MultiDrone: Multiple drone imaging

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731667 (MULTIDRONE)

Multidrone case study: sports AV shooting

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Drone vision objectives and challenges

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- A) Improved multiple drone decisional autonomy, robustness and safety.
- B) Innovative, safe and fast multiple drone active perception and AV shooting.

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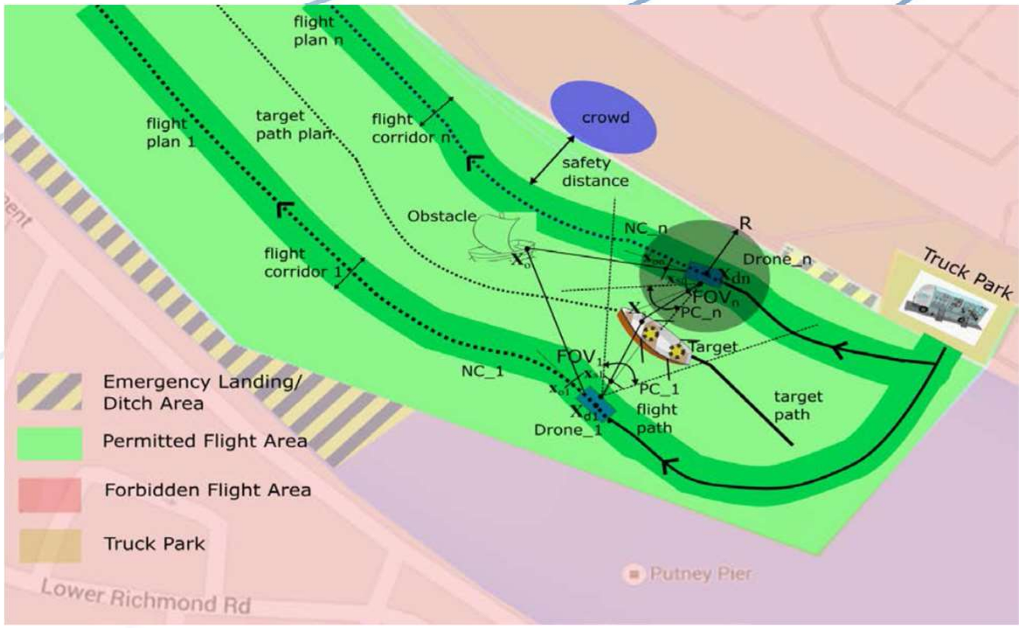
Challenges in boat race shooting

- A) Drone decisional autonomy, robustness and safety:
  - Crowd, obstacle detection and avoidance
  - Emergency landing site detection.
- B) Multiple drone active perception and AV shooting:
  - Target tracking and following
  - Cinematographic shooting



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Methodology

- **End user requirements.**
- **HW/SW system specs, design, implementation, integration.**
- Strong interplay between:
  a) mission (AV shooting) planning, mission control/execution;
  b) active perception
- **Pre-production:**
  - semantic world mapping
  - mission planning.

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Methodology

- **Production:**
  - multiple drone flight/formation control
  - active perception (multiple drone and target localization tracking),
  - cinematographic AV shooting.
  - safety/emergency monitoring/sensing
  - emergency handling at the production phase.

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System Platform requirements

- These requirements are from the point of view of media production, therefore they are mainly about:
  - Drone physical parameters (weight, maximum speed, etc.)
  - Autonomy in flight and in perception
  - Storage, communication, control
  - Logistics
  - Interfaces to studio
  - Director and flight supervisor dashboards.

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Drone vision for cinematography: HW issues

MultiDrone

1. **Drone platform:**
   1. Flight machine
   2. AV and visual perception payload
2. **Ground station platform**
3. **Drone-ground station communications**
4. **Human centered interfaces:**
   1. Director, (photographers?)
   2. Flight supervisor, (pilots?).

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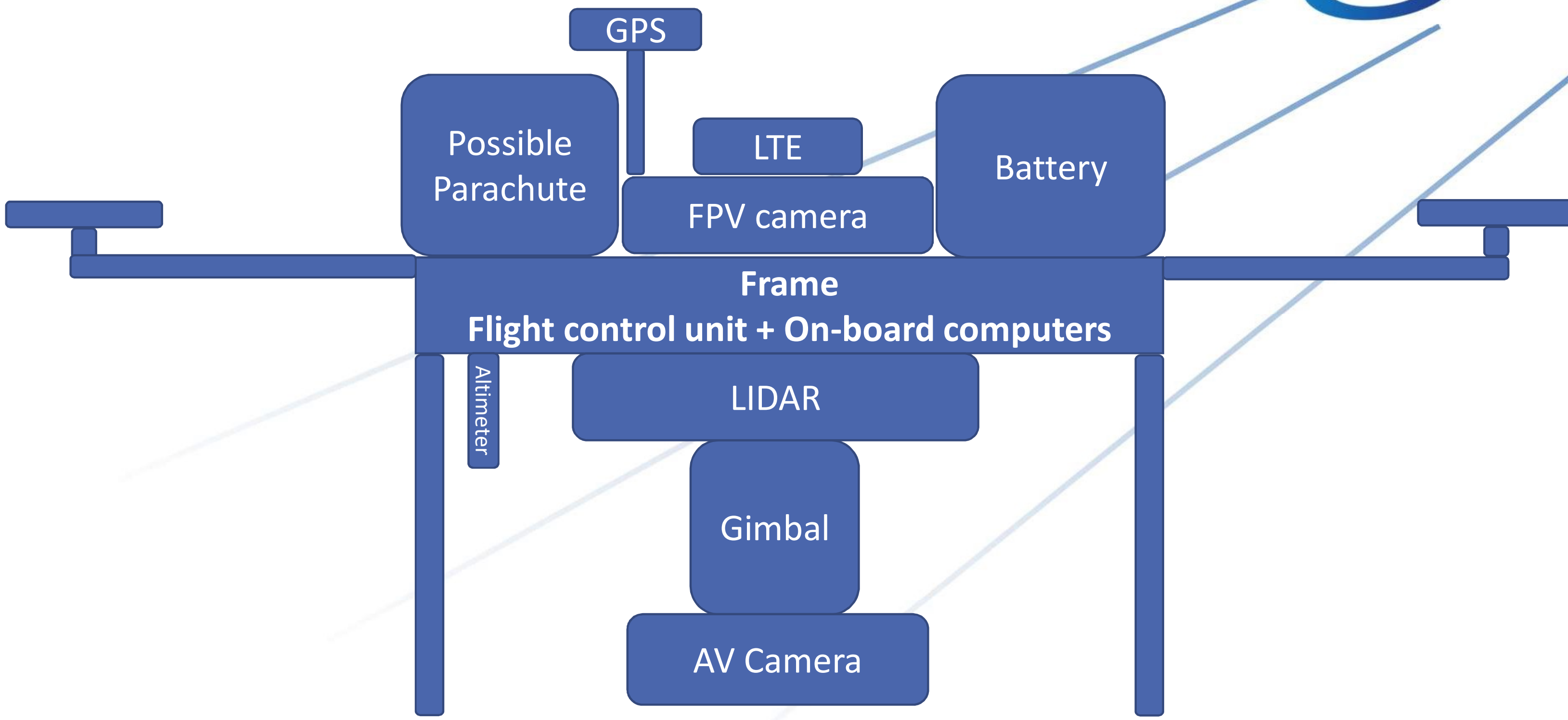
General Drone Architecture



