Sensing and Big Data Analytics for Natural Disaster Management

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Version 2.1

Artificial Intelligence & Information Analysis Lab

Big Data Analytics for Natural Disaster Management

- **Natural Disaster Management**
- NDM Concept and Objectives
- NDM Sensing
- Big NDM Data Analytics
- Horizon Europe R&D project TEMA

Natural Disaster Management

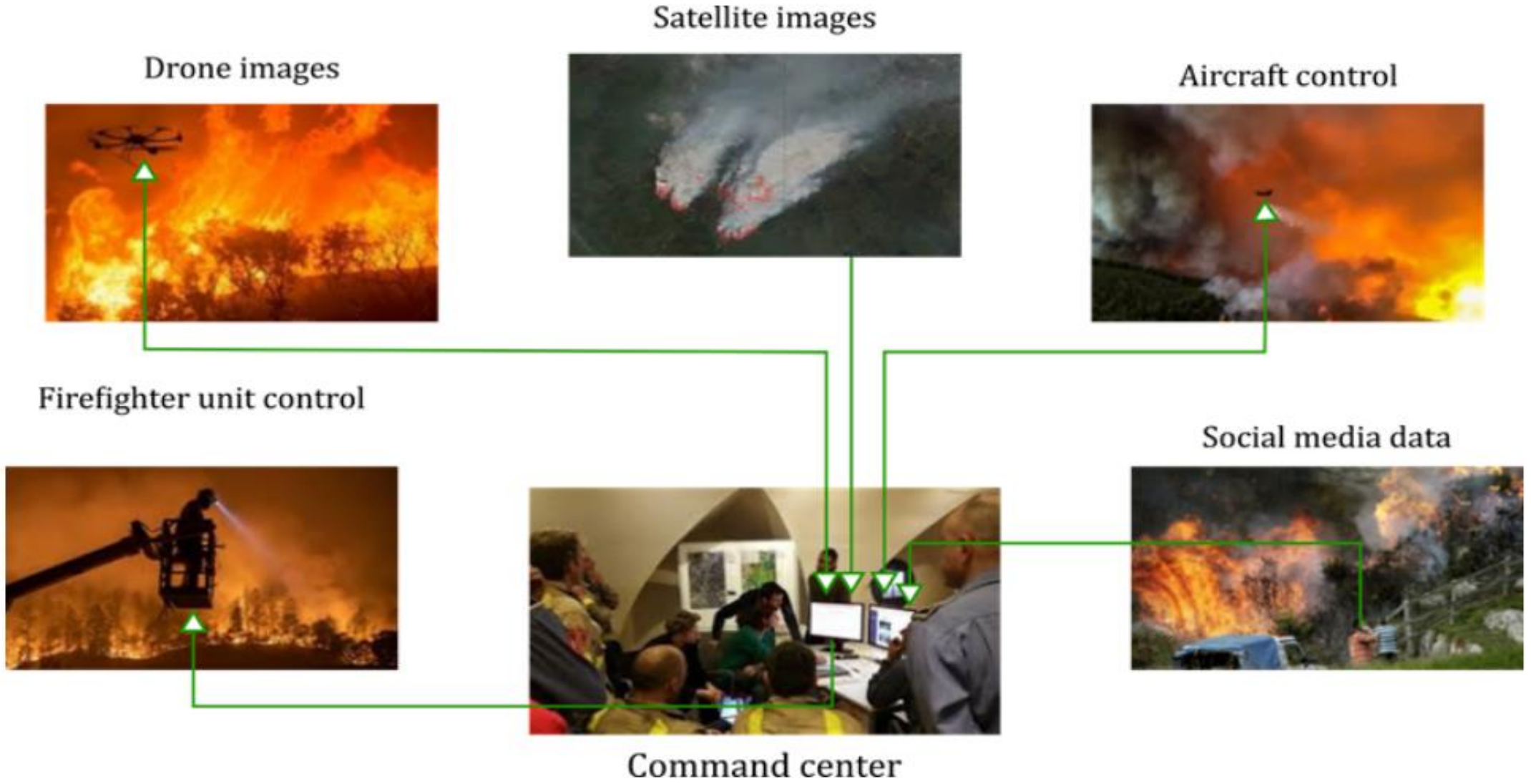
Natural Disaster Management (***NDM***) examples:

- forest fires, floods.

Big data issues in NDM:

- precise semantic mapping and phenomenon evolution predictions in ***real-time.***
- ***Heterogeneous extreme data sources***:
  - AI-capable autonomous devices and smart sensors at the edge
  - satellite images,
  - topographical data,
  - official meteorological data and predictions/warnings published in the Web
- ***Multilingual data***
  - geosocial media data (including text, image and videos).

