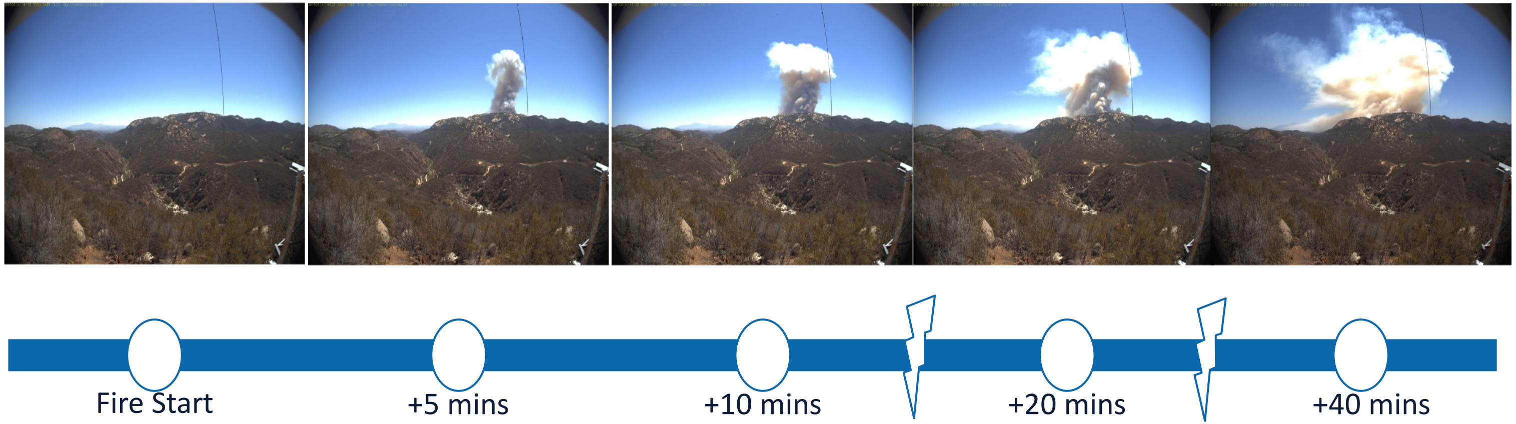
SmokeyNet for Wildfire Smoke Detection

Mai H. Nguyen
San Diego Supercomputer Center
UC San Diego

Motivation

- Size and frequency of wildfires in U.S. have increased in recent years
- Since 1980, 20 major wildfires in U.S. exceeded $1 billion in damages
  - 16 of these events have occurred since 2000
- Wildfires can spread quickly; thus, early detection is essential to minimize damage

Fires can spread quickly:

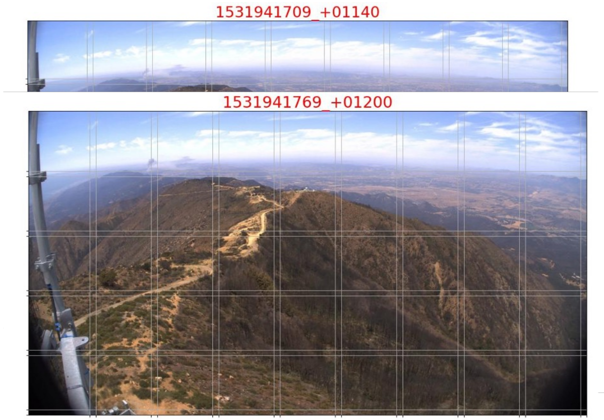


Challenges

- Smoke is transparent and amorphous
- Smoke plumes can be small, faint, dissipating
- Many false positives from clouds, fog, haze