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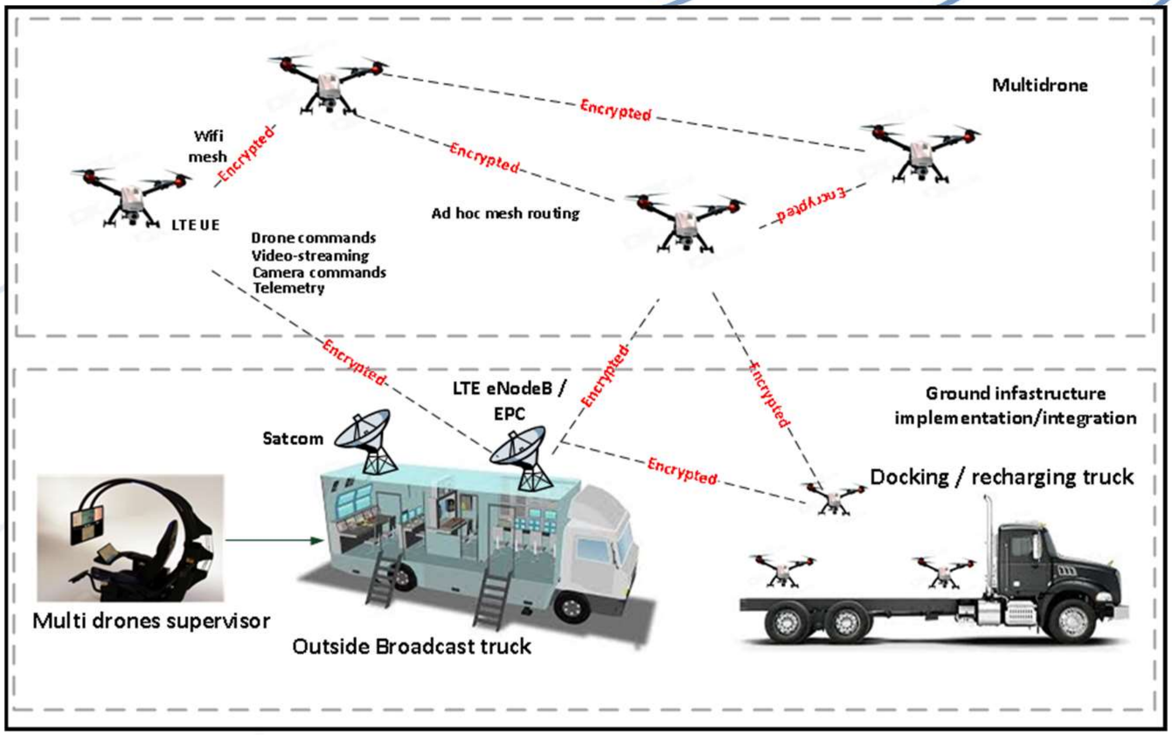
Communication infrastructure

- Drone 2 Drone Communication
- Drone 2 Ground communication
- Live broadcasting



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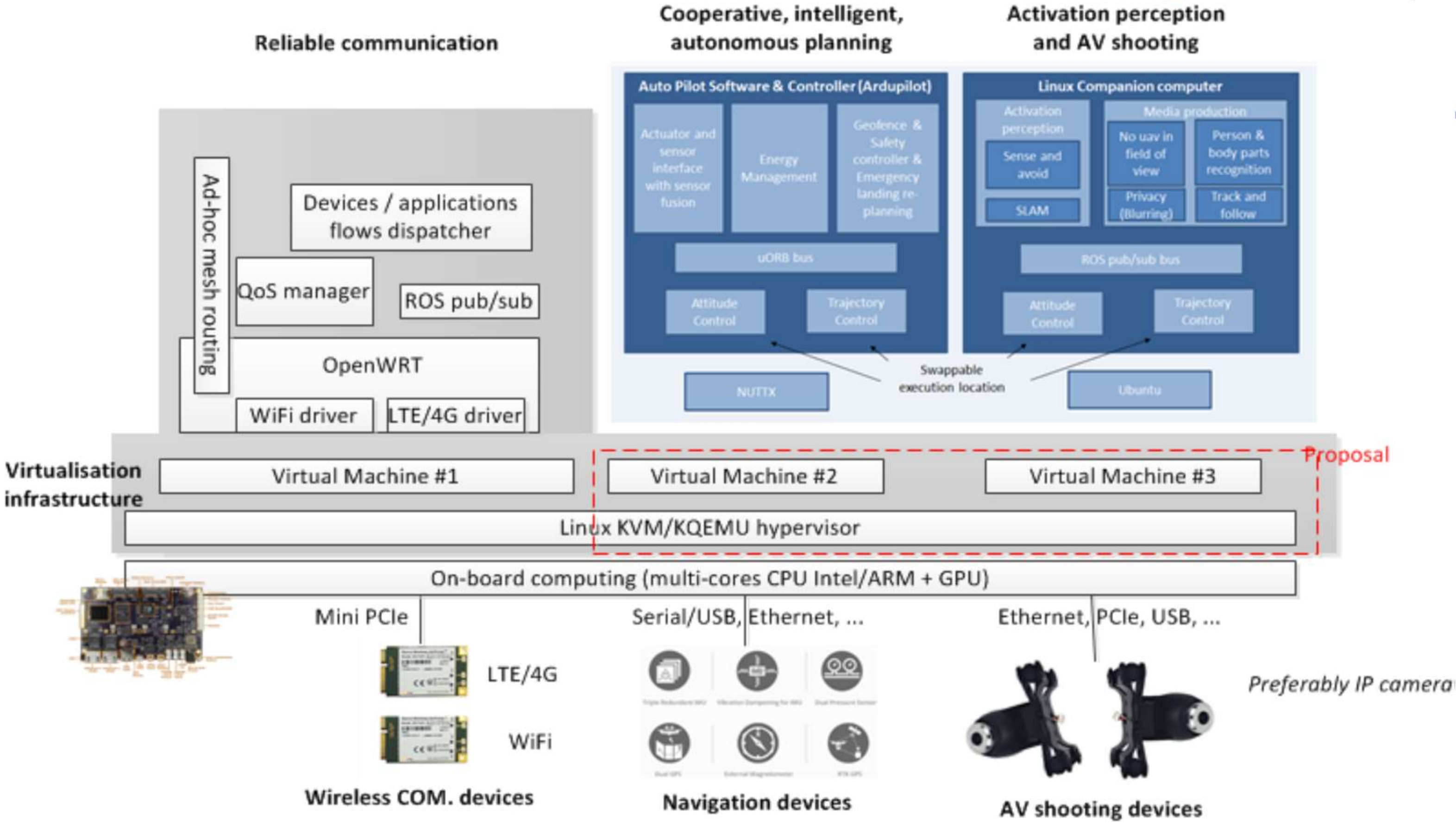
Integrated software and hardware target



