TAT-11: Earth Observation and Machine Learning for Disaster Mapping
Mediterranean Agronomic Institute of Chania (CIHEAM Chania)
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Deep Learning (and AI) in Fire Mapping

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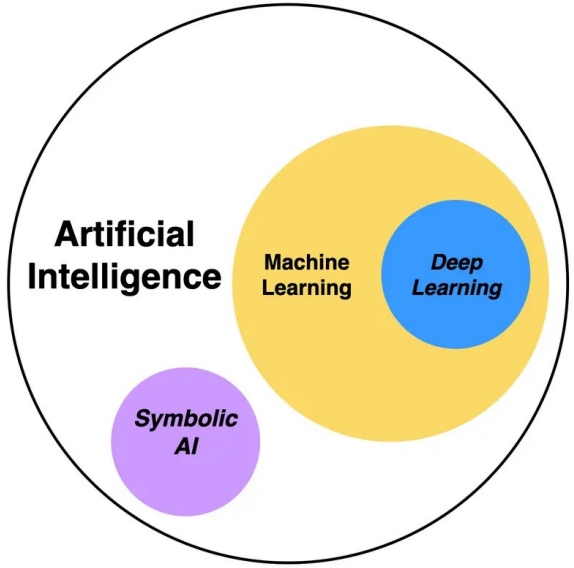
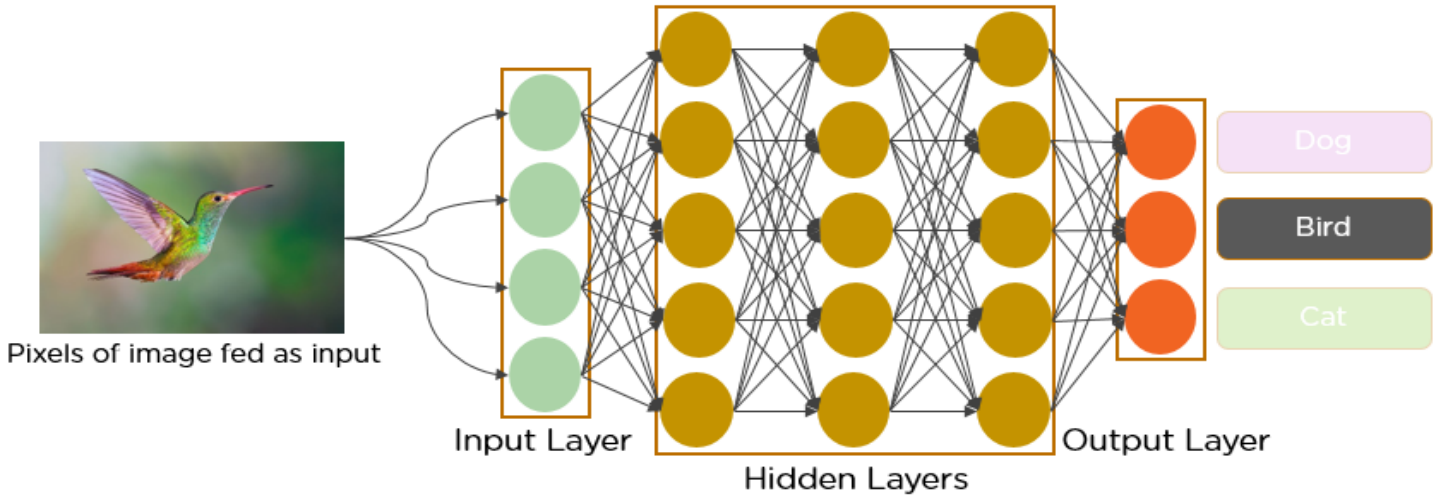
What is Artificial Intelligence?

- Technology that enables computers and machines to simulate human intelligence and problem-solving capabilities
- Catchy term coined in 1956 by John McCarthy (developed of the Lisp family of programming languages)
- Funding fathers: Alan Turing, John McCarthy, Marvin Minksy, Nathaniel Rochester, Claude Shannon
- Several sub-fields:
  - Symbolic AI
  - Large Language Models (LLMs)
  - Machine learning
  - Pattern recognition
  - Deep learning



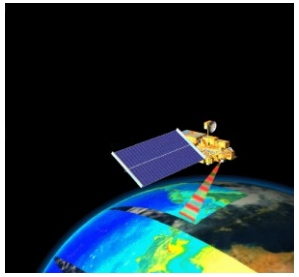
What is Deep Learning?

- A method in artificial intelligence (AI) that teaches computers to process data in a way that is inspired by the human brain
- Deep learning models can recognize complex patterns in pictures, text, sounds, and other data to produce accurate insights and predictions

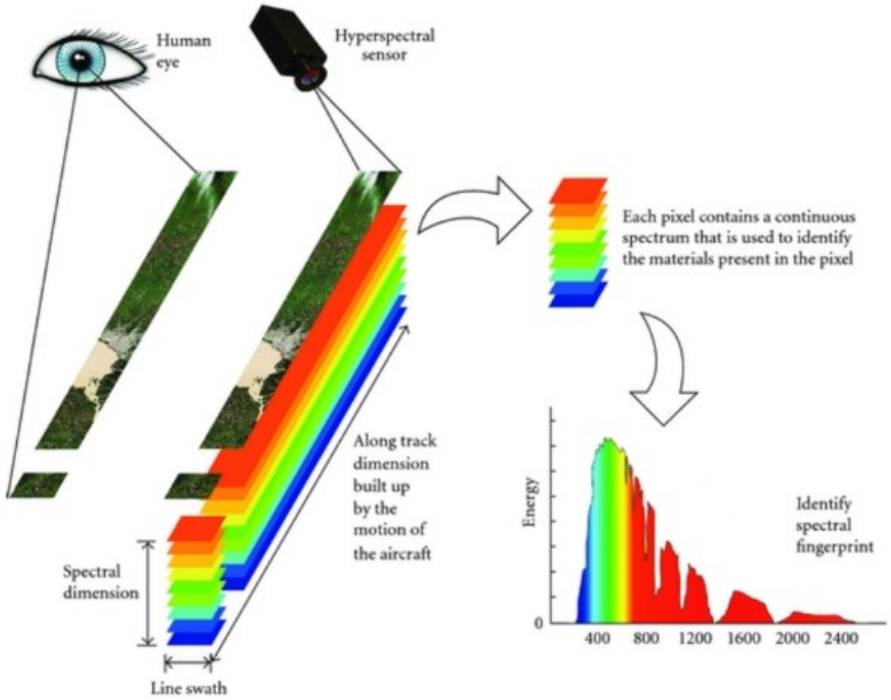


Convolutional Neural Networks architecture (example)

Fire monitoring tools/sensors

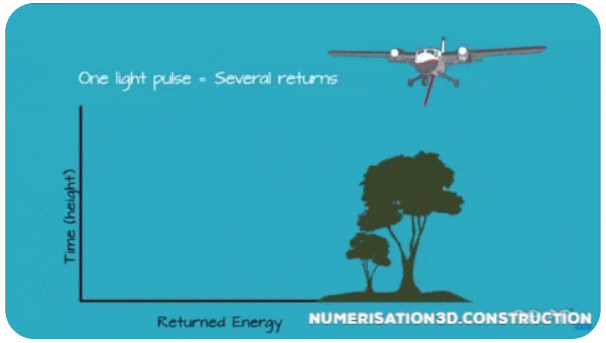


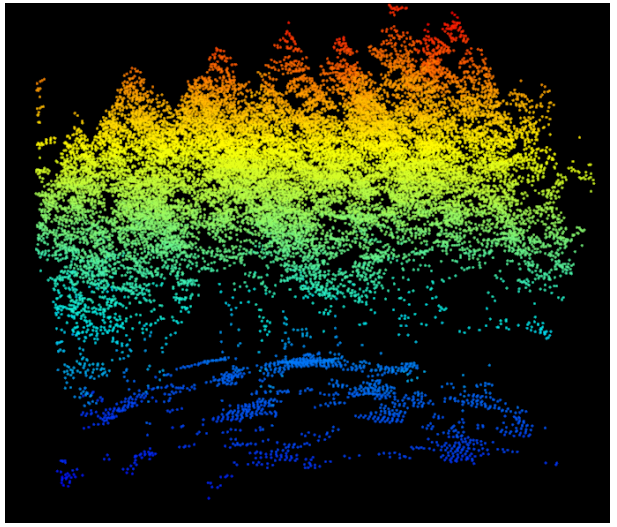
- A variety of available remote sensing data:
  - **Multispectral and hyperspectral optical sensors,** recording (except for the visible) the non-visible part of the sun's electromagnetic spectrum