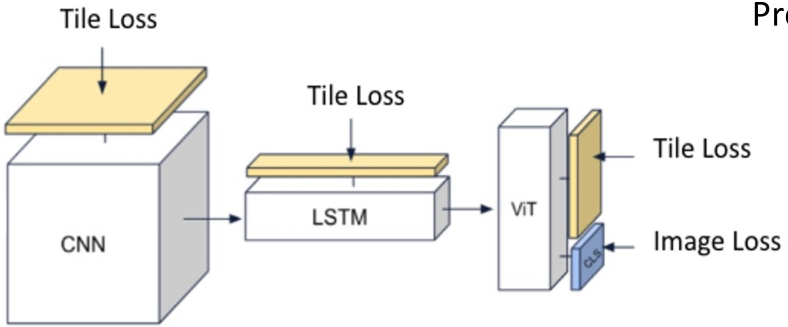



SmokeyNet

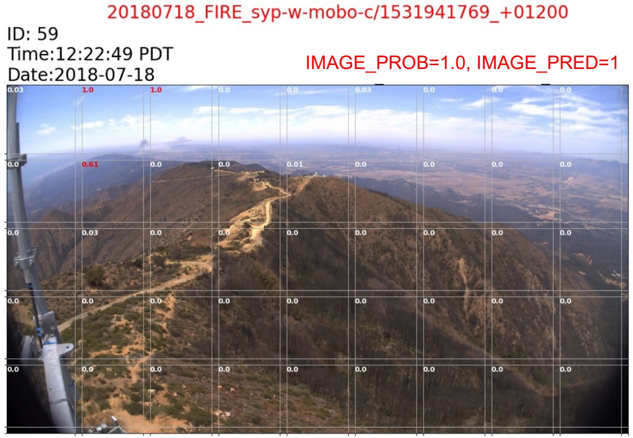


Tiled Image Sequence

SmokeyNet



CNN: convolutional neural network
LSTM: long short-term memory
ViT: vision transformer



Predicted Tile & Image Probabilities

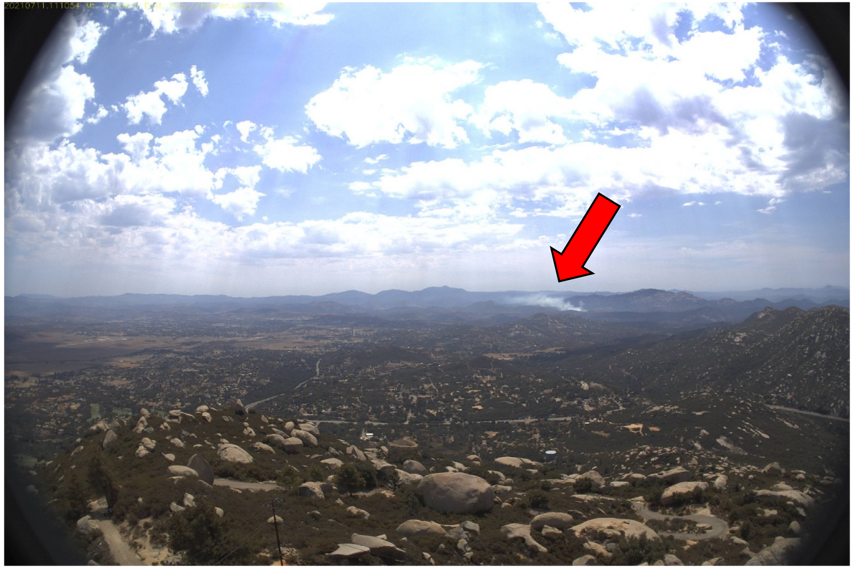
NRP NATIONAL RESEARCH PLATFORM

NRP Nautilus

FIgLib Dataset

Fire Ignition images Library (FIgLib)

- 315 sequences of wildland fire images from optical cameras
- ~25,000 images
- 101 cameras across 30 weather stations
- San Diego, Riverside, Imperial counties
- 3 July 2016 to 12 July 2021
- Each sequence consists of
  - Images at 1-minute intervals
  - Typically 40 minutes before and 40 minutes after ignition
- Part of HPWREN
  - High Performance Wireless Research and Education Network
  - https://hpwren.ucsd.edu/HPWREN-FIgLib/