Drone vision for cinematography: Functionalities (1)

MultiDrone

1. **(Multiple) drone mission planning.**
2. **(Multiple) drone mission control.**
3. Active perception.
4. AV shooting.

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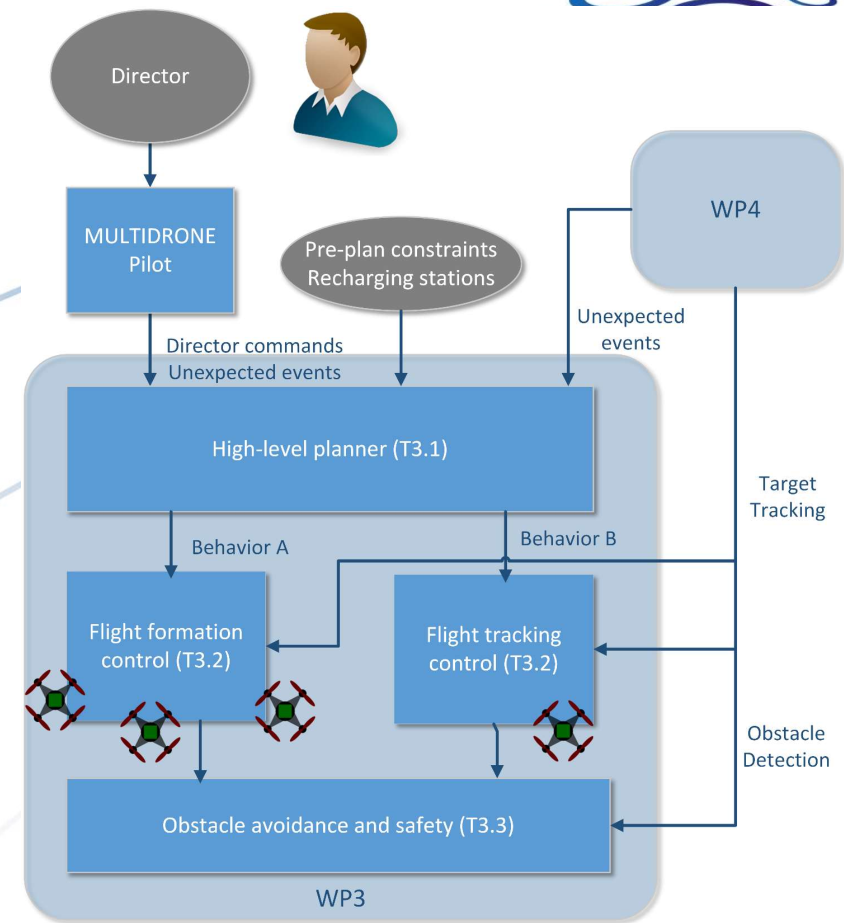
High-level pre-production/production mission planning

MultiDrone

- **High-level planner** assigns different behaviours/tasks to the multidrone team according to director and environmental requirements.
- The multidrone planner needs to be **scalable** with multiple actors, since on-line re-planning could be needed as events happen or execution is performed.



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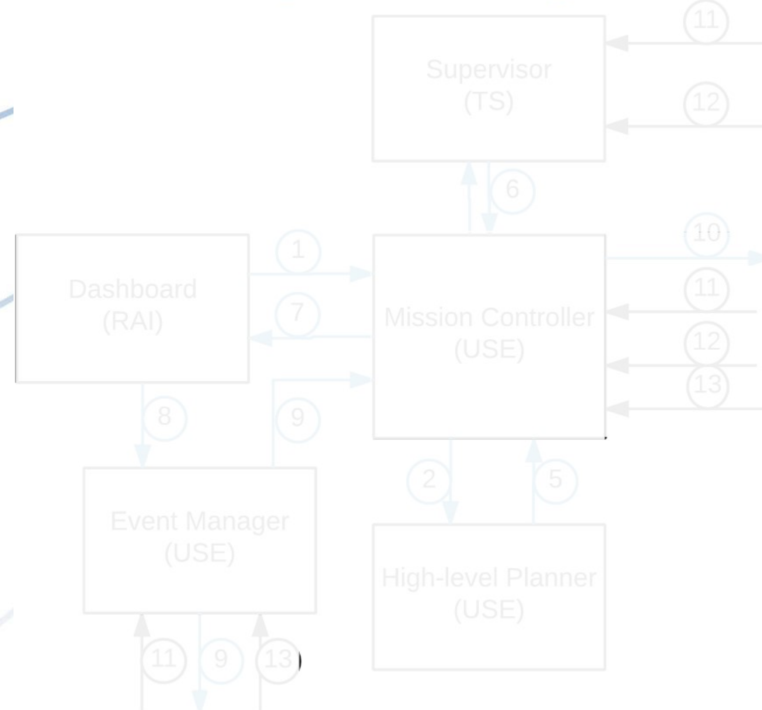
Mission Planning/Control
On ground modules

- **Mission Controller:**
  - Interacts with **High-level Planner** to produce a mission plan.
  - Monitors mission execution.
  - Asks for replanning if needed.
- **Event Manager:**
  - Receives, manages, and generates events.
  - Sends events to drones to start and stop action execution.