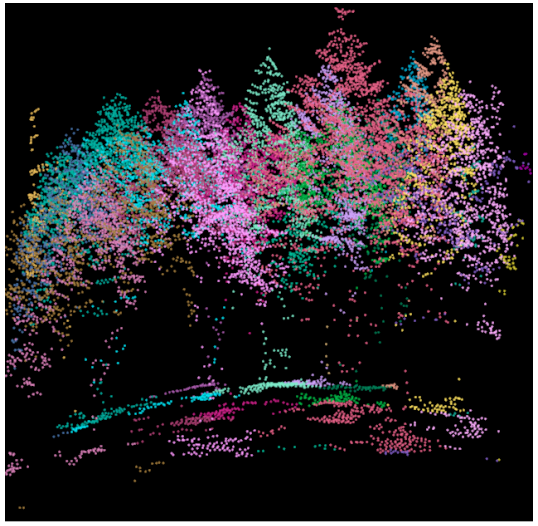


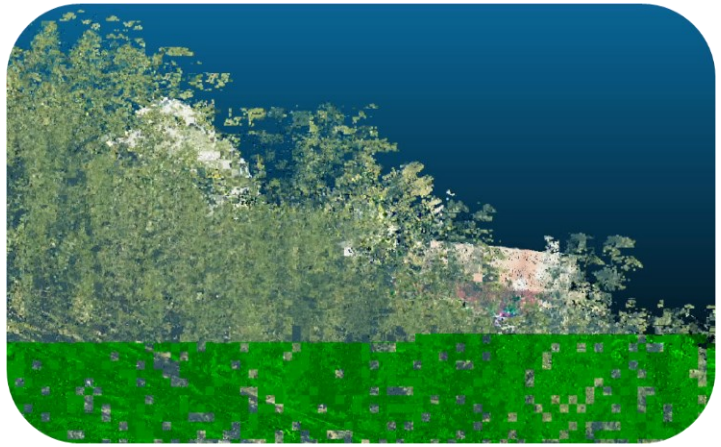
Fire monitoring tools/sensors

- A variety of available remote sensing data:
  - **Point clouds** derived from Unmanned Aerial Vehicles systems (**UAV** — UAS — drones) and active **LiDAR** sensors







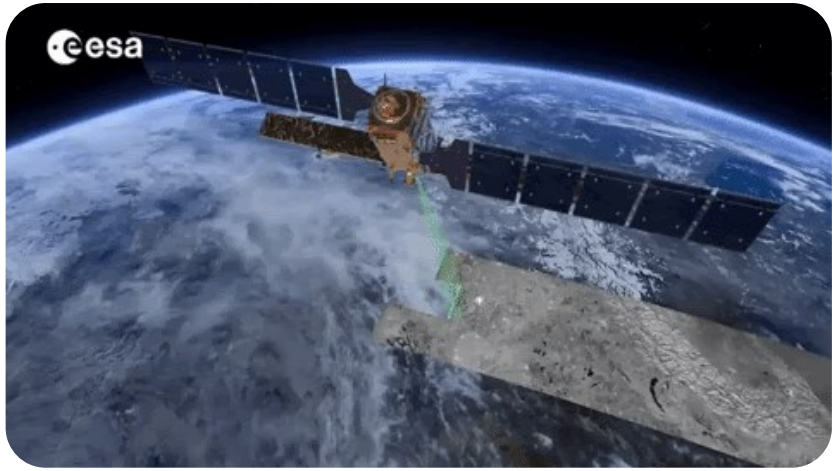


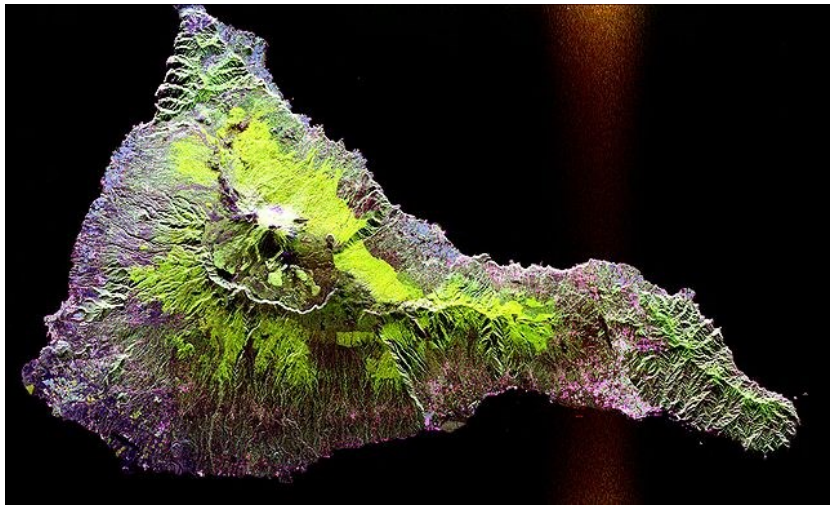
Fire monitoring tools/sensors

- A variety of available remote sensing data:
  - **Cameras & video devices** on terrestrial sensors or droned

Fire monitoring tools/sensors

- A variety of available remote sensing data:
  - **Satellite Synthetic Aperture Radar (SAR),** providing vegetation height and vertical structure





Artificial Intelligence tools

- The volume, the acquisition frequency and the high-resolution characterizing these data pose problems in their analysis
- Need for automated “artificial intelligence” processes:
  - Machine learning
  - Pattern recognition
  - Statistical models
  - Deep learning