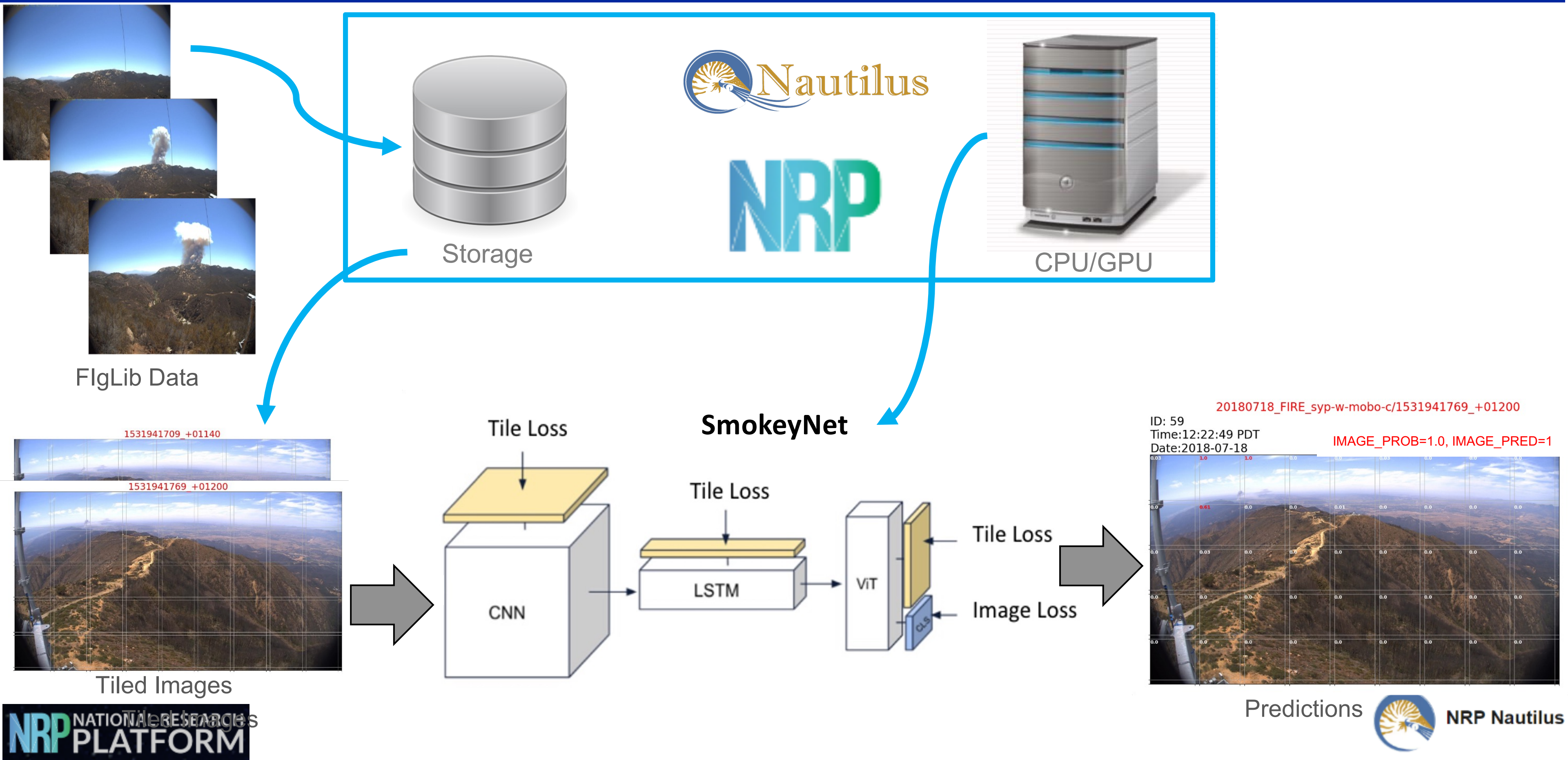
https://hpwren.ucsd.edu/HPWREN-FIgLib/HPWREN-FIgLib-Data/20210711_FIRE_wc-e-mobo-c/1626027054_+00900.jpg

Image sequence: https://hpwren.ucsd.edu/HPWREN-FIgLib/HPWREN-FIgLib-Data/20210711_FIRE_wc-e-mobo-c/20210711_FIRE_wc-e-mobo-c.mp4

NRP NATIONAL RESEARCH PLATFORM

NRP Nautilus

SmokeyNet Workflow Using NRP



Baseline SmokeyNet Results

Model	Params (M)	Time (ms/img)	A	F1	P	R	TTD (mins)
SmokeyNet: ResNet34 + LSTM + ViT (2 frames)	56.9	51.6	**83.49**	**82.59**	**89.84**	76.45	3.12
ResNet50 (1 frame)	26.1	50.4	68.51	74.30	63.35	**89.89**	**1.01**
FasterRCNN (1 frame)	41.3	55.6	71.56	66.92	81.34	56.88	5.01
MaskRCNN (1 frame)	43.9	56.9	73.24	69.94	81.08	61.51	4.18
ResNet34 + LSTM (2 frames)	38.9	53.3	79.35	79.21	82.00	76.74	2.64

Accuracy (A), F1, precision (P), recall (R), and time-to-detection (TTD) on test set, averaged over five runs. Number of params (Params) in millions and inference time (Time) in msec per image are also shown.

