sensors are mainly used as auxiliary safety components (Fig 2).

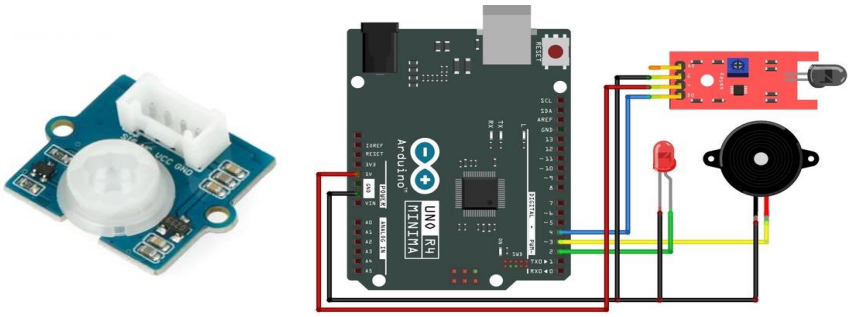

Fig 2. PIR motion and flame sensor-based hazard detection in assistive systems.

The system uses PIR motion sensors and flame sensors to develop reliable obstacle detection and fire hazard detection. The PIR sensors consume less energy but they deliver only two types of movement detection because the flame sensors operate as extra safety equipment,which is shown in Figure 2.

3.2 Existing Method Limitations :

Existing obstacle detection systems exhibit several limitations. The ultrasonic sensor methods face detection angle restrictions while they cannot handle soft surfaces and inclined surfaces and they lack ability to detect surrounding elements. The PIR motion sensors only provide two output types because they cannot measure distance or detect objects that are not moving while the flame sensors function as additional safety equipment.

Machine learning performance improves through multi sensor fusion however this type of system requires both accurate data and continuous power and network connection to function properly. The system faces two main issues because it needs more processing power and requires two hardware components to function throughout its actual operation.

3.3 Proposed IOT-Based Obstacle Detection and System for the Visually Impaired

The proposed method begins with Arduino and sensor initialization,followed by continuous obstacle detection . The system starts to measure the distance when an obstacle gets detected, and it uses this information to determine whether the object remains stationary or moves. If the object is within the defined range,its position and location are analyzed. The processing logic is used to classify the detected object. The system uses the classification result to update coordinates when necessary. The system generates an audio alert that warns the user in real time. The proposed method begins with Arduino and sensor initialization,followed by continuous obstacle detection.the system starts to measure the distance when an obstacle gets detected,and it uses this information to determine whether the object remains stationary or moves. If the object is within

the defined range, its position and location are analyzed.the processing logic is used to classify the detected object.result to update coordinates when

