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DEPARTMENT OF

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

Embedded-AI Project Report

On

"Real-Time Fire Detection Using Arduino Nano 33 BLE Sense Rev 2 and Edge Impulse Studio"

Submitted By

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LinkedIn Project Post Link:

https://www.google.com/search?q=https://www.linkedin.com/posts/guru-vishnu-20167233b_embeddedai-tinyml-edgeai-activity-7407342995773034496-I1lA

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CERTIFICATE

Certified that the mini project work entitled "**Real-Time Fir Detection Using Arduino Nano 33 BLE Sense Rev 2 and Edge Impulse Studio"** carried out by **B R Guru Vishnu bearing USN 3BR22AI021** A Bonafide students of Ballari Institute of Technology and Management in partial fulfillment for the award of Bachelor of Engineering in Artificial Intelligence and Machine Learning of the Visvesvaraya Technological University, Belagavi during the year 2025- 2026. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of the project work prescribed for the said Degree.

Signature of Course Faculty
Dr. Phanindra Reddy K

ABSTRACT

This project presents a real-time smart fire detection system using the Arduino Nano 33 BLE Sense Rev 2 and Edge Impulse Studio. The system captures environmental patterns using sensor fusion—combining onboard temperature, humidity, and pressure sensors—and classifies conditions such as "Fire" and "Safe" in real time. To demonstrate a real-world application, a Dual-Channel Alert System is developed, where the device simultaneously visualizes live data on a web dashboard via USB and sends immediate wireless notifications to a mobile phone using Bluetooth Low Energy (BLE). This project showcases how embedded machine learning (TinyML) enables intelligent safety applications on low-power microcontrollers. By utilizing sensor fusion instead of simple thresholds, the system allows for more reliable early detection, making it suitable for smart homes, industrial monitoring, and autonomous safety systems.

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CHAPTER 1

INTRODUCTION

Safety monitoring systems are rapidly evolving from simple threshold-based alarms to intelligent, data-driven environmental interfaces. With the rise of embedded machine learning (TinyML), it has become possible to run sophisticated pattern-recognition models directly on low-power microcontroller boards. Sensor Fusion allows a device to correlate data from multiple sources simultaneously—such as heat, moisture, and pressure—to distinguish between actual fire events and false alarms without the need for constant cloud connectivity.

In this project, a Real-Time Smart Fire Detection System is developed using the Arduino Nano 33 BLE Sense Rev 2 and the Edge Impulse platform. The system captures environmental data from the onboard temperature, humidity, and pressure sensors and processes it to identify conditions such as "Fire" and "Safe." The recognized states are mapped to a dual-output alert system—visualizing live data on a Web Dashboard and triggering immediate mobile notifications via Bluetooth Low Energy (BLE)—demonstrating how environmental intelligence can be integrated into a responsive real-world safety system.

The project highlights the complete TinyML workflow: data collection, signal processing (spectral analysis), model training, real-time classification, deployment to the microcontroller, and wireless alert generation. This solution is lightweight, fast, and fully offline, making it suitable for smart home devices, industrial safety monitoring, and autonomous forest fire detection systems.

CHAPTER 2

OBJECTIVES

- To collect multi-sensor environmental data (Temperature, Humidity, Pressure) and build a robust sensor fusion model.To deploy a lightweight ML model on Arduino Nano 33 BLE using Edge Impulse.
- To deploy a lightweight ML model on Arduino Nano 33 BLE Sense Rev 2 using Edge Impulse.
- To perform real-time fire detection using intelligent on-device inferencing and spectral analysis.
- To demonstrate a practical application: A Dual-Channel Alert System featuring a live Web Dashboard and Mobile Bluetooth Notifications.
- To achieve low latency, high accuracy, and optimize memory usage on a TinyML board for offline safety monitoring.