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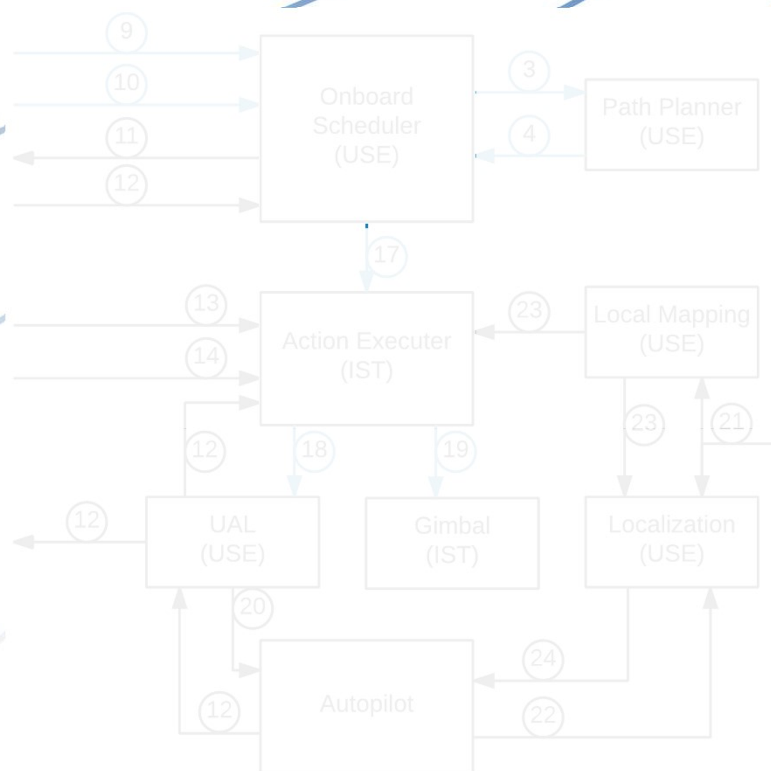
Mission Execution
On drone modules

- **Onboard Scheduler:**
  - Receives list of actions
  - Receives events to trigger action execution
  - Activates the Action Executer
  - Sends drone status to ground
- **Action Executer:**
  - Translates Shooting Actions into desired drone+camera configurations
  - Interacts with other modules to produce commands for autopilot, camera and gimbal



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Drone vision for cinematography: Functionalities (2)

MultiDrone

1. **Perception and localization. SLAM:**
   1. Semantic 3D world mapping
   2. Drone localization.
2. **Visual and perception data analysis for AV Shooting:**
   1. 2D target (athlete, boat, cycle) detection and tracking
   2. 3D target localization and following
   3. Drone cinematography
   4. Target pose estimation.

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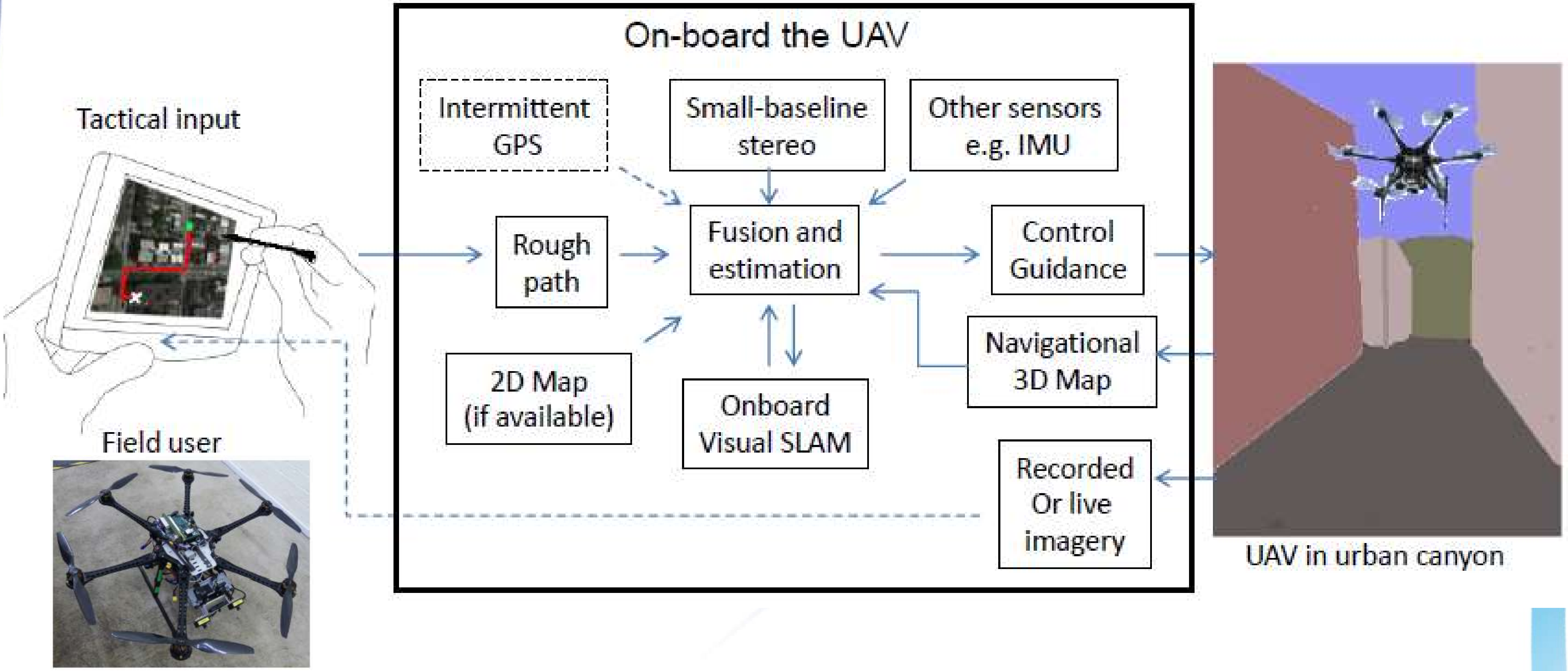
UAV Simultaneous Localization and Mapping



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Object detection

- **State-of-the-art** object detectors are based on **very Deep** and **multiple-channel CNNs.**
- **Multiple** layers of **many** convolutional filters are applied to the input image, forming a *very deep* architecture of successive convolutions and optionally some fully connected components.

