Introduction to Multiple Drone Systems Summary

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Artificial Intelligence & Information Analysis Lab

Drone vision objectives

- **Navigation**
  - Environment mapping.
  - Self localization.
  - Obstacle detection.
  - Imaging for drone safety.
  - Vision for multiple drone navigation
- **Environment visualization and mapping**
  - Semantic 3D environment mapping.
  - Object/target detection, tracking.
  - 6D object/target localization.

Drone vision applications

- **Filming**
  - **Drone cinematography**
  - Terrain filming, Sports filming
    - target detection, tracking, localization
- **Infrastructure inspection**
  - Semantic 3D infrastructure mapping.
- **Visual surveillance**
  - Object/target detection, tracking.
  - 6D object/target localization.
- **Aerial co-working.**

Multiple drones for sports AV shooting

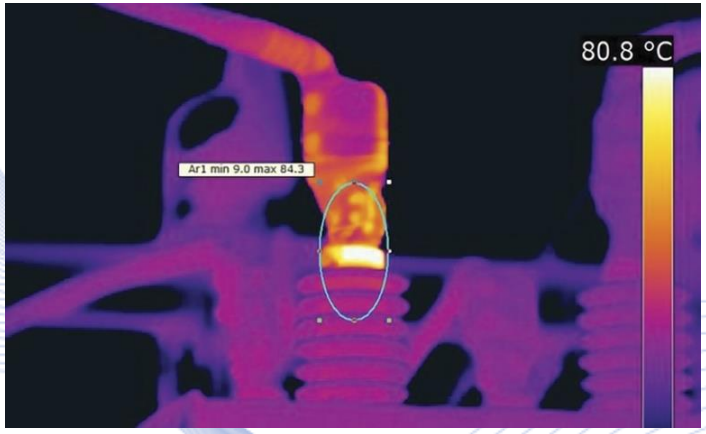
Multiple drones for sports AV shooting

Rowing boat race

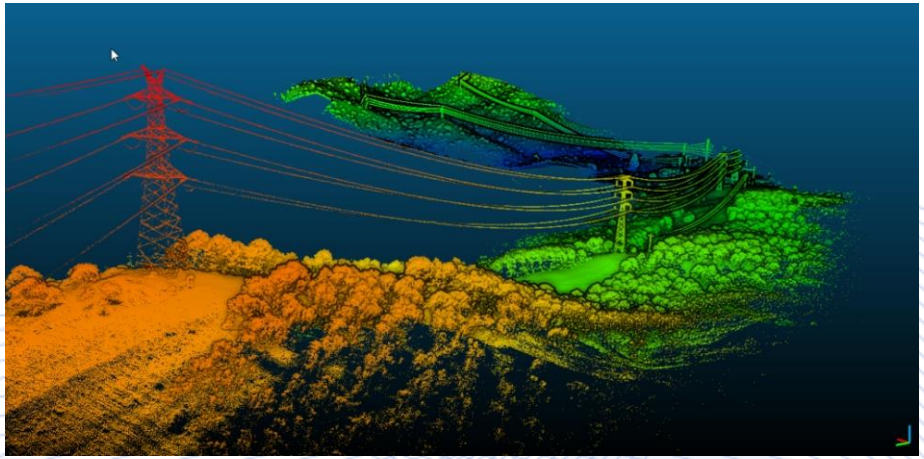
Infrastructure inspection applications

- Aerial robots with different characteristics must be integrated for:
  i. Long range and local very accurate inspection of the infrastructure
  ii. Maintenance activities based on aerial manipulation involving force interactions
  iii. Aerial co-working safely and efficiently helping human workers in inspection and maintenance

Electrical power line inspection



Thermography



3D mapping (LIDAR)

Camera & video

Aerial co-working applications

Aerial robots can interact with humans:

- Tool handover.
- Inspection of worker safety.

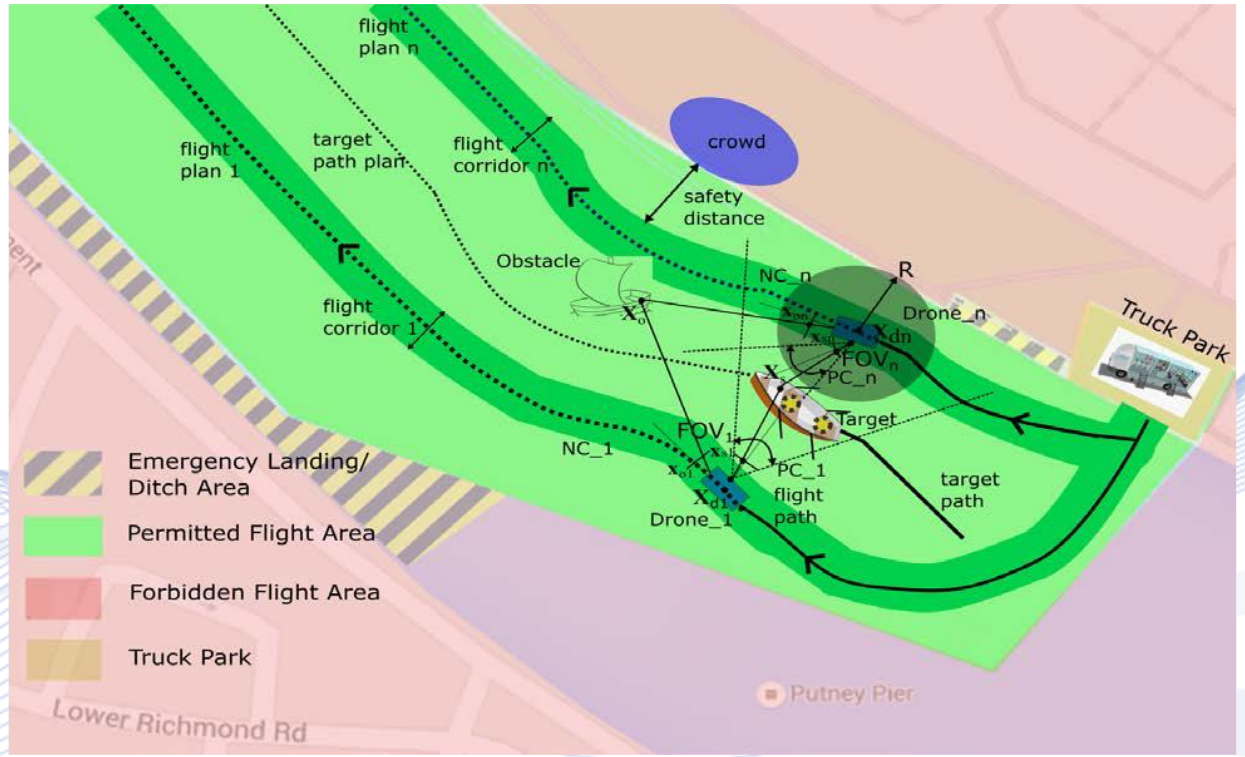
Manipulation while holding/perching

Coordination of a Heterogeneous Team of ACWs

- 3 main ACW activities:
- Safety-ACW - equipped with a surveillance camera (blue).
- Inspection-ACW – inspection sensor (red).
- Physical-ACW - equipped with a manipulator to provide tools required by workers