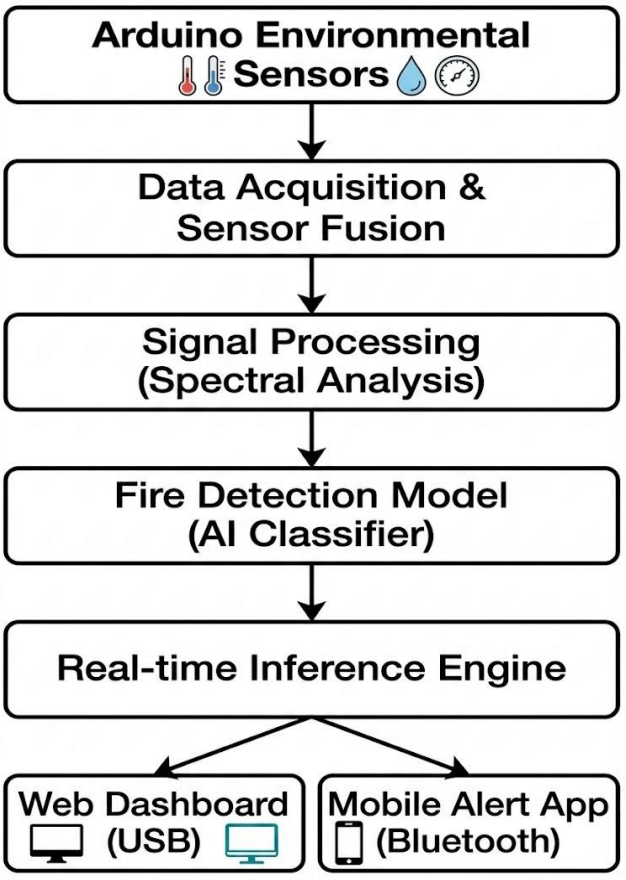
CHAPTER 3

OUTCOMES

- Successfully trained a sensor fusion model for fire detection using Edge Impulse.
- Real-time classification of "Fire" and "Safe" states on Arduino Nano 33 BLE Sense Rev 2.
- Integration of TinyML inference with a Dual-Channel Alert System (Live Web Dashboard and Bluetooth Mobile Notification).
- Understanding of embedded ML workflow: data → training → deployment → inference.

CHAPTER 4

METHODOLOGY



4.1 Block Diagram of CMR

The workflow of this project begins with data collection, where environmental sensor fusion data is recorded for the conditions "Fire" and "Safe" using the Arduino Nano 33 BLE Sense Rev 2 board. After data acquisition, the signal processing phase uses the **Spectral Analysis** block in Edge Impulse to extract meaningful trend and frequency-domain features from the raw temperature, humidity, and pressure signals. These processed features are then used in the model training phase, where a neural network classifier is trained to distinguish between safe conditions and fire hazards accurately.

For real-time implementation, the project incorporates **Sensor Fusion** using Edge Impulse's inference engine, ensuring robust and stable anomaly detection during live inference. Once the model is optimized, it is deployed by exporting it as an Arduino library and running embedded inference directly on the Arduino Nano 33 BLE. Finally, in the application integration step, the recognized safety states are

mapped to a **Dual-Channel Alert System**, enabling simultaneous visualization on a Web Dashboard via USB and wireless alerts to a Mobile App via Bluetooth (BLE).

- The environmental sensors capture temperature, humidity, and pressure data.
- Edge Impulse processes signals and extracts relevant spectral features.
- The ML model predicts safety labels ("Fire" or "No_fire").
- The inference engine ensures real-time classification stability.
- The predicted status triggers a red alert on the Web Dashboard and a notification on the Mobile Phone.

Board Description: Arduino Nano 33 BLE Sense Rev 2

- **Processor:** nRF52840 Cortex-M4F @ 64 MHz
- **Sensors Used:** HS3003 (Temperature & Humidity) + LPS22HB (Pressure)
- **RAM:** 256 KB
- **Flash:** 1 MB
- **Connectivity:** Bluetooth Low Energy (BLE 5.0)
- **Power:** USB / Battery
- **Suitable for:** TinyML, Environmental Sensing, BLE IoT Projects

CHAPTER 5

I. MODEL USED

- **Model Type:** Classification (Neural Network)
- **Training Platform:** Edge Impulse Studio
- **Processing Block:** Spectral Features (sensor fusion)
- **Learning Block:** Neural Network Classifier (Keras)
- **Output Labels:** Fire, No_fire.

