AN EPHEMERAL INVESTIGATION ON FOREST FIRE, WILDLIFE PRESERVATION, AND TRIBAL PREPAREDNESS USING DEEP LEARNING AND IOT

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Abstract— Forest fire is a serious threat to the environment and wildlife. It can also harm the tribal community as well as the people living in close vicinity to forest areas. Early detection and mitigation are crucial to avoid their destructive impact. By using the cameras used to track movement of wildlife we can capture real- time images and videos of the forest area. The data collected by these cameras is transmitted to a control center via wireless communication, where a deep learning algorithm is used for analysis. These algorithms can accurately identify smoke, flames, and fire within the image.

Once the fire threat is detected, the system automatically triggers immediate responses, which includes alerting authorities and deploying firefighting measures. Preventive measures such as sprinkler systems could be used to mitigate the spread of the fire. The real-time monitoring of forest allows early detection and rapid response to outbreaks. This approach not only protects forests and the ecosystems but also alerts the wildlife and tribal community by sound waves of high frequency for resettlement of animals and voice signals for tribal community.

Keywords— Forest fire, IoT, Deep Learning, Detection, Early Warning, Mitigation, Wildlife, Tribal.

I. INTRODUCTION

Forest fires pose a significant threat to the environment, wildlife, and human communities around the world. These destructive events can cause irreparable damage, loss of life, and significant economic costs. Therefore, the early detection of Wildfire and mitigation is important. In recent times, The incorporation of both Internet of Things and advanced deep learning methods has delivered the way of approaching forest fire detection and prevention. This combination has enabled more efficient and provident strategies to minimize the impact of wildfires.

A. Deep Learning in Forest Fire Detection:

Deep learning has proven to be highly effective in processing and analysing the vast amount of data generated by devices for forest fire detection. Deep learning models analyse images and videos from surveillance cameras to detect flames and smoke, as well as their locations within the forest. This enables rapid response to potential fire outbreaks.

B. IoT in Forest Fire Detection:

IoT plays a important role in continuously monitoring the environmental conditions and transmitting data to a central system. High-resolution cameras equipped with infrared and night vision capabilities are used for visual monitoring of forested areas. These cameras detect flames and smoke even in low-visibility conditions, allowing for early detection. Wildlife cameras employ wireless communication protocols such as Wi-Fi, Bluetooth, or cellular networks. Wi-Fi is relevant for short to medium-range communication, while cellular networks enable long-range connectivity, making them suitable for remote forest areas. Deep learning algorithms can integrate data from various IoT sensors to create a comprehensive understanding of the environment.

C. Deep Learning & IoT in Forest Fire Mitigation:

Deep learning algorithms can analyse historical data and environmental factors to predict the likelihood of a forest fire in a specific area. IoT devices can trigger automated alert systems that notify local authorities and emergency responders instantly when fire is detected. This immediate response can help to reduce fires before they spread extensively.

The proactive management of wildfires has greatly benefited from the amalgamation of IoT and deep learning technologies, facilitating the identification and extinguishing of forest fires.. These innovations facilitate the early identification and enhance the precision of predictions, and expedite response times. Ultimately, these improvements contribute to minimizing the harmful effects of forest fires on both ecosystems and communities.

II. LITERATURE SURVEY

The survey conducted for this study is summarized in a tabular format, providing a comprehensive overview of relevant research works. The table encompasses crucial details such as the name of the study, author(s), publication year, research objectives, and key advantages and disadvantages identified in each work.

