Forest Fire Detection Review Report

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Applications

The application on the wild fire can be sperated into 6 domians (the problem domain):

- fuels characterization, **fire detection and mapping**
- fire weather and climate change
- fire occurrence and risk
- **fire behavior prediction**
- fire effects
- **fire management**

ML Methods

The most often used ML model across all of the problem domains:

- Traditional Methods:
  - random forest (RF)
  - * maximum entropy (MaxEnt)[1]
  - artificial neural network (ANN)
  - decision tree (DT)
  - support vector machine (SVM)
  - genetic algorithm (GA)
- Modern Methods:
  - deep learning (including the CNN, LSTM and other object detection methods)
  - agent-based learning (including the Renforcement Learning)

[1] The item with * should be studied later if needed.

1. fuels characterization, **fire detection and mapping:**
   - **Detection (Classification + Regression problem → Object Detection):** Automatically detecting the wildfires as soon as possible, even it is realtively small, with heat signatures or smoke in infra-red or optical images, which can extend spatial and temporal coverage of the detection.
   - **Mapping (Classification):** Classify the burned and unburned area to get the perimeter
2. **fire behavior prediction (Regression)**[1]:
   The papers in this area mainly deal with the larger scale processes and characteristics to predict or estimate the fire spread rates, fire growth, burned area, and fire severity.
3. **fire management (Optimization, Regression)**:
   To have the appropriate amount of fire on the land.
   - Optimize the allocation of the people, watchtower or other fire-managing elements.
   - Estimate the relationship of the fire characteristics and the wild fire responds and even the social factors.

However, may be we can do more further about these applications!

[1] not sure.

The input data could be images, infra-images, multispectral images and MOIDS hotpot data from the UAVs, manned aircraft, watchtower, and satellite

Application Type	Traditional Methods	Modern Methods
fire detection	ANN+infra SVM+video GA+LiDAR ANFIS	CNN LSTM YOLO Optica-Flow 3D-CNN
fire mapping	RF ANN SVM GPR(GP regression) AdaBoost	DNN
fire behavior prediction	RF BNs KNN GA+physical model MDP	CNN LSTM
fire management	GA(optimization) BN ANN	\

Table: proposed methods

- **Traditional Methods:** Usually extract the images' feature with the computer vision technology, for example, the color(may under differernt color sapce) , texture, feature descriptors, etc.
- **Modern Methods:** usually the end-to-end model, use the convolution layers to 'extract features', the features are usually incomprehensible.
- **Mixed Methods:** Fast-RCNN, Faster-RCNN+feature selecting based on fuzzy logic

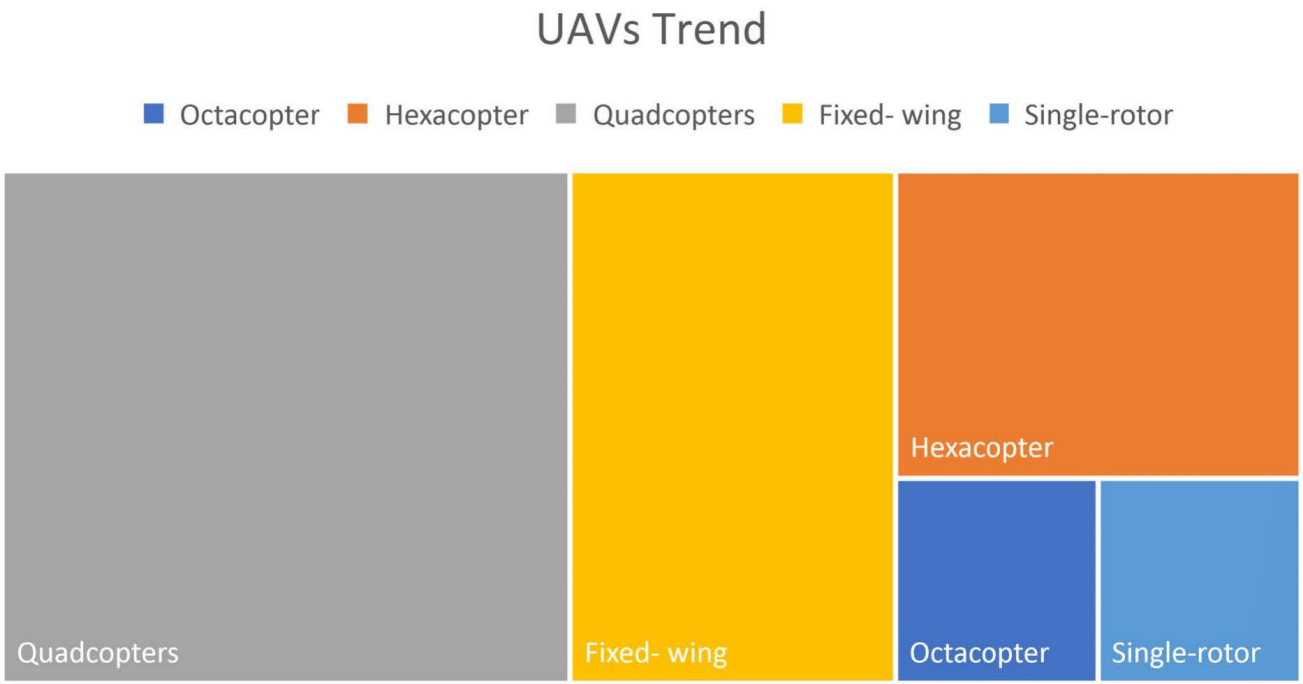
Computer Vision for Fire Detection on UAVs—From Software to Hardware

—— Algorithm

The UAVs with the payload on them(thermal camera, RGB camrea, etc.), the fire detection algorithms and the open data set of the forest fire are introduced.