Multiple Data Sources

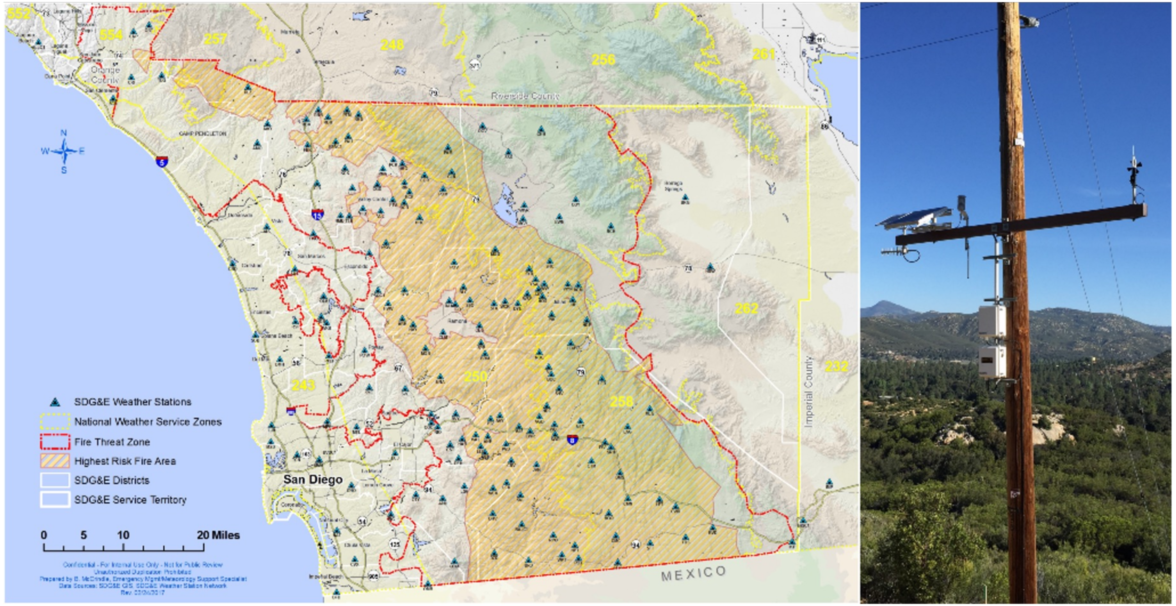
Can incorporating other types of data help performance?

Use multiple input data sources:

FIgLib images + **Weather Data** + **Satellite-Based Detections**

Weather Data

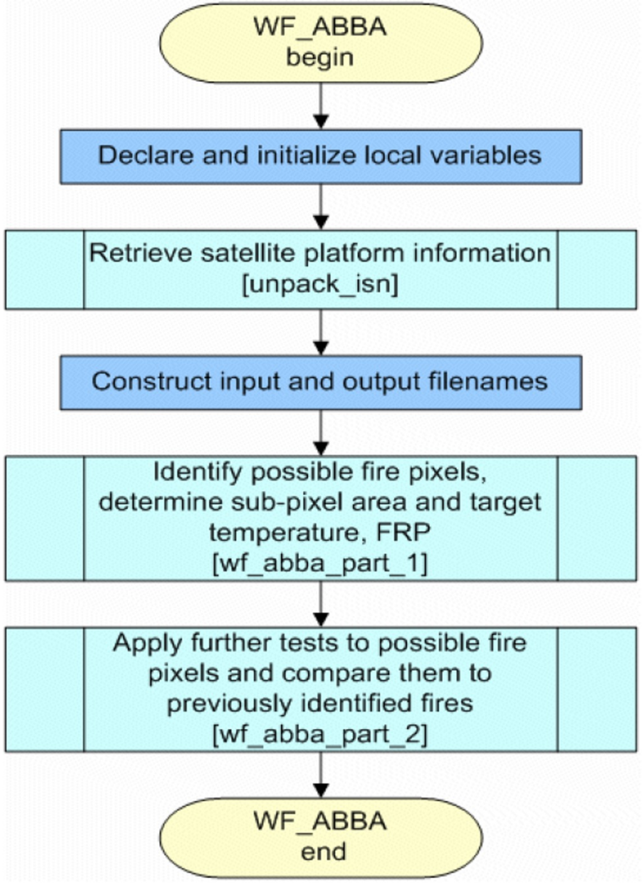
- Weather data is captured for each FIgLib image
- Weather data from HPWREN, SDG&E, SC-Edison weather stations
- Weather features
  - Air Temperature
  - Relative Humidity
  - Wind Speed
  - Wind Gust
  - Wind Direction
  - Dew Point Temperature