Natural Disaster Management

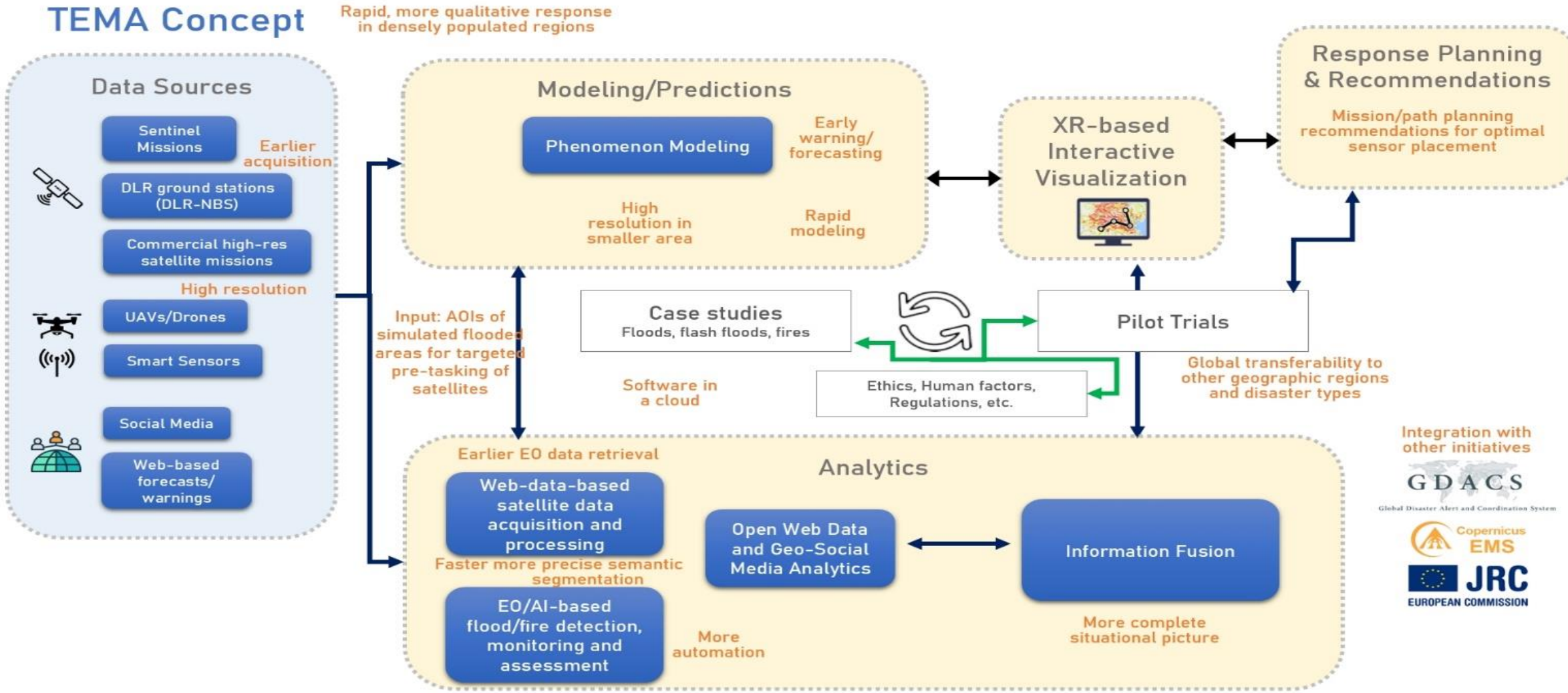


NDM Overview.

Big Data Analytics for Natural Disaster Management

- Natural Disaster Management
- **NDM Concept and Objectives**
- NDM Sensing
- Big NDM Data Analytics
- Horizon Europe R&D project TEMA

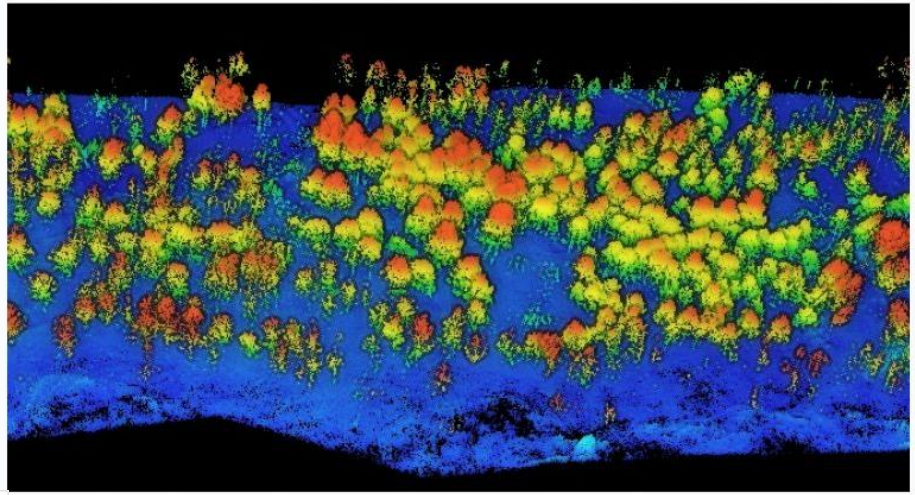
NDM Concept and Objectives

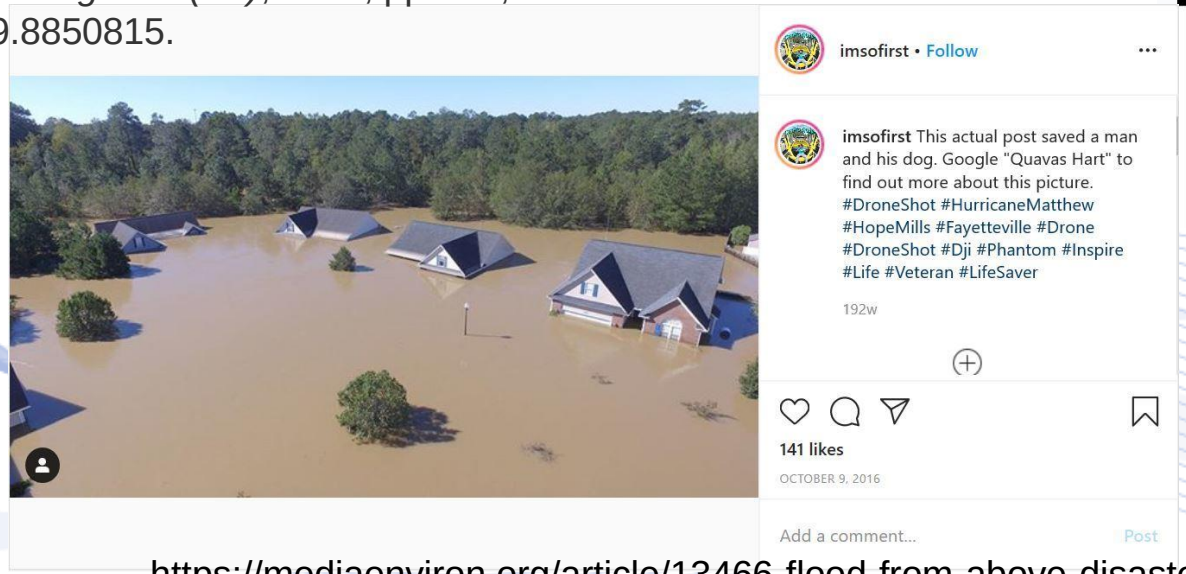


TEMA NDM Architecture.

NDM Concept and Objectives

Z. Jiao *et al*., "A Deep Learning Based Forest Fire Detection Approach Using UAV and YOLOv3," *2019 1st International Conference on Industrial Artificial Intelligence (IAI)*, 2019, pp. 1-5, doi: 10.1109/ICIAI.2019.8850815.