Challenges in multiple drone vision

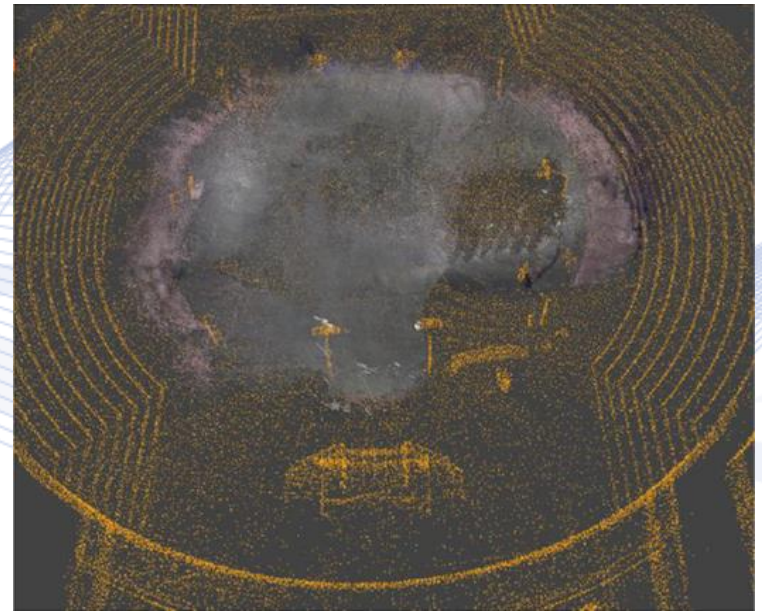
- A) Drone decisional autonomy, robustness and safety:
  - Obstacle detection and avoidance
  - Emergency landing site detection.
- B) Multiple drone active perception and AV shooting:
  - Target tracking and following
  - Cinematographic shooting



Multiple drone active perception and AV shooting

Fast multiple drone semantic world modelling:

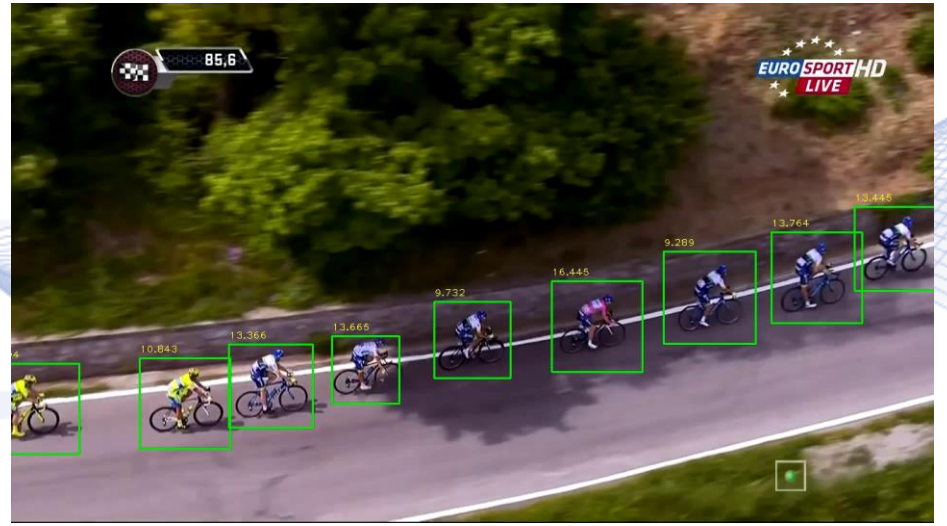
a) 3D world modelling.
b) Design and population of KML 3D map semantics.



Multiple drone active perception and AV shooting.

Fast drone vision/GPS target tracking:

- Novel real-time embedded target (e.g., boat, cyclist, football player) detection and tracking.



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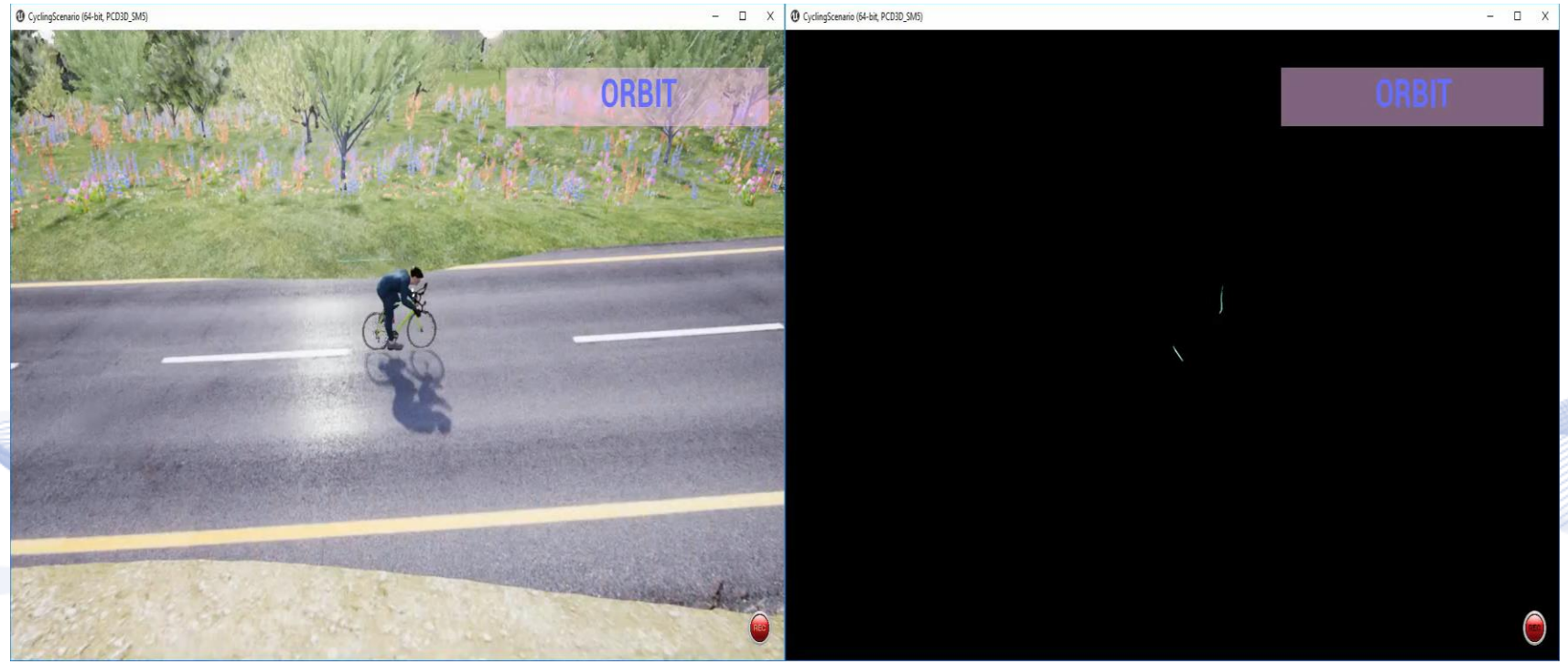
Multiple drone active perception and AV shooting

- Embedded robust real-time target detection/tracking using deep CNNs and correlation trackers.