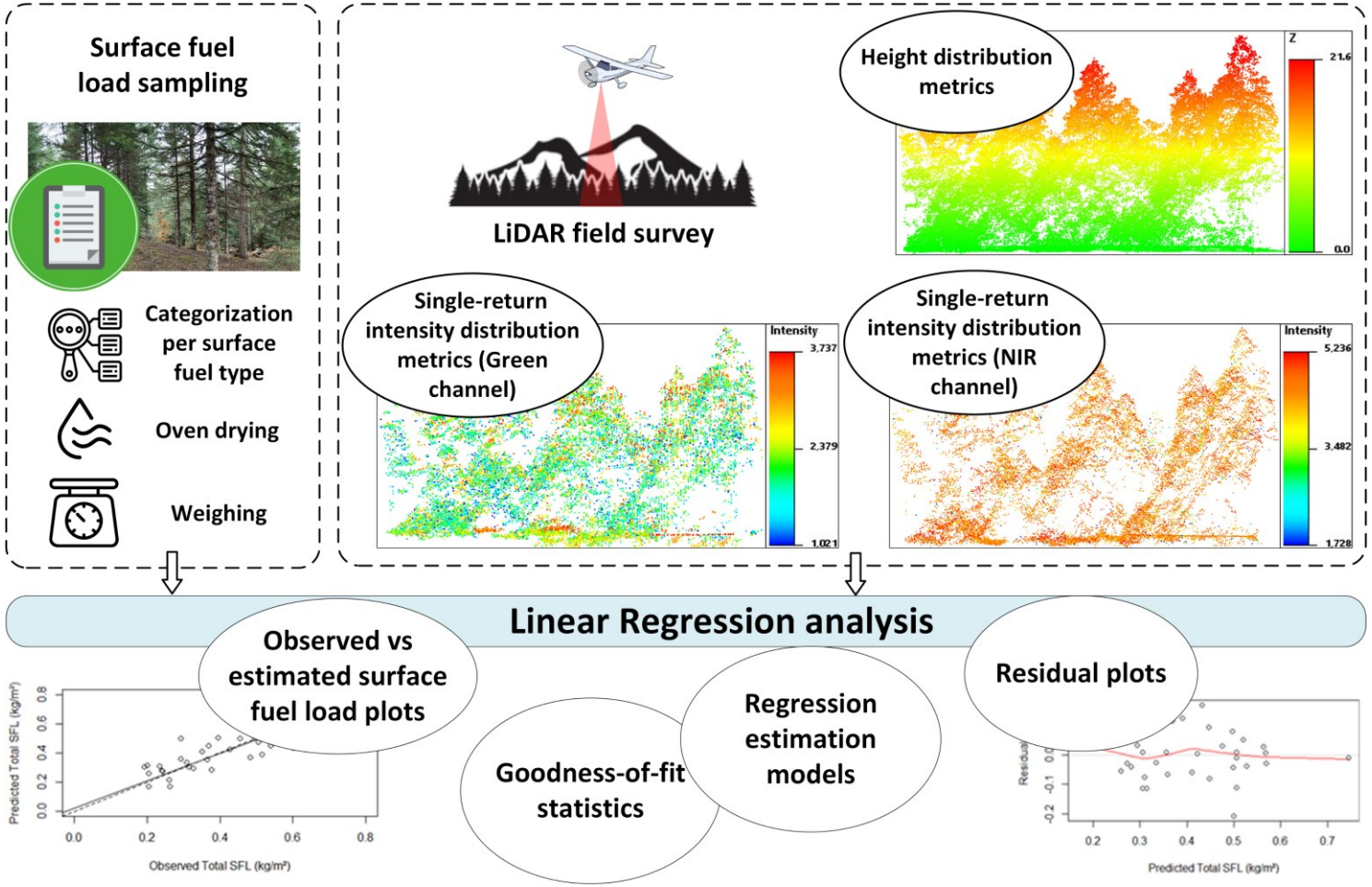
Fuel Mapping

Fuel types/models mapping

- Forest fuels: Any living or dead organic matter available for combustion.
- Fuel types: They describe the physical characteristics of fuels that exhibit specific combustion behaviour under specified fire conditions.
- Fuel models: Numerical description of fuel types.




Estimation of fuel properties



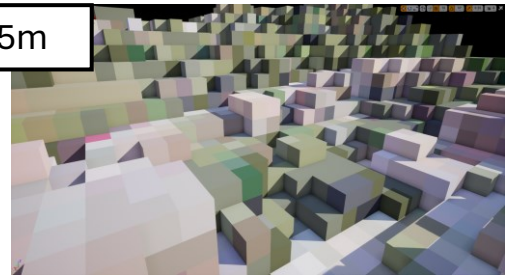
- Use of LiDAR data and machine learning models for surface fuel load estimation

Stefanidou, A.; Z. Gitas, I.; Korhonen, L.; Georgopoulos, N.; Stavrakoudis, D. Multispectral LiDAR-Based Estimation of Surface Fuel Load in a Dense Coniferous Forest. Remote Sens. 2020, 12, 3333. https://doi.org/10.3390/rs12203333

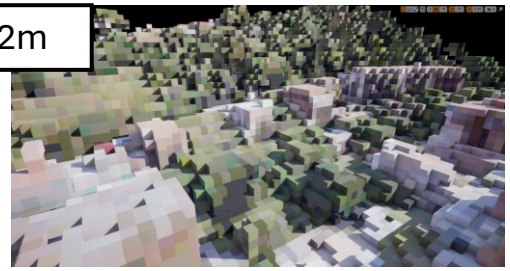
Point Cloud Segmentation for Fuel Type Classification

Point cloud (LiDAR, RGB,...) → Voxelization

5m

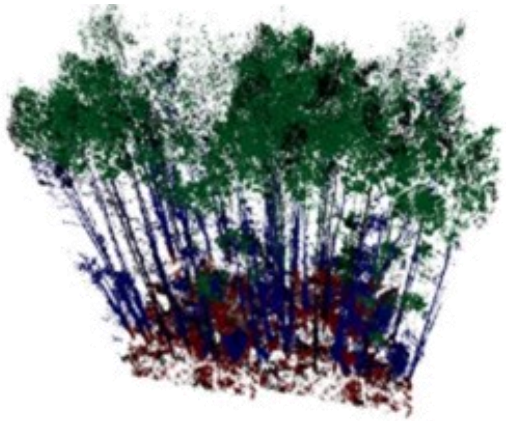


2m

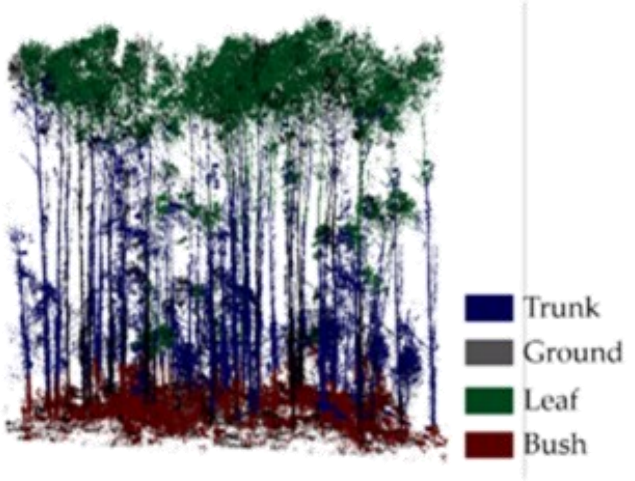


1m

Fuel (canopy, bark, understory, shrub, etc.) & buildings classification via Graph Convolutional Networks (e.g., Zhang et al., 2023)



(b)



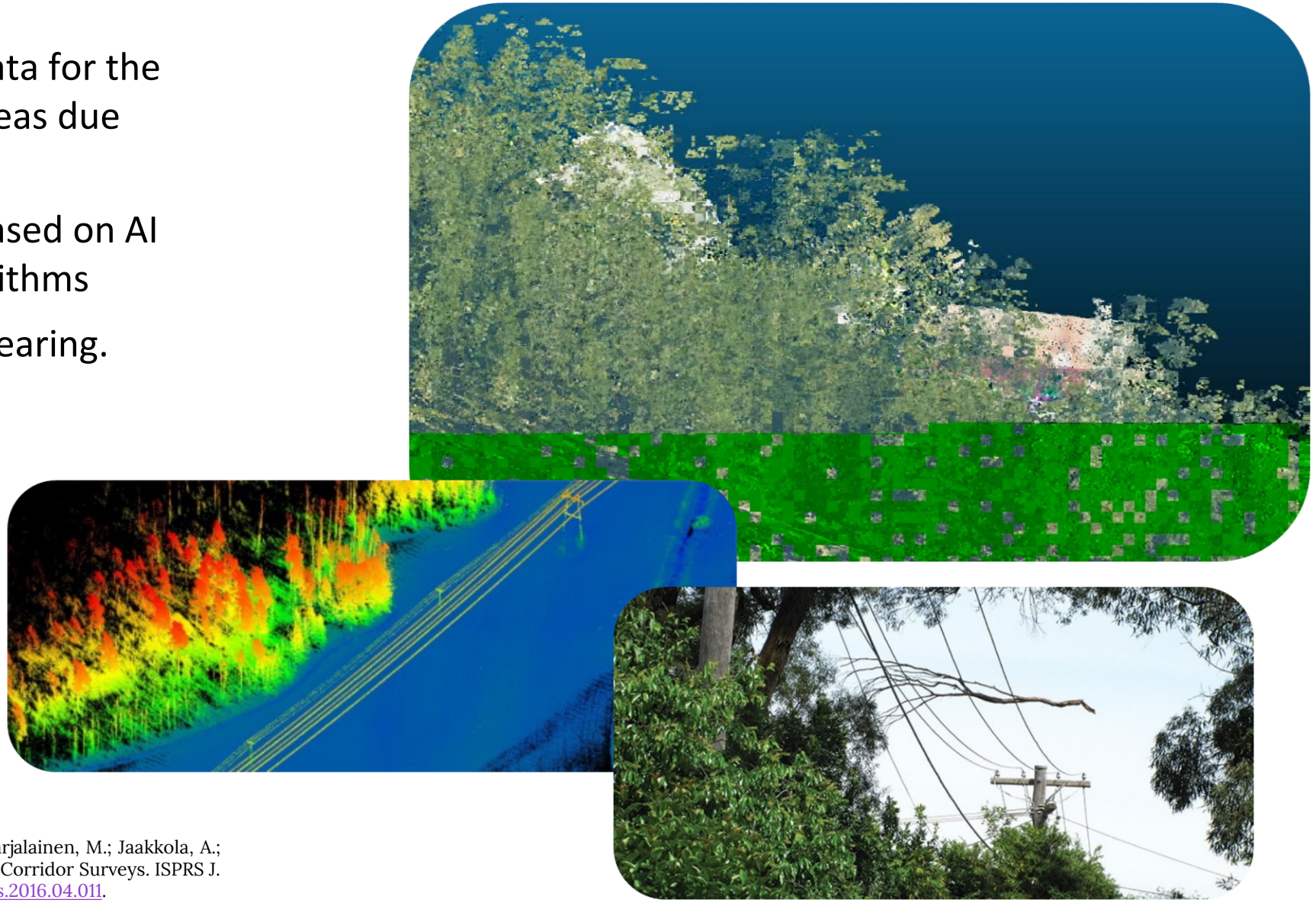
Source: Ma Z, Dong Y, Zi J, Xu F, Chen F. 2023. Forest-PointNet: A Deep Learning Model for Vertical Structure Segmentation in Complex Forest Scenes. Remote Sensing. 15(19):4793. https://doi.org/10.3390/rs15194793