  - Trained on large-scale datasets, such as
    - VOC2007 with 10k images depicting ~**24k objects** belonging to **20 classes**
    - VOC2012 with ~11k images depicting **~27k objects** belonging to the same **20 classes** as VOC2007
    - COCO with 328k images, about **2.5 million objects** belonging to **91 classes.**

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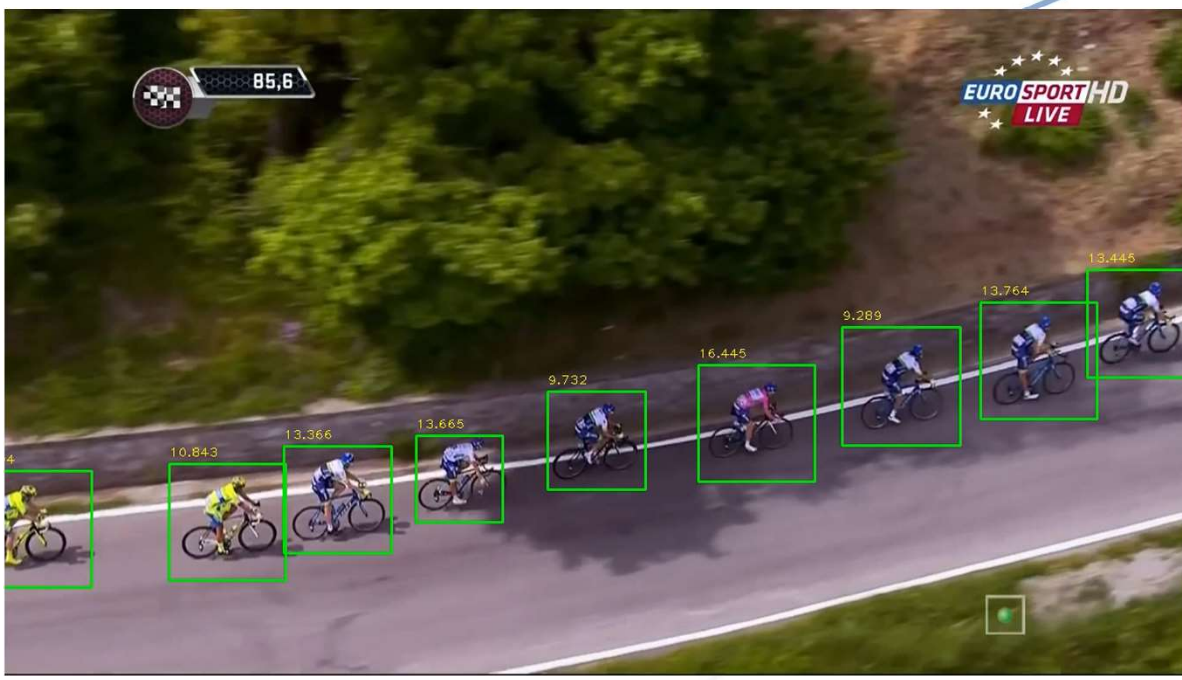
Object detection

- Both are very capable of accurately detecting objects



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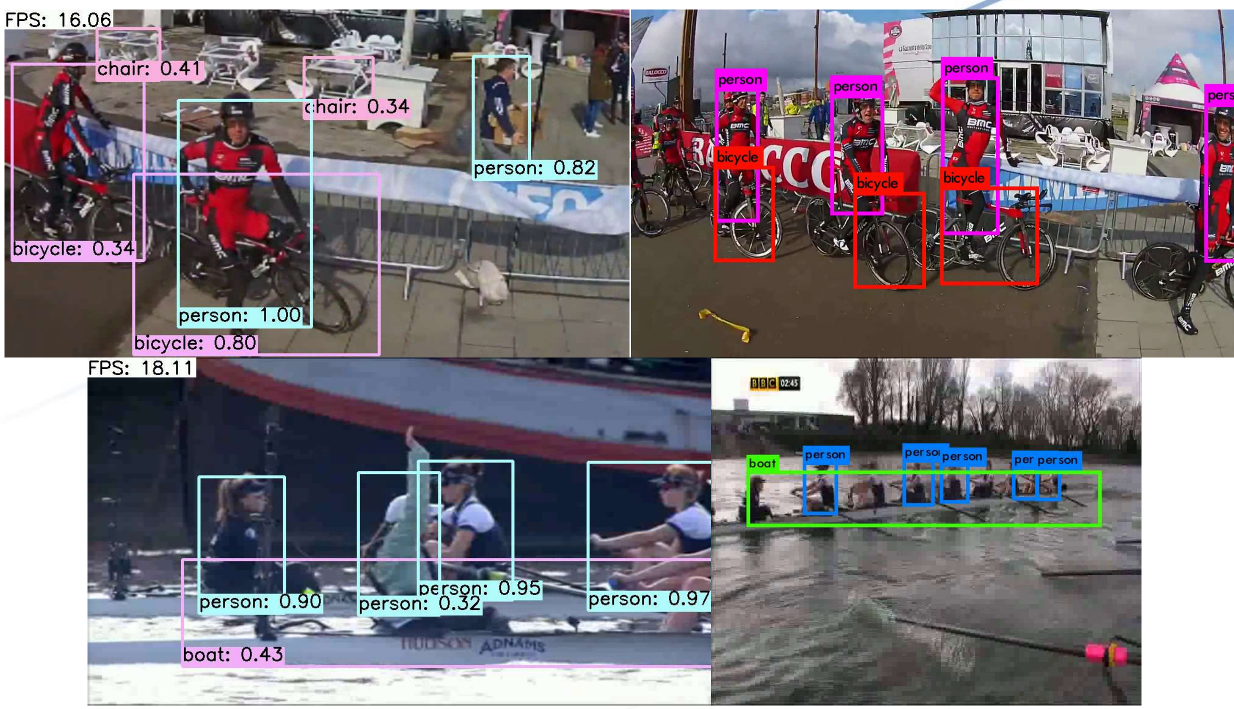
Object detection

- Current neural detectors are very capable of accurately detecting objects



SSD YOLO

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Object detection acceleration

- Tiny YOLO: low precision, but very lightweight.
- Evaluation on VOC (Mean average precision, time):

Input Size	FPS	mAP	Forward time (ms) No TensorRT	Forward time (ms) TensorRT	Forward time (ms) FP16
608	6.5	51.28	76.5	37.5	22.1
544	8.2	52.93	68.4	34.8	20.5
480	13.4	55.00	50.1	17.2	11.7
416	16.5	56.28	49.9	15.7	10.3
352	20	55.05	37.1	13.0	7.9
320	23	53.81	34.0	11.7	7.2

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UAV Object Tracking specs

- 2D visual tracking will be employed for target following.
- Satisfactory performance in UAV sports footage is required.
- Target tracking should be performed in real-time, i.e., > 25 fps.
- On drone implementation might be required as well, thus low computational complexity is preferred.
- Parallel or parallelizable methods (e.g., with CUDA implementations) should be preferred as well.
- Assuming 2D target tracking methods operate faster than combining target detection and recognition methods, long-term UAV tracking is also preferred.

