Prediction and Prevention of forest fires in India

An Engineering Project in Community Service

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Abstract

Forest fires are a recurring threat in India, causing ecological and economic damage. This group project investigates methods for predicting and preventing forest fires. We explore the use of machine learning techniques to develop a model that can predict forest fire occurrences based on historical data on environmental factors like temperature, humidity, rainfall, and wind speed. Additionally, we analyze existing forest fire prevention strategies in India and identify areas for improvement.

The project aims to:
1.Develop a machine learning model for forest fire prediction in India.
2.Evaluate the model's accuracy and effectiveness.
3.Analyze existing forest fire prevention strategies in India.
4.Recommend improvements for forest fire prevention based on the project's findings.
5. Developing an app for informing about the same to the concerned authorities.

This project contributes to a more proactive approach to forest fire management in India, potentially minimizing fire damage and protecting valuable ecosystems.

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INTRODUCTION

India, endowed with diverse ecosystems and rich biodiversity, is home to vast expanses of forests that play a pivotal role in maintaining ecological balance and sustaining life. However, the increasing frequency and intensity of forest fires pose a significant threat to these invaluable ecosystems, jeopardizing the delicate equilibrium that supports both flora and fauna. In recent years, the occurrence of wildfires has escalated, exacerbating environmental degradation, compromising air quality, and causing irreparable damage to the natural heritage of the nation.

Recognizing the urgency of addressing this challenge, this report delves into the multifaceted aspects of forest fire prediction and prevention in India. By examining the underlying causes, understandingthe prevalent environmental conditions, and evaluating existing mitigation strategies, this comprehensive analysis aims to provide actionable insights for policymakers, researchers, and local communities. The goal is to develop a robust framework that not only anticipates potential fire outbreaks but also implements effective preventive measures, ensuring the preservation of our forests and safeguarding the well-being of the ecosystems they support.

Against the backdrop of climate change and anthropogenic activities, it becomes imperative to adopt an integrated approach that combines cutting-edge technology, community engagement, and sustainable forest management practices. This report explores the integration of artificial intelligence, satellite monitoring, and community-driven initiatives to create a proactive fire management system that minimizes the risk of wildfires and enhances the overall resilience of India's diverse landscapes.

As we embark on this journey to mitigate the impact of forest fires, collaboration among governmental bodies, environmental agencies, local communities, and research institutions becomes paramount. By fostering partnerships and leveraging the collective wisdom and resources available, India can pave the way for a future where its forests thrive, providing ecological benefits, supporting biodiversity, and contributing to the overall well-being of the nation. This report serves as a call to action, urging stakeholders to unite in the pursuit of sustainable practices that will protect our forests for generations to come.

1.1 Motivation

The urgency and significance of this endeavor are underscored by the multifaceted impacts of wildfires on our environment, communities, and overall sustainability. Below are key motivations driving our commitment to this essential project:

Preserving Biodiversity: India's rich and diverse ecosystems are home to a wide array of flora and fauna. The development of a fire prediction model is crucial for the preservation of biodiversity, as wildfires can have devastating effects on indigenous plant and animal species.

Protecting Valuable Natural Resources: Our country's forests are valuable resources that provide timber, non-timber forest products, and ecosystem services. By predicting and preventing wildfires, we aim to safeguard these resources, ensuring sustainable utilization and minimizing economic losses.

Enhancing Air Quality:Wildfires release pollutants into the atmosphere, affecting air quality and public health. The report on building a fire prediction model addresses this issue, aiming to improve airquality and create healthier living conditions for communities in and around forested areas.

Protecting Agricultural Lands: Agriculture is a cornerstone of our economy, and wildfires pose a threat to crops and livelihoods. The fire prediction model will contribute to the protection of agricultural lands, minimizing the impact of fires on food security and rural economies.

Ensuring Human Safety: Wildfires endanger human lives and settlements. The report emphasizes the development of a fire prediction model as a critical component of disaster management, enabling timely evacuation, emergency response planning, and overall enhancement of community safety.