Title	Authors	Year	Objectives	Advantages	Disadvantages
Assessment of forest fire danger using automatic weather stations and MODIS TERRA satellite datasets for the state Madhya Pradesh, India [1]	Suresh Babu K.V, Venkata Sai Krishna Vanama, Arijit Roy, P. Ramachandra Prasad.	2017	1.Modify the McArthur FFDI by incorporating the Normalized Multiband Drought Index (NMDI) derived from MODIS TERRA satellite datasets. 2.This modification aims to overcome challenges in computing the drought parameter using ground data in India.	1.Utilizing MODIS TERRA satellite datasets provides a broader and more comprehensive perspective, allowing for a larger-scale assessment of wildfire danger. 2. The modified FFDI offers a potentially faster and more efficient way to assess forest fire danger by relying on satellite data	1.The accuracy of the drought factor estimation (NMDI) is crucial. Any errors in this may impact the reliability of danger assessment. 2.Satellite data may have limitations in temporal resolution, which could affect real time fire danger assessment.
Forest Fire Alerting System with GPS Co-ordinates Using IoT. [2]	Jayaram K, Janani K, Jeyaguru R, Kumaresh R, Muralidharan N	2019	1. Implement a system that not only detects the occurrence of a fire but also determines its exact location using GPS coordinates. 2. Establish a real-time monitoring system that continuously tracks temperature and smoke levels in the forest, providing timely information to relevant authorities.	1.Facilitates efficient allocation of fire fighting resources by pinpointing the exact location of the fire 2. Provides continuous monitoring of forest conditions, allowing for proactive measures and preventive actions 3.Enables timely response to forest fires, reducing the potential for widespread damage.	1. Remote locations might pose challenges for regular maintenance and troubleshooting. 2. The IoT nature of the system could be vulnerable to cyber threats, necessitating robust security measures. 3. The effectiveness of the system may be limited to the areas where the sensors are deployed.
IoT Enabled Forest Fire Detection And Early Warning System. [3]	A.Divya, T.Kavithanjali , P.Dharshini	2019	1. Improve changeable sensory parameter and Reduce error perception and update imperfections through IoT. 2. Incorporate D2D association for a sustainable ecosystem and provide information to experts through IoT using MQTT protocol.	1. Prior detection of forest fires and provides response time to emergency situations. 2. One-time installation for sensors. 3. Continuous monitoring of the workers' environment.	1. Installation cost is high and complex fault detection in wired communication. 2. Dependence on MQTT protocol without addressing potential drawbacks.
An Improved Approach for Fire Detection using Deep Learning Models. [4]	Mohit Dua, Mandeep Kumar, Gopal Singh Charan, Parre Sagar Ravi	2020	1.Enhance early detection of fires through the use of deep learning models, reducing response time and minimizing potential damage. 2.Improve accuracy to minimize false alarms, ensuring that the system reliably distinguishes between actual fire events and non-threatening situations. 3.Enable real-time monitoring to provide immediate alerts, allowing for swift response and intervention.	1.Deep learning models can analyse visual data in real-time, enabling early detection of fires before they escalate, allowing for quicker response and mitigation. 2.Deep learning algorithms can be trained on diverse datasets, enhancing their ability to accurately differentiate between actual fires and false alarms, reducing the risk of unnecessary emergency responses.	1. Running complex deep learning models on edge devices, such as cameras or sensors, might consume significant energy. This can be a concern for devices with limited power sources. 2. Implementing and maintaining a deep learning-based fire detection system may involve significant costs, including infrastructure, training, and on-going updates to keep the model effective.

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Early Detection of Forest Fire using Deep Learning. [5]	Medi Rahul, Karnekanti Shiva Saketh, Attili Sanjeet and Nenavath Srinivas Naik	2020	1. Develop a model for high detection rates across multiple databases using transfer learning. 2. Apply the preprocessing and data augmentation to enhance the image data. 3. Utilize VGG16, ResNet50, and DenseNet121 for the image classification. 4.Implement ResNet50 with fine-tuning for better reliability and performance.	1. Addresses the challenge of achieving high detection rates across multiple databases. 2. Utilizes transfer learning and data augmentation to enhance the model performance. 3. Provides a clear model architecture involving data preprocessing, augmentation, and classification. 4. Demonstrates the reliability and performance of ResNet50 with fine-tuning.	1.Transfer learning, model may not perform well if it encounters completely different types of forests, landscapes, or fire conditions which are not represented in the training data. 2. Implementing the model in a real-time scenario using Unmanned Aerial Vehicles (UAVs) may pose logistical and regulatory challenges.
IoT and Image Processing based Forest Monitoring and Counteracting System. [6]	Shivam Pareek, Shreya Shrivastava, Sonal Jhala	2020	1. Design a forest fire monitoring system with two parts: transmitting (microprocessor, camera, sensors) and receiving (computers at base station). 2. Process data using MATLAB at the base station. 3.Control a submersible pump to counteract the fire. 3. Utilize image processing to understand situations and respond accordingly. 4.Present experimental setup with the sensors and a Wi-Fi camera for real-time monitoring.	1. Integrates IoT and image processing for effective forest fire monitoring. 2. Uses a variety of sensors for comprehensive data collection. 3. MATLAB based image processing for fire detection. 4. Counteraction system with a submersible pump to extinguish fires. 5. Potential for future enhancements, such as distinguishing animals and protecting endangered species.	1. Ultrasonic sensor limitations for precise trespasser detection. 2. Potential false fire detection due to line-of-sight issues.
Forest Fire Detection and Guiding Animals To A Safe Area By Using Sensor Networks And Sound. [7]	Vignesh Tarun.M.G, Sankhasubhra Nandi S Sriram.M J Asbok.PS	2021	1.Develop a Wireless Sensor Network (WSN) system for real-time forest fire detection and wildlife evacuation. 2.Utilize sensors for temperature, humidity, smoke, wind, and sound. Implement machine learning to predict fire movement.	1.Saves wildlife and reduces environmental damage. 2.Real-time detection with WSN. 3. Informs first responders and civilians. 4.Guides animals to safety through distress signals. 5.Economic feasibility for implementation.	1. The effectiveness of distressing sounds is dependent on the coverage of sound waves across the forest area. 2. While the system focuses on guiding wildlife away from the fire, it does not directly address the prevention of the fire itself.