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UAV Object Tracking benchmarking

- 14 top performing 2D trackers [VOT 2016] were implemented in MATLAB using the UAV123 dataset interface.
- Performance was evaluated in 26 UAV videos obtained from UAV123 and YouTube, including long term videos as well.
- 3-fold evaluation:
  - Precision plot (the ratio of successful frames, where the tracker output is within the given threshold (x-axis of the plot, in pixels) from the ground-truth, measured by the center distance between bounding boxes)
  - Mean time before success rates falls below $y\%$, $y = 10, .., 100$
  - Operation speed.
- Evaluation platform: Ubuntu 16.04, 8GB ram, i7

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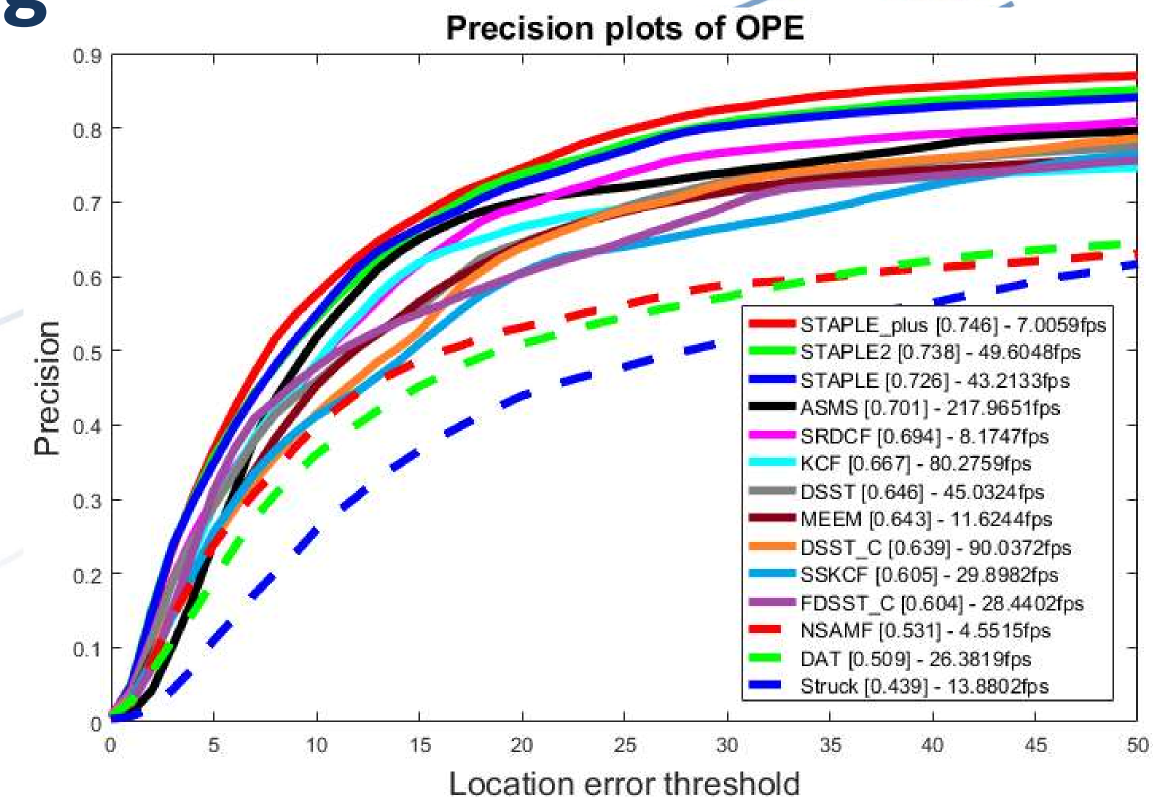
UAV Object Tracking benchmarking

- ASMS provides a good compromise between accuracy and fps rate



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Convolutional Object Tracking

- Preliminary experiments on VOT benchmark indicated potentially more robust trackers

Ranking

	baseline
	Expected overlap
SiamFC_2x2_pool	0.2612
SiamFC_5s_3x3_pool	0.2570
SiamFC_5s_2x2_pool	0.2505
SiamFC_3x3_pool	0.2491
SiamFC_3s	0.2485
SiamFC_5s	0.2413

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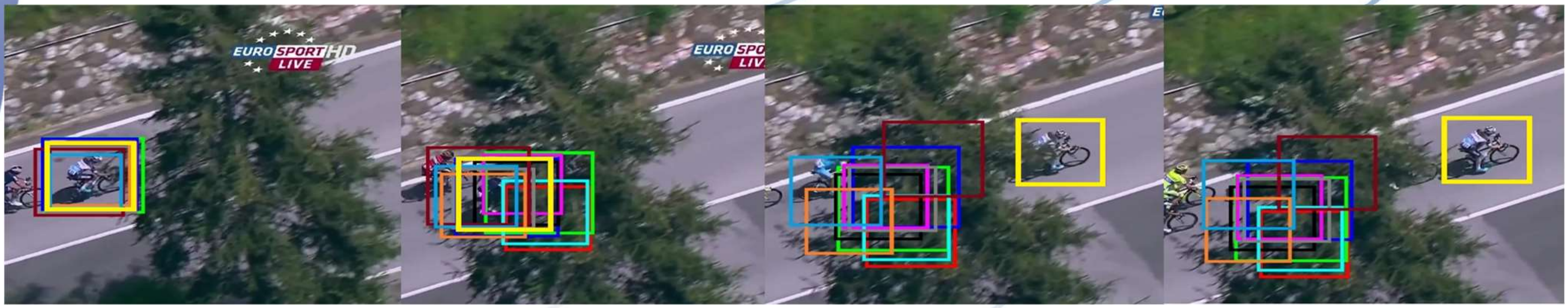
Joint Detection & Tracking

- Target reinitialization by the detector in hard tracking cases when tracking algorithms fail



