Sensing and Big Data Analytics for Natural Disaster Management

N. Militsis, V. Mygdalis, Prof. I. Pitas
Aristotle University of Thessaloniki
pitas@csd.auth.gr
www.aiia.csd.auth.gr
Version 4.3

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:

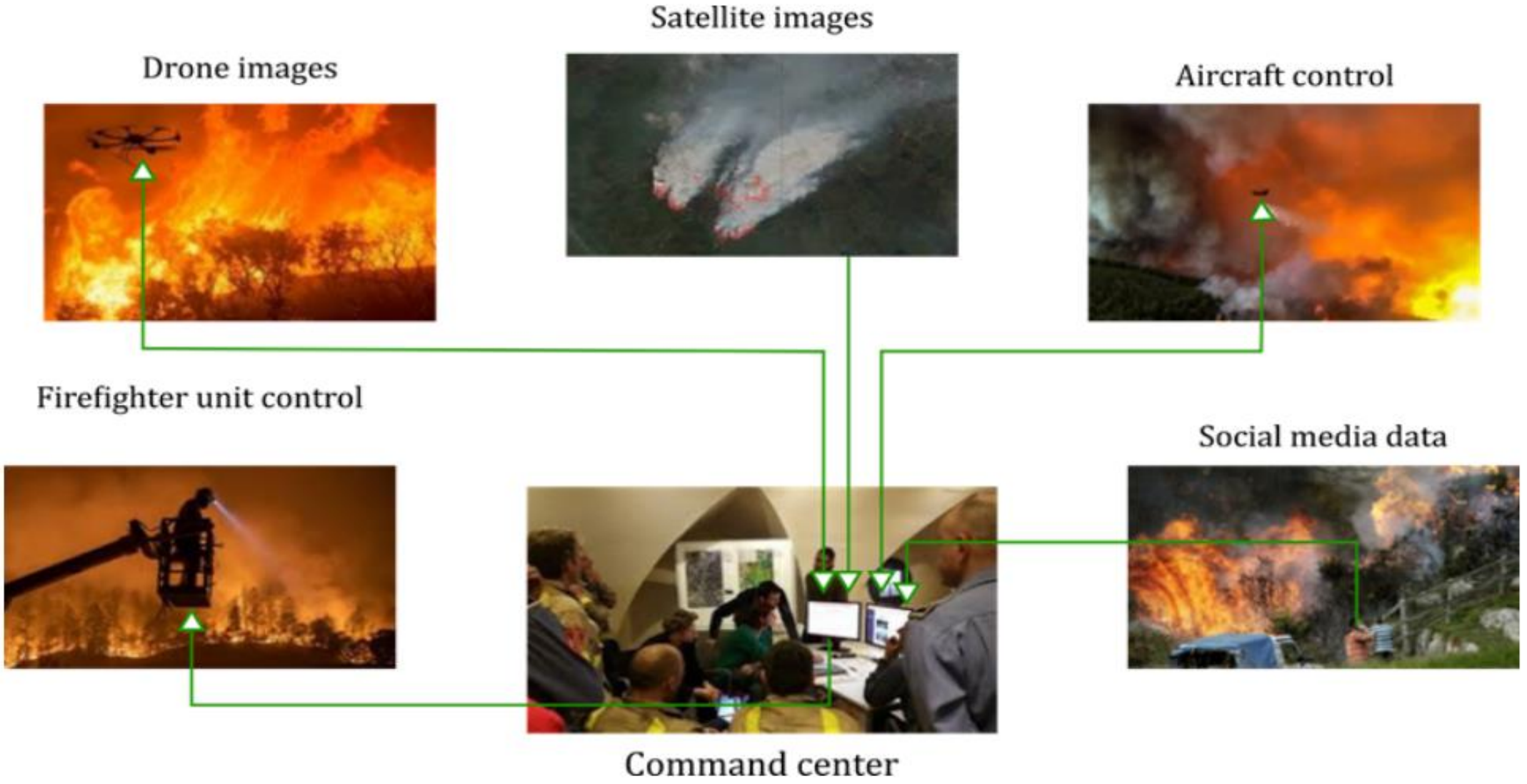
- precise semantic mapping and phenomenon evolution predictions in ***real-time.***
- ***Heterogeneous extreme data sources***:
  - AI-capable autonomous devices and smart sensors at the edge
  - satellite images,
  - topographical data,
  - official meteorological data and predictions/warnings published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

Natural Disaster Management

Trusted Extremely Precise Mapping and Prediction for Emergency Management (***TEMA***):

- It aims to aid and improve NDM for forest fires, floods.
- It will employ automated means for ***precise semantic mapping*** and ***phenomenon evolution predictions*** in real-time, by performing ***analysis of 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
  - geosocial media data (including text, image and videos).

Natural Disaster Management

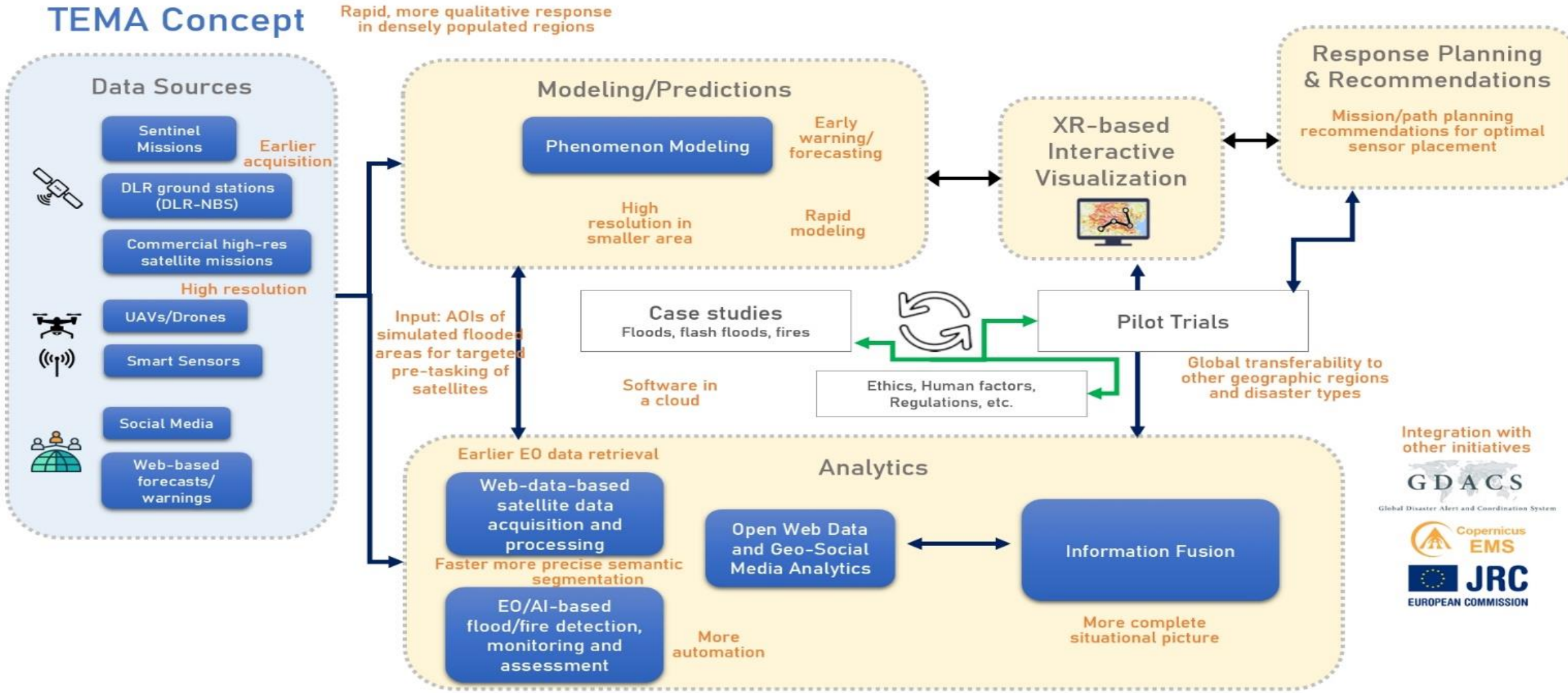


NDM Overview.

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

Objectives

- Improve and accelerate ***extreme data analytics***.

- Improve and accelerate ***emergency phenomenon modeling, evolution predictions***, simulation and interactive visualization

- Improve NDM using new digital technologies and extreme data analytics.