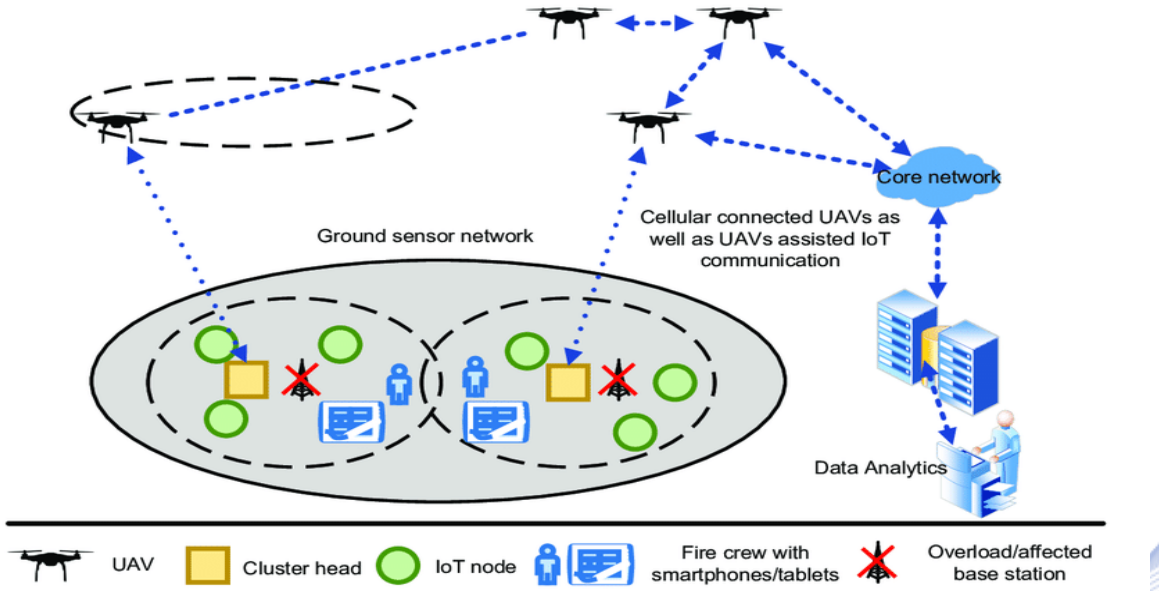




https://mediaenviron.org/article/13466-flood-from-above-disaster-mediation-and-drone-humanitarianism

https://www.gim-international.com/content/news/predicting-fire-risk-with-uav-lidar

NDM Concept and Objectives



Sun H, Dai X, Shou W, Wang J, Ruan X. An Efficient Decision Support System for Flood Inundation Management Using Intermittent Remote-Sensing Data. *Remote Sensing*. 2021; 13(14):2818. https://doi.org/10.3390/rs13142818

Ejaz, Waleed & Azam, Muhammad Awais & Saadat, Salman & Iqbal, Farkhund & Hannan, Abdul. (2019). Unmanned Aerial Vehicles enabled IoT Platform for Disaster Management. Energies. 12. 10.3390/en12142706.

NDM predictions and decision-making.

NDM Concept and Objectives

TSYL Wildfire Analyst®

NS 3Di ® Flood forecasting

Simulation and visualization.

NDM Concept and Objectives

NDM Tasks

Requirements/Specifications

Trustworthy federated analytics

- *Trustworthy AI*
- *Visual data analysis and remote sensing*
- *Geosocial media and news analysis*
- *Federated analytics on an edge-to-cloud continuum*

Predictions and decision-making

- *Decision support service for remote sensing*
- *Information fusion*
- *NDM phenomenon modeling*
- *Automated response recommendations*

Simulation and visualization

- *Digital Twin*
- *Geovisual analytics*
- *Interactive visualization*

Integration and validation

- *HW/SW integration*
- *Pilot trials*

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Monocular images

- A single monocular image does not convey depth information.
- But it can detect points at any range.

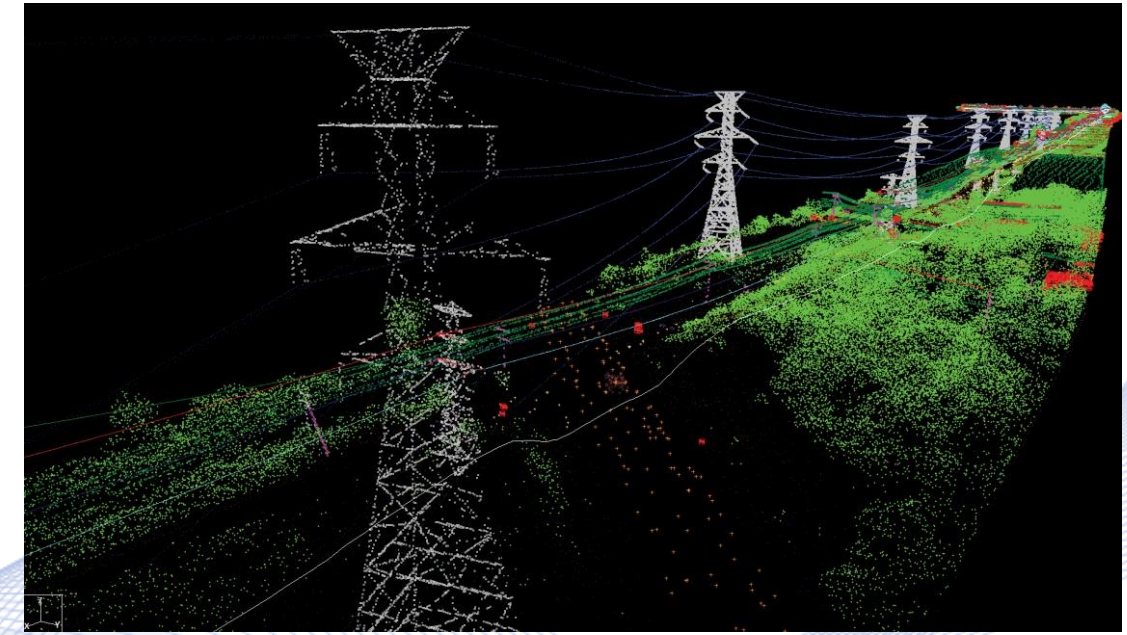
Stereo imaging

- Two cameras in known locations.
- Calibrated cameras.
- Stereo images can create a disparity (depth) map.
- Their range (in m) is limited, when high accuracy is desired.

Stereo image pair of a forest road.