Utilizing Technological Advancements:The project leverages cutting-edge technology, including remote sensing and machine learning, to develop an advanced fire prediction model. This not only contributes to scientific innovation but also showcases our commitment to harnessing technology for the benefit of society and the environment.

Informing Policy and Planning: The insights derived from the fire prediction model will inform evidence-based policies and planning related to land use, fire management, and resource allocation. This ensures a more effective and sustainable approach to addressing the challenges posed by wildfires.

Promoting Community Awareness: Integrating the fire prediction model into public awareness campaigns is integral to the project. By educating communities on wildfire risks and fostering responsible practices, we contribute to building resilience and reducing the occurrence of human-induced fires.

In conclusion, the motivations behind our report on building a fire prediction model in India are deeply rooted in our commitment to environmental stewardship, community well-being, and sustainable development. We are confident that this report will serve as a valuable resource for informed decision-making and strategic interventions.Thank you for your support and commitment to this crucial undertaking.

1.2 Objective

Predicting and preventing forest fires in India is a critical and challenging task that involves the integration of technology, data analytics, and proactive measures. The objective of a project focused on prediction and prevention of forest fires in India might include:

1. Early Detection and Prediction: Develop and implement an advanced system for early detection and prediction of forest fires. This can involve the use of satellite imagery, remote sensing technology, weather data, and machine learning algorithms to identify potential fire-prone areas and predict fire risks.

2. Data Integration and Analytics: Integrate various data sources, such as satellite data, weather information, topography, and historical fire data, to create a comprehensive database for analytics. Analyze this data to identify patterns, trends, and potential hotspots for proactive measures.

3. Monitoring and Surveillance: Implement a real-time monitoring and surveillance system using IoT (Internet of Things) devices, drones, and sensors placed strategically in forested areas. This can help in continuous monitoring and immediate response to any detected fires.

4.Early Warning Systems: Develop and deploy early warning systems that can alert authorities, local communities, and firefighting teams in advance of potential fire outbreaks. This can involve automated messaging systems, sirens, and mobile applications.

5. Community Engagement and Education: Conduct awareness campaigns and educational programs to engage local communities in fire prevention and response. Educate people about the risks of fire, safe practices, and the importance of reporting potential fire hazards.

6. Collaboration with Authorities: Collaborate with government agencies, forestry departments, and firefighting teams to ensure a coordinated and swift response to detected fires. This can involve the integration of the developed system with existing firefighting infrastructure.

7. Mitigation Strategies: Implement mitigation strategies such as creating firebreaks, controlled burns, and other preventive measures to reduce the impact and spread of fires in vulnerable areas.

8. Continuous Improvement: Establish a system for continuous improvement by regularly updating algorithms, incorporating new technologies, and learning from past incidents to enhance the effectiveness of the overall forest fire prediction and prevention system.

LITERATURE REVIEW

Forest Fire Prediction using Artificial Intelligence George E. Sakr et al. (2010),

An approach to the study of forest fire prediction methods based on artificial intelligence has been suggested. Forest fire risk forecast algorithm is built on help vector machines. Lebanon data was used for the application of the algorithm and has proven the ability to correctly estimate the risk of fire.

Forest fires are a regular phenomenon in our country often observed during summers. A number of **52,785 forest fires were detected using MODIS** (Moderate Resolution Imaging Spectro-radiometer) sensor and **3,45,989 forest fires were detected using SNPP-VIIRS** (Suomi-National Polar-orbiting Partnership - Visible Infrared Imaging Radiometer Suite)in forest fire season from Nov 2020 to June 2021. Severe fires occur in many forest types particularly dry deciduous forest, while evergreen, semi-evergreen and montane temperate forests are comparatively less prone (ISFR 2015). More than 36% of the country's forest cover has been estimated to be prone to frequent forest fires. Nearly 4 % ofthe country's forest cover is extremely prone to fire, whereas 6% of forest cover is found to be very highly fire prone (ISFR 2019) . Every year large areas of forests are affected by fires of varying intensity and extent. Based on the forest inventory records, **54.40% of forests in India are exposed to occasional fires, 7.49% to moderately frequent fires and 2.40% to high incidence levels while 35.71% of India's forests** have not yet been exposed to fires of any real significance. Precious forest resources including carbon locked in the biomass is lost due to forest fires every year, which adversely impact the flow of goods and services from forests. Satellite based remote sensing technology and GIS tools have been effective in better prevention and management of fires through creation of early warning for fire prone areas, monitoring fires on a real time basis and estimation of burn scars.