Multiple drone active perception and AV shooting

- Drone cinematography taxonomy.
- Novel path/formation/gimbal/camera control techniques.



Multiple drone active perception and AV shooting

Drone human-centered visual information analysis:

- Fast and improved pedestrian detection.
- Fast and improved crowd detection.
- Fast novel real-time cyclists, parkourist, football player detection and tracking.

Heterogeneous drone swarms

Heterogenous drones (vehicle, payload differences)

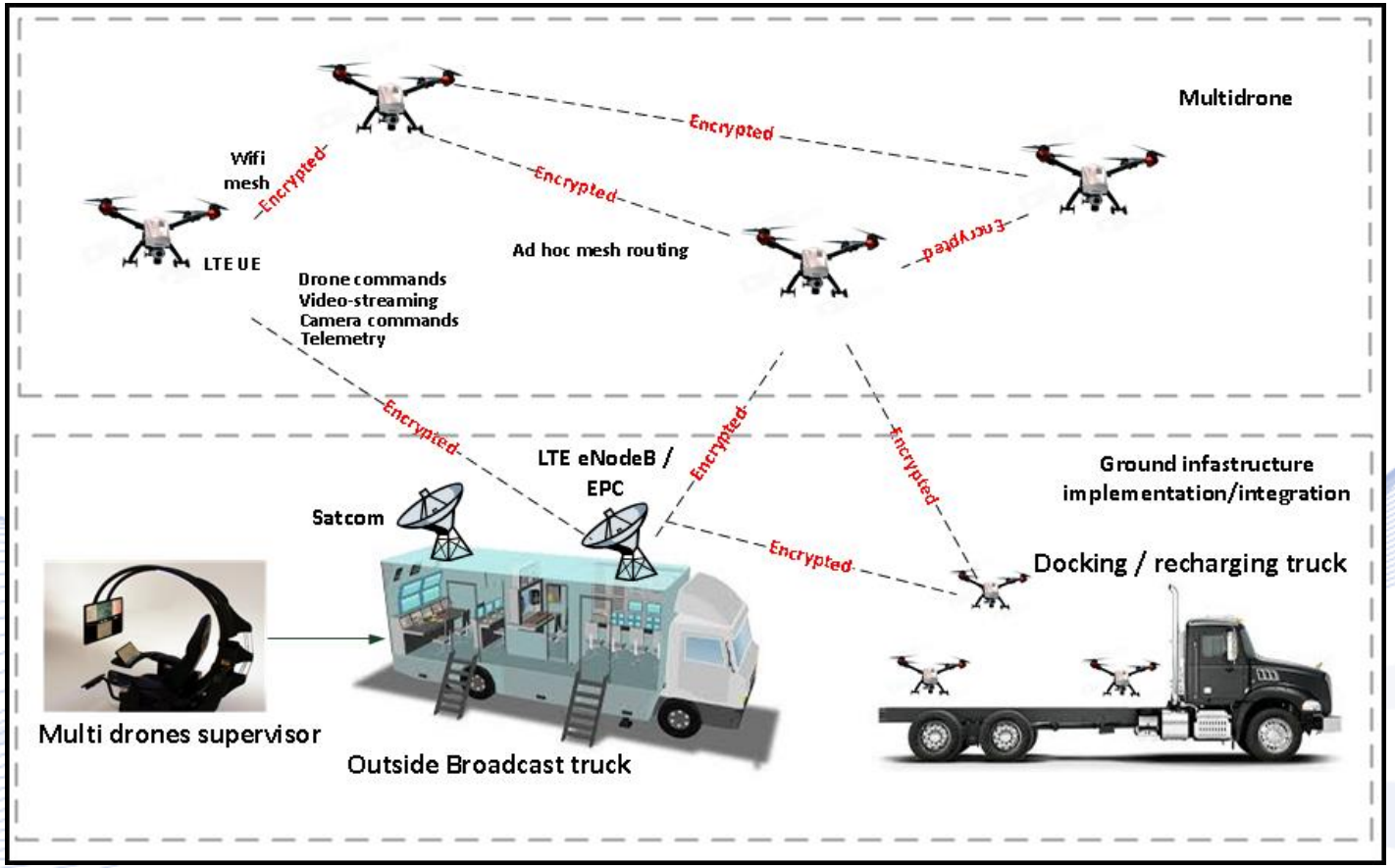
- DJI DS1000+, Hexadrone, Proskytec drones.

