TINY ML BASED EARLY WILDFIRE DETECTION

Gampalage Isara Subasana Pathmendra Fonseka

208525F

Degree of Master of Science in Artificial Intelligence

Departments of Computational Mathematics

Faculty of Information Technology

University of Moratuwa

Sri Lanka

April 2025

TINY ML BASED EARLY WILDFIRE DETECTION

Gampalage Isara Subasana Pathmendra Fonseka

208525F

Dissertation submitted in partial fulfillment of the requirements for the degree
Master of Science in Artificial Intelligence

Departments of Computational Mathematics

Faculty of Information Technology

University of Moratuwa

Sri Lanka

April 2025

DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 26.06.2025

The above candidate has carried out research for the Masters dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisor: Prof. Thushari Silva

Signature of the Supervisor: Date: 26/06/2025

DEDICATION

This thesis is dedicated to my parents who support and encourage me all the time. Without their sacrifices, I wouldn’t be able to come this far in my academic journey. To my mentors and friends who always stood by my side through every challenge I faced during this master’s study, thank you for believing in me and encouraging me when I doubt myself. Research in this field is limited. Therefore, I dedicate this research to the whole world.

ACKNOWLEDGEMENT

To my supervisor Prof. Thushari Silva, thank you for your continuous support and advice. It was fortunate to have a supportive and knowledgeable supervisor like you. I would like to mention the help and guidance given by my friends in preparing the research process. Our shared experiences made this journey both enriching and enjoyable. And of course, I could not forget to thank all my friends from Sipearl GmbH for reminding me all the time about the thesis and encouraging me. Finally, I am grateful to my family and my partner for their unconditional love, prayers, and encouragement. Your faith in me has been my greatest strength.

ABSTRACT

Wildfire is an enormous and increasing threat to the global ecosystems, human settlements, and climatic conditions. Traditional methods for wildfire detection such as satellite imaging and ground-based monitoring methods are not providing timely and spatially focused warnings, especially in remote forest regions. This research introduces a novel Tiny Machine Learning (TinyML) based Wireless Sensor Network (WSN) model to meet the critical demand for a strong, real-time, and energy-efficient early wildfire warning system. The proposed TinyML Wildfire Detection System (TWDS) integrates low-power sensors with on-device machine learning to detect environmental abnormalities typical of fire occurrences, such as temperature spikes, humidity declines, and particulate matter or gas detection, such as Total Volatile Organic Compound (TVOC) and Carbon Dioxide (CO_2).

Decentralized processing is emphasized in the system design, where sensor nodes process information locally using a lightweight Deep Neural Network (DNN) trained on historical wildfire datasets. This method reduces latency and power consumption by reducing reliance on continuous data streaming to a central server. Hardware implementation of the sensor node uses an Arduino Nano 33 BLE Sense Lite, DHT22 temperature and humidity sensors, and SPG30 gas sensors. The model training was done by using TensorFlow and converting them using TensorFlow Lite and TensorFlow Lite Micro for deployment in TinyML devices. Evaluation metrics such as accuracy, precision, recall, F1-score, and Area Under Curve (AUC) establish the system to be reliable in detecting fire conditions and non-fire conditions. The results validate the system's performance in early wildfire detection with improved responsiveness and scalability, making it a viable candidate for deployment in resource-constrained forest environments. TWDS offers an advanced approach for wildfire prevention through the use of energy efficiency, low-latency, and scalability by combining WSN and TinyML technologies.

Keywords: Wildfire Detection, TinyML, WSN, On-device Processing

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Table Description **Page**

LIST OF ABBREVIATIONS

Abbreviation	Description
ANN	Artificial Neural Network
AVHRR	Advanced Very High-Resolution Radiometer
CNN	Convolutional Neural Networks
CO_2	Carbon Dioxide
CO	Carbon Monoxide
DNN	Deep Neural Network
FWI	Fire Weather Index
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
LoRaWAN	Long Range Wide Area Network
ML	Machine Learning
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NN	Neural Network
RH	Relative Humidity
SNPP	Suomi National Polar-orbiting Partnership
TFL	TensorFlow Lite
TFLM	TensorFlow Lite Micro
TinyML	Tiny Machine Learning
TVOC	Total Volatile Organic Compounds
TWDS	TinyML Wildfire Detection System
UAV	Unmanned Arial Vehicle

VIIRS	Visible Infrared Imaging Radiometer Suite
VWW	Visual Wake Words
WSN	Wireless Sensor Networks

LIST OF APPENDICES