WUI mapping using UAV point clouds

- Fuel mapping in WUI (Wildland Urban Interface) areas
- Use of point clouds derived from very high-resolution aerial photos acquired by UAVs
- 3D vegetation representation
- Use of contemporary deep learning techniques (i.e., graph convolutional neural networks) for the detailed vegetation and residential buildings mapping

WUI mapping using UAV/LiDAR point clouds

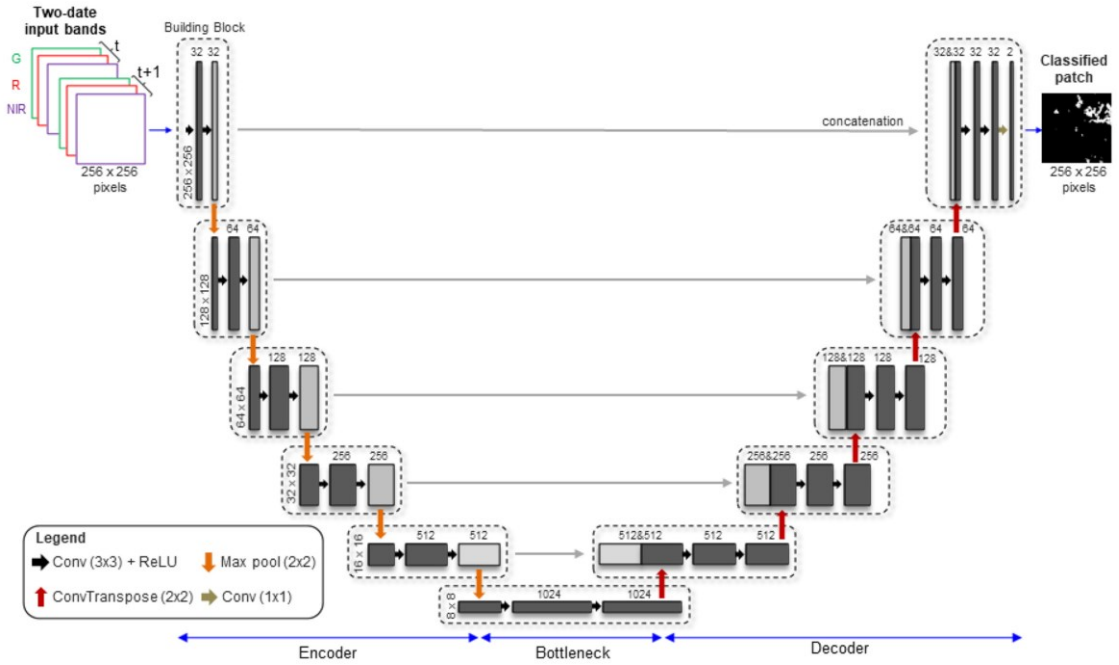
- Use of LiDAR or/and UAV data for the detection of endangered areas due to power lines crossing.
- Automated methodology based on AI (Artificial Intelligence) algorithms
- Identification of areas for clearing.



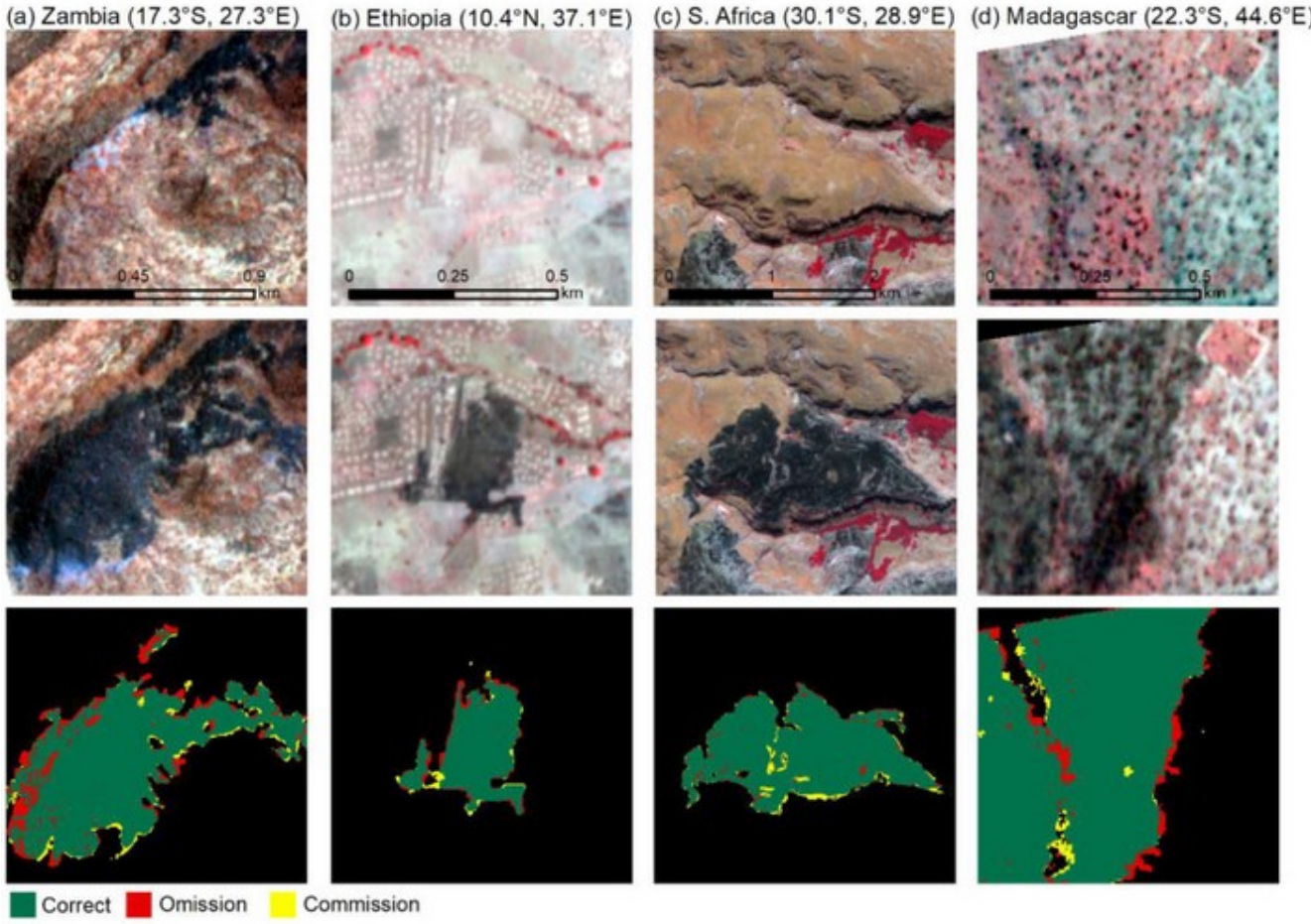
Source: Matikainen, L.; Lehtomäki, M.; Ahokas, E.; Hyyppä, J.; Karjalainen, M.; Jaakkola, A.; Kukko, A.; Heinonen, T. Remote Sensing Methods for Power Line Corridor Surveys. ISPRS J. Photogramm. Remote Sens. 2016, 119, 10–31, doi:10.1016/j.isprsjprs.2016.04.011.