Satellite based remote sensing technology and GIS tools have been effective in better prevention and management of fires through creation of Forest Fire Danger Rating System based on Fire Weather Index (FWI) of Canadian Forest Fire Danger Rating System (CFFDRS), Monitoring Forest Firedetections and Large Forest Fire on real time basis and estimation of fire affected areas.

Timeline of Forest Fire activities at FSI -

YEAR	MILESTONE
2004	Started dissemination of forest fire alerts based on MODIS data up to district level through email/FAX
2008	Initiation of SMS alerts on number of fires in State/District
2012	1. Introduced KML files in email alerts up to district level along with SMS alerts 2. Publication of "Vulnerability of India's forests to fires" report
2016	1. Introduction of automated email alerts to nodal officers using python script 2. Pilot study on country-wide burnt scar assessment for 2015 and 2016 3. Pre-warning alerts piloted for Uttarakhand, Himachal Pradesh and Madhya Pradesh
2017	1. Complete automation of entire FSI Forest Fire Alert System 2. SNPP-VIIRS sensor added to FSI forest fire monitoring system 3. Forest Fire Alert dissemination up to beat level 4. Pre-Fire Alerts piloted for pan India
2018	Introduction of improved feedback system for forest fire alerts
2019	1. Initiation of satellite based large forest fire monitoring program 2. FSI Van Agni Geo-portal 3. Pre-Fire Alert based on Fire Weather Index 4. Identification of Fire prone forest area
2020	1. Introduced forest fires danger rating 2. Strengthening of large forest fire monitoring system and FSI Van Agni Geo-portal 3. WMS and API to state forest department
2021	1. Special monitoring of large forest fire events like Dzukou Valley, Similipal TR, Bandhavgarh TR etc 2. Special report of unusual increase of forest fire alert in the State 3. Special report of Pre-Fire Alerts

Identification of Fire Prone Forest Areas

FSI has carried out a study based on spatial analysis of forest fire points detected by FSI in the last 17 years (2004-2021) to identify fire prone forest areas in the country. Extent of forest cover under different fire prone classes has also been determined for each State/UT. Frequency of detected forest fires in an area over a period of time indicates proneness of the area to forest fires. Map showing forest area in different classes of fire proneness can be an effective management tool for controlling forest fires. Such a map can be used for optimally utilizing scarce resources available for controlling forest fires in the fire season. Increased vigil in highly fire prone forest areas may effectively prevent forest fires. Considering the usefulness of mapping fire prone forest areas, analysis of the detected forest fire points in GIS framework along with a grid coverage of 5 km X 5 km and latest forest cover has been done for the whole country.Highlights of the study:

• Nearly 10.66% area of Forest Cover in India is under extremely to very highly fire prone zone, as per the long-term trend analysis performed by FSI.

• States under the North-Eastern Region, showed the highest tendency of forest fire, as these states are falling under extremely to very highly forest fire zones.

• States like Mizoram, Tripura, Meghalaya, and Manipur in North-Eastern Part of India exhibit the highest forest fire probability in terms of its frequency of event occurrence.

• Parts of Western Maharashtra, Southern part of Chhattisgarh, Central part of Odisha and few parts of Andhra Pradesh, Telangana and Karnataka are showing patches of extremely and very highly fire prone zones.

