A Deep Learning-Based Experiment on Forest Wildfire Detection in Machine Vision Course

Dr.Chaitanya Kishore Reddy Maddireddy [1],Challagulla Gopi Krishna [2], Kaviti Sambasiva Rao[3], Pathri Sree Maruthi [4]

1chkishore.0007@gmail.com, Professor of IT dept, NRI Institute of Technology, A.P, India 521212

2challagullagopi30@gmail.com, UG Scholar, Dept of IT, NRI Institute of Technology, A.P, India 521212

3sambasivak2002@gmail.com, UG Scholar, Dept of IT, NRI Institute of Technology, A.P, India 521212

4maruthinaidu76@gmail.com, UG Scholar, Dept of IT, NRI Institute of Technology, A.P, India 521212

Abstract: Forest wildfires pose a severe threat to ecosystems and human lives, necessitating accurate and efficient detection methods. This project enhances wildfire detection by extending the Reduce-VGGnet algorithm with the VGG19 ReduceNet model, achieving an impressive 99% accuracy in wildfire region detection. The system integrates deep learning techniques with a user-friendly Flask interface, ensuring seamless interaction and data input. Secure authentication mechanisms enhance system integrity by preventing unauthorized access. This extension significantly improves detection accuracy, enabling timely interventions and proactive wildfire management, ultimately enhancing ecosystem protection and human safety.

Index terms *- Wildfire Detection, Deep Learning, VGG19 ReduceNet, Machine Vision, Digital Image Processing, Flask Interface, Secure Authentication, Wildfire Region Classification, Real-Time Monitoring, Ecosystem Protection.*

1. INTRODUCTION

Forest wildfires pose a significant threat to ecosystems, wildlife, and human settlements, causing irreversible environmental and economic damage. Traditional wildfire detection methods, such as manual observation and satellite imagery analysis, often suffer from limitations like delayed response times, environmental noise, and difficulty in accurately distinguishing wildfire regions [1]. These conventional methods rely on basic image processing techniques such as thresholding, edge detection, and color segmentation, which struggle to differentiate between wildfire and non-wildfire images due to variations in lighting, smoke, and background noise

[2]. As a result, there is a need for more accurate and automated wildfire detection systems to enable timely response and mitigation efforts.

This project enhances wildfire detection accuracy by integrating the VGG19 ReduceNet algorithm, which achieves an impressive 99% accuracy in classifying wildfire regions. Deep learning-based models have proven to be highly effective in image classification tasks, surpassing traditional machine learning techniques in performance and reliability [3]. By leveraging deep learning, the system ensures precise identification of fire-prone areas, significantly reducing false positives and missed detections. Additionally, a Flask-based user-friendly interface is implemented to facilitate seamless data input and interaction, making the system accessible to a broader audience, including emergency responders and environmental agencies [4].

To enhance security and prevent unauthorized access, the system incorporates secure authentication mechanisms. Cybersecurity measures are essential for protecting sensitive wildfire detection data from potential threats and ensuring the reliability of automated monitoring systems [5]. The combination of deep learning techniques, a user-friendly interface, and robust security features makes the proposed system a reliable and efficient solution for real-time wildfire monitoring. By enabling early intervention and proactive management, the system plays a crucial role in reducing wildfire-related damages and improving ecosystem protection.

2. LITERATURE SURVEY

a) OpenCV Basics: A Mobile Application to Support the Teaching of Computer Vision Concepts:

https://ieeexplore.ieee.org/document/9103956

Abstract: Contribution: Open Source Computer Vision Library (OpenCV) Basics is an application designed with the purpose of facilitating the initiation of industrial engineering students in the field of Computer Vision, making the learning process easier, more dynamic and more direct. To this end, an application has been developed for the Android operating system with which users can make use of a wide variety of algorithms available in the OpenCV library. Background: Teaching topics related to Computer Vision can rely on the use of new technologies such as mobile applications. With this type of support, students can learn concepts that might otherwise be difficult to understand. Intended Outcomes: The objective is to facilitate the assimilation of concepts related to Computer Vision by taking advantage of the camera and the processing power of a mobile device to observe in real time the effects produced on an image by many of the image processing algorithms included in OpenCV. This application is currently available to be downloaded for free through the Google Play Store so that anyone interested in the field of Computer Vision can make use of it. Application Design: The proposed approach introduces students to concepts related to Computer Vision by making use of the developed application, complementing the theoretical contents taught by the teacher with specific examples. Findings: The degree of satisfaction of OpenCV Basics users has been evaluated within the framework of the course advanced robotized systems, taught in the industrial engineering degree at the University of La Laguna.