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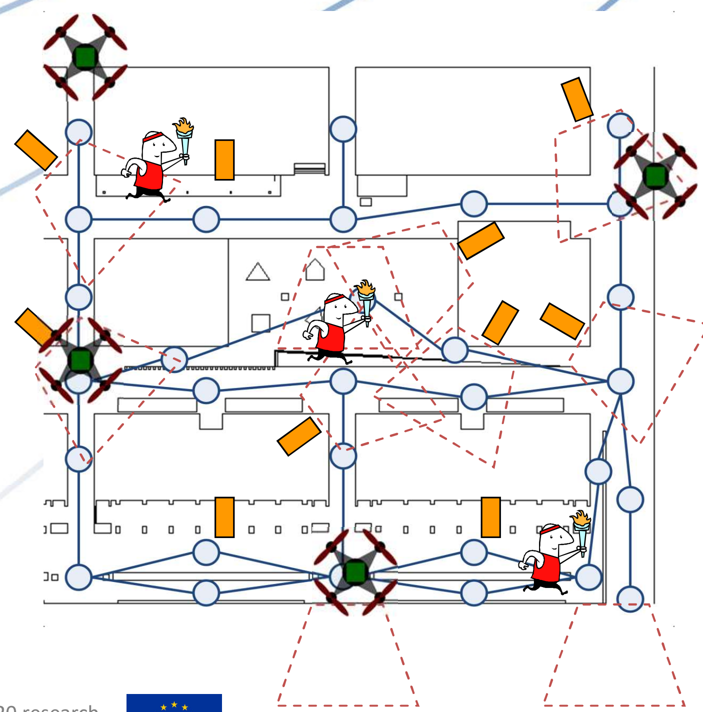
Optimal multi-sensor multi-drone 3D target localization, tracking & following

MultiDrone

- Problem: maximize a merit metric resulting from multi-drone object tracking
- Assumptions:
  - M drones
  - All cameras can be oriented
  - Drones motion is assumed known
- Objective: maximize a merit metric resulting from multi-drone



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Target Pose Estimation

- **Machine Learning Approach**
  - We integrated a pre-trained yaw estimation model of facial pose (DeepGaze library) into the SSD-300 object detector (trained to detect human faces)
  - Varying illumination conditions seem to affect the estimation.

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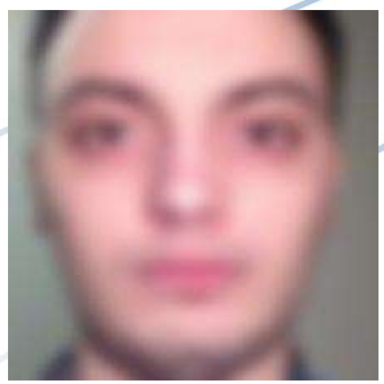
Privacy Protection: acceptable facial image quality?

Original Image



Gaussian blur with std. deviation of 5

Hypersphere projection with radius of 8

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Face recognition/de-identification/privacy protection

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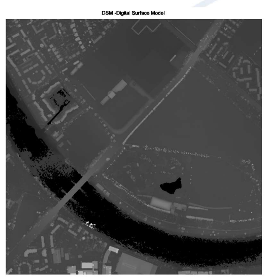
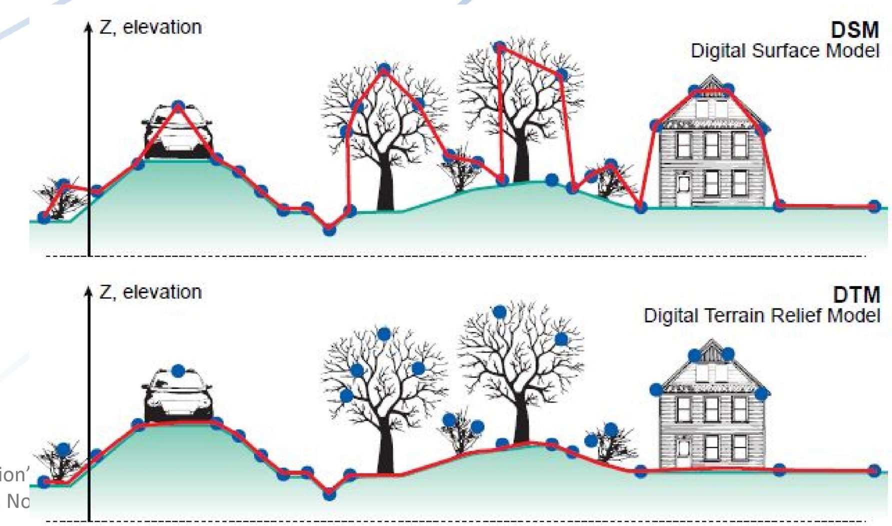
Potential Landing Site Detection

- Algorithm for identification of potential landing areas using digital elevation models (DEM) consists of five discrete steps:
  - input consists of two digital elevation models namely
    - the digital surface model (DSM) and
    - the digital terrain model (DTM) of a region
    - in raster format, i.e., as a regular grid of elevation values of a depicted terrain.

DTM

DSM





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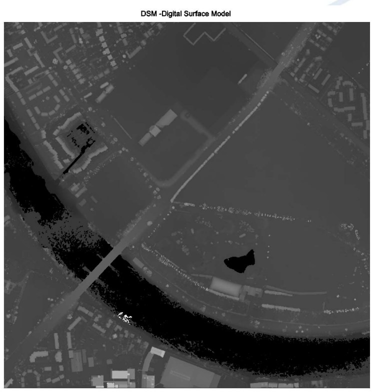
Potential Landing Site Detection

- Number of areas depicted in the DEM data from the publicly available dataset provided by UKs Environment Agency
  - DEM covering urban, suburban, rural and bush areas
  - Spatial resolutions (pixel size per dimension) ranging from 0.25m to 2m
- Areas no 1 and 2, resolution 0.25m refer to an urban environment with many obstacles such as buildings and trees
- Area no 3, resolution 2m is a rural environment with steep downhill descent parts
- Ground truth (potential landing sites, areas not suitable for landing) was manually constructed through visual inspection of the DEMs and satellite images (the latter were obtained by Google Maps).