TOPIC OF THE WORK

a)System design and Architecture

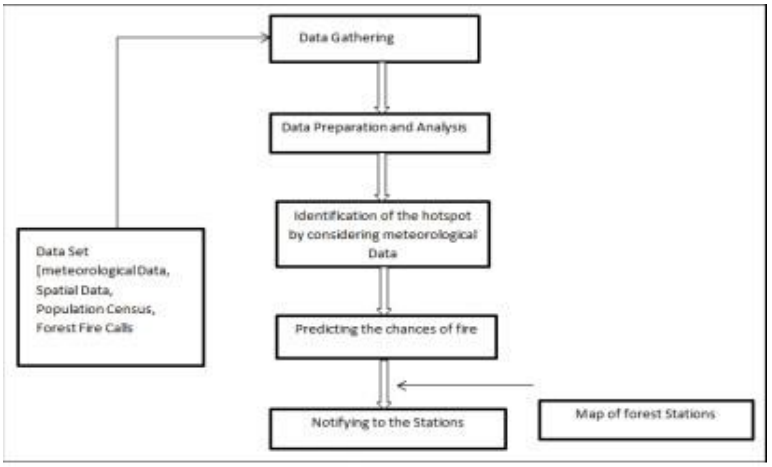


Fig. 1. Block diagram of Forest Fire Prediction.