San Diego Gas and Electric (SDG&E) weather stations

Satellite-Based Fire Detections

- WFABBA: Wildfire Automated Biomass Burning Algorithm
- Rule-based system used to detect fires from the satellite images
- Uses heuristics to determine thermal anomalies that can be associated with wildfires
- Input: Satellite image data from the GOES-R series Advanced Baseline Imager (ABI)
- We use WFABBA detections from GOES-16 and GOES-17

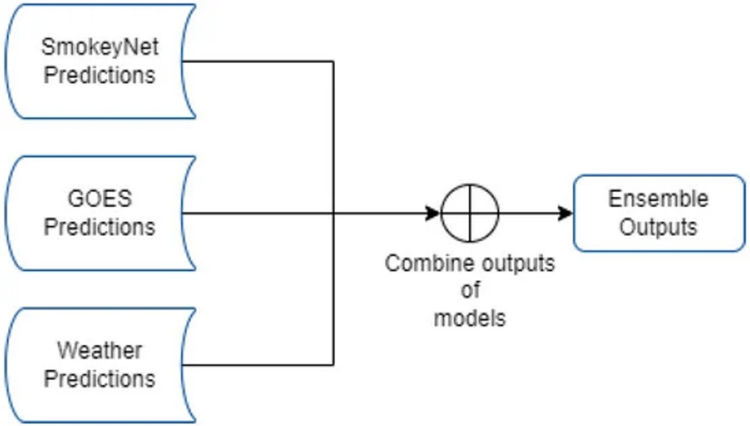


NRP NATIONAL RESEARCH PLATFORM

ıtilus

SmokeyNet Ensemble

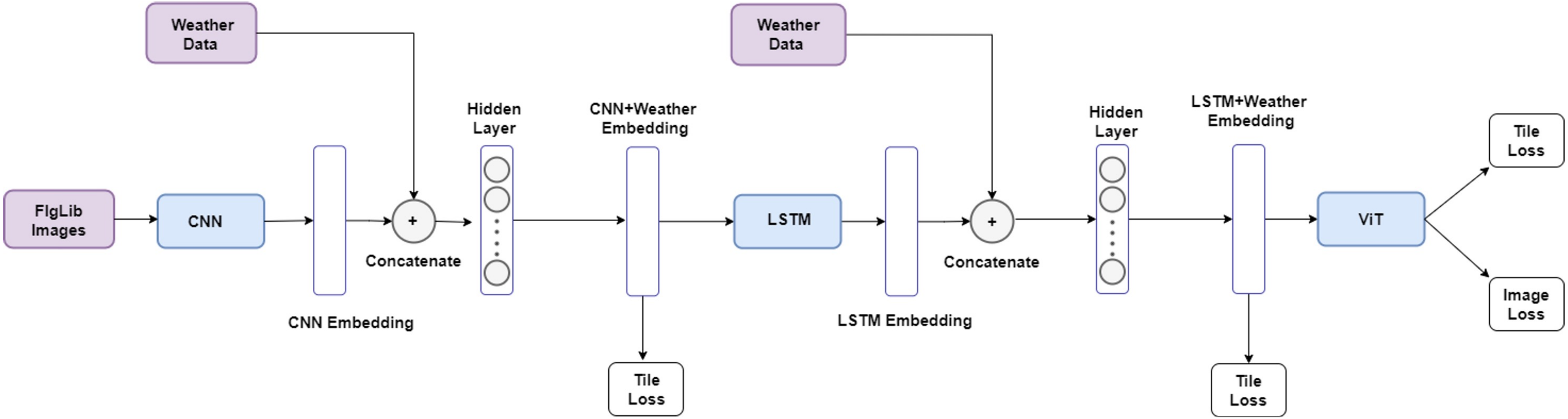
- FIgLib images + weather data + satellite-based fire detections
  - weather data: sensor measurements from weather stations
  - satellite data: fire detections from WFABBA based on GOES-16 & GOES-17



- Findings
  - Performance of the ensemble model is not much better than baseline SmokeyNet
  - GOES and Weather models are weak signals, and hence the ensemble models learn to give the largest weight to input signals coming from baseline SmokeyNet