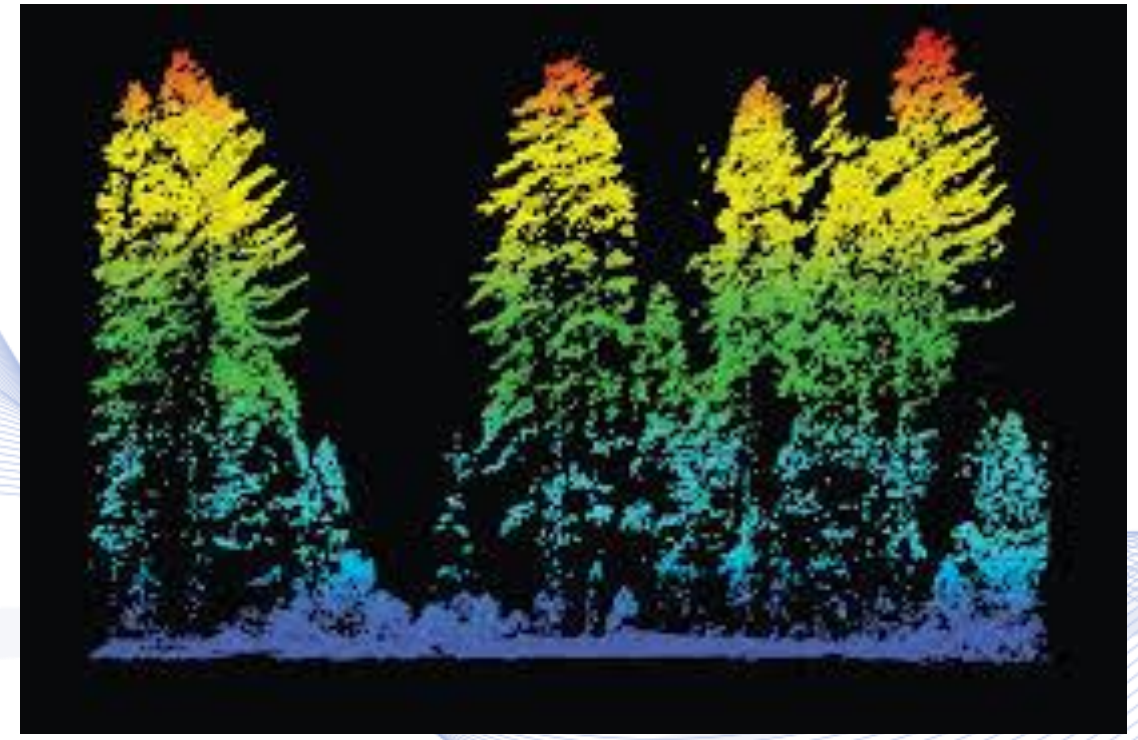
Lidars

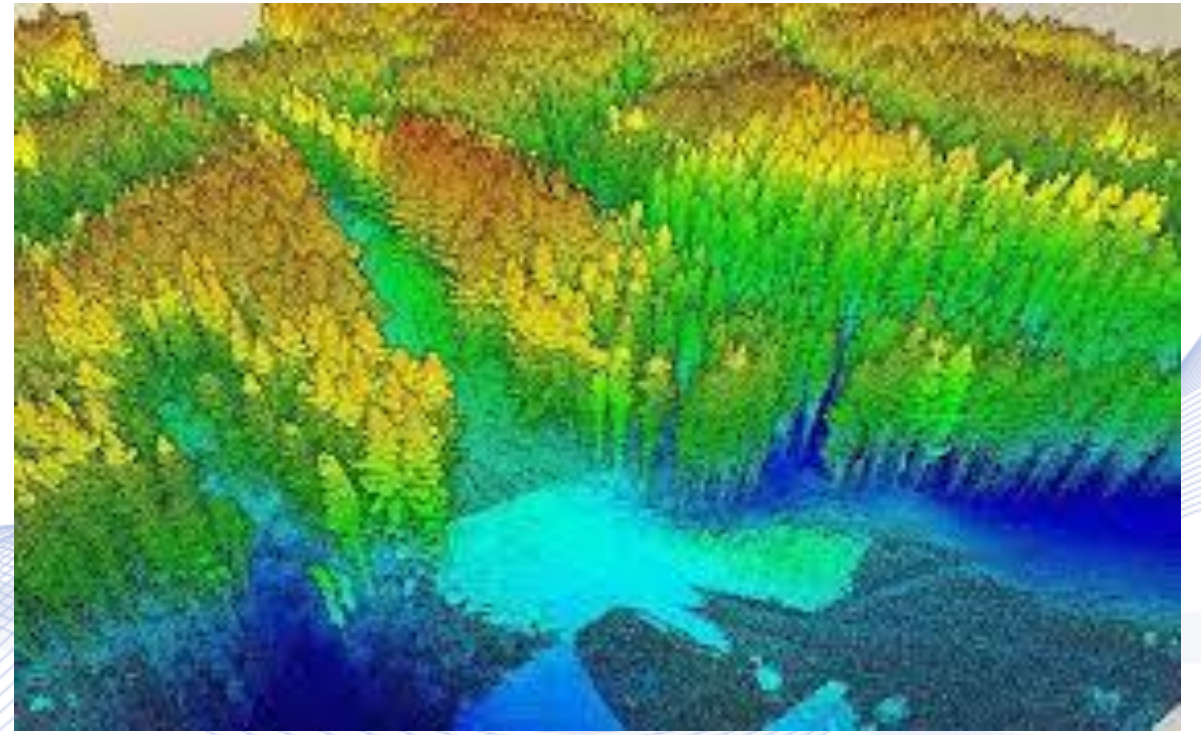
- Lidar measures the distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor.
- Differences in laser return times and wavelengths can then be used to make digital 3D representations of the target.



http://eijournal.com/print/articles/understanding-the-benefits-of-lidar-data?doing_wp_cron=1517767340.6914100646972656250000

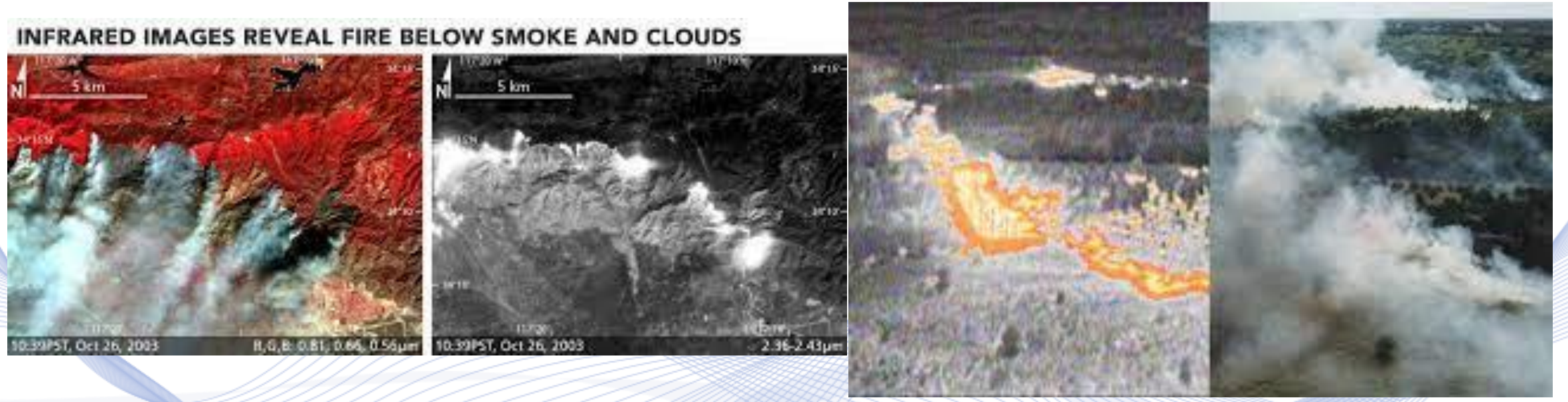
Lidars





Lidars and forest imaging.