Burned area mapping

Burned Area Mapping using Deep Learning



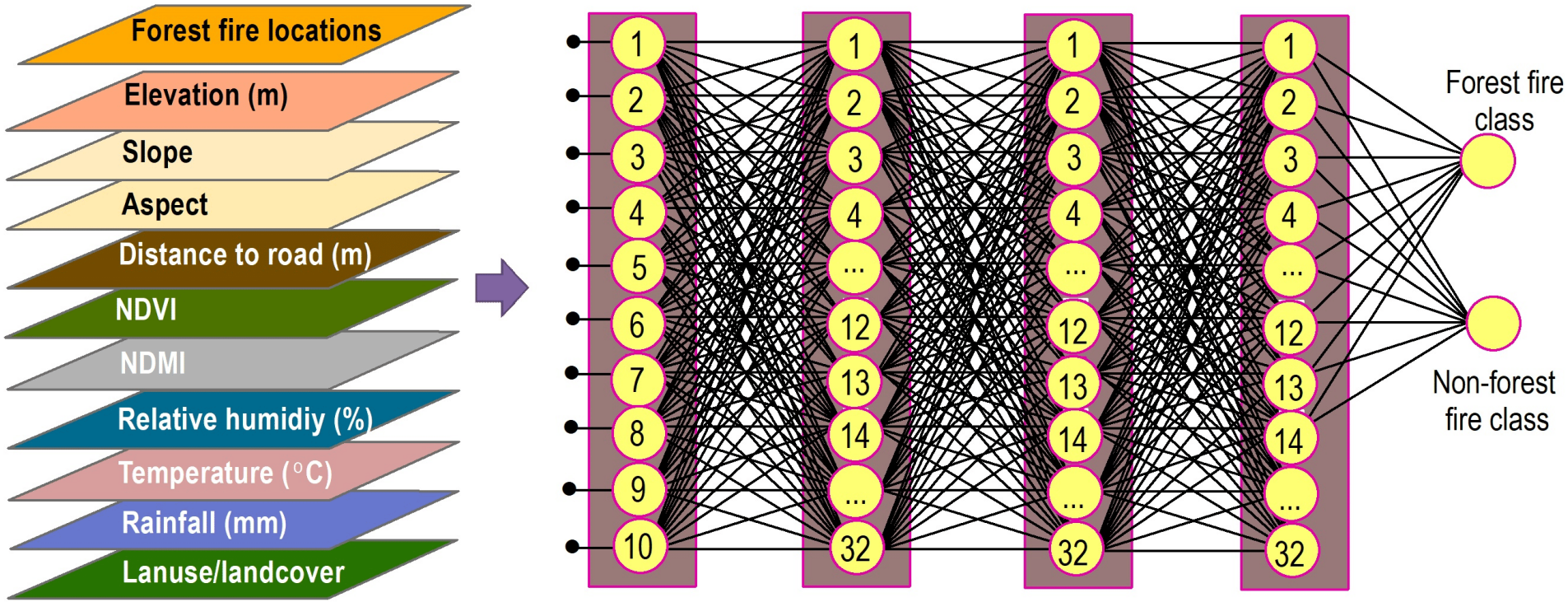
Algorithm architecture

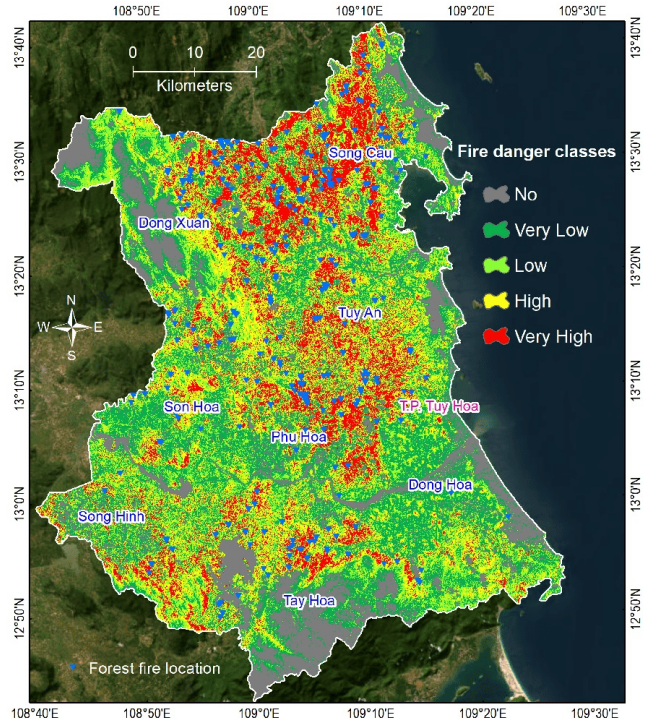


Examples of burned area classification results

Source: Martins VS, Roy DP, Huang H, Boschetti L, Zhang HK, Yan L. 2022. Deep learning high resolution burned area mapping by transfer learning from Landsat-8 to PlanetScope. Remote Sensing of Environment. 280:113203. https://doi.org/10.1016/j.rse.2022.113203

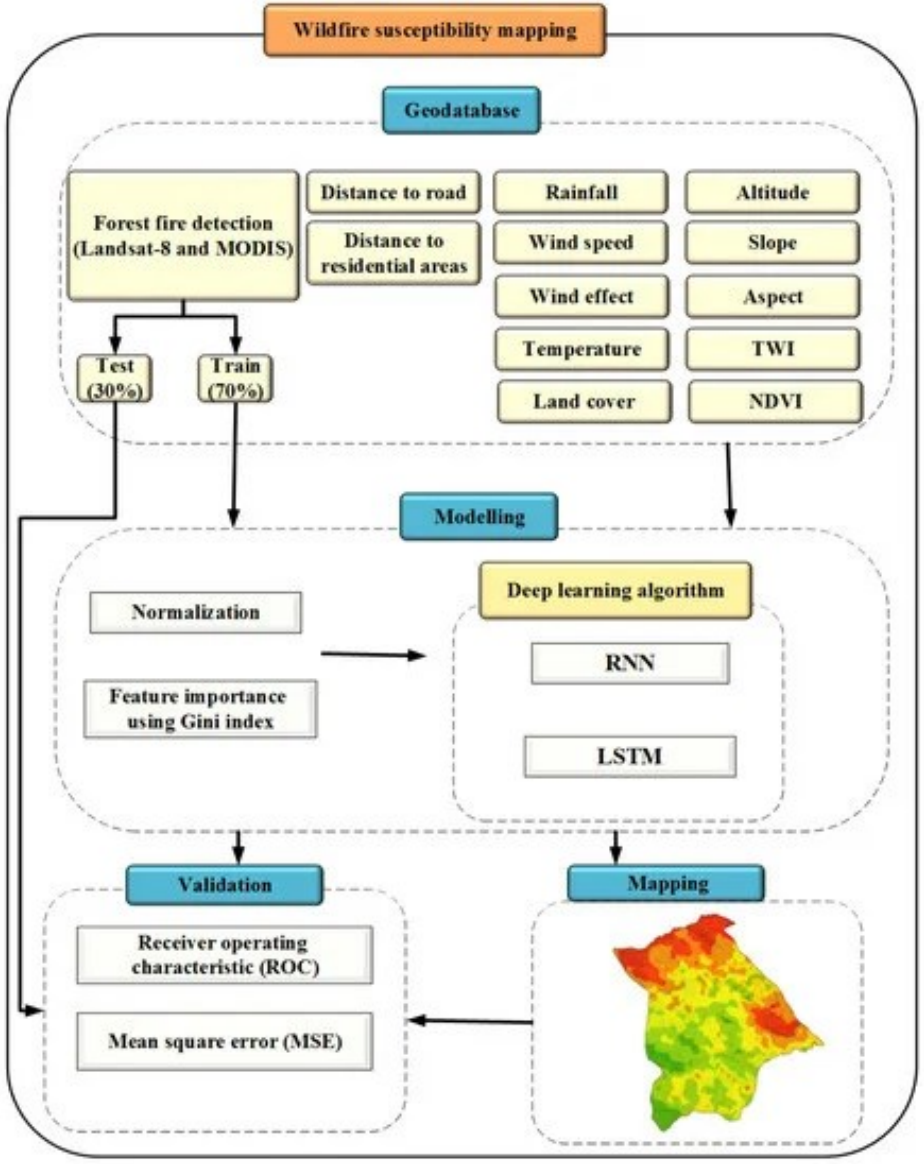
Fire Danger Prediction using Deep Learning