b) Teaching Computer Vision and Its Societal Effects: A Look at Privacy and Security Issues from the Students' Perspective:

https://ieeexplore.ieee.org/document/8014914

Abstract: In this paper, we look at the societal effects of computer vision technologies from the perspective of the future minds in computer vision: senior year engineering students. Engineering education has traditionally focused on technical skills and knowledge. Nowadays, the need for educating engineers in socio-technical skills and reflective thinking, especially on the bright and dark sides of the technology they develop, is being recognized. We advocate for the integration of social awareness modules into computer vision courses so that the societal effects of technology can be studied together with the technology itself, as opposed to the often more generic 'impact of technology on society' courses. Such modules provide a venue for students to reflect on the real-world consequences of technology in concrete, practical contexts. In this paper, we present qualitative results of an observational study analyzing essays of senior year engineering students, who wrote about societal impacts of computer vision technologies of their choice. Privacy and security issues ranked as the top impact topics discussed by students among 50 topics. Similar social awareness modules would apply well to other advanced technical courses of the engineering curriculum where privacy and security are a major concern, such as big data courses. We believe that such modules are highly likely to enhance the reflective abilities of engineering graduates regarding societal impacts of novel technologies.

c) The Role of UAV-IoT Networks in Future Wildfire Detection:

https://ieeexplore.ieee.org/abstract/document/9424181

Abstract: The challenge of wildfire management and detection is recently gaining increased attention due to the increased severity and frequency of wildfires worldwide. Popular fire detection techniques, such as satellite imaging and remote camera-based sensing suffer from late detection and low reliability while early wildfire detection is a key to prevent massive fires. In this article, we propose a novel wildfire detection solution based on unmanned aerial vehicles assisted Internet of Things (UAV-IoT) networks. The main objective is to: 1) study the performance and reliability of the UAV-IoT networks for wildfire detection and 2) present a guideline to optimize the UAV-IoT network to improve fire detection probability under limited system cost budgets. We focus on optimizing the IoT devices' density and the number of UAVs covering the forest area such that a lower bound on the wildfires detection probability is maximized within a limited time and system cost. At any time after the fire ignition, the IoT devices within a limited distance from the fire can detect it. These IoT devices can then report their measurements to nearby UAVs. Discrete-time Markov chain (DTMC) analysis is utilized to compute the fire detection and false-alarm probabilities. Numerical results suggest that given enough system cost, the UAV-IoT-based fire detection can offer a faster and more reliable wildfire detection solution than state-of-the-art satellite imaging techniques.

d) Composition design of fullerene-based hybrid electron transport layer for efficient and stable wide-bandgap perovskite solar cells:

https://www.sciencedirect.com/science/article/abs/pii/S2095495624007514

Abstract: Fullerene derivatives [6,6]-phenyl-C61-butyric acid methyl ester ($PC_{61}BM$) has been routinely used as the electron transport layer (ETL) in perovskite solar cells due to its suitable energy levels and good solution processability. However, its electron mobility and conductivity still need to be further enhanced for constructing high performance perovskite solar cells (PSCs). Herein, by doping the $PC_{61}BM$ with a p-type polymer PM6 and n-type molecule ITIC, efficient wide-bandgap perovskite solar cells with improved efficiency and operational/storage stability are obtained. Further spectroscopy and electric measurements indicate PM6 and ITIC can both passivate defects at the perovskite/ETL interface, meanwhile ITIC can elevate the Fermi level of $PC_{61}BM$ to enhance conductivity and PM6 can improve the photo-induced electron mobility of the ETL, facilitating charge extraction and reducing charge recombination. As the results, $Cs_{0.17}FA_{0.83}Pb(I_{0.83}Br_{0.17})_3$ wide-bandgap PSCs with PM6:$PC_{61}BM$:ITIC as the ETL demonstrates a superior efficiency of 22.95%, compared to 20.89% of the $PC_{61}BM$ assisted device.