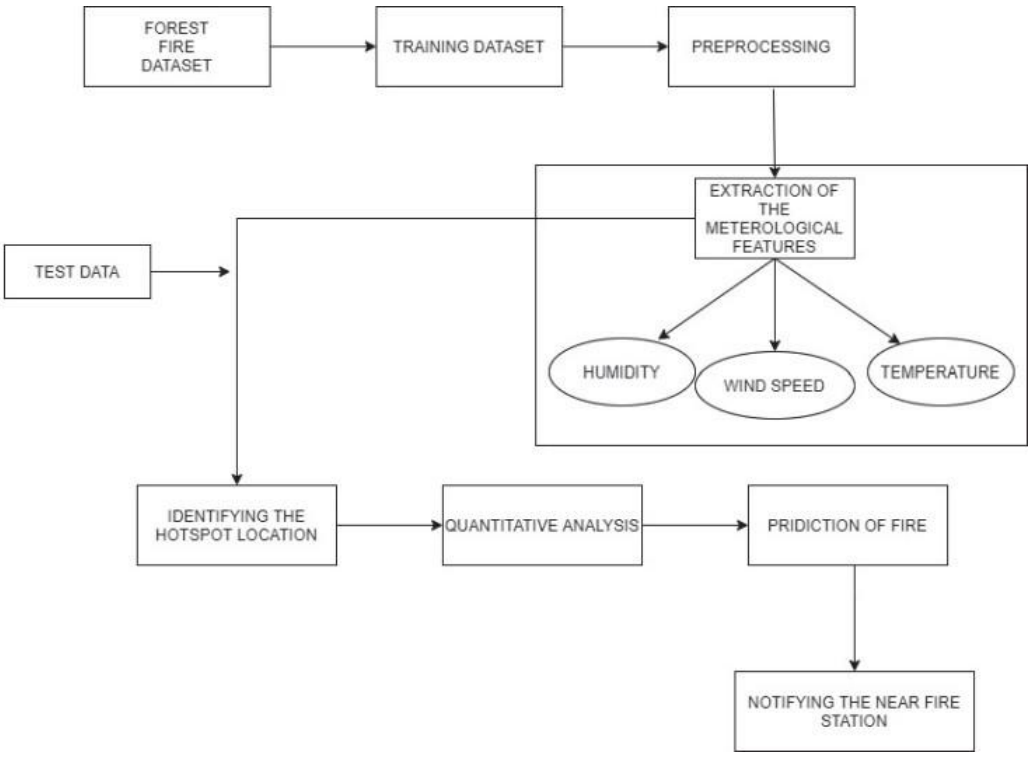


Fig. 2. Low level Diagram

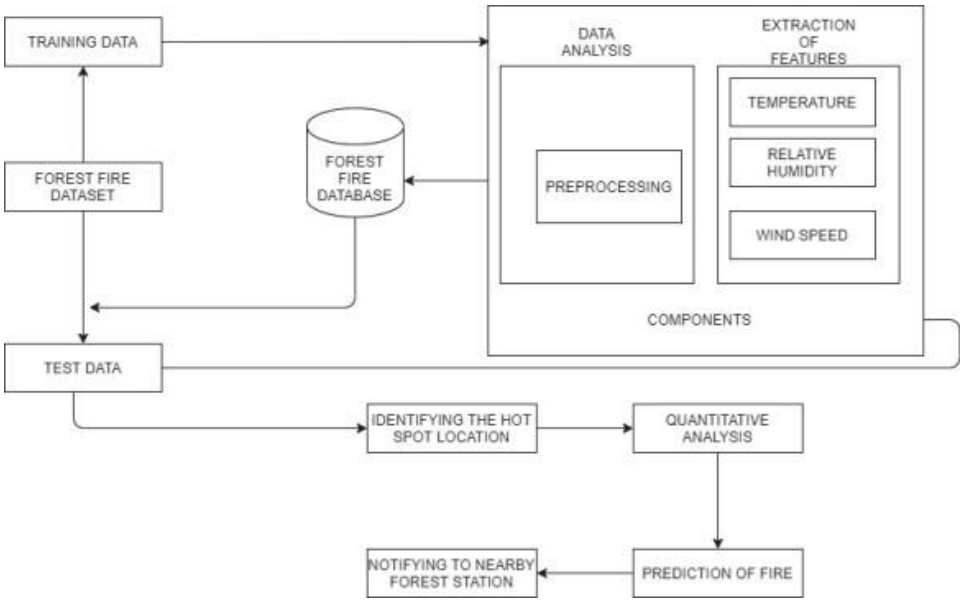


Fig. 3. Architectural Diagram

b)Working Principle

Machine Learning Model -

1. Data Collection:

- Google Earth Engine (GEE): Utilize GEE to gather satellite imagery for monitoring weather conditions, heatmaps, and terrain features. Extract relevant information about the areas prone to forest fires.
- Camera-Assisted Detection: Integrate cameras in the forest area to capture real-time images and videos. These cameras will be strategically placed for optimal coverage.

2.Preprocessing:

- GEE Data Processing: Preprocess GEE data to extract relevant satellite images of areas that are prone to forest fire and analyze them.
- Camera Data Processing:Preprocess camera images to enhance features for better detection. Apply techniques such as image resizing, normalization, and color correction.

3. Fire and Smoke Detection:

-Fire and Smoke areas are detected using the satellite over the areas which we have manually identified using the data available about forest fires in India.

-YOLOv8 Implementation: Employ YOLOv8 for object detection in camera images. Train the model to recognize fire and smoke patterns.

-Integration: Combine YOLOv8 results with GEE data for a comprehensive understanding. Implement algorithms to filter false positives and improve accuracy.

Application Development -

Developed a fire detection app using Flutter, featuring two main pages: Upload and Maps.

- **Upload Page:**

  Users upload satellite images for analysis.
  Advanced algorithms detect fire evidence.
  Instant display of analysis results aids quick decision-making.
  Stack Information -
  FilePicker package for picking images
  ML Model hostel to a server
  HTTP post request to upload to server
  Response -> 0,1,2
  0 -> No fire detected
  1 -> Fire Detected
  2 -> Fire and smoke detected
  packages used -
  file_picker: ^8.0.3 -> for picking images
  http: ^1.2.1 -> POST request to server
  latlong2: ^0.9.1 -> managing coordinates

- **Maps Page:**

  Real-time fetching of satellite images for up-to-date fire detection.
  Integrated maps visualize fire incidents and their distribution.
  Location-based filtering enables targeted analysis and response planning.