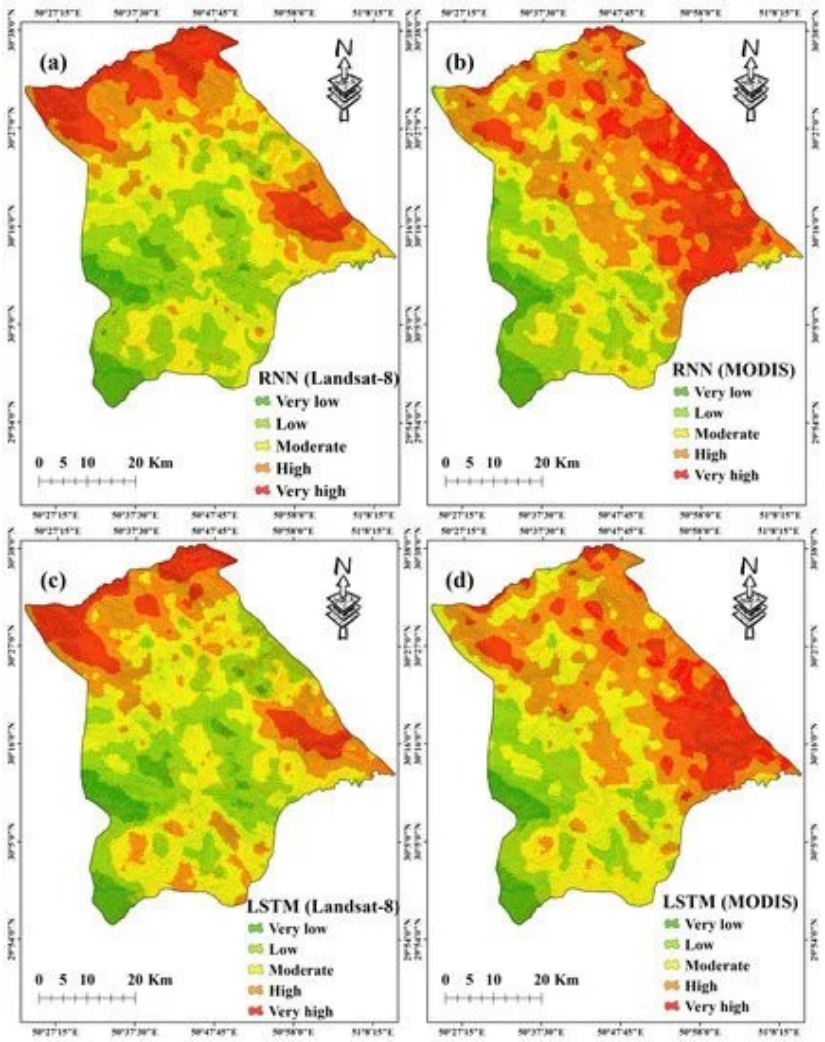




Source: Truong TX, Nhu V-H, Phuong DTN, Nghi LT, Hung NN, Hoa PV, Bui DT. 2023. A New Approach Based on TensorFlow Deep Neural Networks with ADAM Optimizer and GIS for Spatial Prediction of Forest Fire Danger in Tropical Areas. Remote Sensing. 15(14):3458. https://doi.org/10.3390/rs15143458

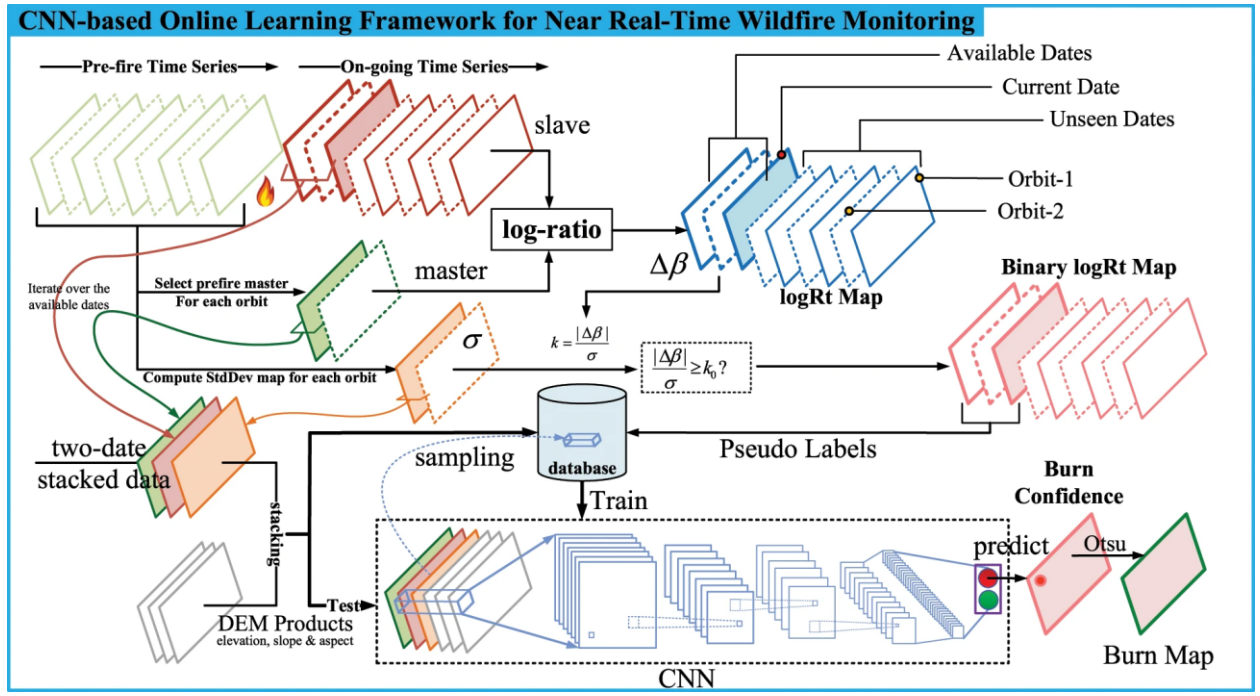
Fire Susceptibility Mapping using Deep Learning