Drone Communications

- **Communication infrastructure**
- Video streaming

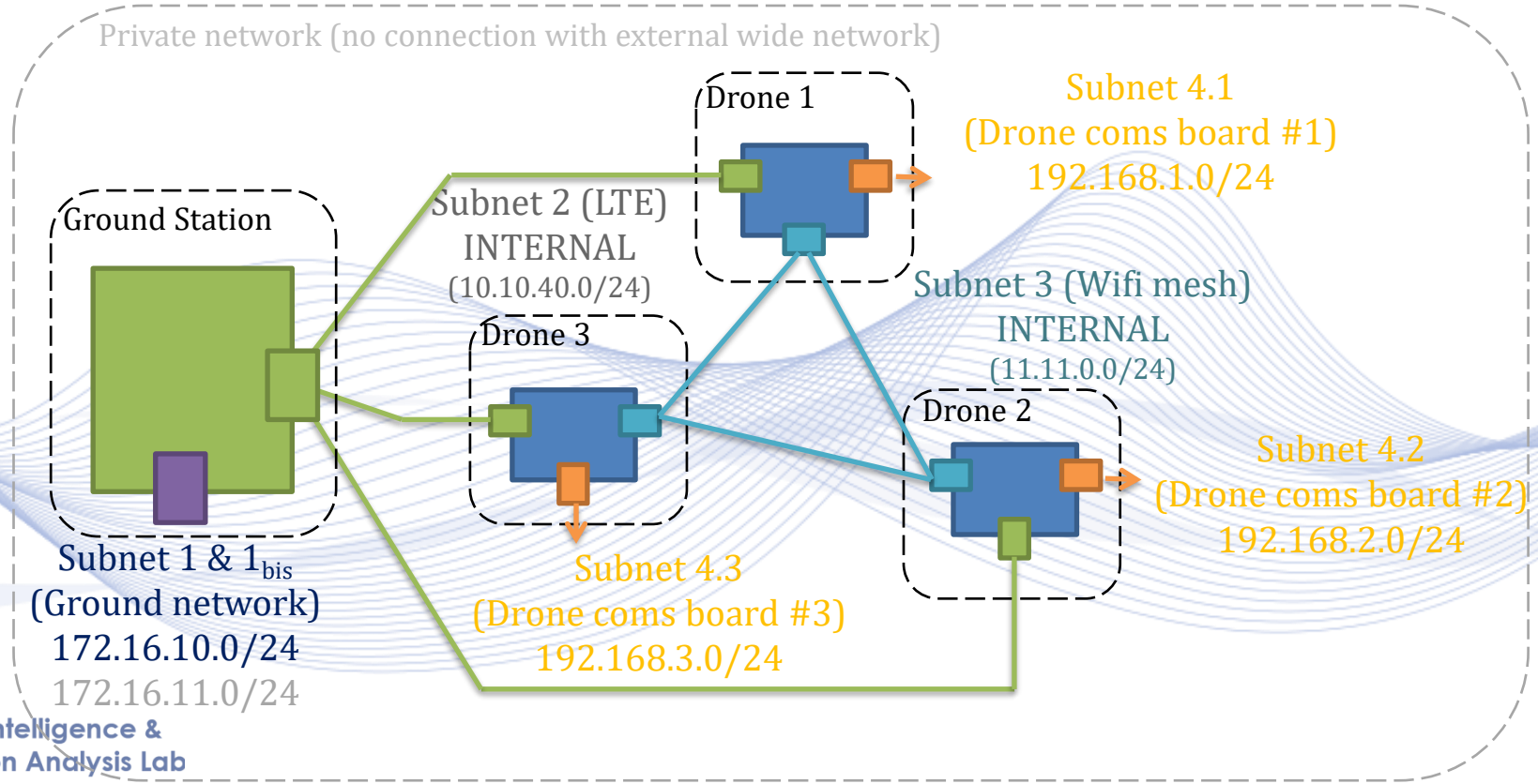
Communication infrastructure

- Drone2Drone Communication.
- Drone2Ground communication.
- Media applications: Live broadcasting.



Communications Infrastructure

Secure and resilient transparent IP access to drones / ground station (LTE and WiFi).



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Multi-source video streaming

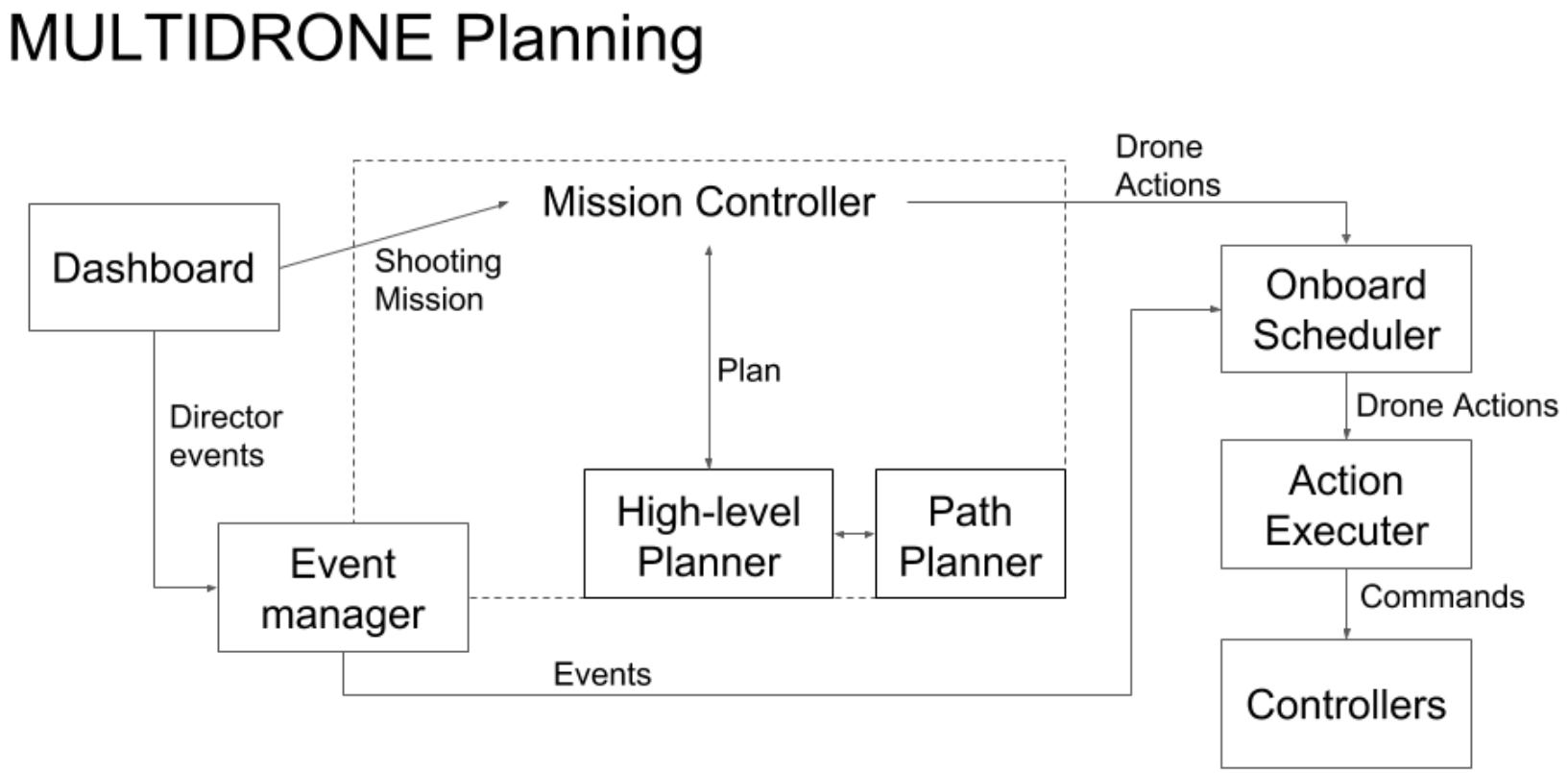
- LTE Drone2ground video streaming is essential within a multiple drone system for:
  - On-board and on-ground video analysis.
  - Mission Director Dashboard (Mission monitoring).
  - Supervisor Station (Security monitoring).