  Getting the closest forest satellite image, can chose location on map
  click on fetch button to fetch the closest forest satellite image

  Stack Information -
  openmaps used for displaying maps with
  open source tile template url -> http://{s}.tile.osm.org/{z}/{x}/{y}.png -> used with flutter_map to display map
  packages used -
  flutter_map: ^6.1.0 -> Displaying map
  flutter_map_animations: ^0.6.0 -> custom map animations
  flutter_map_math: ^0.1.7 -> finding the closest forest location from selected position
  geocoding: ^3.0.0 -> getting additional information about the selected location
  http: ^1.2.1 -> fetching satellite image from server
  Emergency Dialog:
  To call and/or alert local emergency services
  Alert:
  Send the coordinates of the user's current location along with the link to google maps to the local emergency services.
  twilio + http: ^1.2.1 -> Service used for alerting i.e., sending message with user details to local emergency services
  geolocator: ^11.0.0 -> Getting user's current location
  Call:
  url_launcher: ^6.2.6 -> To call local emergency services
  State Management:
  provider: ^6.1.2 -> for global state management
  Additional feature -> state persistence

Data Integration:

- The backend integrates data from multiple sources, such as satellite imagery, remote sensing technology, weather data, and historical fire data.
- It creates a comprehensive database by combining these diverse data sources, enabling comprehensive analytics and modeling.

c) Results

The model for fire and smoke detection worked with accuracy of 97 percent.-

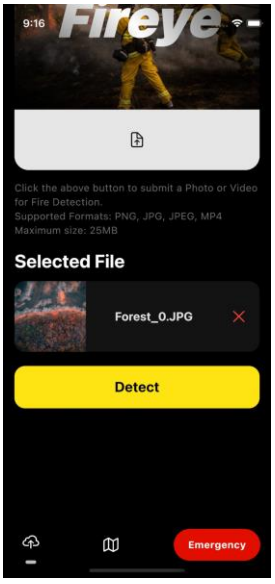
Fire Detection Application Using Flutter-

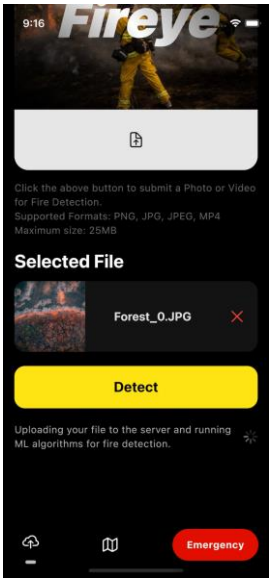
We have developed a cutting-edge fire detection application using the Flutter framework, designed to provide real-time insights into fire occurrences and locations. The application consists of two main pages: the Upload page and the Maps page. These pages offer users seamless access to fire detection and visualization functionalities, enhancing their ability to monitor and respond to fire incidentseffectively.

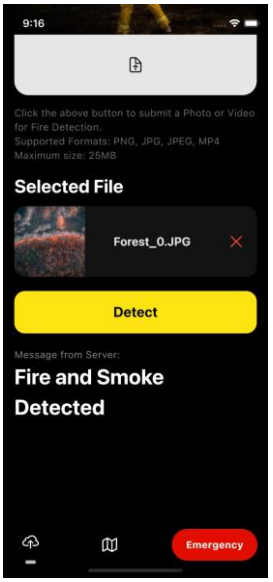
1. Upload Page:

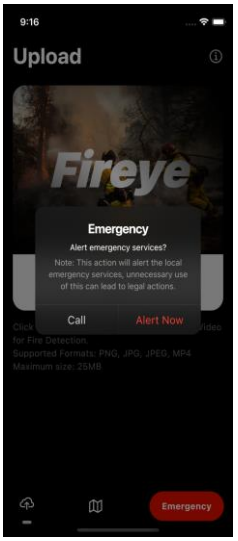
The Upload page serves as the primary interface for users to analyze satellite images for fire detection. Key features of this page include:

- Image Analysis: Users can upload satellite images to the application for analysis.
- Fire Detection: Utilizing advanced image processing algorithms, the application determines whether the uploaded image contains evidence of fire.
- Result Display: The analysis results are promptly displayed to users, indicating whether the image contains fire or is fire-free.