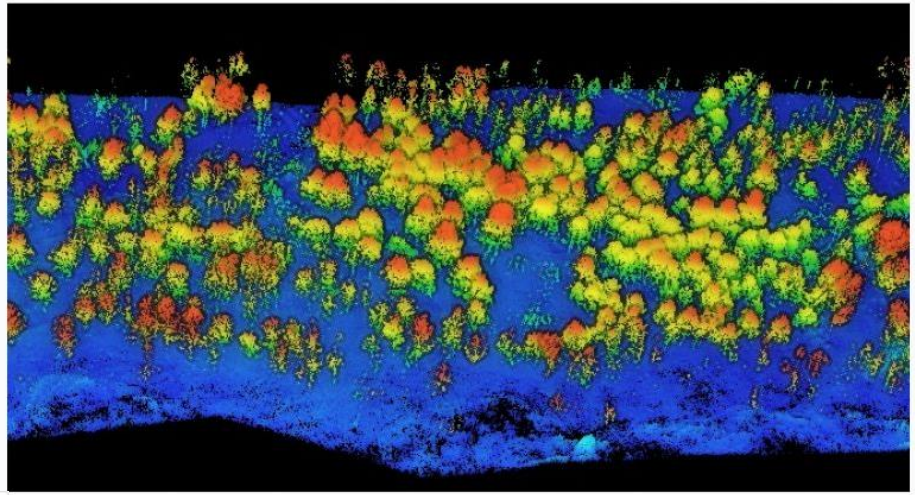
NDM Concept and Objectives

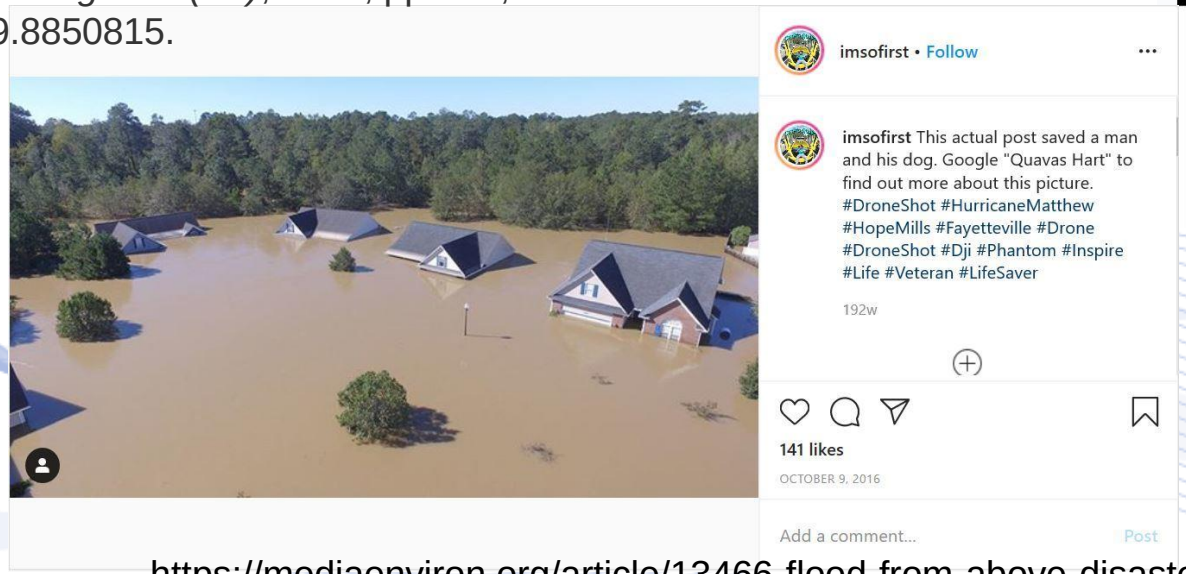
Improve and accelerate extreme data analytics

- ***Increase trustworthiness of extreme data analysis algorithms***
  - Speed of local & global XAI explanations.
- ***Increase accuracy of extreme data analysis algorithms***
  - Semantic/instance segmentation, object detection, Image recognition
- ***Increase responsiveness/speed of extreme data analysis algorithms***
  - Visual analysis, social media analysis speed.
- ***Reduce latency by innovative federated data analysis on a cloud-to-edge continuum***
  - Reduce computational latency, data migration.

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

Improve and accelerate emergency phenomenon modeling, evolution predictions, simulation and interactive visualization

- ***Increase model-based prediction responsiveness/speed for evolving phenomena***
  - Increase dispersion model, flood model update rates.
- ***Increase model-based prediction accuracy for evolving phenomena***
  - Fire simulation, estimated smoke plume and concentration distribution, flood simulation.

NDM Concept and Objectives

TSYL Wildfire Analyst®

NS 3Di ® Flood forecasting

Simulation and visualization.

NDM Concept and Objectives

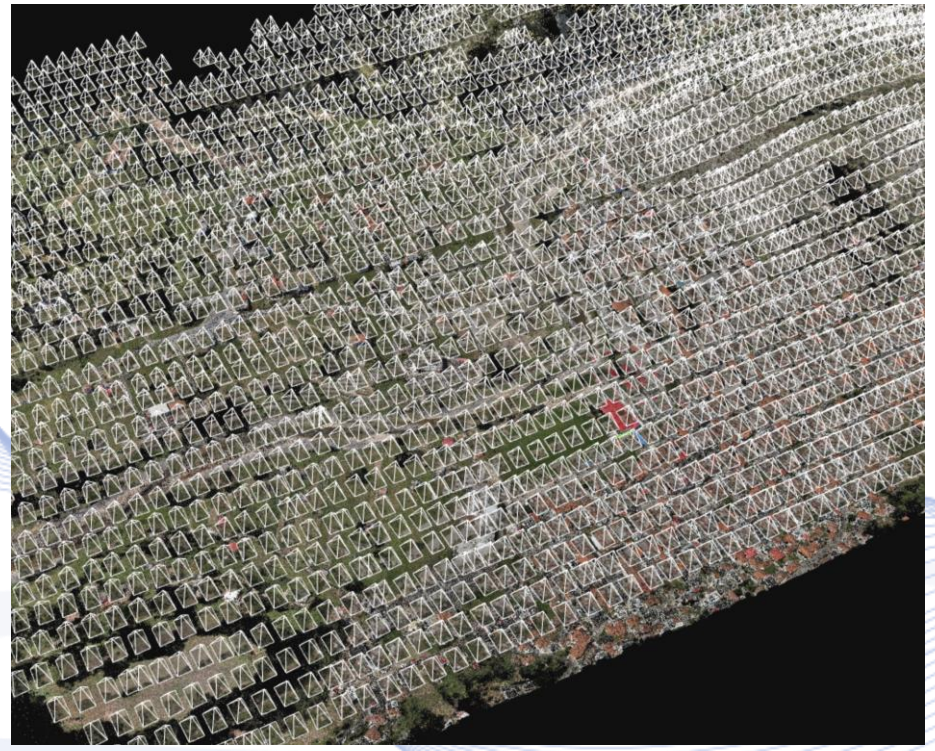
Improve and accelerate emergency phenomenon modeling, evolution predictions, simulation and interactive visualization

- ***Improve responsiveness and interactivity of visualization mechanisms for evolving phenomena***
  - Responsiveness of visualization mechanisms, content customization increase in Augmented Reality Immersion score).
- ***Improve accuracy of visualization mechanisms for evolving phenomena***
  - Digital Twin accuracy, merged spatial 3D map resolution increase.

NDM Concept and Objectives

Generating georeferenced 3D digital twin models (Northdocks)

- Use of drone images/videos and historical data.