DSM



Ground Truth

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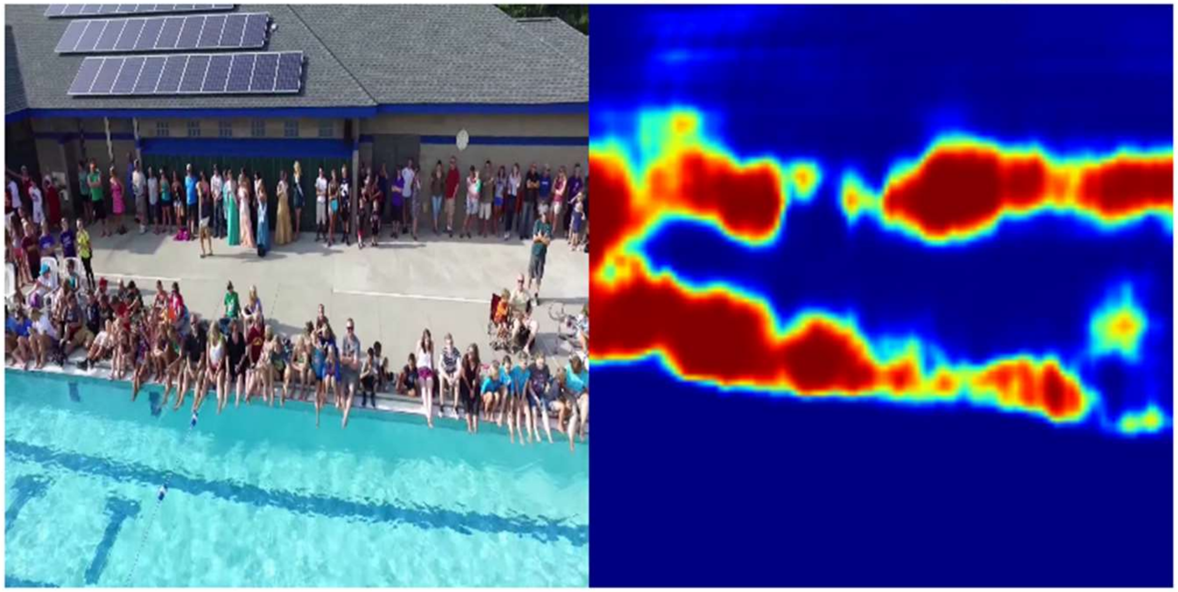
Crowd Detection

- A *Fully Convolutional Neural Network* can be trained for Crowd Detection
- The result is a heatmap



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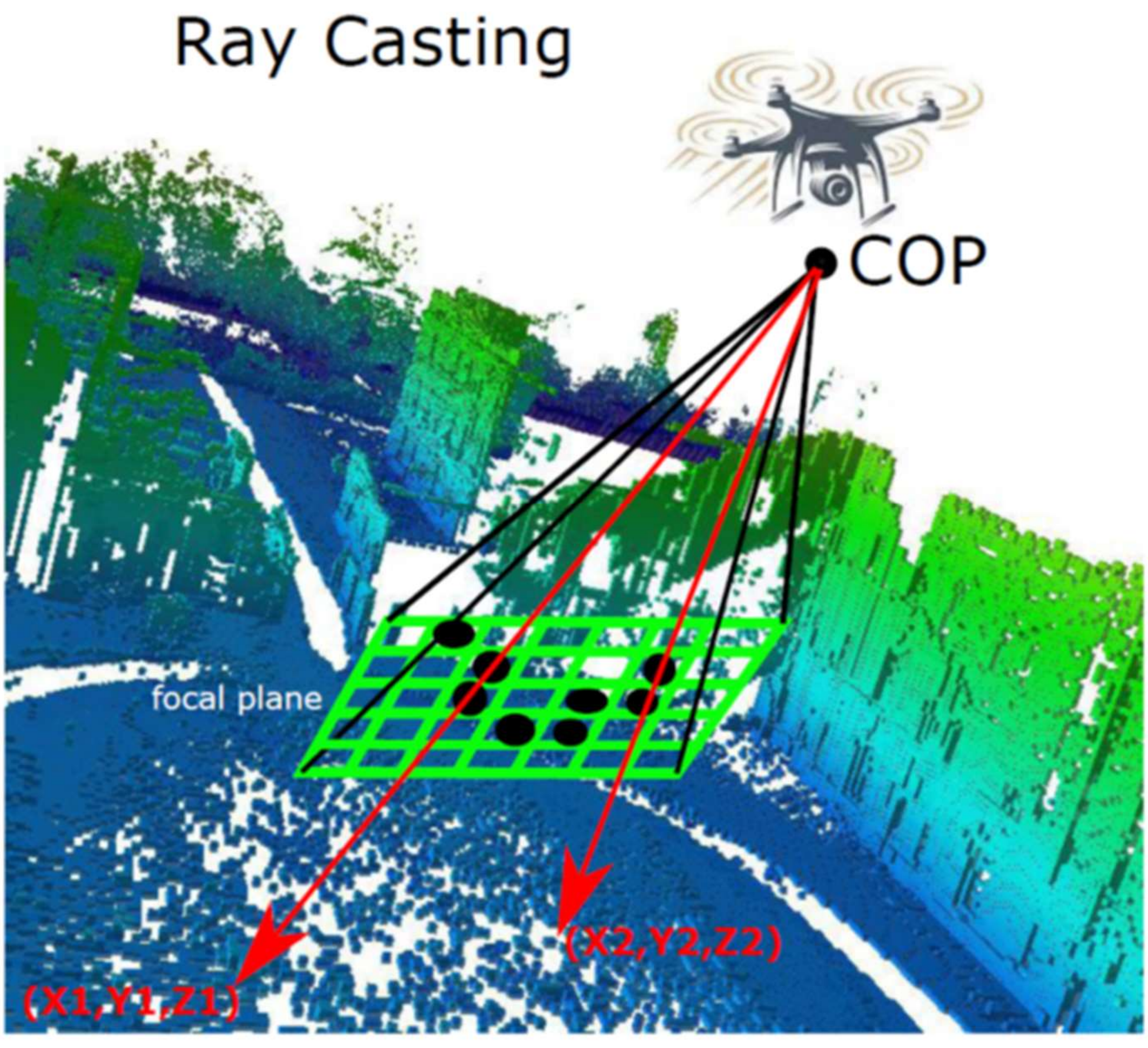
Ray Casting
COP
focal plane
(X1,Y1,Z1)
(X2,Y2,Z2)

Multidrone Consortium

1. Aristotle University of Thessaloniki, Greece (Coordinator)
2. Thales Communications & Security SAS
   a. Thales Services
3. University Of Bristol
4. The University of Seville
5. Deutsche Welle (DW)
6. RAI Radiotelevisione Italiana (RAI)
7. Alerion
8. Instituto Superior Técnico, Portugal

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Joint dissemination activities

MultiDrone

- **Drone summer school, Thessaloniki, Greece 8/2018**
- **Icarus.aiia: student forum on drone technologies.**
- Creation of a SIG on drone technologies.
- **IEEE ICIP2018 tutorial on drone imaging.**
- Competitions on drone cinematography.
- **Joint ERF2019 worskshop on drone technologies**
- Organization of an open call workshop in 2019.
- Special sessions and special issues.
- **Open to any new idea and cooperation options!**
    - **Send message to pitas@aiia.csd.auth.gr**

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Cooperation with other labs, R&D groups and projects

MultiDrone

- **Have a look at www.multidrone.eu**
- Icarus.aiia: student forum on drone technologies.
- Creation of a SIG on drone technologies.
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Q & A

Thank you very much for your attention!

Contact: Prof. I. Pitas
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