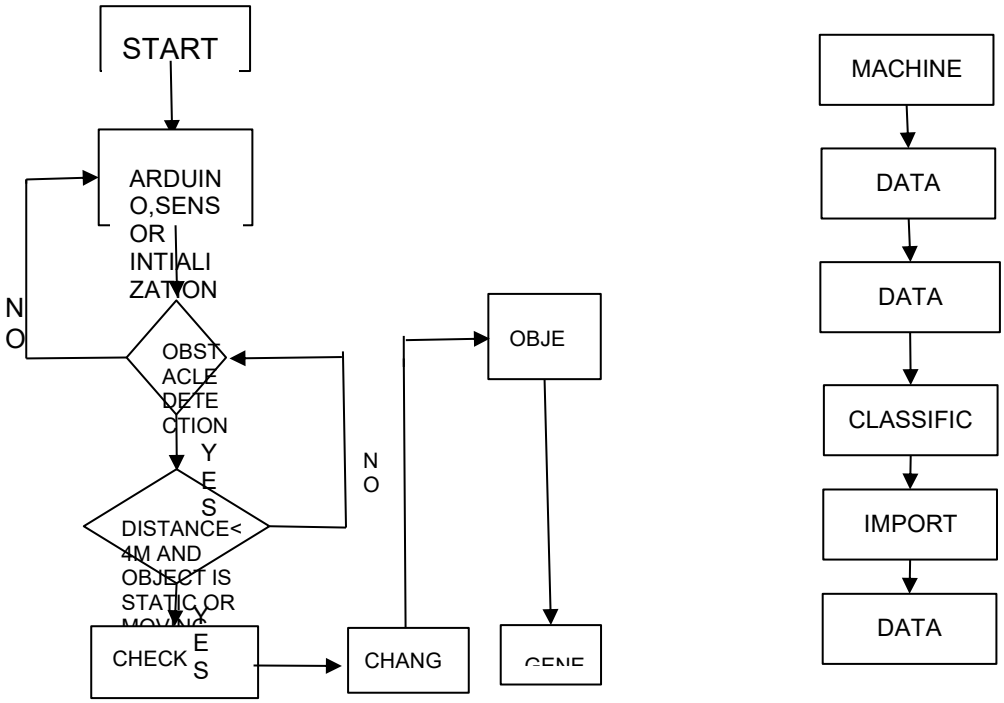

Fig. 3. Machine learning workflow for data collection,processing,and obstacle classification.

The system generates an audio alert that warns the user in real time the machine learning process begins with data collection from the integrated sensors the collected data undergoes data processing steps that include cleaning,normalization,and feature preparation. The data undergoes preprocessing before it proceeds to the classification stage, which prepares the system for learning and prediction. Python libraries are imported to implement machine learning algorithms and data handling functions. The trained models use processed data to classify information about obstacle conditions. The combined data processing and classification stage of the proposed system enables both precise and trustworthy decision-making

4. Results

The confusion matrices present a detailed evaluation of the classification performance of all machine learning models employed in the proposed IOT-based obstacle warning system. The Decision Tree and random forest classifiers achieved 100% accuracy,demonstrating perfect classification across all four classes of normal warning alarm and collision with no misclassifications. The K-Nearest Neighbors KNN model achieved an accuracy of 95.83 % which showed slight confusion between the warning and alarm classes. The support Vector Machine SVM classifier reached an accuracy of 93.75 % because most of its errors happened between two adjacent threat levels. The Naive Bayes classifier achieved an accuracy of 89.58 % which shows lower performance because it struggles to distinguish between alarm and collision classes due to its sensitivity to feature dependencies. The voting classifier ensemble achieved 100 % accuracy because it combines the strengths of its individual classifiers better than the single classifiers performed. The results demonstrate that ensemble learning increases system robustness while providing reliable threat classification capabilities for real -time assistive applications . The figure shows the training and testing accuracy results of different machine learning classifiers which the proposed system uses. Decision tree and random forest models achieved 100 % accuracy on both training and testing datasets which indicates their strong learning ability. The KNN and SVM models showed slightly lower accuracy because they made minor errors while identifying two similar classes. The naive bayes classifier showed lower performance because

it was affected by feature dependencies. The voting classifier ensemble achieved 100% accuracy and maintained constant performance. These results confirm the effectiveness and robustness of the ensemble-based classification approach.