Multimodal SmokeyNet

Incorporate weather data directly into SmokeyNet



Multimodal SmokeyNet Results

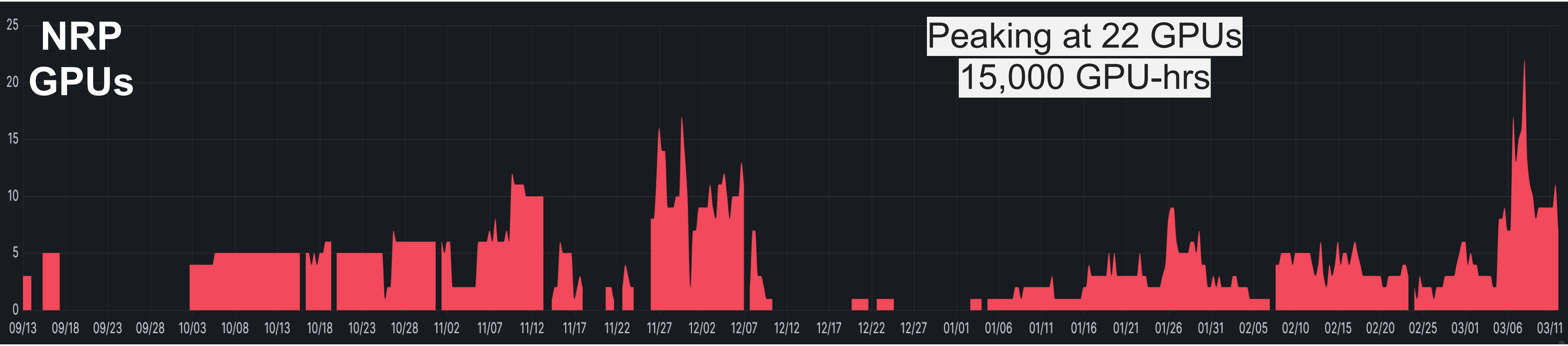
Model	Accuracy	F1	Precision	Recall	TTD (mins)
SmokeyNet	80.12	77.52	**90.43**	68.00	4.70
SmokeyNet with Random Weather	79.50	76.96	88.22	67.92	4.77
Multimodal SmokeyNet	**80.48**	**78.62**	88.19	**71.20**	**4.06**

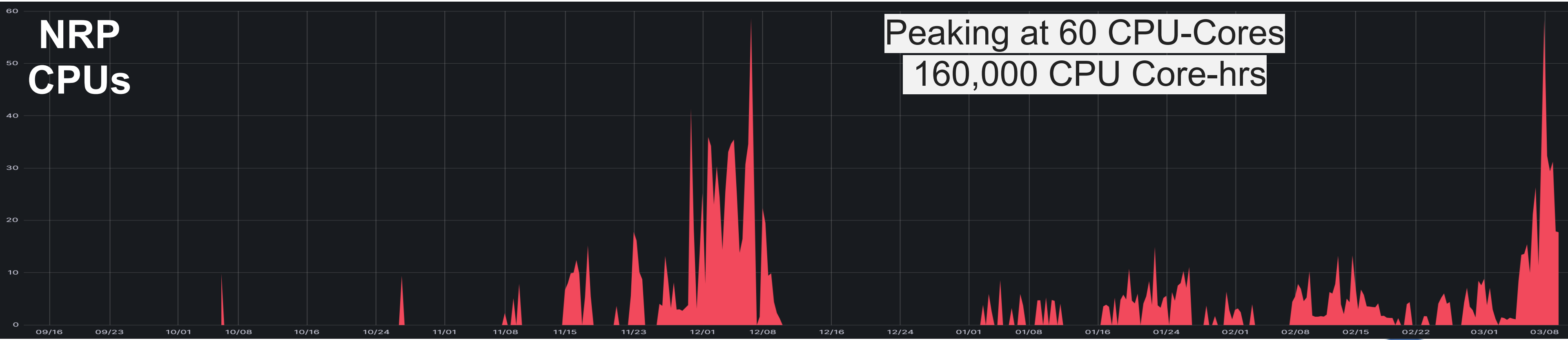
Accuracy, F1, Precision, Recall, and Time-to-Detection (TTD) on test set, averaged over eight runs