- Constraints:
  - LTE bit-rate, quality, latency,
  - time-stamping for multisource video synchronization.

Mission Planning Vocabulary

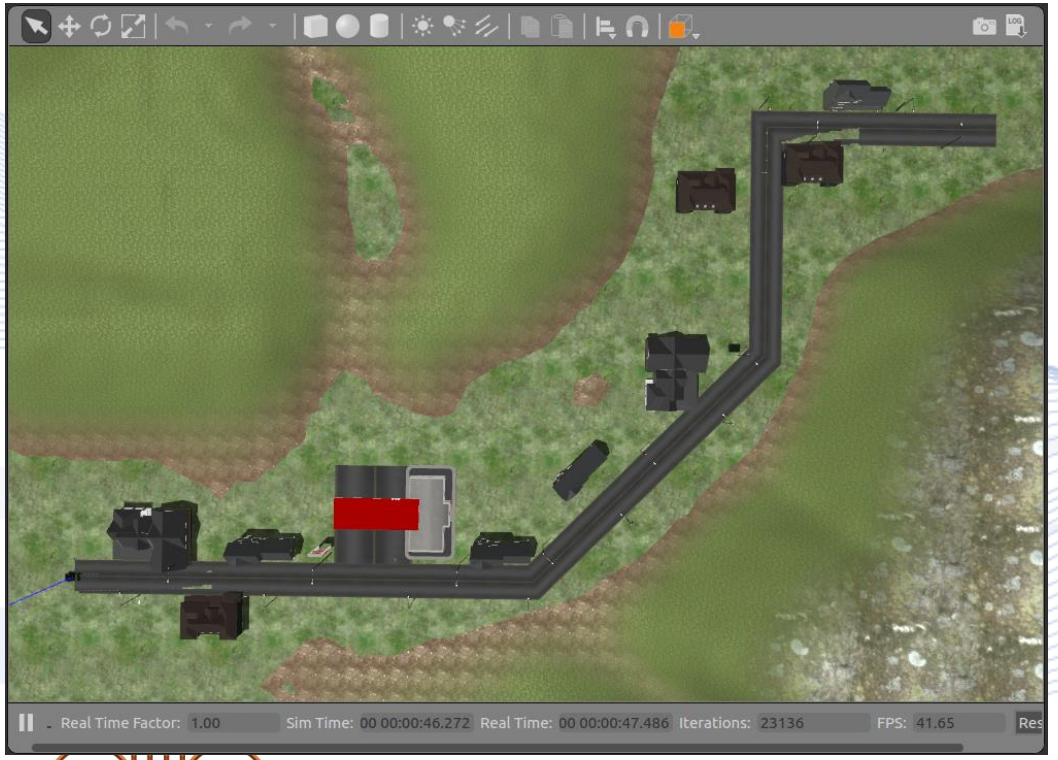
- Multiple drone **Mission**: list of multiple **actions** developing over time.
- Example: **AV shooting mission.**
- Types of actions:
  - **Shooting Actions**: drone + camera
    e.g., Lateral Tracking, Fly-Over, Orbit, …
  - **Navigation Actions**: drone action only, does not involve shooting
    e.g., Take-off, Land, Go-to-waypoint, …
- Shooting Actions are *event-triggered:*
  - A start event is associated to each Shooting Action, which will trigger the action when it occurs.
    E.g., target reaches a milestone, start of race, …

