**Outdoor Fire Alarm System: A Deep Learning-Based Approach**

# **1. Introduction**

Wildfires and outdoor fires pose significant threats to ecosystems, human settlements, and infrastructure. Traditional fire detection methods primarily focus on indoor environments, leaving outdoor spaces vulnerable. The increasing frequency of wildfires due to climate change, coupled with labor shortages in firewatching roles, highlights the necessity for automated outdoor fire detection solutions. This project aims to develop an **Outdoor Fire Alarm System** leveraging Deep Learning to detect fire and smoke in outdoor environments and provide real-time alerts.

# **2. Business Understanding**

The proposed system targets organizations, businesses, and entities responsible for managing outdoor spaces. Given that the fire analysis segment is expected to grow at a **high CAGR by 2027**, there is a strong business case for integrating automated fire detection systems. The system provides functionalities such as:

* Real-time fire and smoke detection
* Camera personalization and switching
* Secure access sharing for stakeholders
* A graph of a forest service

  Description automatically generatedAutomated alert notifications

Number of fires larger than 1,000 acres per year on U.S. Forest Service land1

# A diagram of a fire safety system Description automatically generated**3. Data and Model Development**

The system utilizes a **Deep Learning-based Image Classification Model** trained to distinguish between three classes:

* Fire
* Smoke
* No danger (field)

A dataset of approximately **300 images per class** was collected, with the data split into **70% training, 20% validation, and 10% test sets**. The system was benchmarked against:

* **Random Guess Accuracy**: 33.33%
* **Human-Level Performance**: 90.48%
* **Basic Multilayer Perceptron Accuracy**: 89.67%

# **4. Model Performance and Evaluation**

The main model's performance was evaluated using standard classification metrics:

* **Accuracy**: 76%
* **Precision, Recall, and F1 Score** (to be specified for different classes)
* **Confusion Matrix Analysis**

The system operates under a **1-minute time limit**, ensuring prompt detection and response.

# **5. Responsible AI and Model Interpretability**

To balance **accuracy and interpretability**, Explainable AI (XAI) methods were integrated:

* **Grad-CAM (Gradient-weighted Class Activation Mapping)** to visualize critical image areas influencing model decisions.
* **LIME (Local Interpretable Model-Agnostic Explanations)** for detailed insights into classification decisions.

# **6. User-Centric Design and Feedback Integration**

A **think-aloud study** was conducted to evaluate user interaction with the system. Key insights from the study included:

* Users understood core functionalities but required better instructions.
* Some users expressed confusion in navigation.
* Feedback-driven improvements included:
  + Enhanced instructional clarity
  + Increased system responsiveness to user actions
  + Addition of requested features

# **7. Conclusion and Future Work**

The **Outdoor Fire Alarm System** demonstrates the potential of deep learning in **automated fire detection** for outdoor environments. The current model achieves **76% accuracy**, with future improvements focusing on:

* **Expanding the dataset** for greater generalizability
* **Improving model accuracy** with advanced architectures
* **Deploying the system** for real-time field testing
* **Enhancing user experience** based on continuous feedback

By integrating **AI-driven fire detection**, this project contributes to enhanced safety measures, early fire prevention, and efficient resource utilization in outdoor fire monitoring.