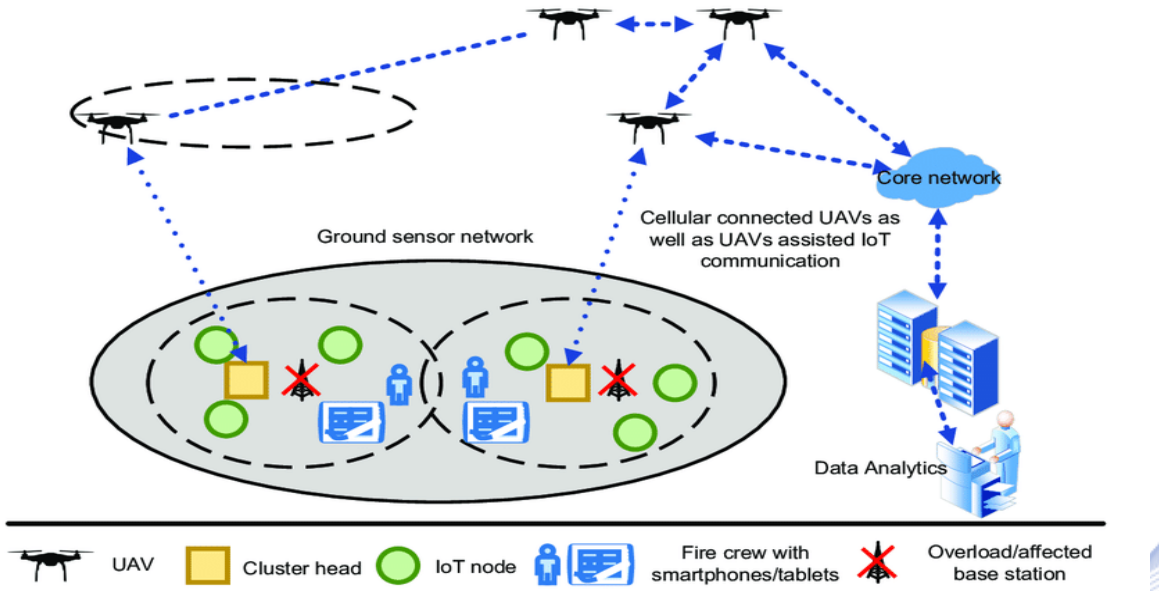
Drone image acquisition and digital twin of Larissa floods (Greece, 9/2023).

NDM Concept and Objectives

Improve NDM using new digital technologies and extreme data analytics.

- ***Reduce latency in NDM***
  - Speed of satellite-based crisis mapping, Frequency of wildfire burnt area product availability, reduction of time between sensing and satellite data availability.
- ***Increase situational awareness in NDM***
  - Heterogeneous data sources/modalities to semantically annotate the 3D map, Evaluation of contingent response alternatives ,Temporal resolution of map updates.
- ***Reduce mental load for human operators in NDM***
  - Workload from retrieval of satellite position and acquisition data, Transparency, automation and improvement of communication.
- ***Prototype a proof-of-concept TEMA system for NDM in forest fires, flash floods, and regional floods.***

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.

Big Data Analytics for Natural Disaster Management

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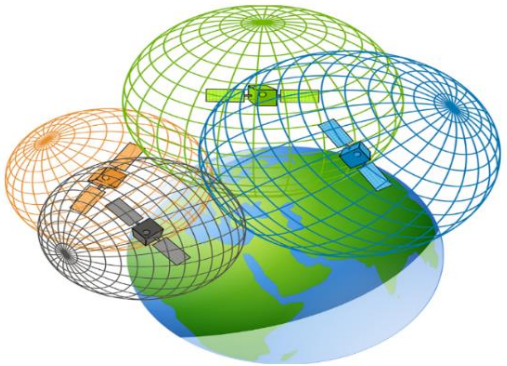
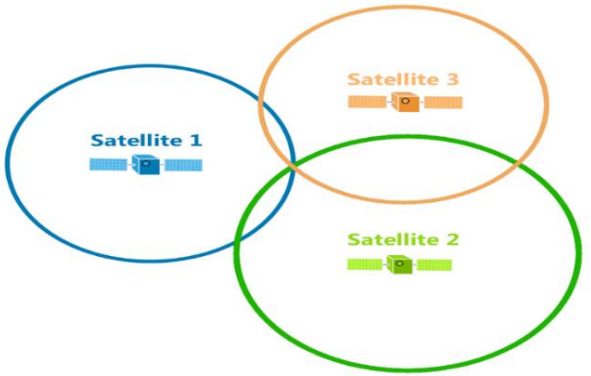
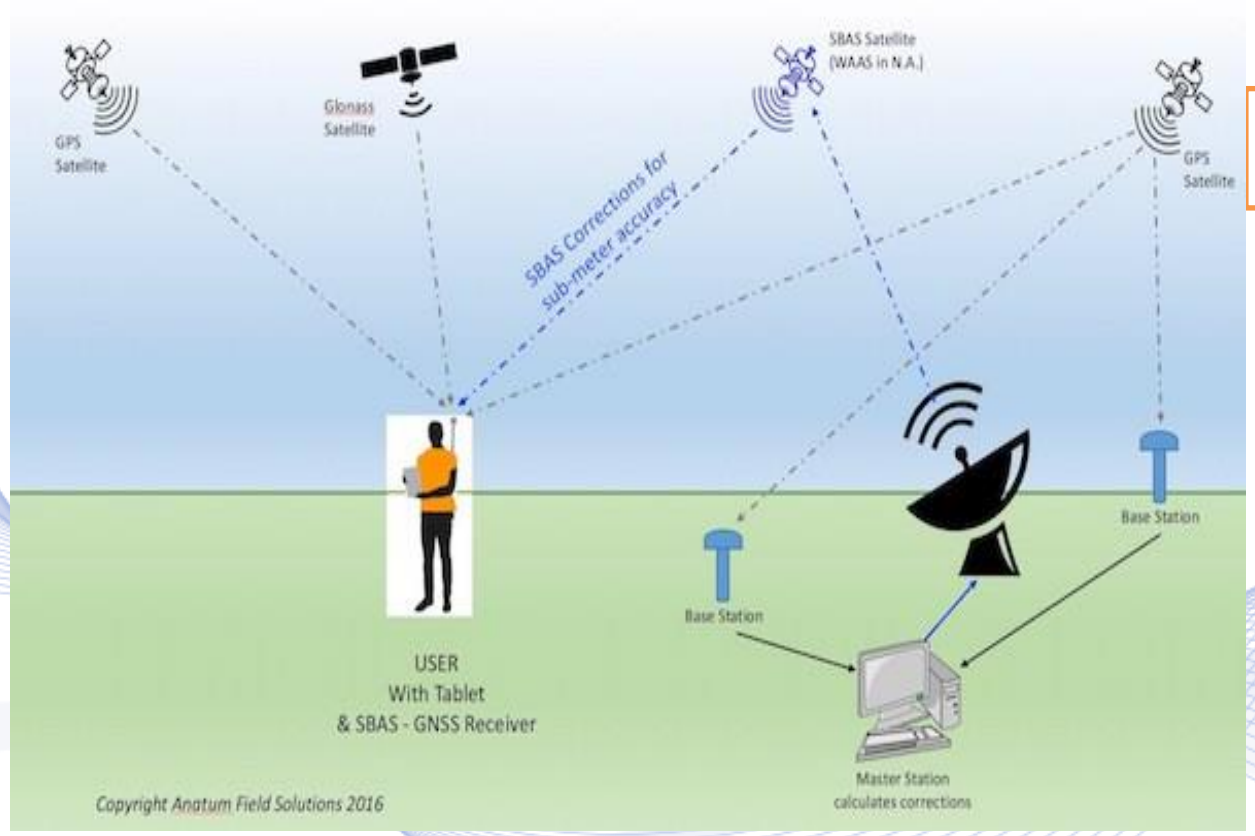
GPS

- The ***Global Positioning System*** (***GPS***) is a constellation of 27 Earth-orbiting satellites (24 in operation and three extras, in case one fails).
- GPS receivers receive position information from ***GPS satellites*** and then calculate the device geographical position (difference from Satellite position).





