Fire Detection with CNNs and Optical Flow

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Introduction

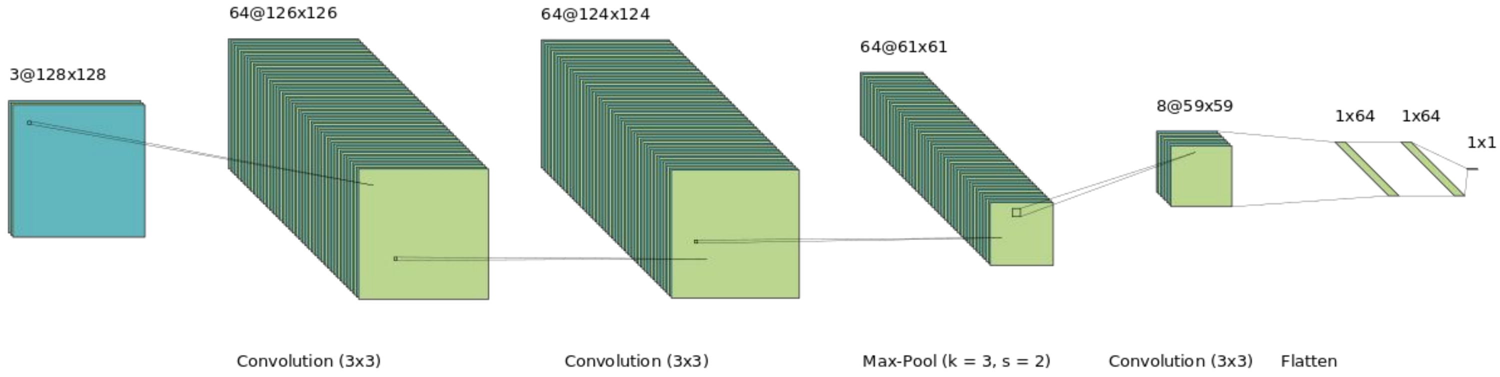
- 6,581 fire-related casualties recorded across forty-four cities over a four-year period (CTIF)
- Particle-based sensors are unreliable outdoors and slow
- Advances in digital camera technology and image processing opens the door for vision-based detection methods

Related Work

- Classic Computer Vision methods for fire detection:
  - Liu and Ahuja used shape and temporal features fires with a SVM classifier to classify fire images (2004)
  - Chen et al. (2004) used color segmentation and region growth (over time) to detect early fires in video feeds
- Optical Flow
  - Farneback Optical Flow is a lightweight method that uses polynomial approximation to estimate flow
  - Mueller et al. (2013) uses Optical Mass Transport to track fire mass and edge features across frames
- Deep Learning Based Methods
  - Muhammud et al. (2018) tuned GoogleNet for fire classification
  - Frizzi et al. (2016) used trained AlexNet-like architecture from scratch to classify and segment fire and smoke

Proposed Solution - Deep Learning

- Train a lightweight CNN on fire and no-fire images to give a label to frames in a video feed
- Resize to 128x128 and normalize with ImageNet values
- ~9k fire images from Roboflow, ~9k non-fire images from Places 365
- 80/10/10 train, val, test split



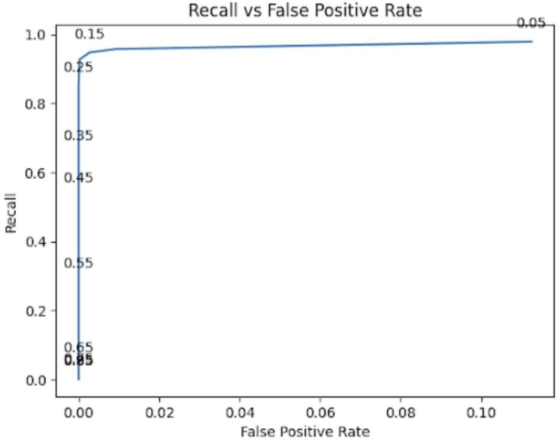
Proposed Solution - Optical Flow

- Calculate Farneback Optical flow between consecutive frames in video feed
- Determine magnitude of flow in regions with flame-like color
  - RGB values between (150,50,0) and (255,255,150) are considered flame-like
  - Generate mask from previous frame
- Calculate proportion of flow magnitude in flame regions out of the total flow magnitude

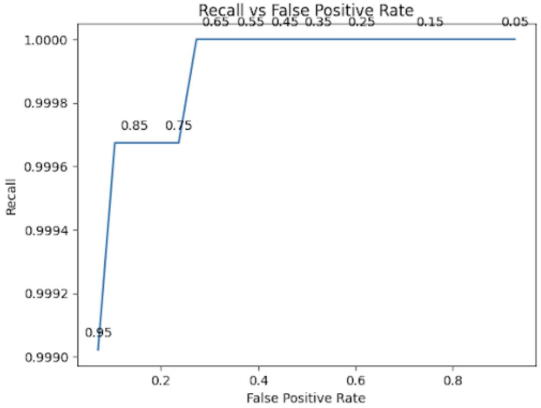
$$P_{\text{fire}} = \frac{\sum ||\vec{v}||_{\text{fire-colored}}}{\sum ||\vec{v}||_{\text{all pixels}}}$$

Results

Optical Flow



CNN



Test Video Results

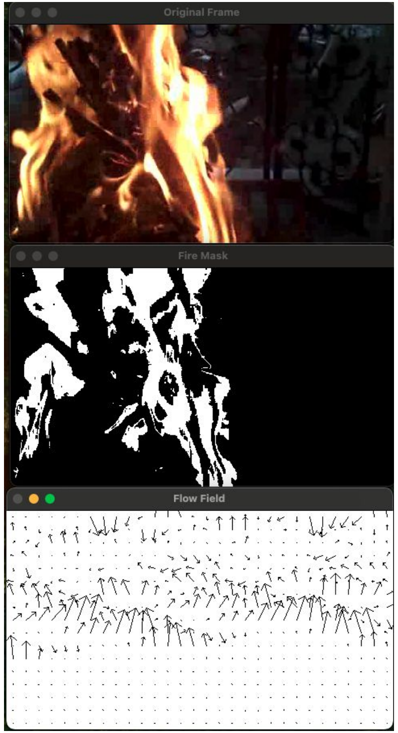
Model	Accuracy	Recall	FPR	Avg Time (ms)	FPS	t
CNN	0.9354	0.9997	0.1054	8.043	124.3	0.9
Optical Flow	0.9781	0.9478	0.0027	61.43	16.2	0.15

Demo + Extra Analysis

[Demos of both models]

First Layer of CNN

Optical Flow Field + Fire Masking



Conclusion

- We developed two frame-level models for real-time fire detection in live video streams
- The CNN-based model shows the most promise due to its high inference speed and strong generalizability across diverse fire patterns
- Optical Flow model excels at classifying large fires, but struggles to generalize to smaller fires
- Future Work
    - Temporal modeling with Recurrent or 3D CNNs
    - Optical Flow feature map in CNN
    - Reduce FPR or CNN