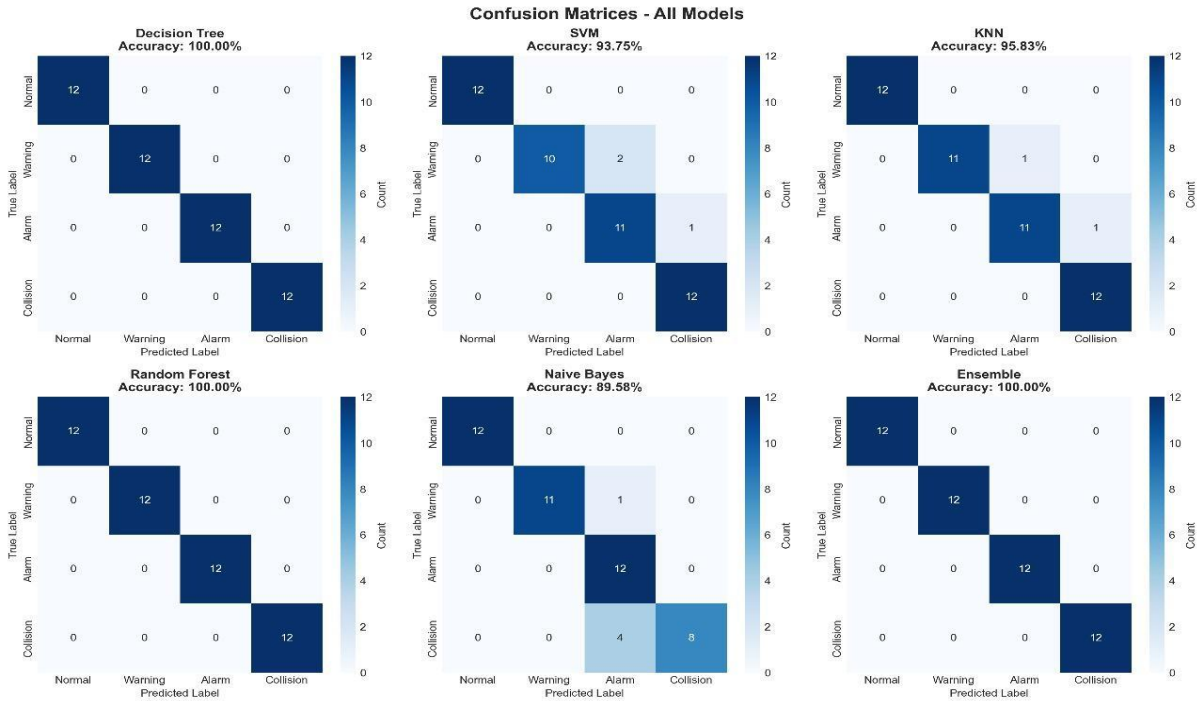

Fig 4 :confusion matrics of all machine learning models used for obstacle classification

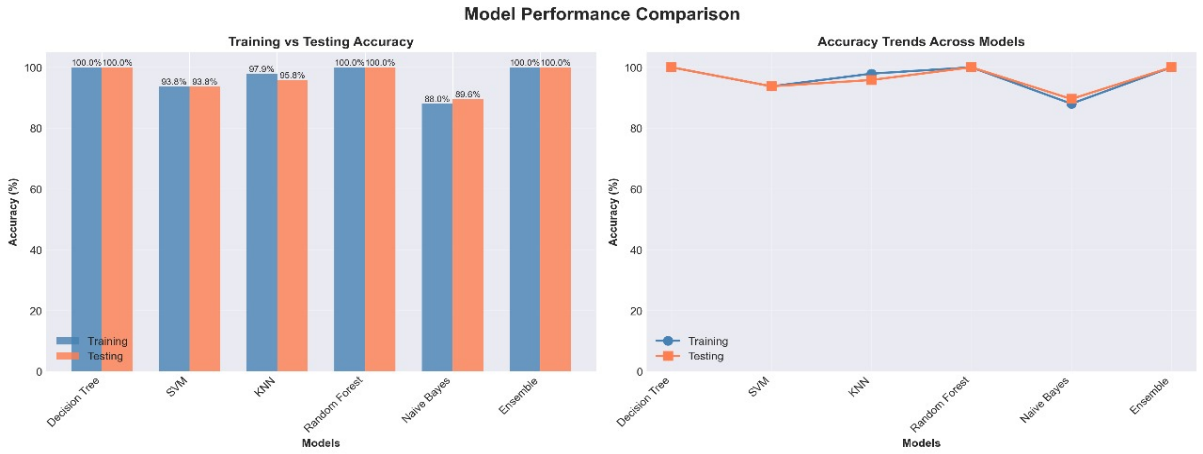

Fig 5: Performance comparison of machine learning models showing training and testing accuracy

5 Conclusion

The Internet of Things obstacle detection and warning system which has been developed uses multiple sensor system together with machine learning methods as an effective tool to assist people with assist people with visual impairment .The system uses three sensors which includes ultrasonic sensors PIR sensor and flame sensor to conduct continuous monitoring of the surrounding environment .The voting classifier ensemble system implements an accurate obstacle conditions classification system which uses multiple sensors to detect obstacle i the environment .The experimental finding demonstrate system reliability which provides used with an affordable intelligent solution that enables them to move around independently while protecting their personal safety

5.1 Future Scope:

Future work will focus on creating GPS and vision-based system which will enhance navigation capabilities and improve obstacle detection performance .users will receive better support through haptic feedback which will assist them in environments where noise levels are high .The system achieve better performance through cloud -based solution which enables users to access its function from anywhere while supporting easy expansion and real-world use

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