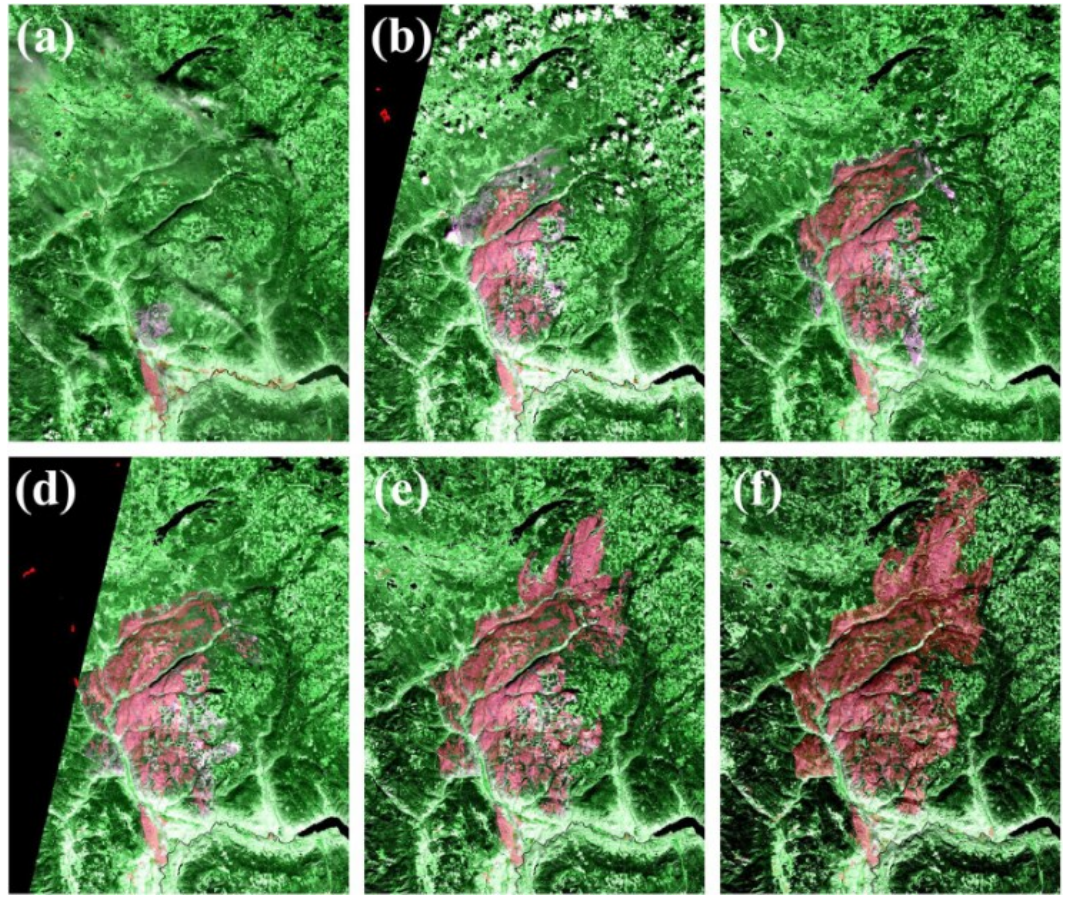




Source: Bahadori N, Razavi-Termeh SV, Sadeghi-Niaraki A, Al-Kindi KM, Abuhmed T, Nazeri B, Choi S-M. 2023. Wildfire Susceptibility Mapping Using Deep Learning Algorithms in Two Satellite Imagery Dataset. Forests. 14(7):1325. https://doi.org/10.3390/f14071325

Wildfire Progression Monitoring using Deep Learning



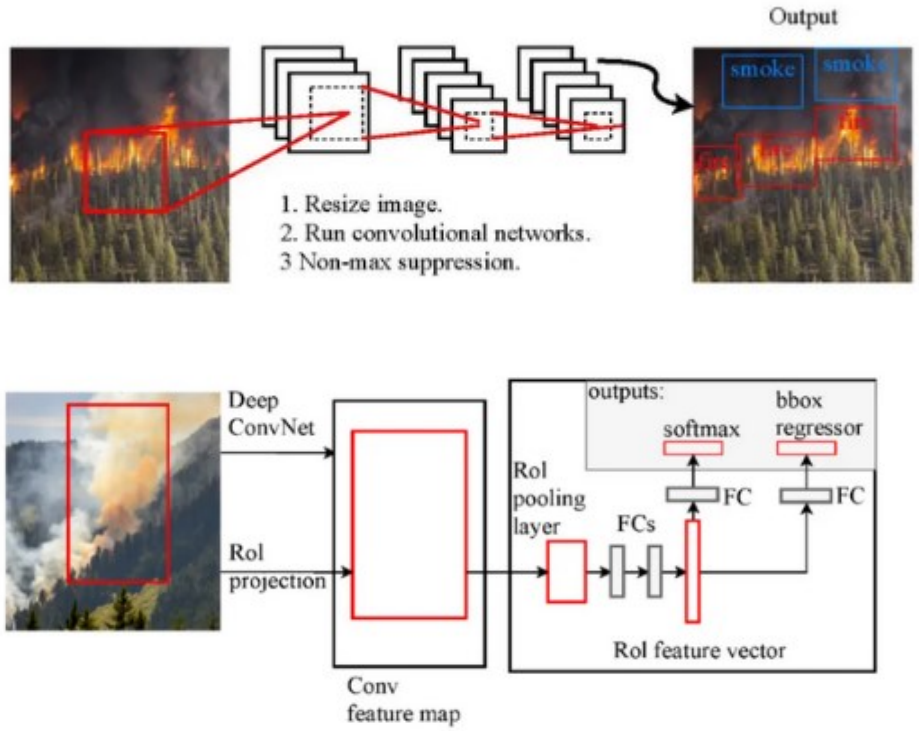


Example of Sentinel-1 based wildfire progression maps

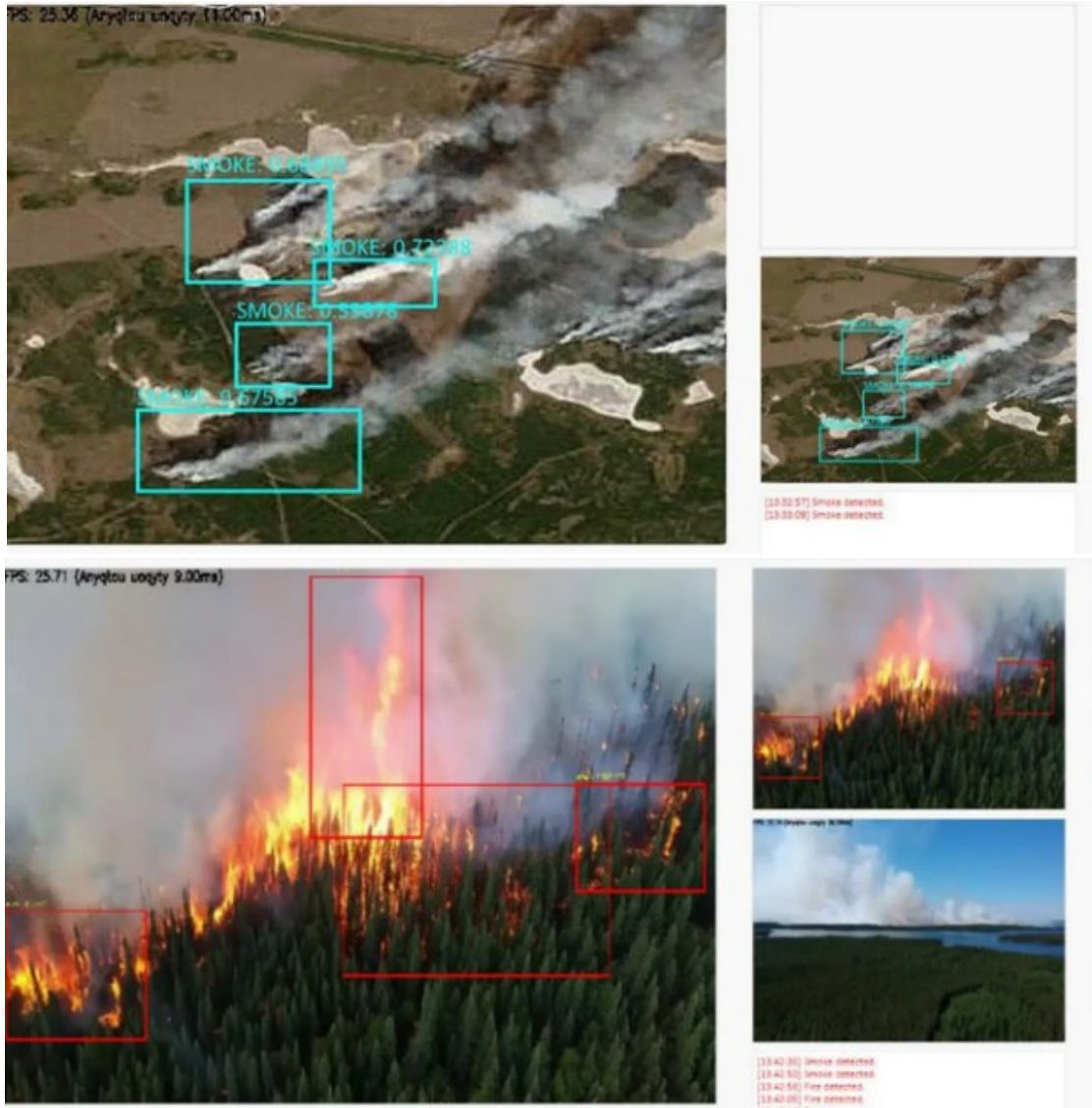
Source: Ban Y, Zhang P, Nascetti A, Bevington AR, Wulder MA. 2020. Near Real-Time Wildfire Progression Monitoring with Sentinel-1 SAR Time Series and Deep Learning. Sci Rep. 10(1):1322. https://doi.org/10.1038/s41598-019-56967-x