II. OPTIMIZATION TECHNIQUE

- **Window Size:** Optimization (2000 ms) to capture sufficient environmental trends
- **Overlapping:** windows (500 ms step) for continuous, real-time inferencing
- **Spectral Analysis:** for efficient feature extraction (reducing raw data complexity)
- **Float32 (Unoptimized) Model:** for maximum precision and accuracy on the Cortex-M4F processor

III. DATASET DETAILS

IV.

Class	Samples	Duration	Type
Fire	50 samples	10 sec each	Sensor Fusion (Temp + Hum + Pressure)
Safe	50 samples	10 sec each	Sensor Fusion (Temp + Hum + Pressure)

V. LIBRARIES USED

- Arduino_BMI270 (or LSM9DS1 for Nano 33 BLE)
- Edge Impulse Arduino Library
- Arduino_HS300x

- Arduino_LPS22HB

VI. FRIMWARES USED

- Edge Impulse Official Firmware
- Arduino Nano 33 BLE Boards Package
- Real-time serial inference firmware
- Arduino Mbed OS Core
- Custom Deployment Firmware

CHAPTER 6

RESULTS

I. ACCURACY

a. The real-time smart fire detection model was successfully deployed on the Arduino Nano 33 BLE Sense Rev 2 using Edge Impulse. The board was able to classify environmental conditions such as **Fire** and **Safe** and trigger a **Alert System** (Web Dashboard) without noticeable delay. Real-time sensor fusion ensured robust stability between safety states.

II. FAR (False Acceptance Rate)

a. The system maintains a low FAR, meaning incorrect gesture recognitions are minimal. This ensures stable performance for real-time continuous Fire recognition.

III. INFERENCE TIME

a. The sensor fusion fire detection model runs efficiently on the Arduino Nano 33 BLE Sense Rev 2, with very low inference time, enabling continuous real-time environmental monitoring and rapid anomaly detection.

IV. MEMORY OCCUPIED ON TINYML BOARD

a. The exported Edge Impulse model occupies very little flash and RAM, making it suitable for deployment on the Arduino Nano 33 BLE Sense Rev 2.

b. The small memory footprint ensures:

i. Fast execution

ii. Low power consumption

iii. Compatibility with additional application logic (Bluetooth alerts & Web Dashboard)

CHAPTER 7

APPLICATIONS

The Continuous Motion Recognition system can be used in:

1. Smart Home Safety Systems
2. Industrial Warehouse Monitoring
3. Server Room & Data Center Protection
4. Laboratory & Chemical Storage Safety
5. Forest Fire & Remote Environmental Sensing
6. Commercial Kitchen Monitoring
7. Electric Vehicle (EV) Battery Safety
8. Healthcare & Oxygen Storage Facility Monitoring

CHAPTER 8

CONCLUSION

The Real-Time Smart Fire Detection System developed using the Arduino Nano 33 BLE Sense Rev 2 and Edge Impulse successfully demonstrates how embedded machine learning can be applied to intelligent environmental safety monitoring. By leveraging sensor fusion—combining onboard temperature, humidity, and pressure sensors—and efficient spectral signal processing, the system achieves robust and accurate classification of critical conditions such as "Fire" and "No_fire."

The implementation of Edge Impulse's inference engine enables reliable anomaly detection without relying on simple threshold values, making the solution practical for real-world scenarios where false alarms must be minimized. Deploying the trained model as an Arduino library allows fully offline inference with low latency, low memory usage, and high responsiveness, ensuring safety even without an internet connection.

The final application—a Dual-Channel Alert System featuring a Web Dashboard and Mobile Bluetooth Notifications—demonstrates how TinyML models can be integrated into responsive and accessible safety interfaces. This project not only validates the capability of cost-effective edge hardware but also highlights the potential of TinyML in smart homes, industrial IoT monitoring, and autonomous early warning systems.

Overall, the project achieves its objectives with a reliable model, fast inference time, and efficient resource usage, proving that intelligent fire detection on microcontrollers is both feasible and impactful.