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Forest-Fire Response System Using Deep-Learning-Based Approaches With CCTV Images and Weather Data. [8]	Dai Quoc Tran, Minsoo Park, Yuntae Jeon, Jinyeong Bak, and Seunghee Park	2022	1. Develop a DetNAS-based searching backbone algorithm for early forest fire detection 2. Propose a Bayesian Neural Network (BNN) model for real-time damage area estimation using weather data. 3. Create a web-based visualization platform for real-time monitoring and response scenarios.	1. Outperforms existing backbones, including hand-crafted and NAS-based models, with a DetNAS-based searching backbone. 2. Achieves smoke and fire detection with an acceptable mAP of 27.9 3. Develops a web-based visualization platform for forest-fire response scenarios.	1. Limited mAP score due to potential false positive cases in smoke detection. 2. Overfitting issues observed in decision tree models. 3. Unclear whether the BNN's higher accuracy can improve performance. 4. CCTV cameras might not withstand harsh weather conditions of the forest.
Video Based Forest Fire and Smoke Detection Using YoLo and CNN. [9]	Sayali Madkar, Anagha P Haral, Dr. Dipti Y Sakhare, Kirti B Nikam, Komal A Phutane, S Tharunyha	2022	1. Train a system for forest fire and smoke detection using YoLo and CNN which provides accurate detection. 2. Implement data preprocessing and enrichment techniques. 3. Utilize UAVs and remote sensing for data collection and explore the capabilities of alerting signals using IoT technology.	1. Early detection of forest fires using a combination of remote sensing and deep learning. 2. Data augmentation for increased dataset and model accuracy. 3. Live monitoring of forest regions for real-time processing.	1. Adapt to different environmental conditions such as lighting. This is important for the models to perform consistently in dynamic outdoor settings. 2.Small dataset might limit the generalization capability of the models, especially considering the complexity of fire and smoke patterns.
A Lightweight Hierarchical AI Model for UAV-Enabled Edge Computing with Forest-Fire Detection Use-Case. [10]	Mostafa M. Fouda, Sadman Sakib, Zubair Md Fadlullah, Nidal Nasser, and Mohsen Guizani	2022	1. Formulate a multi-objective optimization problem to balance detection correctness and computational cost. 2. Design an adaptive inference algorithm switching between basic and advanced AI models. 3. Optimize the hierarchical framework using a hyperparameter.	1. Utilizes lightweight edge computing for UAVs, leveraging their mobility and flexibility. 2. Addresses resource depletion in UAVs during early detection of forest fires. 3. Demonstrates the viability of the proposed framework through extensive experiments on real datasets. 4. Offers a multi-objective optimization approach for balancing accuracy and computational cost.	1. UAVs have inherent resource constraints, including limited computing power, storage capacity, and energy resources. 2. UAVs often have limited payload capacities, restricting the types of sensors and equipment they can carry. 3. Unfavourable weather conditions may affect UAV stability, navigation, and data acquisition, impacting overall system reliability.
Event Classification and Intensity Discrimination for Forest Fire Inference with IoT. [11]	Vishal K. Singh, Chhaya Singh, and Haider Raza.	2022	1. Develop a fuzzy system based on meteorological variables (Temperature, Humidity, Wind Speed, Smoke) for accurate event detection and intensity discrimination. 2. Analyse the impact of different permutations of these variables on the fire index.	1.Comprehensive analysis of four meteorological variables. 2. Fuzzy logic-based method for accurate classification and intensity discrimination.	1. Complexity increases with the exponential growth of fuzzy rules. 2. Dependent on meteorological variables; other factors like atmospheric stability, cloud development, and surface conditions not considered.