IR measurement and imaging



IR imaging of forest fires.

Lidar smoke detection

It detects smoke instead of fire.

- Remote 3D monitoring.
- Area with ~5 km radius.
- Spatial resolution 15 meters, temporal resolution 5 minutes.

Lidar smoke detector.

Meteorological Sensors

- ***Wind sensors*** determine the wind speed, direction and temperature.
  - Temperature range: [-20°C, +70°C].
  - Altitudes up to 4000m.
  - Lightweight, low power design.

- ***Temperature sensors.***
- ***Humidity sensors.***

UAV Wind sensor.

Drones for ND observation

- External hardware can be attached to drones (e.g., PEC, XR cameras).
- ***Optimal sensor placement.***
- Obstacle Detection technologies.
- SDK for high-level UAV control.
- IP45 ISO Protection level for flight resilience.

Drones for ND observation

UAV Sensors

DJI ZENMUSE H20T and Gimbal.

- Visual Camera: 23x zoom, 20 Mpx, Focal Length (FL): 7-120 mm.
  - Video: 3840×2160(px) @ 30 fps
  - Images: 5184×3888(px)
- Wide angle camera: 12 Mpx, FL 24mm.
- Radiometric Thermal Camera: 640x512px, FL: 13.5 mm, 30Hz
- Laser RangeFinder: 1200m Range.

Autonomous Fire Fighting Drones

BEHA M1-AT

- Autonomous flight.
- 10 tons payload capability.
- Possible drone fleet operation.
- ‘Triple box-wing’ configuration which allows it to takeoff and land in a very short time.

Autonomous Fire Fighting Vehicles

https://www.popsci.com/technology/estonian-firefighting-robot/

Big Data Analytics for Natural Disaster Management

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Big NDM Data Analytics

Underlying DNN and CV technologies

- Object detection
- Region segmentation

NDM cases

- Fire detection/segmentation
- Flood detection/segmentation

Big NDM Data Analytics

Social Media Analytics

- Geosocial analytics
- Semantic topic extraction
- Text sentiment analysis

Fast NDM Data Analytics

- DNN acceleration

Big NDM Data Analytics

Trustworthy NDM Data Analytics

- DNN robustness
- Privacy protection
- DNN Explainability

Other NDM Data Analytics Issues

- Information fusion
- Visualization tools

Object Detection

Object detection and tracking.

- Periodical object detection followed by object tracking.
- Tracking is much faster than DNN object detection.

- Problems due to occlusion, self-occlusion or clutter.

Person Detection

Person detection in a flooded area.

Image Segmentation

Crowd detection, segmentation and tracking.

Segmentation of a crowd area.

Image Segmentation

Flooded and burnt area segmentation.

Segmentation of a flooded area.
This video is from the flood in Mandra, Attica region, Greece (2017).

Fire Detection

Why new Mean Average Precision?

- Fire is an object with no fixed shape, leading e.g., to over/mis-segmentation.
- In this scenario, classical Mean Average Precision is not a good detection performance measure.
- The proposed new Mean Average Precision uses the ***Intersection over Union*** (IoU) of all predicted and all all ground truths bounding boxes.
-

Fire region bounding box predictions.

Fire Detection

- Training Dataset:
  31.000 images(over 15.000 annotated fire images).

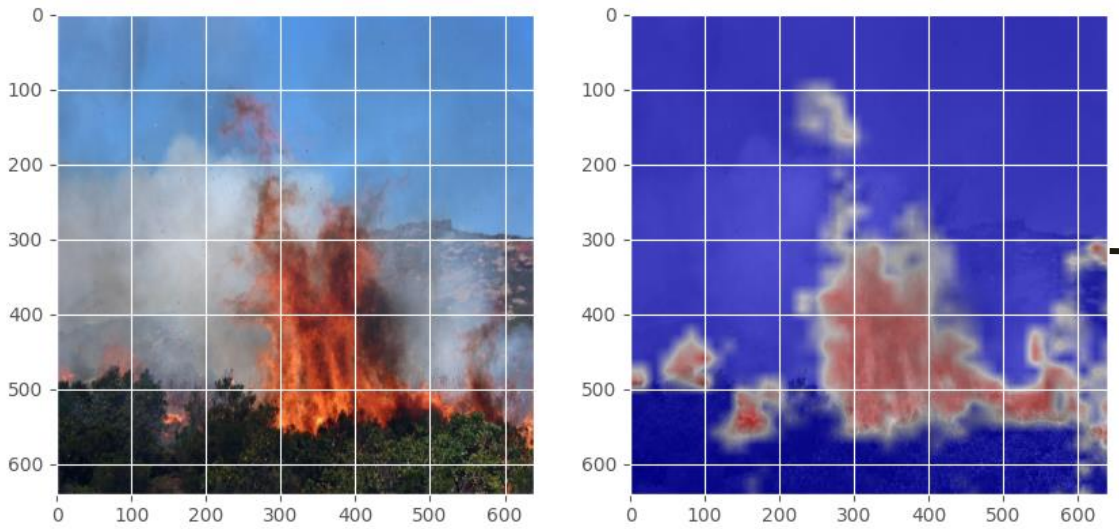
- Trained object detection architectures:
  CNNs as backbone (ResNet50).
  Transformers as backbone (Visual Transformers - ViT).

Results on a new Mean Average Precision (IoU threshold = 0.5).

CNN	ViT
89.97	87.66

Fire Detection

Improved Visual Transformers as backbones for fire detection tasks.



A vector embedding mechanism adds more weight on the corresponding ‘fire’ vectors of the ViT output.

Improved new Mean Average Precision.