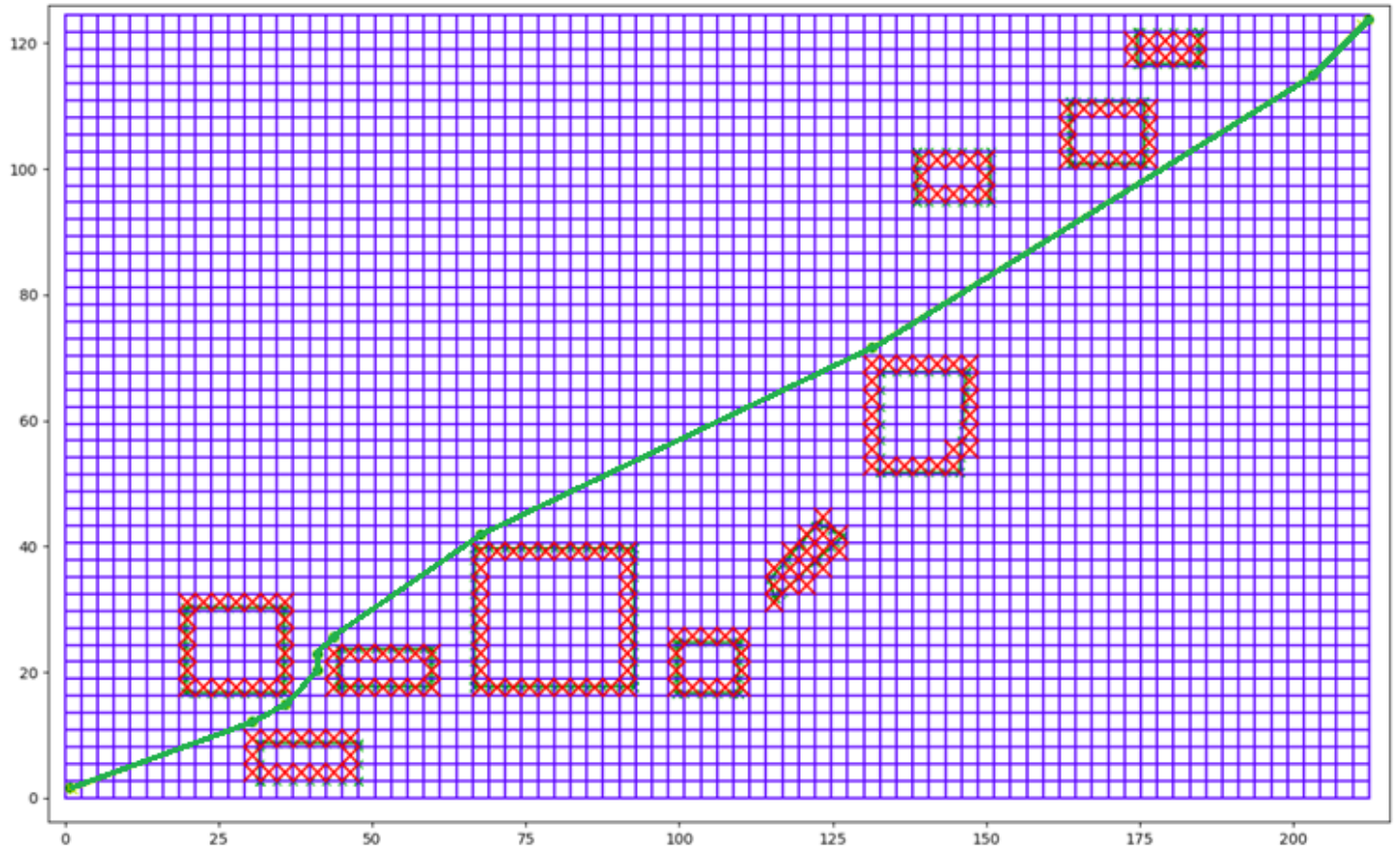
Mission Planning architecture



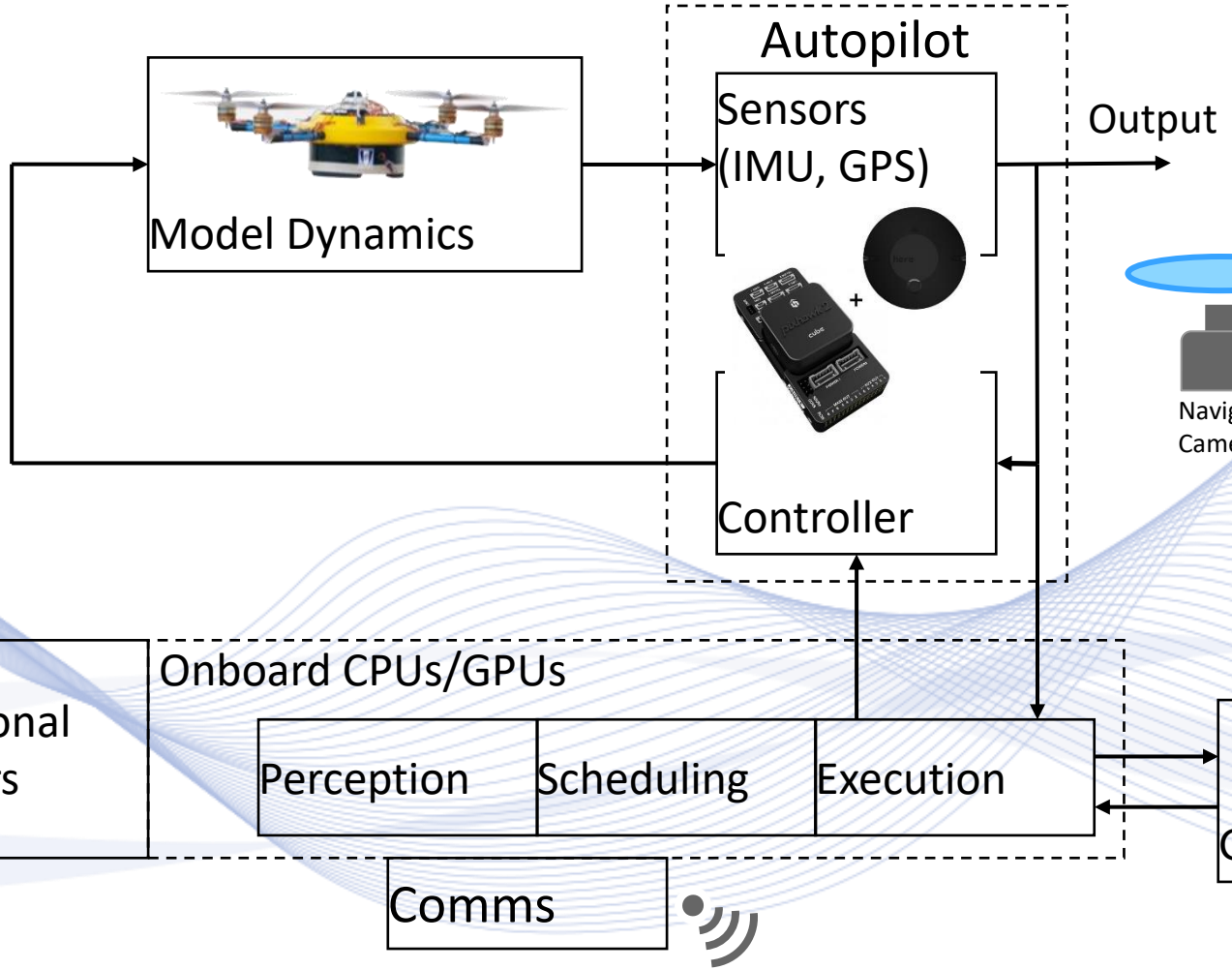
Path Planner Example

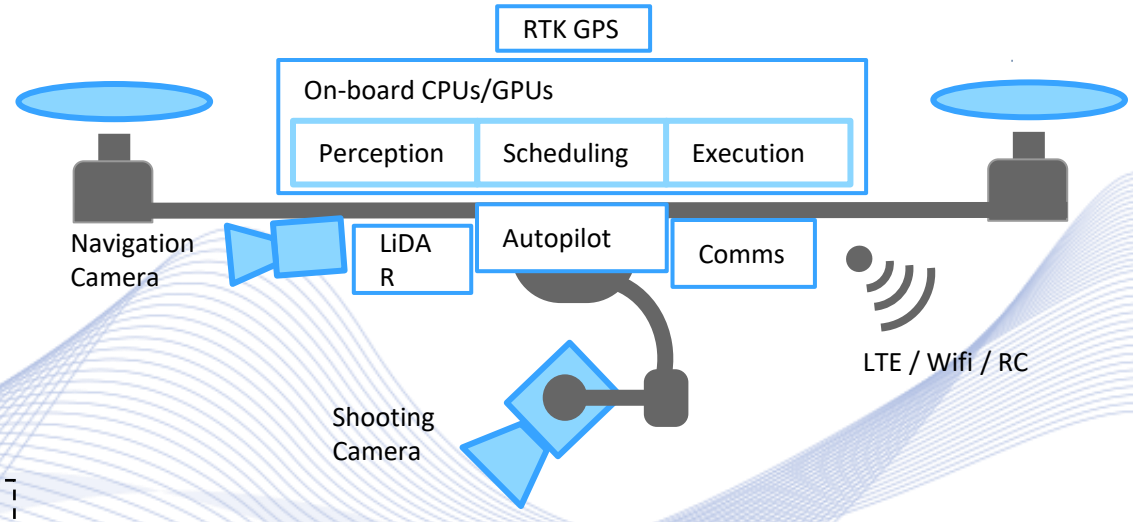
- Path from one corner to the other. Buildings labeled as no-fly zones (obstacles represented as red crosses in the grid).
- Solved in 66 ms.