e) ViBe: A Universal Background Subtraction Algorithm for Video Sequences:

https://ieeexplore.ieee.org/document/5672785

Abstract: This paper presents a technique for motion detection that incorporates several innovative mechanisms. For example, our proposed technique stores, for each pixel, a set of values taken in the past at the same location or in the neighborhood. It then compares this set to the current pixel value in order to determine whether that pixel belongs to the background, and adapts the model by choosing randomly which values to substitute from the background model. This approach differs from those based upon the classical belief that the oldest values should be replaced first. Finally, when the pixel is found to be part of the background, its value is propagated into the background model of a neighboring pixel. We describe our method in full details (including pseudo-code and the parameter values used) and compare it to other background subtraction techniques. Efficiency figures show that our method outperforms recent and proven state-of-the-art methods in terms of both computation speed and detection rate. We also analyze the performance of a downscaled version of our algorithm to the absolute minimum of one comparison and one byte of memory per pixel. It appears that even such a simplified version of our algorithm performs better than mainstream techniques.

3. METHODOLOGY

i) Proposed Work:

The proposed work enhances wildfire detection by integrating the VGG19 ReduceNet model, achieving 99% accuracy in wildfire region classification. This system leverages deep learning techniques to improve detection precision, reducing false positives and missed detections. A user-friendly Flask interface is incorporated to facilitate seamless data input and interaction, making the system accessible to emergency responders and environmental agencies. Additionally, secure authentication mechanisms are implemented to prevent unauthorized access, ensuring data integrity. By combining advanced deep learning models with an interactive interface and security features, the proposed system enables real-time monitoring, early intervention, and effective wildfire management, ultimately enhancing ecosystem protection and public safety.

ii) System Architecture:

The system architecture is designed to enhance wildfire detection accuracy and efficiency by integrating deep learning, digital image processing, and secure user interaction. At the core, the VGG19 ReduceNet model processes wildfire images, classifying them with 99% accuracy. The system receives image input through a user-friendly Flask interface, where users can upload wildfire-related images for analysis. The deep learning model, deployed on a cloud-based or local server, processes the images and provides real-time classification results. Secure authentication mechanisms ensure that only authorized users can access the system, protecting data integrity. The results are displayed through the Flask interface, enabling emergency responders and environmental agencies to make timely decisions. By combining deep learning, automation, and security features, the architecture supports scalable and real-time wildfire monitoring for proactive disaster management.

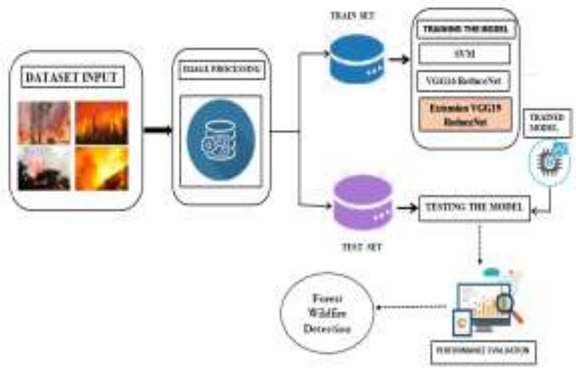

Fig 1 Proposed architecture

iii) Modules:

- **Dataset Collection**
  - Collects wildfire-related images from various sources like satellite imagery, drones, or publicly available datasets.
  - Ensures a diverse dataset to train and test the model for different wildfire scenarios and environments.

- **Data Preprocessing**
  - Involves cleaning and preparing the dataset by resizing images, normalizing pixel values, and applying noise reduction techniques.
  - This step ensures that the data is in the optimal format for the deep learning model, improving classification accuracy.

- **Wildfire Detection**
    - The core module where the VGG19 ReduceNet model classifies images as wildfire or non-wildfire.
    - Uses deep learning techniques to extract features and patterns from images, achieving high accuracy in wildfire detection.