CNN	ViT	Weighted ViT
89.97	87.66	92.05

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Fire Segmentation

Segmentation Architectures

MODELS	MEAN IoU
BiseNet	0.9140
BiseNet-Resnet101	0.86989
PID-Net	0.91408

New fire segmentation evaluation metrics accounting for:

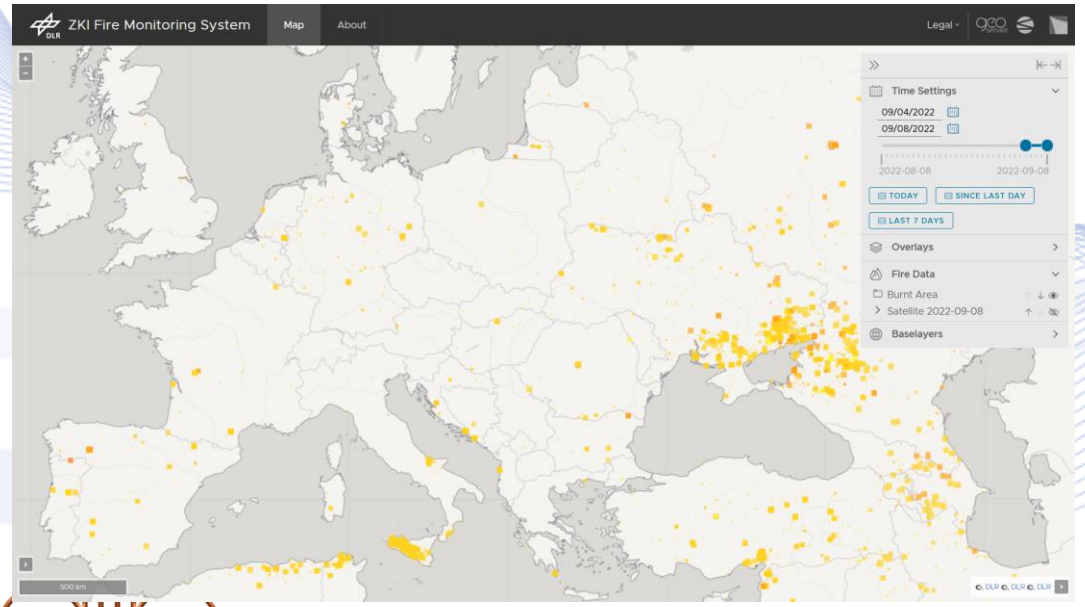
1. The number of fire hot-spots in a frame.
2. The distance between the fire hot-spots.
3. The spread of the fire.

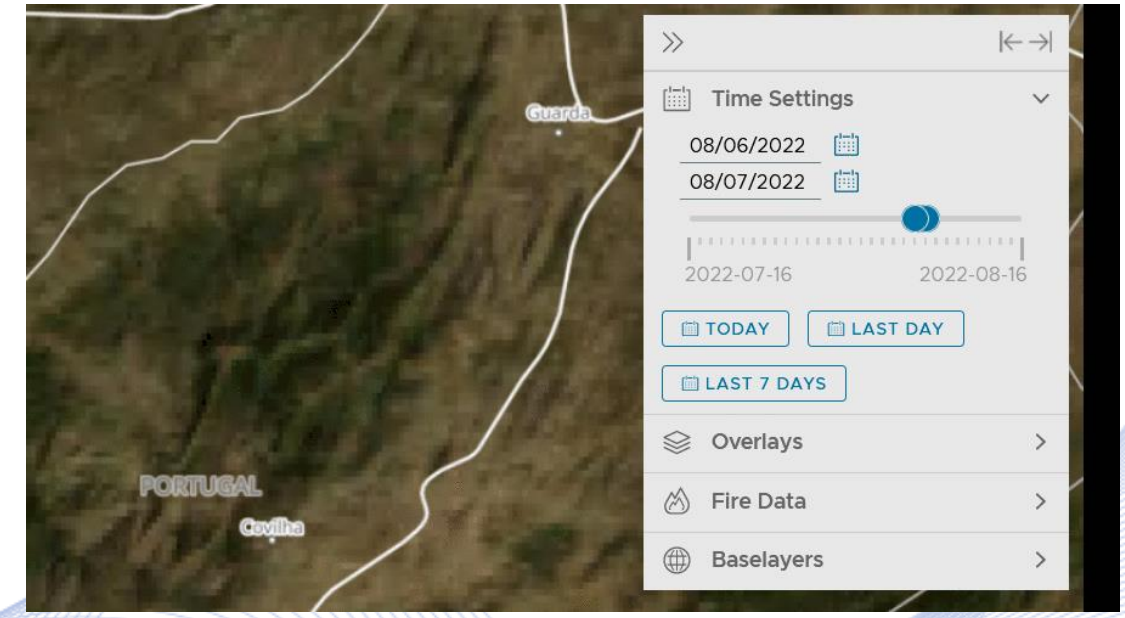
Fire Segmentation.

Burnt area monitoring

Near real-time burnt area monitoring

- Burnt area monitoring system in satellite images.
- It allows overview of current wildfire activity throughout Europe: https://services.zki.dlr.de/fire
-





Zoom region: Huge wildfire in Portugal over several consecutive days (August 2022).

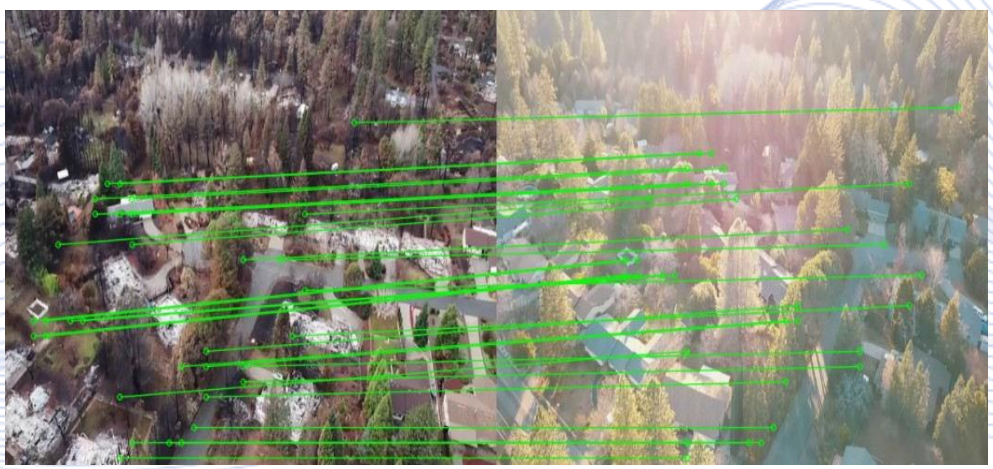
Georegistration

Geovisual analytics refers to the ***analytical reasoning with visual geospatial information***.

- Geospatial data include location information on Earth surface.
- Disaster area images/videos must be geolocalized on:
  - Orthophotomaps
  - Geolocalized pre-event images and videos.
- ***Georegistration***
  - Visual place recognition DNNs can be used to retrieve a ***pre-event image*** from a database, given a ***post-event image***.
  - RANSAC can find patch correspondences between the two such images.
  - Then the centers of these patches are given as prompts to a region segmentation algorithm to acquire a ***region similarity map***.

Georegistration

Burnt region georegistration.