NRP NATIONAL RESEARCH PLATFORM

NRP Nautilus

Mai H. Nguyen, UC San Diego
GPU/CPU Usage Per Day, Last 6 Months





NRP NATIONAL RESEARCH PLATFORM

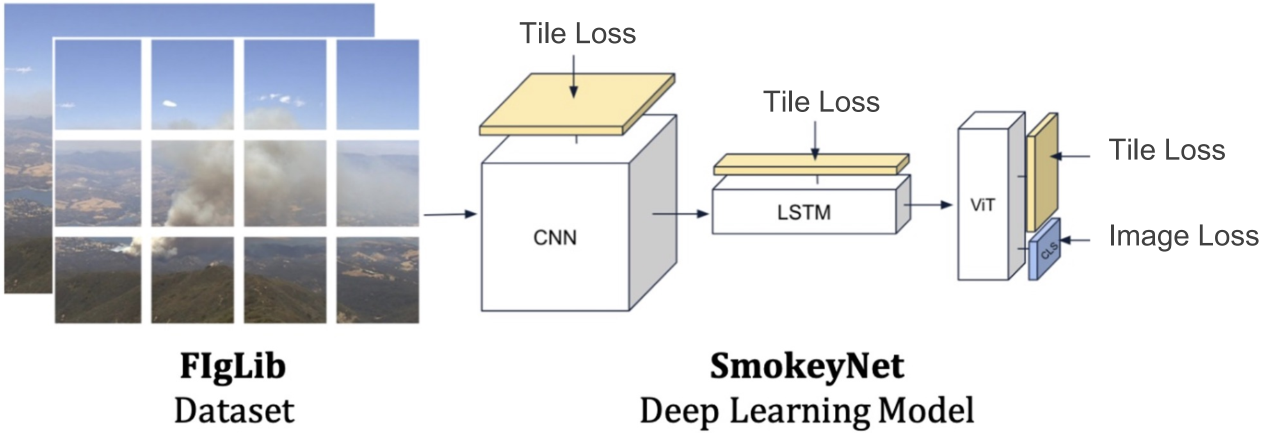
Namespace digits

NRP Nautilus

Summary

- SmokeyNet: Deep learning approach for detecting smoke plumes from wildfires
  - Can incorporate different data sources for multimodal wildfire smoke detection
  - Can be used for early notification of wildfires