- **Fire Detection Framework:**
  - Preprocessing: reduce the noise, normalization, etc.
  - Segmentation: based on the colors, motion or even intensities.
  - Fire Detection and Feature Extracting: Feature is aimed to identify the key points of interest.
- Traditional Methods:
  - Optimal Residual Network-Based Features Extraction algorithm (O-RNBFE) for feature extraction and a Latent Variable Support Vector Machine (LVSVM) for classification.
  - descriptor: Gray Level Co-occurrence Matrix (GLCM), Spatial and Geometric Histograms (SGH) descriptor, Local Binary Pattern (LBP)
- But the **Deep Learning-based methods** greatly simplify the segmentation and feature extracting.
  - VGG-16, Resnet34, Resnet50, U-Net and MobileNet
  - Faster-RCNN
  - YOLO
  - Mobilenet(lightweight framework, see also YOLO-fast, YOLO-tiny and Mobilenet-SSD)
  - SSD(Single Shot MultiBox Detector)
- **Softwares:**
  - ROS
  - OpenCV
  - DroneDeploy+PIX4D

- UAVs classifications and Trends:



- Cameras: Visible Spectrum, IR System, Multispectral/Hyperspectral
- Platform: Raspberry, ARM, FPGA, IMU, GPS, GNSS, On-board Computer.

Design and Implementation of a Drone-based Forest Fire Monitoring System Including an Exclusive Hardware-in-the-Loop Simulator

A fire detection drone system is developed which can be separated into 3 parts:

- **Autopilot Design**:
  - Hardware choosing and design(embeded system design)
  - Flight control algorithm design and implementation:
    Including the state estimation, control and waypoint navigation.
- Ground Control Station designing and implementation
- **Simulation software design and implementation**
  - Dynamic model implementation
  - Data communication designing

Ideas:

- The detecting methods could be improved.
- Processing the images on the on-board computer instead of the Autopilot.

Conclusion and Ideas:

Conclusions:

- The ML application in wild fire is following after the framework the standalone ML models.
- The work associated with the predictive problem (e.g., predicted fire behavior) or prescriptive analytics (e.g. optimizing fire management decisions) has relatively less number than that in other problem domains.
- In terms of vehicles, multicopters seem to be the most suitable for such applications

Ideas:

- The drones can combine with the more wild fire science tightly, not only act as a platform to load the equipments. In other words, the application such as 'control and navigation applications in the wild fire can be developed.'
- 3 (or even more) scales should be used to classify the researches in the wild fire:
  - Large scale: Fire line, fire moving direction etc.
  - Middle scale: fire zone, fire rough location.
  - Small scale: Detailed fire map.

Conclusion and Ideas:

Combine the wildfire application with UAVs and Drones advantages: High Flexibility→Diving into forest.

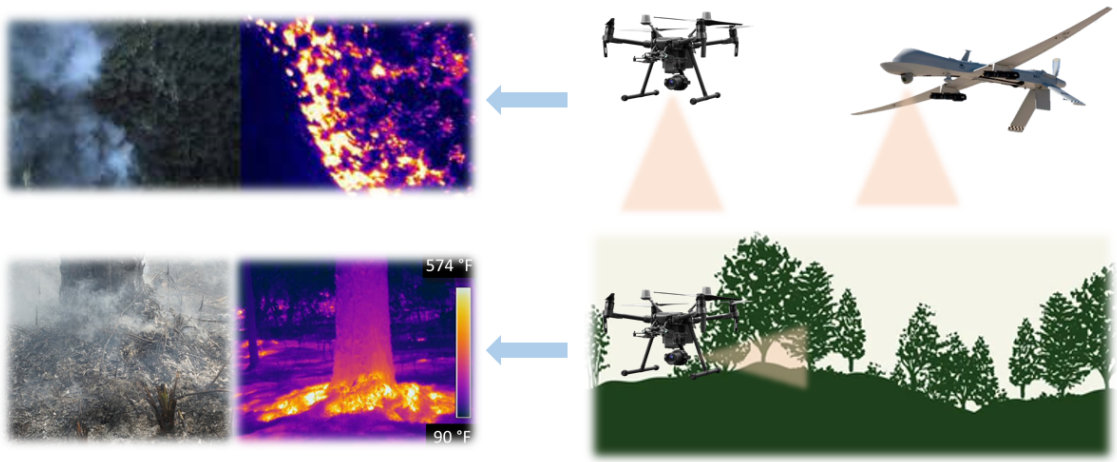


Figure: different missions according to the altitude

Ideas:

- Thermal, LiDAR and vision-based navigation method for wildfire UAVs
- Detection and Mapping:
  - Smoldering detecting and mapping
  - Thermal-aided SLAM for wildfire
- Prediction: Estimate the wind direction and strength from the **smoke**
- Management: Path planning for the fireman and fire robots.

References

[1] Jain P; Coogan S.C.P; Flannigan M.D; Subramanian S.G; Crowley M; Taylor S. A Review of Machine Learning Applications in Wildfire Science and Management. Environmental Reviews 2020, 28 (4), 478–505 DOI: 10.1139/ er-2020-0019.

[2] Moumgiakmas, S. S.; Samatas, G. G.; Papakostas, G. A. Computer Vision for Fire Detection on Uavs—from Software to Hardware. Future Internet 2021, 13 (8), 200–200 DOI: 10.3390/fi13080200.

[3] Hossein Jamshidi. Design and Implementation of a Drone-based Forest Fire Monitoring System Including an Exclusive Hardware-in-the-Loop Simulator

Thank you!