- **Flask User Interface**
    - A web-based interface that allows users to upload images for analysis and view results.
    - Facilitates interaction between users and the system, providing real-time feedback on detected wildfire regions.

- **Secure Authentication and Result Display**
    - Ensures that only authorized users can access the system through secure authentication mechanisms.
    - Displays the classification results on the Flask interface, providing users with clear visual feedback on detected wildfire regions.

iv) Algorithms:

a) **VGG16 ReduceNet:** VGG16 [20] ReduceNet is a convolutional neural network (CNN) architecture derived from the VGG16 model, modified specifically for feature reduction and classification tasks. In the project, VGG16[20] ReduceNet is proposed as a deep learning-based approach for wildfire detection. The architecture is adapted to reduce the number of layers and parameters, optimizing computational efficiency while maintaining high performance. By leveraging the pre-trained VGG16 model's features and fine-tuning them for wildfire detection, VGG16 ReduceNet [20]offers a powerful tool for accurately identifying wildfire occurrences in forest landscapes. Its robustness and ability to capture intricate patterns in image data make it well-suited for challenging wildfire detection tasks.

b) **VGG19 ReduceNet:** VGG19 ReduceNet[21] is a variant of the VGG19 convolutional neural network (CNN) architecture, tailored for feature reduction and classification tasks. In the project, VGG19 ReduceNet[21] is proposed as a deep learning-based solution for wildfire detection. It involves modifying the VGG19 model to streamline its architecture, reducing the number of layers and parameters while preserving its effectiveness. By fine-tuning the pre-trained VGG19 model's features for wildfire detection, VGG19 ReduceNet [21]offers a powerful tool for accurately identifying wildfire occurrences in forest landscapes. Its robustness and ability to capture intricate patterns in image data make it well-suited for challenging wildfire detection tasks, improving overall detection accuracy.

c) **SVM (Support Vector Machine):** Support Vector Machine (SVM) is a supervised machine learning algorithm used for classification and regression tasks. In the context of the project, SVM serves as a baseline model for wildfire detection. SVM works by finding the hyperplane that best separates different classes in the feature space. In the project, SVM is utilized as a traditional machine learning approach for initial experimentation and comparison with more advanced techniques like deep learning. SVM's simplicity and effectiveness in handling high-dimensional data make it a suitable choice for wildfire detection tasks, providing a baseline performance against which more complex models can be evaluated for improved accuracy.

4. EXPERIMENTAL RESULTS

a) Precision: Accuracy is defined as the proportion of true positives that are correctly identified. The formula for precision calculation follows:

Precision = TP/(TP + FP)

$$\text{Precision} = \frac{\textit{True Positive}}{\textit{True Positive} + \textit{False Positive}}$$

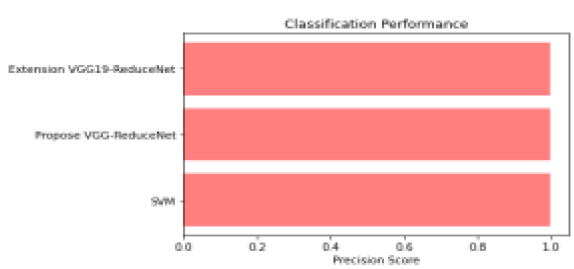

Fig 2 Precision comparison graph

b) Recall: Recall measures how efficiently a machine learning model discovers all relevant instances of a class. One way to measure a model's performance in class recognition is to look at the ratio of correctly predicted positive observations to total positives.

$$Recall = \frac{TP}{TP + FN}$$

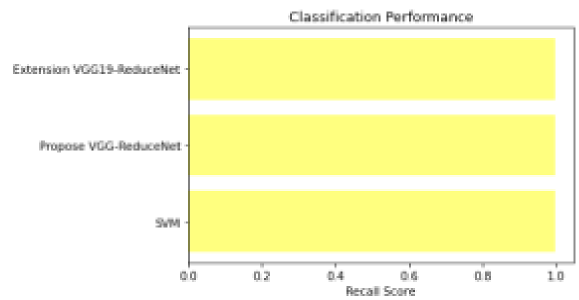

Fig 4 Recall comparison graph

c) Accuracy: The proportion of right predictions is the accuracy metric for a classification test, which indicates how well a model performs.