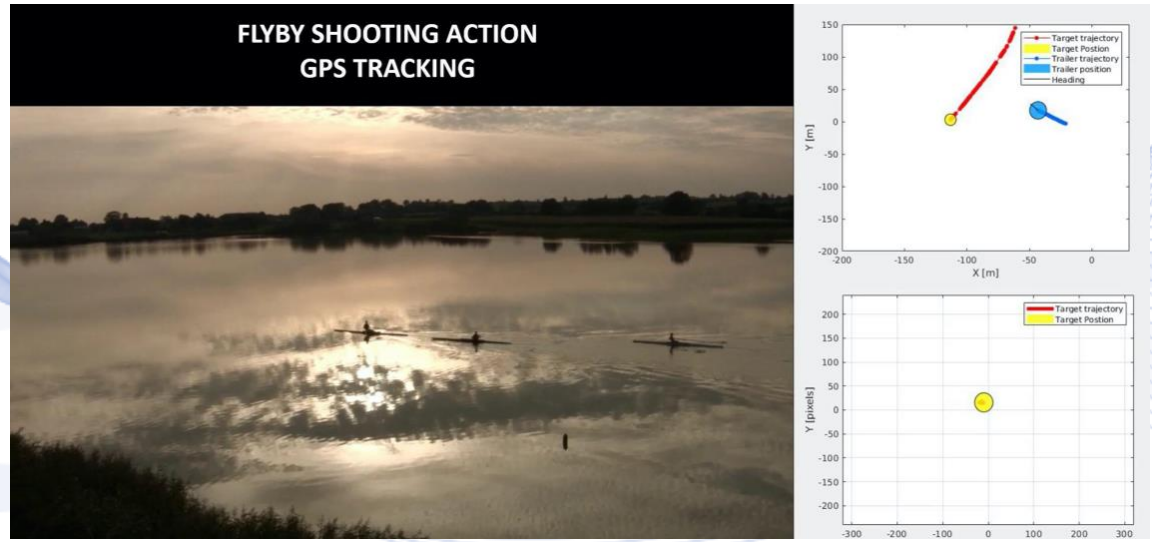
Drone Control Architecture

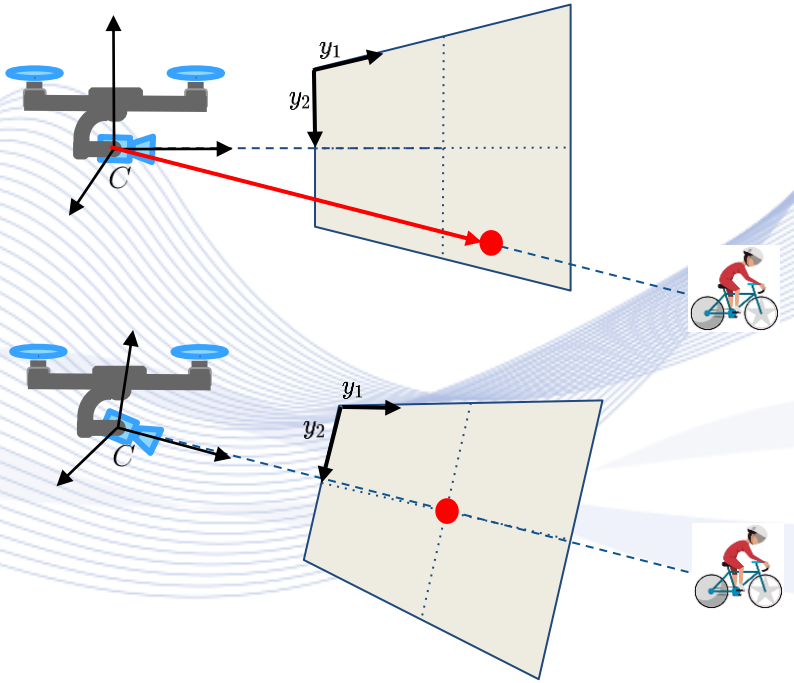




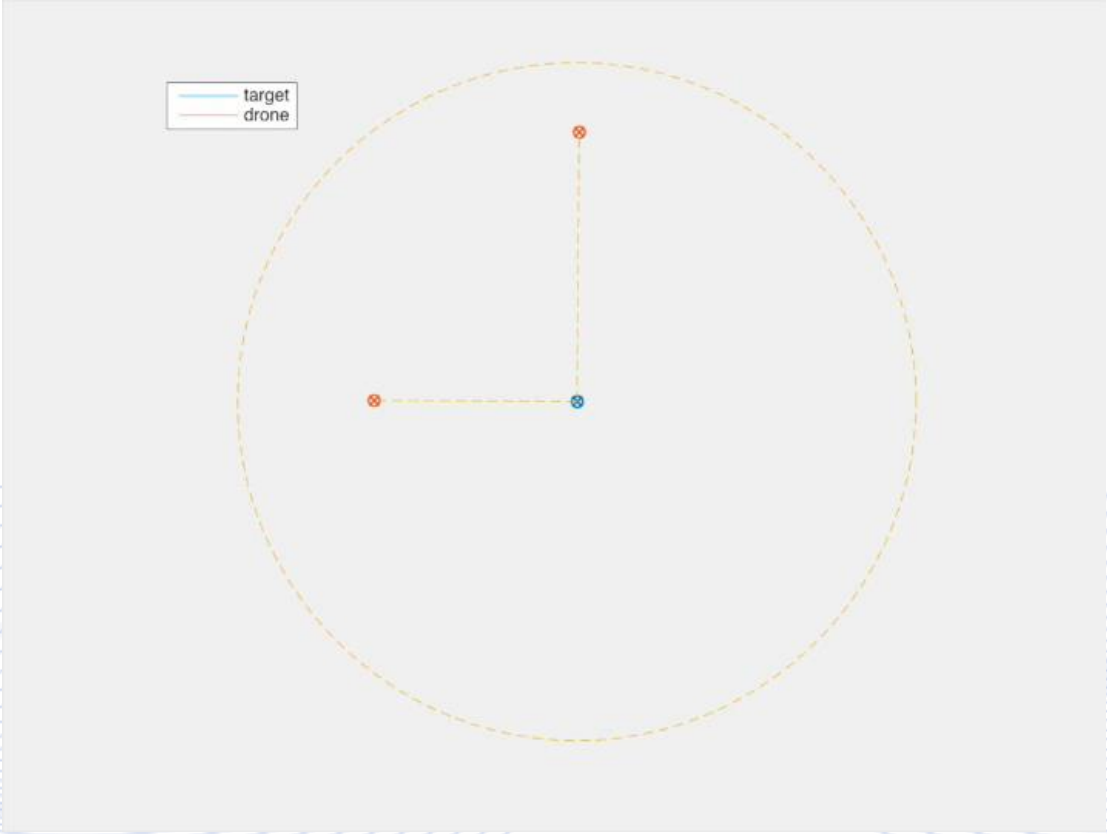
Camera and gimbal control

- 3-axis gimbal and camera control for aerial cinematography:
  - Vision-based and GPS-based.
  - Automatic focus and zoom adjustment.