RTK GPS

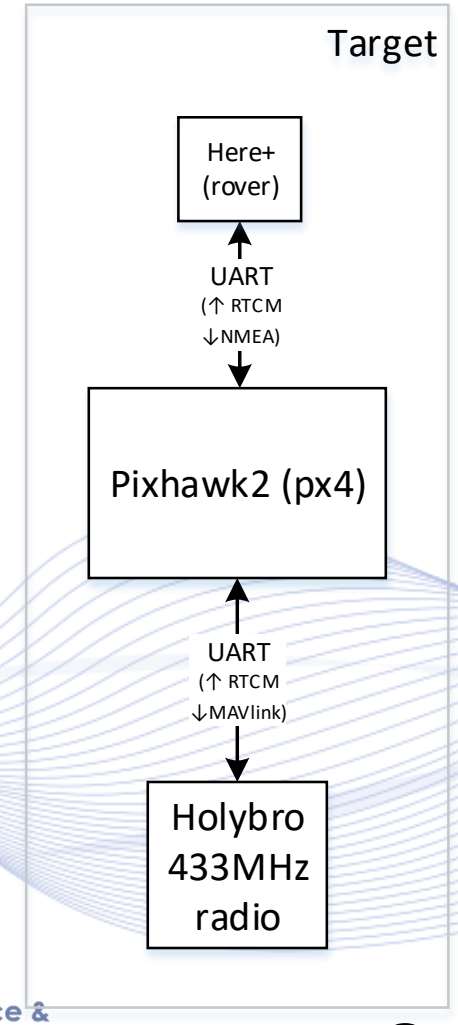


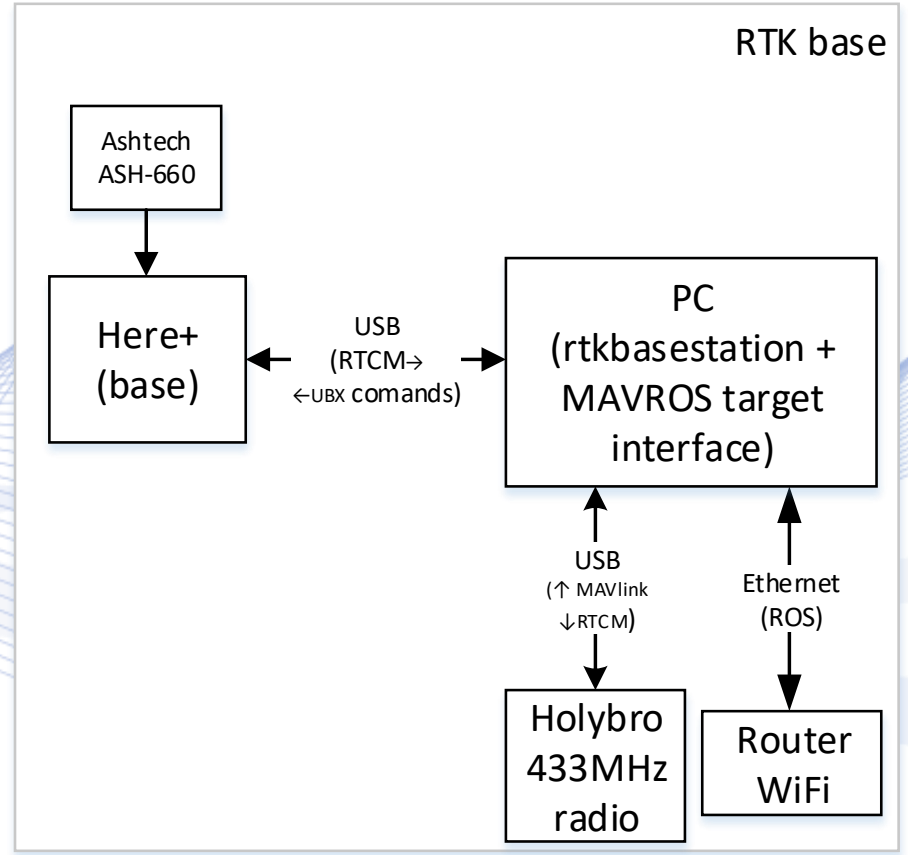
Base Station

Rover

RTK-GPS receiver.

GPS Target Tracking





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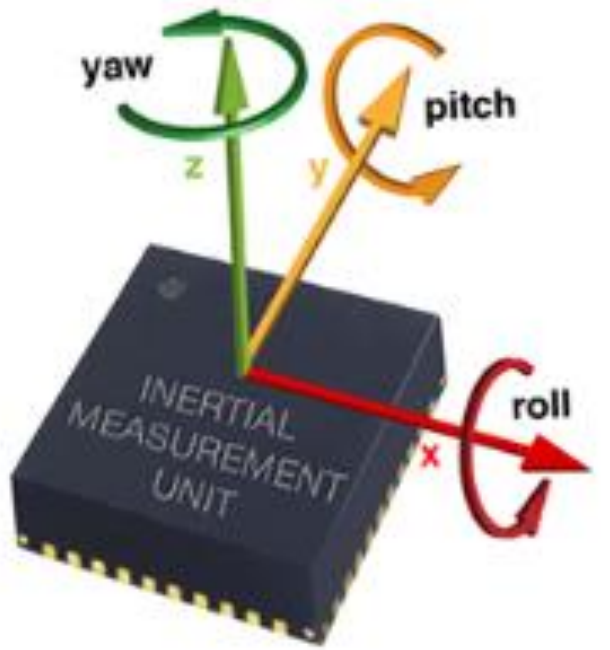
On-target RTK-GPS receiver.

IMU

Inertial Measurement Unit (***IMU***):

- It measures and reports a body's specific force, angular motion rate and, sometimes, the magnetic field surrounding the body.



- It uses a combination of accelerometers, gyroscopes and, sometimes, also magnetometers/electronic compass.

Monocular images

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

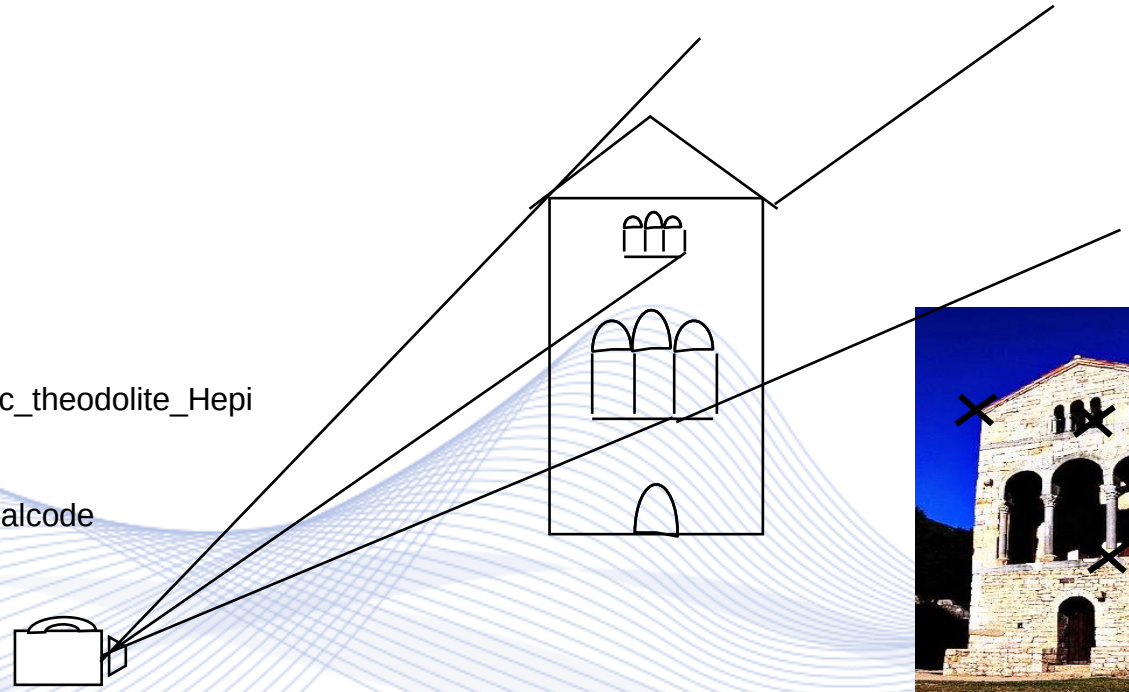
https://www.youtube.com/watch?v=8LWZSGNjuF0

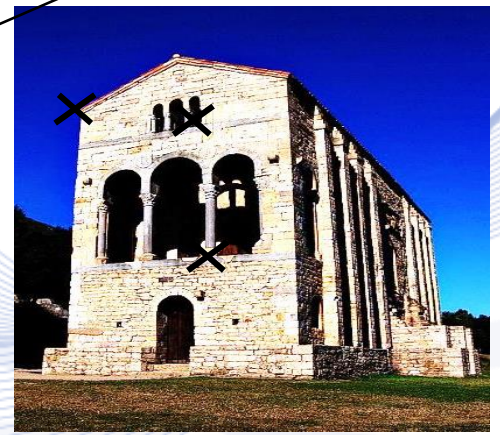
Calibrated monocular image

- Light rays can backproject a target image to the 3D world model.
  - ***Azimuth*** and ***elevation*** angles per pixel of this light ray can have accuracy ranging from $0{,}1^o$ to $0{,}01^o$ degrees.
  - Color of the reflected light is available for each scene point on a per pixel basis.
  - Millions of pixels per image.
  - Tens of images per second.