Burnt region, pre-fire image, and their correspondences.

Georegistration

Burnt region georegistration.

Burnt region, pre-fire image, and their similarity map.

Flood Segmentation

Supervised DNN training on a flood dataset:

- ***CNN – I2I*** uses ***Bisenet*** as main branch, and a generator network as an auxiliary neural branch.
  - **Result: 87.65 % mIoU** at the validation set.

- ***PSPNet (Pyramid Scene Parsing)*** with *Resnet50* as backbone.
  - **Result: 87.5 % mIoU** at the validation set.
- Test DNN ability to generalize on unknown target domains (different regions, different sceneries).

Flood Segmentation

Flood in Emilia-Romagna, Italy (May 2023), (**81.84% mIoU**).

Object Detection and Tracking in Floods

DNN models, pretrained on COCO dataset were used to detect classes of interest (***cars, persons***) that may be in danger).

YOLOv6 4.0 small version in person, car detection in Thessaly floods, Greece (September 2023).

Flood mapping

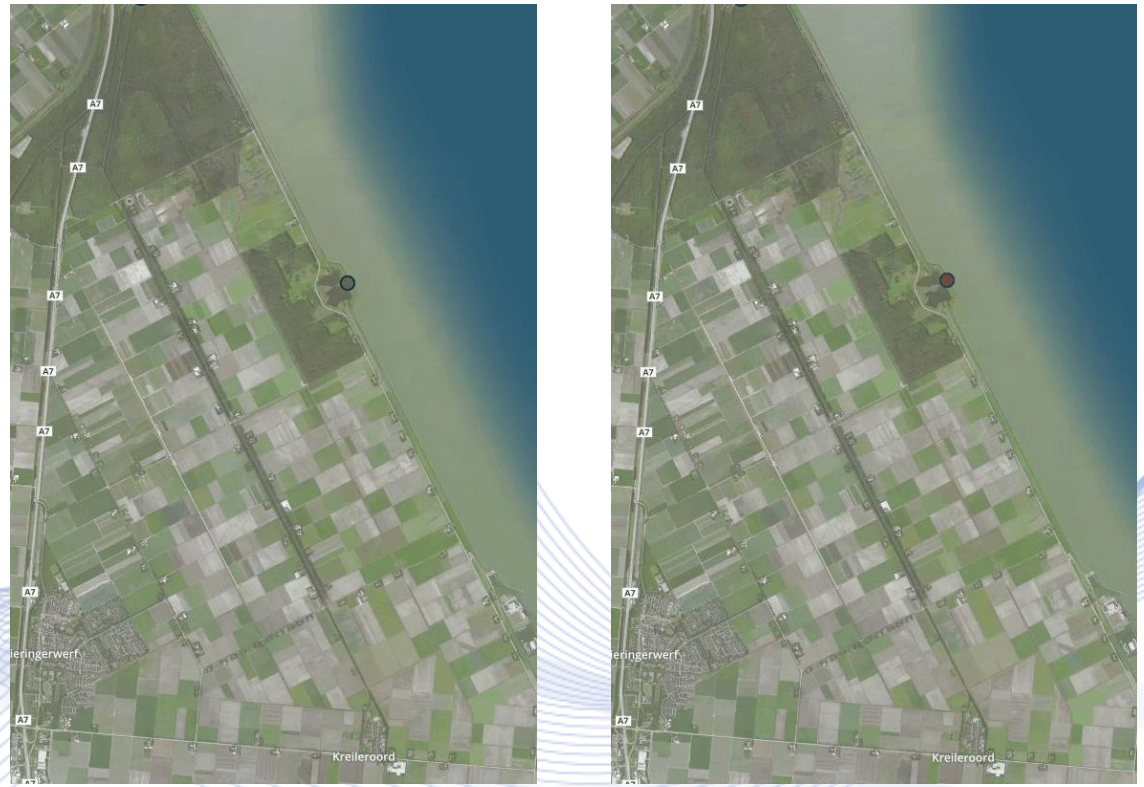
Buildings Vehicles

Flood mapping using satellite and aerial images.

Flood Modeling - prediction

Hydrodynamic simulation software

- Flood modelling in urban-suburban areas.
- Projection of results in a 2D map.