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Class Activation Map-Based Data Augmentation for Satellite Smoke Scene Detection. [12]	Junwei Xie, Fan Yu, Hanxiang Wang, and Haotian Zheng	2022	1. Evaluate the impact of Class Activation Map-based Mixing method (CAMMix),a new MSDA Method on the classification performance of various smoke detection models. 2. Provide visualization of Grad-CAM and heatmap to showcase the impact of Data augmentation (DA) methods on spatial resolution.	1. Achieves significant improvement in overall accuracy for smoke detection models with CAMMix. 2. Overcomes issues of confusing and unnatural samples introduced by other DA methods. 3. Provides visualizations showing the impact of CAMMix on the important regions in input images.	1. Small smokes under thick canopy can go undetected. 2. Cannot distinguish between controlled burning and forest fire.
A Deep Learning-Based Experiment on Forest Wildfire Detection in Machine Vision Course. [13]	Lidong Wang, Huixi Zhang, Yin Zhang, Keyong Hu and Kang An.	2023	1. Evaluate wildfire image classification using accuracy metrics. 2. Employ precision, recall, and accuracy for wildfire region detection. 3. Compare SVM, Reduce-VGGNet, and CNN-based spatial and temporal features for wildfire detection.	1. CNN-based spatial and temporal features result in 97.35% accuracy for wildfire region detection. 2. Outperforms state-of-the-art object detection algorithms. 3. Comprehensive experiment covering digital image processing, machine learning, and deep learning.	1. Specific dataset used (FLAME) may limit generalization. 2. CNN optimization requires manual annotation for wildfire region detection. 3. some challenges in satellite data processing such as complexity of noise information is not resolved
MMFNet: Forest Fire Smoke Detection Using Multiscale Convergence Coordinated Pyramid Network With Mixed Attention and Fast-Robust NMS. [14]	Liangji Zhang, Chao Lu, Haiwen Xu, Aibin Chen, Liujun Li, and Guoxiong Zhou	2023	1. Propose MMFNet for fast and accurate detection of wildfire smoke. 2. Improve detection accuracy using Mixed Attention and MCCPN. 3. Achieve high accuracy metrics (AP, AP50, AP75, AR) and FPS. 4. Compare MMFNet with other detection models for performance validation.	1. Achieves high accuracy metrics on a self-built smoke dataset. 2. Improves detection accuracy for low-concentration smoke using Mixed Attention. 3. Utilizes MCCPN for effective extraction of features at different scales, improving detection rate of small targets.	1. Interference factors in different natural environments may cause misjudgment. 2. Further research needed to study characteristic differences between smoke and interfering objects.
Small Target Forest Fire Recognition Method Based On Deep Learning. [15]	Mingming Luo, Jianhua Huang, Xiyan Sun, Zhengyao Yu, Yixuan Wan	2023	1. Achieve high accuracy in differentiating between actual fire events and false alarms. This minimizes the chances of overlooking real threats or responding to non-fire events. 2. Minimize false positives to prevent unnecessary panic or resource allocation. A low false positive rate is crucial for the practical application of the system.	1.Focusing on small targets can be more resource-efficient and cost-effective, as it minimizes the computational requirements compared to broader fire detection methods, making it suitable for deployment in resource-constrained environments. 2.The model locate and identify small target fires more accurately.	1. The effectiveness of small target recognition heavily relies on the quality of input images. 2.Factors like low-resolution imagery, occlusions, or sensor noise may compromise the model's performance.

III. CONCLUSION

In conclusion, The survey of existing research papers on forest fire detection, mitigation, and related technologies has provided valuable insights into the strengths and limitations of current approaches. The identified drawbacks in various methodologies highlight the need for a comprehensive and integrated solution. We acknowledge the challenges highlighted in the surveyed papers, such as the accuracy of environmental factors, maintenance issues in remote locations, high installation costs, and potential vulnerabilities to cyber threats. These challenges emphasize the importance of a holistic and resilient system that considers the complex dynamics of forest ecosystems, the diverse landscapes encountered, and the various limitations posed by environmental conditions. We seek to overcome these challenges by integrating Deep Learning for accurate and timely forest fire detection, while IoT technology ensures real-time data collection and communication. The inclusion of wildlife preservation and tribal preparedness components demonstrates our commitment to a multifaceted solution that goes beyond fire detection alone. In developing our system, we will be attentive to cost-effectiveness, energy efficiency, and scalability, addressing concerns related to implementation and maintenance costs, energy consumption of edge devices, and the scalability of the system.

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