Calibrated monocular image

Victor Blacus (https://commons.wikimedia.org/wiki/File:Amagnetic_theodolite_Hepites_1.jpg), "*Amagnetic theodolite Hepites 1*", https://creativecommons.org/licenses/by-sa/3.0/legalcode





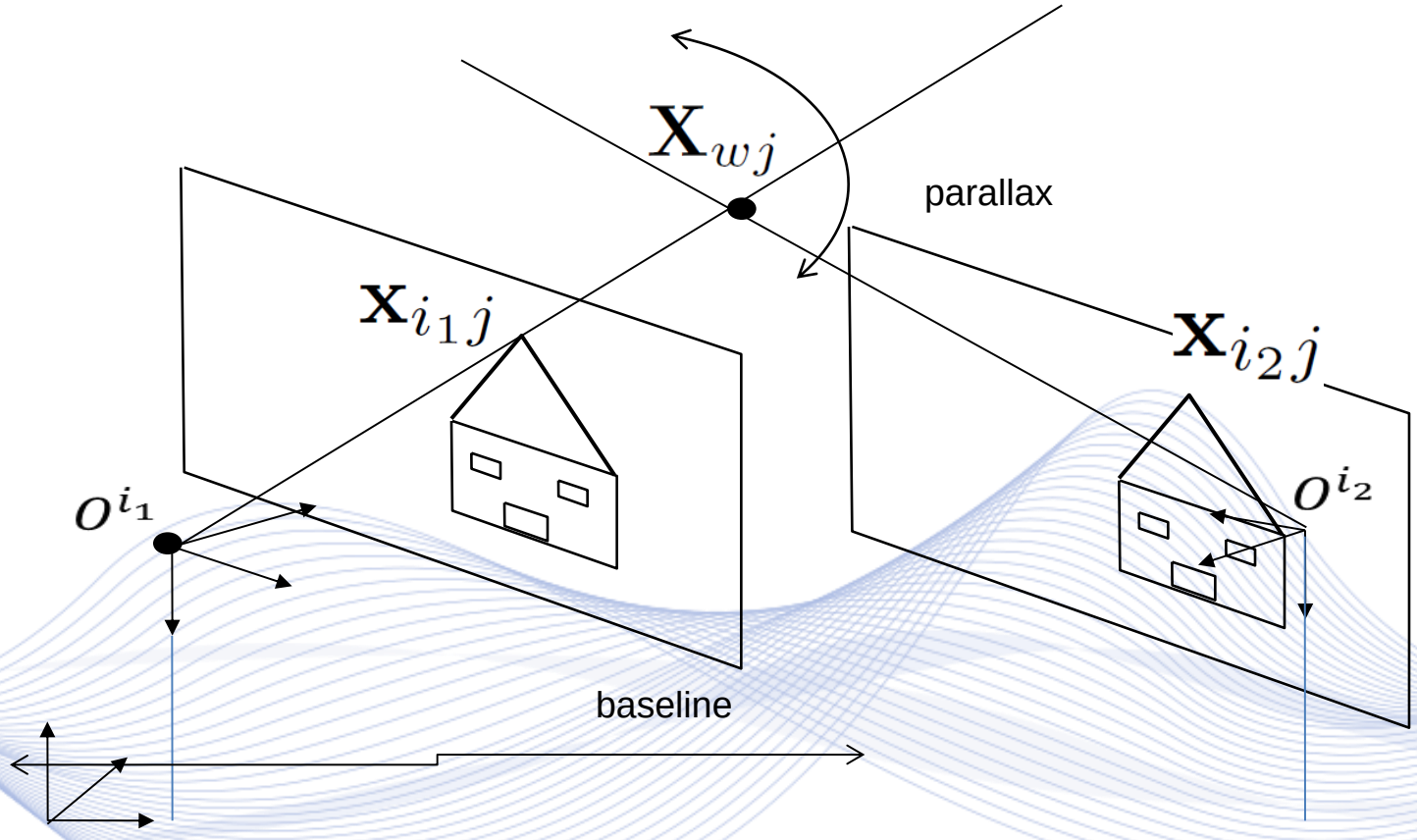
Ángel Miguel Sánchez (https://commons.wikimedia.org/wiki/File:Sta_Maria_Naranco.jpg), "Sta Maria Naranco", modified, https://creativecommons.org/licenses/by-sa/3.0/es/deed.en

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.

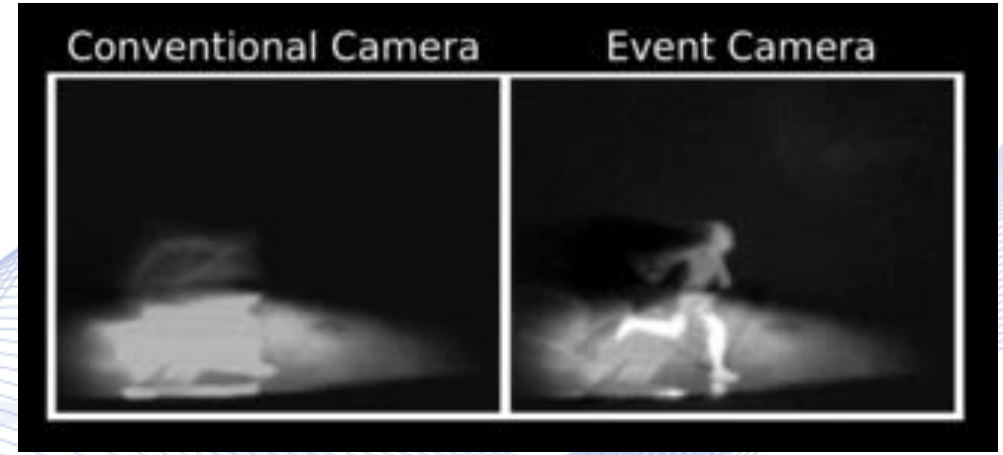
Stereo Imaging



Geometrical accuracy depends on parallax angle.

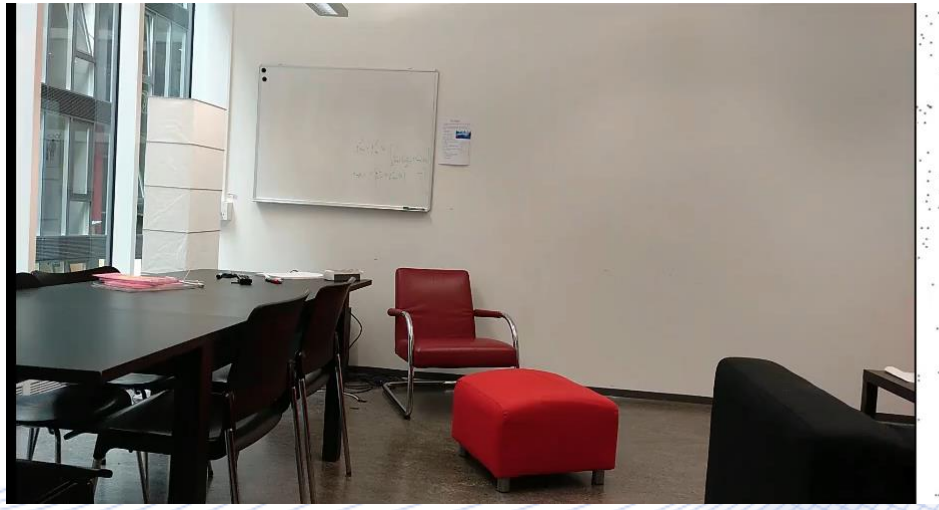
Event cameras

- Novel sensor that measures only ***scene motion***.
- Low-latency (~ 1 μs).
- No motion blur.
- High dynamic range (140 dB instead of 60 dB).
- Ultra-low power (1mW vs 1W).
- Traditional vision algorithms do not work!



Event cameras

Standard Camera

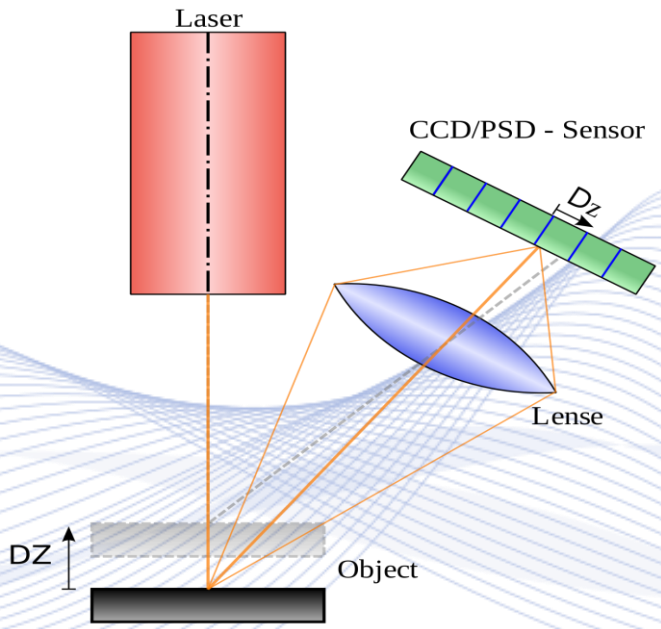


Event Camera (**ON**, **OFF** events)

Δt = 40 ms.