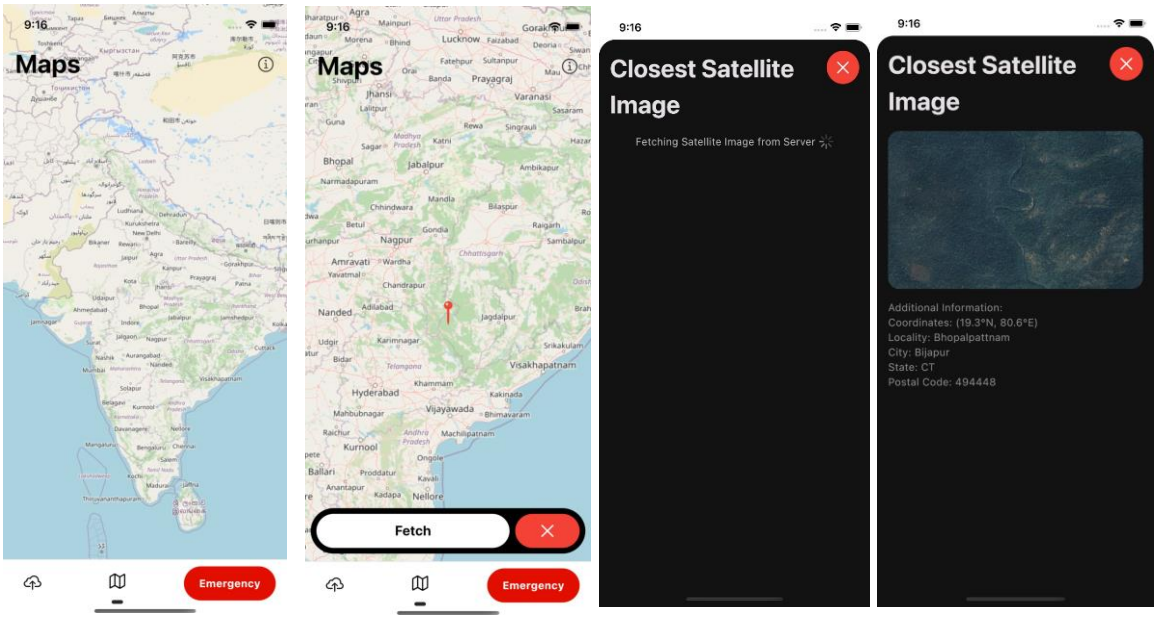




2. Maps Page:

The Maps page offers users an interactive visualization of fire incidents and their geographical distribution. Key features of this page include:

- Real-Time Data Fetching: The application fetches the latest satellite images, incorporating location information to provide up-to-date fire detection results.
- Map Integration: Utilizing mapping services, the application displays satellite imagery overlaid with fire incident markers, allowing users to visualize fire hotspots geospatially.
- Location-Based Filtering: Users can filter fire incidents based on location parameters, facilitating targeted analysis and response planning.



Github link - https://github.com/Team-FireFighters

CONCLUSION

In conclusion, the development of the Fire Detection System using Machine Learning represents a significant stride towards enhancing safety and mitigating the devastating impact of fire incidents.. Through an exhaustive literature review, we gained insights into existing methodologies, allowing us to make informed decisions during the system design.

We trained the model using Computer vision algorithms and exhibited commendable mAP scores in detecting fire and smoke occurrences in test,validation and test set, demonstrating its potential for real-world application. Algorithm ensure the system's adaptability to various environments. The comprehensive exploration of related research laid a solid foundation for our approach, acknowledging the advancements and challenges in the field.

The project has successfully utilized Google Earth Engine to gather satellite data across various states, and through meticulous feature engineering, we've developed a robust model capable of accurately detecting fires in real-time. The Fire Detection System has transitioned from a conceptual endeavor to a practical implementation, demonstrating its potential as a crucial tool in safeguarding lives and property against the threat of fires.

This achievement not only contributes to academic knowledge but also holds significant promise for practical application. It stands as a testament to the impactful synergy between machine learning and safety technologies, paving the way for a safer and more resilient future.

In addition to the successful implementation of the detection system, our efforts are now focused on enhancing usability and accessibility. We have developed an application that will streamline the monitoring process, allowing for efficient real-time tracking and response to fire incidents. This application represents another step towards leveraging technology for the greater good, ensuring that our advancements in fire detection translate into tangible benefits for communities at risk.

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