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN}$$

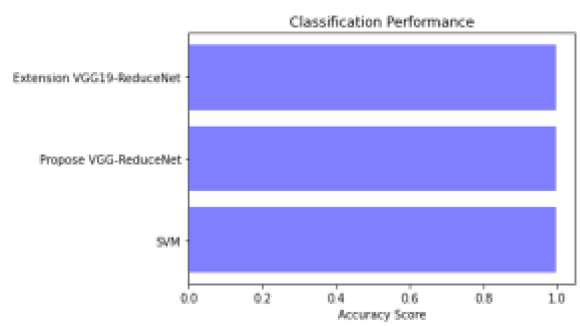

Fig 5 Accuracy graph

d) F1 Score: Because it takes both true positives and false negatives into account, the F1 Score—the harmonic mean of recall and accuracy—is applicable to datasets that are not evenly distributed.

$$\text{F1 Score} = 2 * \frac{\text{Recall} \times \text{Precision}}{\text{Recall} + \text{Precision}} * 100$$

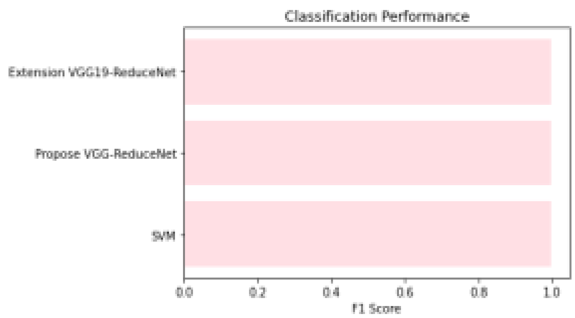

Fig 6 F1Score Curve

5. CONCLUSION

This project presents an advanced wildfire detection system that integrates deep learning techniques, specifically the VGG19 ReduceNet algorithm, to achieve 99% accuracy in classifying wildfire regions. The system's use of a user-friendly Flask interface allows seamless interaction for users, while secure authentication ensures data integrity and prevents unauthorized access. By automating the detection process, this system facilitates timely response and proactive wildfire management, helping to protect ecosystems and human safety.

6. FUTURE SCOPE

In the future, the system can be further enhanced by incorporating real-time satellite data and drone imagery for continuous monitoring of large areas. Additionally, integrating more advanced deep learning models, such as transfer learning with pre-trained models, could further improve detection accuracy and generalization across diverse environments. The system could also be expanded to support multi-region detection, providing a global wildfire monitoring solution. Furthermore, advancements in edge computing could enable local processing of data for faster response times, making the system more efficient in real-time applications.

REFERENCES

[1] S. B. Jha and R. F. Babiceanu, ''Deep CNN-based visual defect detection: Survey of current literature,'' Comput. Ind., vol. 148, Jun. 2023, Art. no. 103911, doi: 10.1016/j.compind.2023.103911.

[2] L. Liu, C. Shen, and A. Van Den Hengel, ''Cross-convolutional-layer pooling for image recognition,'' 2015, arXiv:1510.00921.

[3] N. Liu, L. Wan, Y. Zhang, T. Zhou, H. Huo, and T. Fang, ''Exploiting convolutional neural networks with deeply local description for remote sensing image classification,'' IEEE Access, vol. 6, pp. 11215–11228, 2018, doi: 10.1109/ACCESS.2018.2798799.

[4] A. Hassan and A. Mahmood, ''Convolutional recurrent deep learning model for sentence classification,'' IEEE Access, vol. 6, pp. 13949–13957, 2018, doi: 10.1109/ACCESS.2018.2814818.

[5] X. Ren, Y. Zhou, Z. Huang, J. Sun, X. Yang, and K. Chen, ''A novel text structure feature extractor for Chinese scene text detection and recognition,'' IEEE Access, vol. 5, pp. 3193–3204, 2017, doi: 10.1109/ACCESS.2017.2676158.