Laser scanning

A ***3D laser scanner*** uses a technique that employs reflected laser pulses to create accurate digital models of existing objects.



Laser scanning.

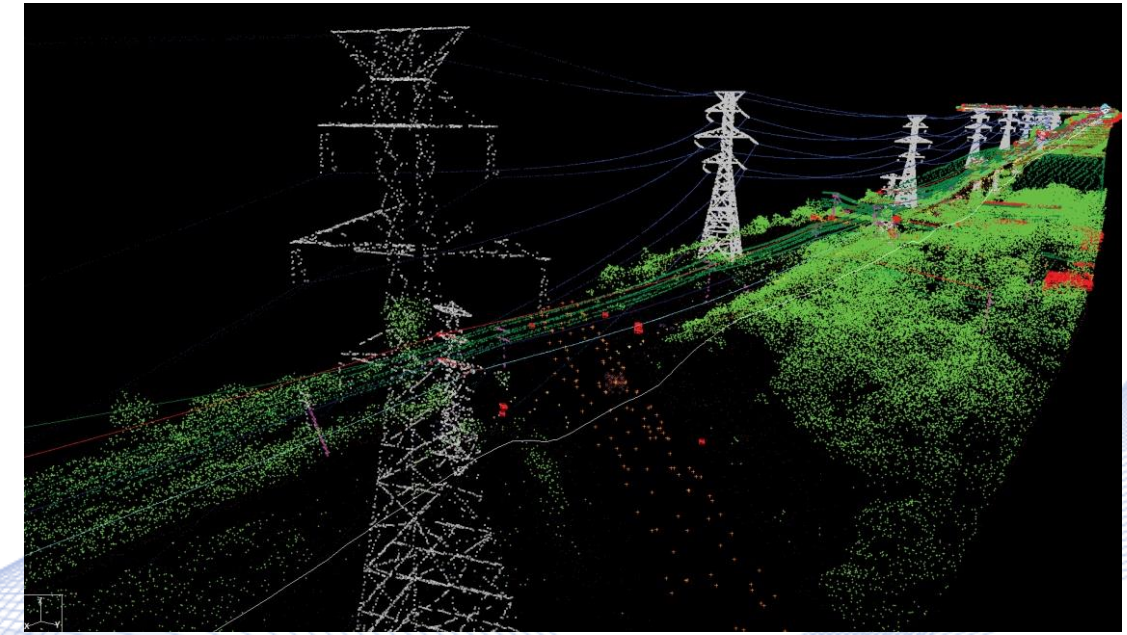
Laser Range Finder

- It emits laser pulses which travel to the ground/obstacle surface, where they are reflected.
- Part of the reflected radiation is detected by the device and stops a time counter started when the pulse was sent out.
- The distance is calculated using the speed of light.

  Typical range 1200 m.
- ***Laser altimeter*** measures the altitude (height) above a fixed ground level.

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

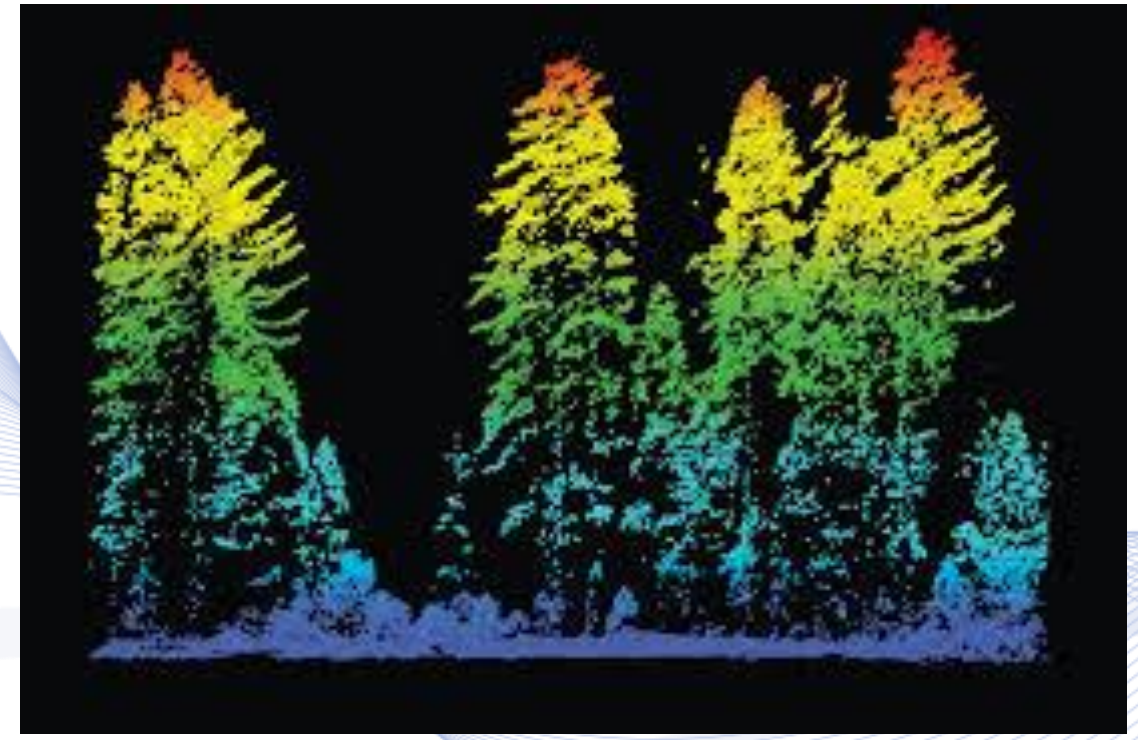
Lidars

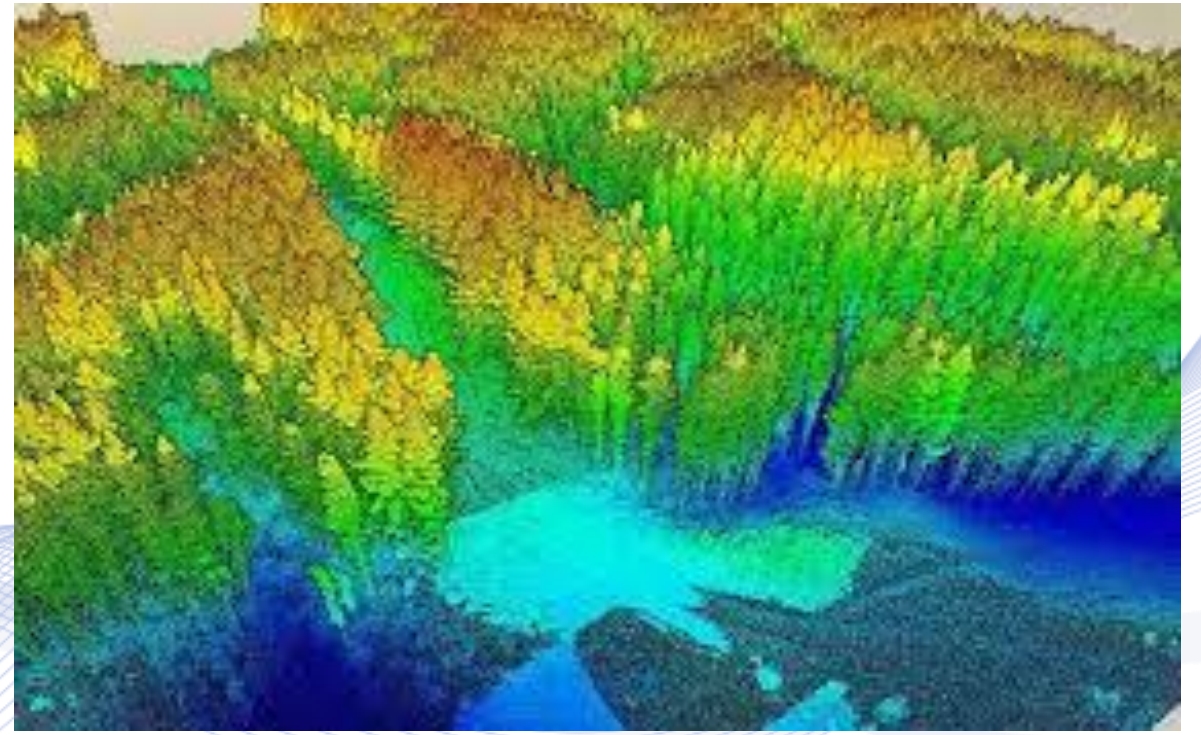
- Lidars provide depth acquisitions at a range of 100 m with a good spatial analysis.
- 3D geometry can be represented by:
  - 3D point clouds;
  - Octomaps or triangulated surfaces.
- Higher-level depth features can be obtained:
  - Depth segmentation.
  - Semantic depth information analysis.