Fire Detection

Fire Detection using Deep Learning



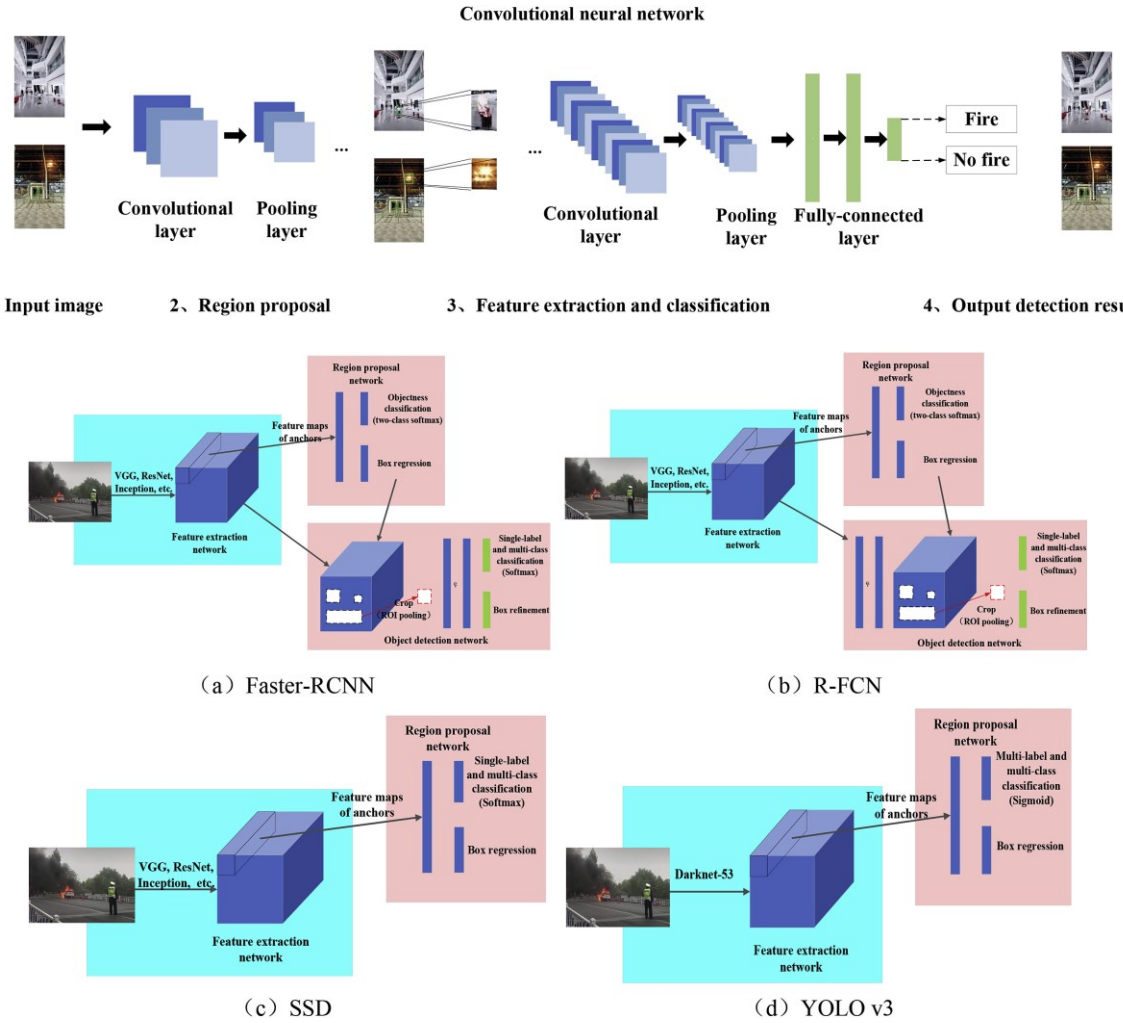
Algorithms' architecture

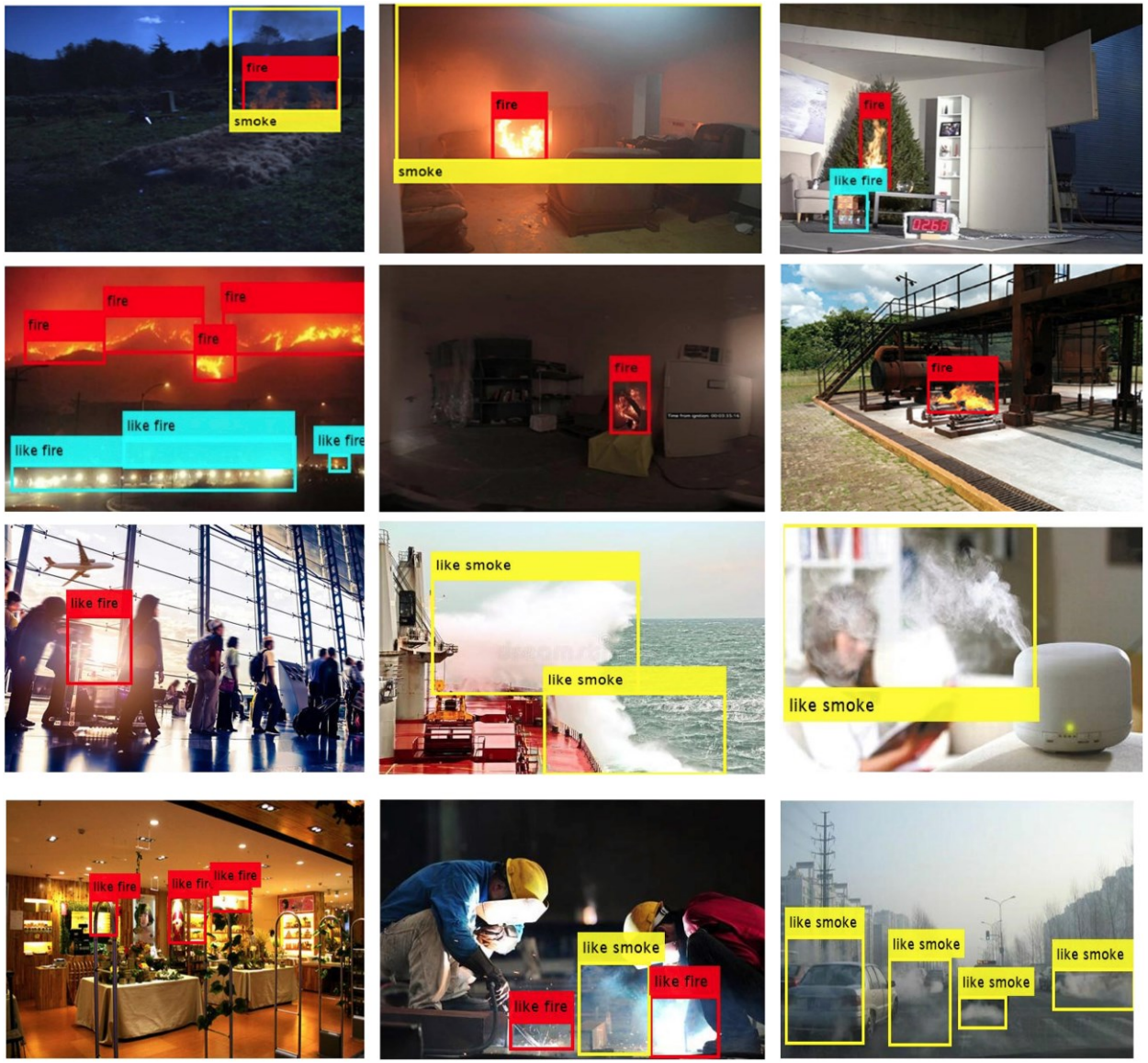


Fire & smoke detection

Source: https://www.slideshare.net/slideshow/fire-detection-using-deep-learning-methods/265111168

Fire Detection using Deep Learning





Diagrams of fire detection algorithms based on the four CNNs.

Source: Li P, Zhao W. 2020. Image fire detection algorithms based on convolutional neural networks. Case Studies in Thermal Engineering. 19:100625. https://doi.org/10.1016/j.csite.2020.100625

Fire smoke detection

- Automated smoke detection through static cameras and image analysis algorithms → early warning
- Use of Neural Networks (Attention Enhanced Bidirectional Long Short-Term Memory Network — ABi-LSTM)

Cao, Y.; Yang, F.; Tang, Q.; Lu, X. An Attention Enhanced Bidirectional LSTM for Early Forest Fire Smoke Recognition. IEEE Access 2019, 7, 154732–154742, doi:10.1109/ACCESS.2019.2946712.

Fire smoke detection

Source: https://www.embention.com/news/drones-against-forest-fires/

Source: https://www.flytbase.com/blog/drone-fire-fighting

Thank you for your attention!

Communication

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