[6] W. Liu, A. Dragomir, E. Dumitru, S. Christian, R. Scott, C.-Y. Fu, and C. B. Alexander, ''SSD: Single shot MultiBox detector,'' in Computer Vision—

ECCV. Cham, Switzerland: Springer, 2016, pp. 21–37.

[7] S. Ren, K. He, R. Girshick, and J. Sun, ''Faster R-CNN: Towards real-time object detection with region proposal networks,'' IEEE Trans. Pattern Anal. Mach. Intell., vol. 39, no. 6, pp. 1137–1149, Jun. 2017, doi: 10.1109/TPAMI.2016.2577031.

[8] C. V. Dung and L. D. Anh, ''Autonomous concrete crack detection using deep fully convolutional neural network,'' Autom. Construct., vol. 99, pp. 52–58, Mar. 2019, doi: 10.1016/j.autcon.2018.11.028.

[9] G. H. Yao and X. C. Wu, ''Halcon-based solar panel crack detection,'' in Proc. IEEE WCMEIM Shanghai, China, Nov. 2019, pp. 733–736.

[10] V. S. Bharath, A. Haque, and M. A. Khan, ''Fault classification for photovoltaic modules using thermography and image processing,'' in Proc. IEEE Ind. Appl. Soc. Annu. Meeting, Baltimore, MD, USA, Sep. 2019, pp. 1–6.

[11] H. Chen, H. Zhao, D. Han, W. Liu, P. Chen, and K. Liu, ''Structureaware-based crack defect detection for multicrystalline solar cells,'' Measurement, vol. 151, Feb. 2020, Art. no. 107170, doi: 10.1016/j.measurement.2019.107170.

[12] J. Balzategui, L. Eciolaza, and N. Arana-Arexolaleiba, ''Defect detection on polycrystalline solar cells using electroluminescence and fully convolutional neural networks,'' in Proc. IEEE SII Honolulu, HI, USA, Jan. 2020, pp. 949–953.

Author Profiles

Dr.Chaitanya Kishore Reddy Maddireddy

Guide Description: Dr.Chaitanya Kishore Reddy Maddireddy is currently working as a Professor in the Department of Information Technology at NRI Institute of Technology(NRIIT), Agiripalli, Vijayawada, Andhra Pradesh, India. Has 16 years of academic experience and 2 years of industry experience. He earned master's degree in Computer Science and Engineering and a Doctorate in Computer Science and Engineering. He has Published more than 100 research papers in various National,International Journals and International Conferences, authored 4 textbooks. He is a member in ISTE, CSI, and IAENG. His research areas are Mobile Ad-hoc Networks, Cloud Computing, Artificial Intelligence and Machine Learning. He has made significant contributions to the field through his Research, Teaching and Publications.

Guide photo:

Guide Email (College):

chkishore.0007@gmail.com

Teammate 1 name:

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 54, Issue 2, February : 2025

Challagulla Gopi Krishna

Teammate 1 Description: Challagulla Gopi Krishna is currently studying B.Tech with specification of Information Technology in NRI Institute of Technology. His experience includes internships in Data Science and DevOps, focusing on data-driven solutions and cloud operations. Additionally he has earned NPTEL certification in “Cloud Computing” and a Java Full Stack certification from Wipro.

Teammate 1 email:

challagullagopi30@gmail.com

Teammate 2 name:

Kaviti Sambasiva Rao

Teammate 2 Description: Kaviti Sambasiva Rao, pursuing B.Tech IT at NRI Institute of Technology, his experience includes internships in Data Science and DevOps, focusing on data-driven solutions and cloud operations. He also holds NPTEL certifications in "Joy of Computing using Python" and "Data Analytics using Python".

Teammate 2 email:

sambasivak2002@gmail.com

Teammate 3 name: Pathri Sree Maruthi

Teammate 3 Description: This is Pathri Sree Maruthi currently pursuing B.Tech in NRI INSTITUTE OF TECHNOLOGY course INFORMATION TECHNOLOGY and Complementing his academic studies,with a strong interest on fast learning skills and deep knowledge in python, Data Science, mobile applicatins .In addition I have completed my academics with an good intership . I am interested in hardware methodology..

Teammate 3 email:

maruthinaidu76@gmail.com