Lidars

- Lidar-generated 3D point clouds are very accurate (much more precise than those provided by cameras).
- Laser pulses may be affected by heavy rain or low hanging clouds, because of ***light refraction***.
- Laser scanning technology does not work well when:
  - there are high sun angles or
  - huge light reflections.
- Lidar laser beams may occasionally affect the human eye.

Lidars

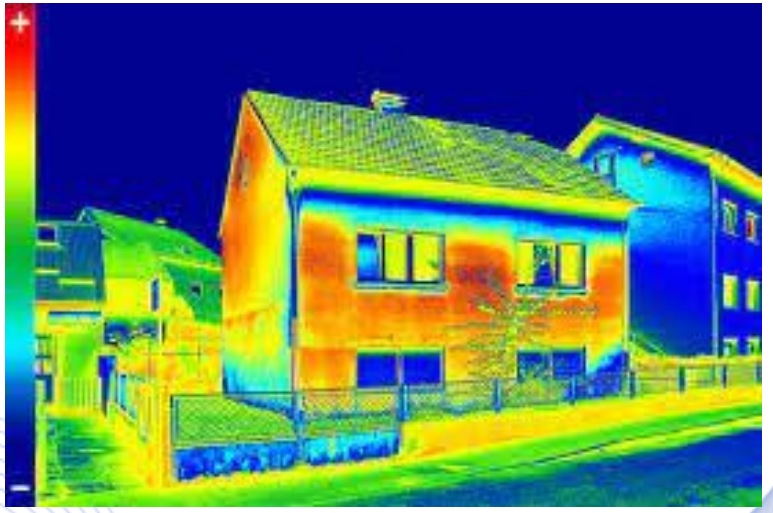




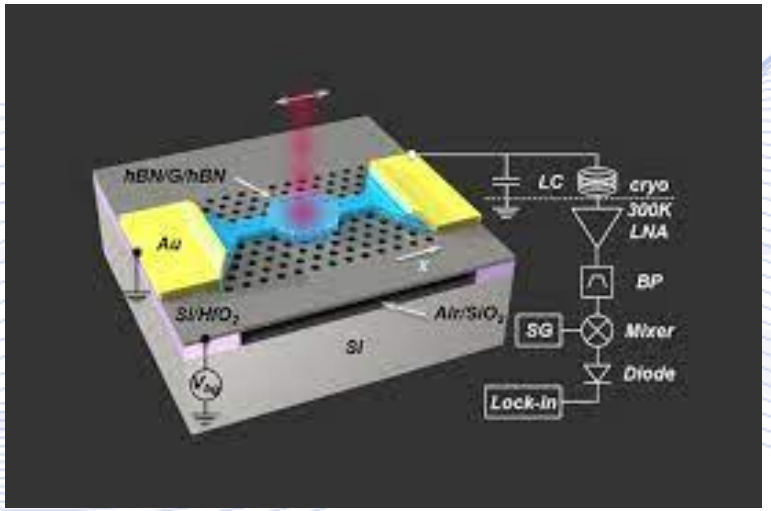
Lidars and forest imaging.

IR measurement and imaging

- ***IR cameras*** produce thermal images of an object.
- ***Bolometer*** measures the radiant heat.

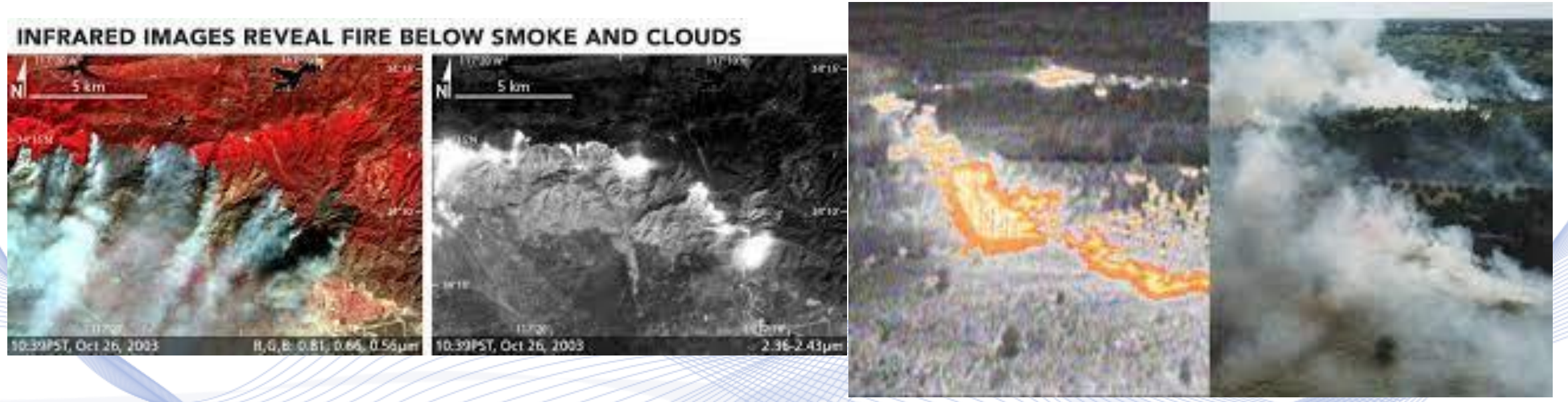


https://www.phase1vision.com/blog/understanding-the-benefits-of-infrared-imaging-cameras



https://phys.org/news/2018-06-bolometer-faster-simpler-wavelengths.html

IR measurement and imaging



IR imaging of forest fires.

Optical Fire Detection Systems

InsightFD Wildfire Detection System (Insight Robotics).

ADELIE (Alert Detection Localization of Forest Fires, Paratronic).

Optical beam smoke detection

Detecting absorption or scattering of light.

- It consists of a light transmitter and a photosensitive receiver.
- Portable, can be used for in-situ and remote measurements.
- Prone to false alarms (dust/dirt).

Smoke detector.

Ionization smoke detection

- It uses radioactive element (Americanium-241) to ionize air.
- ***Fire aerosoles change the ionization current***, triggering a detection.
- They are widely used in consumer market for fire detection.
- They provide in-situ measurements only.

Ionization smoke detector.

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.

Drones for ND observation

UAV Sensors

WIRIS PRO camera+ gimbal.

- Full HD 10x Optical Zoom Camera
- IR Camera Resolution px, 18º,32º,45 and 69º IR Lenses
- 7,5-13.5um Vox microbolometer.

Drones for ND observation

Fotokite Sigma

Actively tethered drones

Pros :

- Thermal camera
- Autonomous flight
- Robust Wind Performance
- 24 hour capacity.

Cons :

- Wired connection
- Does not provide 3D information

https://fotokite.com/situational-awareness-system/

Drones for Fire Fighting

Extinguish fires using drones (Portugal).

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/

Autonomous NDM Vehicles

Clemson University
Deep orange

- Off road autonomous driving
- Equipped with lidars, cameras, and high-accuracy GPS.
- Energy management strategies.

MISSION SCENARIOS

COLD WEATHER
DISASTER RELIEF

URBAN
RECONNAISSANCE

Artificial Intelligence & Information Analysis Lab

http://cuicardeeporange.com/project/do13/

Autonomous NDM Vehicles

Colossus

- Remotely controlled.
- High autonomy: up to 12 hours in operational situations.
- Power: 500 kg carrying capacity and 500 kg pulling capacity.
- Resistant to thermal waves.
- Sized to intervene in both indoor and outdoor environments.

https://www.shark-robotics.com/shark-robots

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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

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.