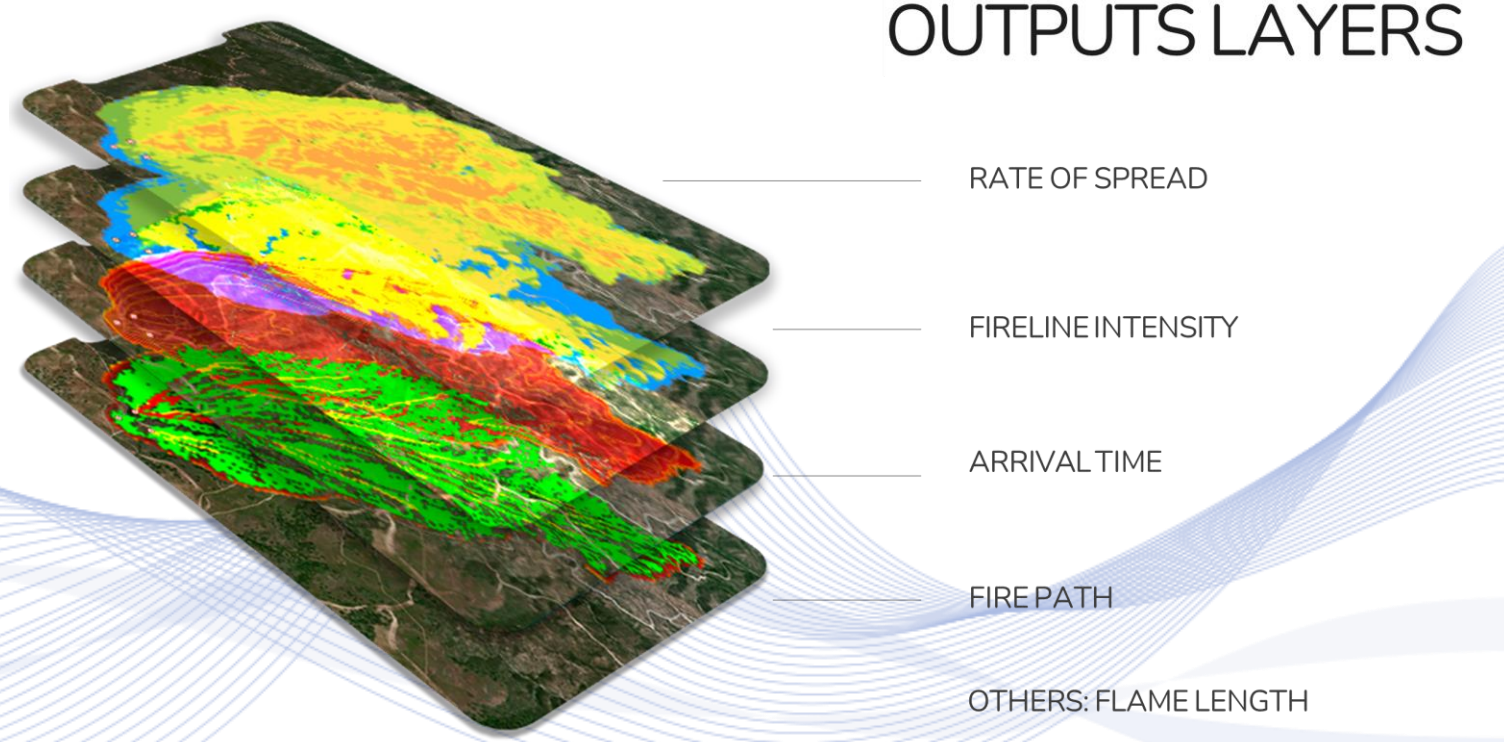


https://3diwatermanagement.com/learn/publications/

Forest fire modeling

Simulation of the ***wildfire spread and behavior*** in space and time.

- Effect of meteorological factors and forest modeling.
- Real-time analysis of wildfire behavior.
- Decision making for suppression activities, resource allocation and population evacuation.



Wildfire Analyst® FireSim.

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TEMA project

Acronym: TEMA

Call: RIA, HORIZON-CL4-2022-DATA-01

Grant agreement number: 101093003

Duration: 01/12/2022 - 30/11/2026

Total Project Funding: 11,340,223.50 €

Funding for AUTH (coordinator): 1,381,875.00 €

TEMA Consortium

- 19 Partners all over Europe
- AUTH is the coordinator

AUTH/AIIA Lab

Machine Learning

Computer Vision

Multimedia & Social Media

Computer Graphics

- *Computer Vision*
  - Semantic image/video analysis
  - Multi-view & stereoscopic image/video analysis
- *Machine Learning*
  - Deep Learning & Neural Networks
  - Kernel Machines
  - Embedded AI for Robotics
- *Multimedia & Social Media*
  - Semantic Multimedia & Social Media Analysis
  - Multimedia Protection and Forensics
  - Intelligent Cinematography
- *Computer Graphics*

AUTH/AIIA Lab

Statistics

- 1250+ papers in academic conferences and journals
- 50 book chapters
- 11 books
- 34500+ citations (source: Google Scholar)

Personnel

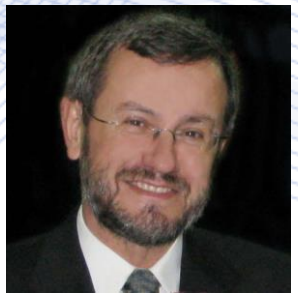
- 5 Faculty Members
- 3 Post-Docs
- 20+ researchers

Leader in SIMAR Tasks

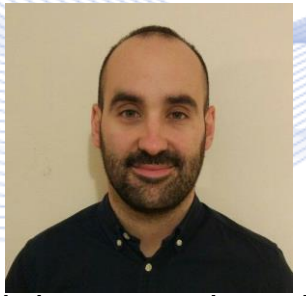
- WP4: Intelligent Support of Workers
- T4.1 Artificial Intelligence system to reduce inspector workload and level of stress
- T5.2 Worker Support Functionalities Integration

Overall: 75 RTD projects (EU and national)

- TEMA, Trusted Extremely Precise Mapping and Prediction for Emergency Management, HE (Coordinator), (ongoing)
- SIMAR, Safe Inspection and Maintenance supporting workers with modular robots, Artificial intelligence, and augmented Reality, HE, (ongoing)
- AI4EUROPE, An AI-On-Demand Platform to support research excellence in Europe, HE, (ongoing)
- AERIAL-CORE, Aerial Cognitive integrated multi-task Robotic system with Extended operation range and safety, H2020. (ongoing)
- AI4Media, A Centre of Excellence delivering next generation AI Research and Training at the service of Media, Society and Democracy, H2020. (ongoing)
- MULTIDRONE, Autonomous UAV fleet for outdoor media production, (Coordinator), H2020



Prof. Ioannis Pitas



Dr. Christos Papaioannidis

Artificial Intelligence & Information Analysis Lab

R&D cooperation opportunities in AIIA Lab

- **Many open Postdoc, PhD, MSc research positions.**

- International AI Doctoral Academy (AIDA)
  - **Short young researcher visits.**

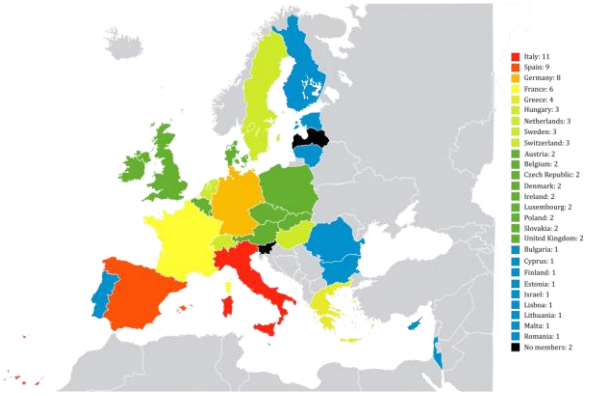
International AI Doctoral Academy (AIDA)

Excellence in AI PhD research and education.

Membership:

78 members (59 AI Universities, and R&D centers, companies).

Geographical coverage of almost the entire Europe.



Operation highlights:

- **AIDA Lecturers**: 128 .
- **AIDA Students**: 201 (186 PhD and 15 Post Docs).
- **Junior fellows exchange program**: **74 applications, 60** completed, 12 in progress, 2 scheduled for next period.
- **AIDA courses**: 60 delivered courses in total (2020-2023), 15 planned ones .
- **AIDA courses** have attracted a total of **1,800+ participants .**
- **AIDA email list registrants**: 806+.
- **37 Lectures** in AI Excellence Lecture Series attracting ~127 attendees on average.
- **144 AIDA AI educational resources.**
- **22 AIDA educational material curators** (15 from AI4Media).

Acknowledgements

- This lecture has received funding from the European Union's European Union Horizon Europe research and innovation programme under grant agreement 101093003 (TEMA).

- ***Several TEMA partners, notably USE, DLR and KEMEA, provided material that was incorporated in this presentation.***

- This lecure reflects only the authors' views. The European Commission is not responsible for any use that may be made of the information it contains.

Q & A

Thank you very much for your attention!

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