- FIgLib: Dataset of labeled wildland fire images

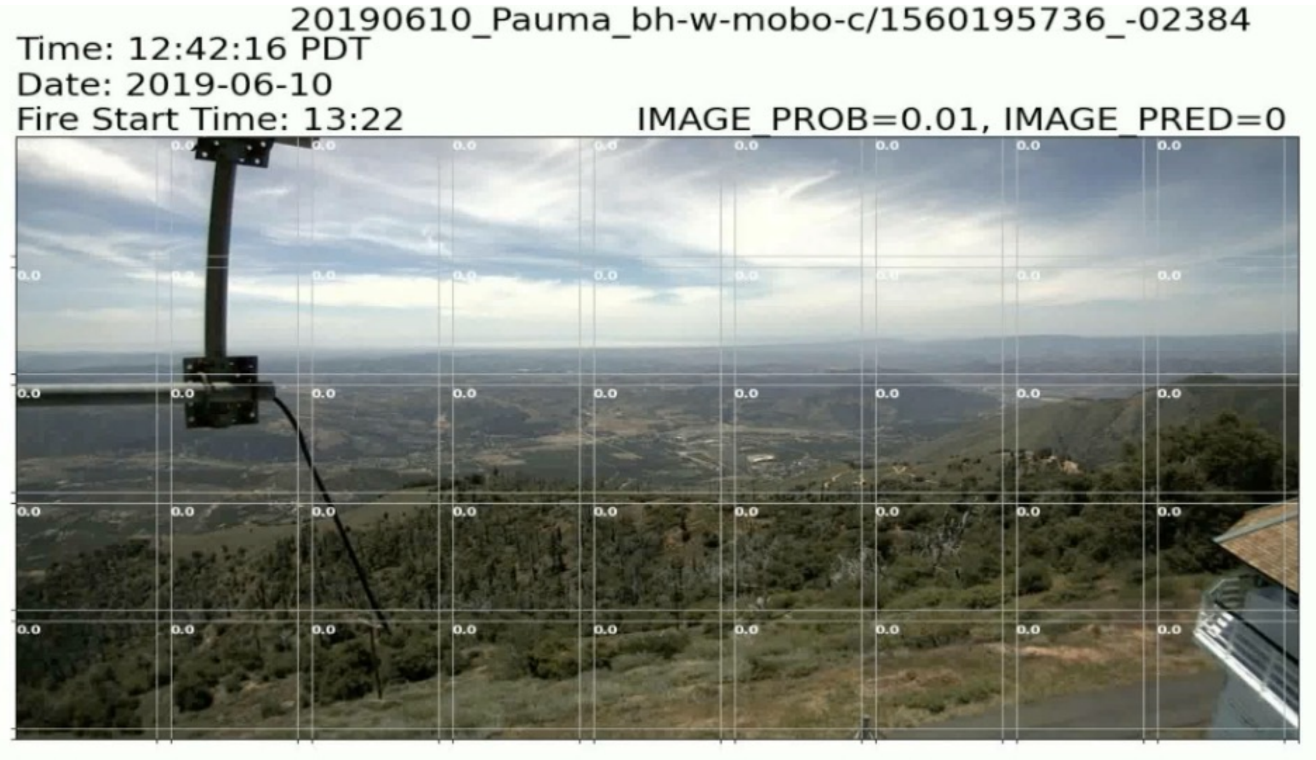


NRP NATIONAL RESEARCH PLATFORM

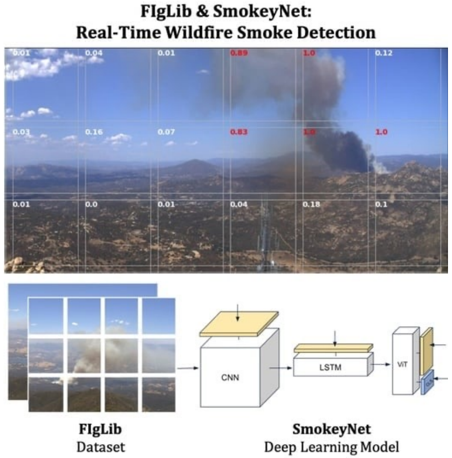
NRP Nautilus

Future Work

- Investigate use of unlabeled data to further improve detection
- Research ways to decrease false positives
- Test generality of approach to other geographical areas and camera types
- Deploy SmokeyNet as an early notification system for effective real-time wildfire smoke detection

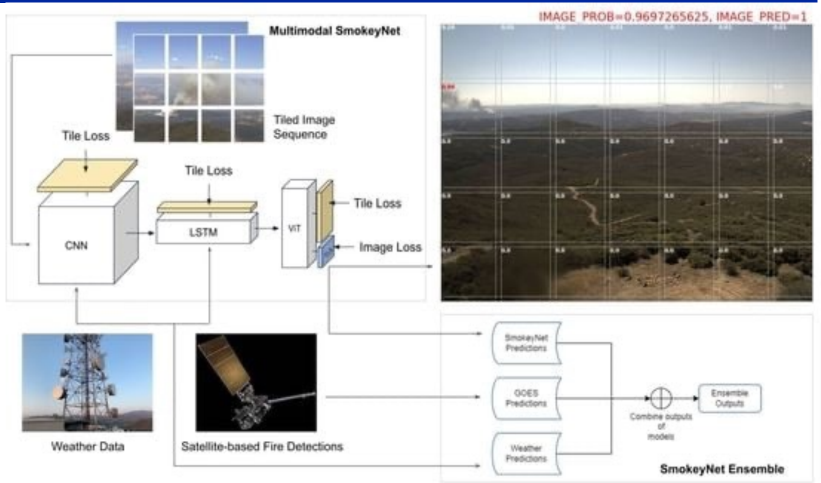


SmokeyNet References



J.K. Bhamra et al.,
Remote Sensing
15(11):2790
https://doi.org/10.3390/rs15112790

A. Dewangan et al.,
Remote Sensing
14(4):1007
https://doi.org/10.3390/rs14041007



kpbs
https://www.kpbs.org/news/science-technology/2023/09/06/can-artificial-intelligence-learn-to-spot-wildfires

Climate Change AI

NeurIPS Workshop on Tackling Climate Change with Machine Learning
https://www.kpbs.org/news/science-technology/2023/09/06/can-artificial-intelligence-learn-to-spot-wildfires

NRP NATIONAL RESEARCH PLATFORM

NRP Nautilus

WIFIRE

The **BurnPro^{3D}** platform gives our public sector partners **next-generation fire science** using **data** and **AI** to optimize prescribed burns at an unprecedented scale.

Collaborators & Acknowledgments


Siddhant Baldota


Jaspreet Kaur Bhamra


Shreyas Anantha Ramaprasad


Anshuman Dewangan


Yash Pande


Hans Werner Braun


Frank Vernon


Ravi Ramachandra


Eugene Zen


Harrison Kim


Shane Luna


Chris Schmidt


Chris Arends


Jessica Block


Ismael Perez


Daniel Crawl


Ilkay Atlintas


Gary W. Cottrell


Mai H. Nguyen

Scott Ehling
Cathy Peters

Funding Sources:
CHASE-CI
SDG&E

Computational Resources:
PRP/Nautilus/NRP

NRP NATIONAL RESEARCH PLATFORM

NRP Nautilus