Big NDM Data Analytics

Social Media Analytics

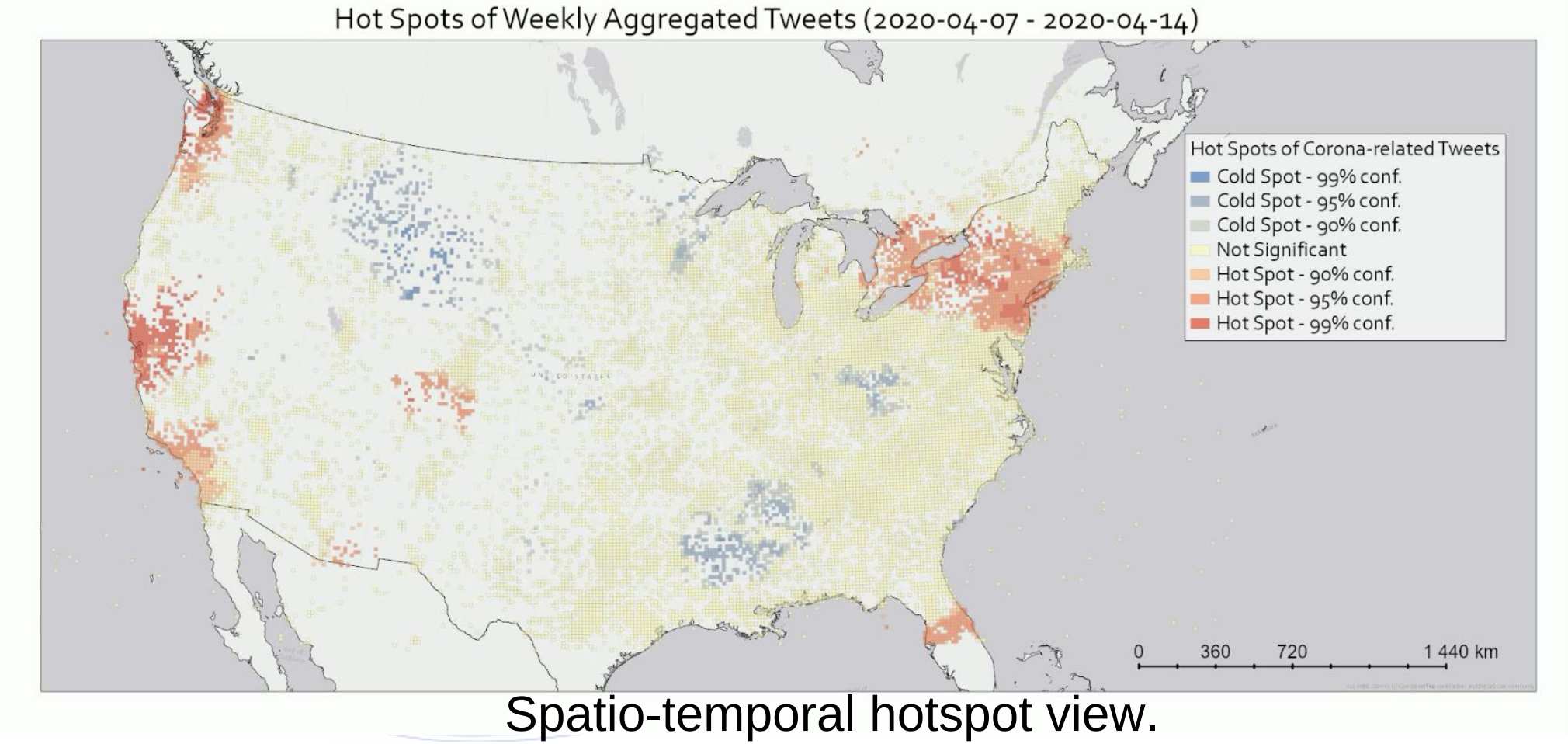
- Geosocial analytics
- Semantic topic extraction
- Text sentiment analysis

Fast NDM Data Analytics

- DNN acceleration

Big NDM Data Analytics

Georeferenced tweet analysis.



Spatio-temporal hotspot view.

Big NDM Data Analytics

Trustworthy NDM Data Analytics

- DNN robustness
- Privacy protection
- DNN Explainability

Other NDM Data Analytics Issues

- Information fusion
- Visualization tools

Big NDM Data Analytics

Visualization Tools

*Smart desk (*KAMK*)*

- The SmartDesk is an application running on a custom-built touchscreen computer
- The application is a mission management tool for civil protection
- It unifies the information and functionalities of TEMA in a single place
- It can be installed on any Windows PC
- Touch input, mouse, and keyboard are supported

AR visualization

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- **Horizon Europe R&D project TEMA**

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

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

AUTH/AIIA Lab

Artificial Intelligence Information Analysis

Statistics

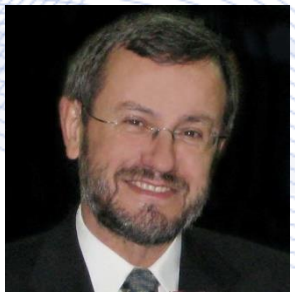
- 1300+ papers in academic conferences and journals
- 54 book chapters
- 15 books
- 38000+ citations (source: Google Scholar)

Personnel

- 5 Faculty Members
- 1 Post-Doc
- 20+ researchers

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)



Prof. Ioannis Pitas

Dr. Vasileios Mygdalis

Artificial Intelligence & Information Analysis Lab

What is on store

- **Coordinator of the International AI Doctoral Academy**

https://www.i-aida.org/

- **232 CVML web lectures: http://icarus.csd.auth.gr/cvml-web-lecture-series/**

- ICARUS http://icarus.csd.auth.gr/
- AI4Media (https://ai4media.eu/)
- TEMA (https://tema-project.eu/)
- CVML email list and resources https://aiia.csd.auth.gr/gr/cvml/

R&D cooperation opportunities in AIIA Lab

- **Many open Postdoc, PhD, MSc research positions.**
  - Computer Vision and Machine Learning
  - Applications in:
    - Natural Disaster Management
    - Industrial Surveillance

- **Short young researcher visits.**

International AI Doctoral Academy (AIDA)

Excellence in AI PhD research and education.

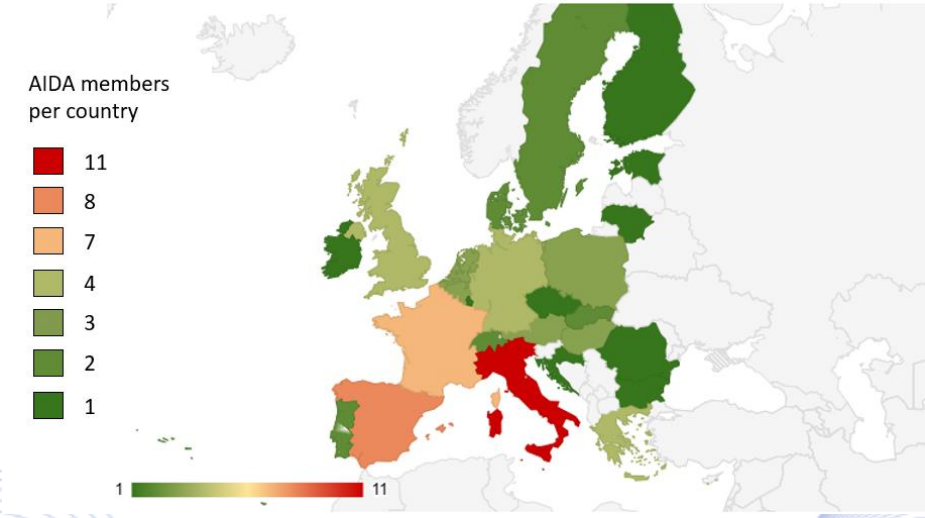
Membership:

80 members (60 AI Universities, and 20 R&D centers, companies).

Geographical coverage of almost the entire Europe.

Operation highlights:

- **AIDA Lecturers**: 160.
- **AIDA Students**: 243 (226 PhD and 17 Post Docs).
- **Junior fellows exchange program**: **88 secondments,** involving 65 organizations across Europe and beyond.
- **AIDA courses**: 82 delivered courses in total.
- **AIDA courses** have attracted a total of **3300+ participants.**
- **AIDA email list registrants**: 1100+.
- **51 Lectures** in AI Excellence Lecture Series attracting ~110 attendees on average.
- **329 AIDA AI educational resources.**
- **22 AIDA educational material curators** (15 from AI4Media).



International AI Doctoral Academy (AIDA)

More infos on AIDA activities: https://www.i-aida.org/

- BSc/MSc/PhD students or graduates on CS/ECE or any scientific discipline from all over the world can join the AIDA courses or attend AIDA AI Excellence Lectures: https://www.i-aida.org/phd-studies/short-courses/

https://www.i-aida.org/event_cat/ai-lectures/

University Professors and/or PhD holders from any Institution worldwide can offer AIDA courses or seasonal schools.

- Procedure and application from in: https://www.i-aida.org/phd-studies/short-courses/

Universities/R&D centers from all over the world can join as AIDA members:

- Procedure and application from in: https://www.i-aida.org/about/members/

Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

Contact: Prof. I. Pitas
pitas@csd.auth.gr