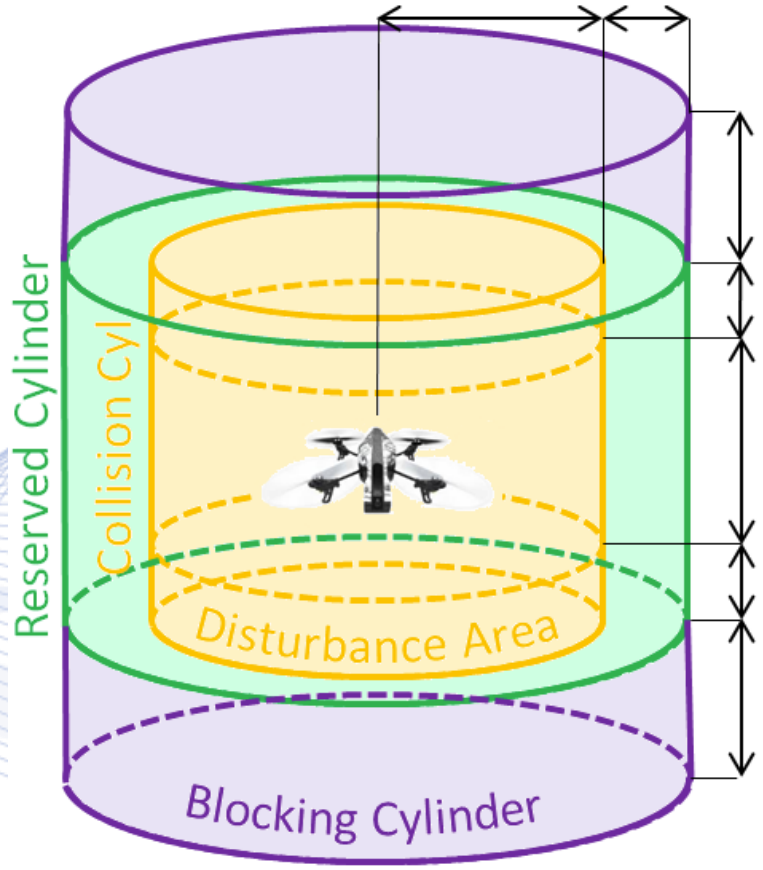


Orbit drone trajectory

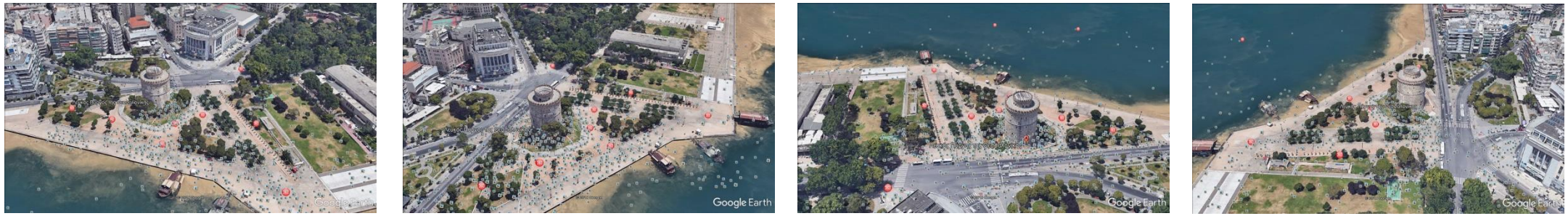


Decentralized 3D collision avoidance

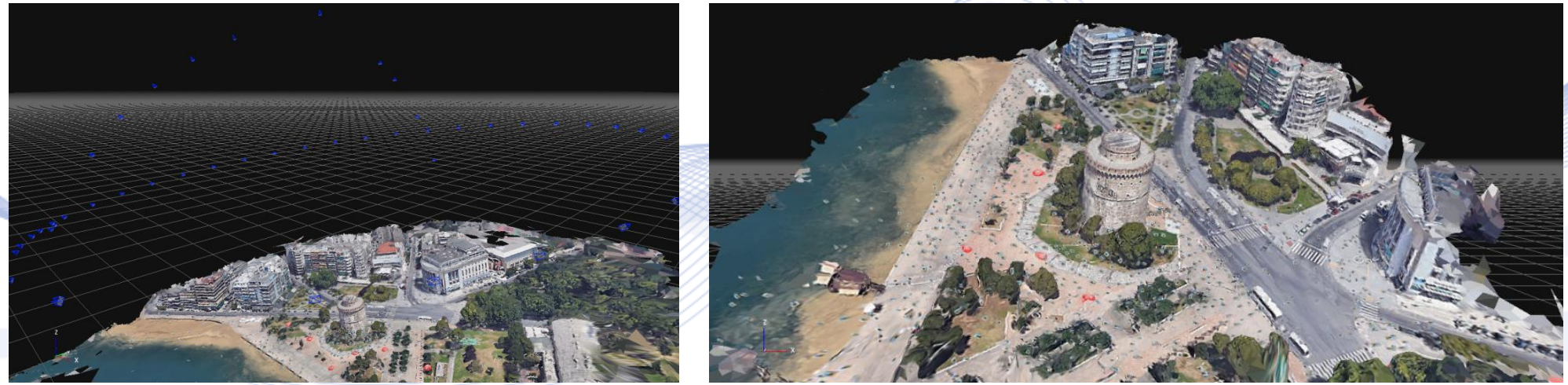
- Collision hull defined as a cylinder (yellow).
- Horizontal conflict when reserved cylinder (green) overlaps with others.
- Vertical conflict when blocking cylinder overlaps with others.
- Cylinders allow drones to brake on time and maneuver to avoid collision.



3D Structure from Motion (SfM)

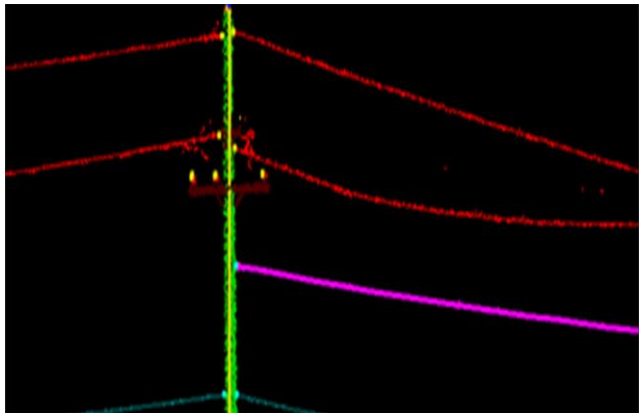


Images obtained from Google Earth



3D models reconstructed in 3DF Zephyr Free using 50 images from Google Earth

Object detection

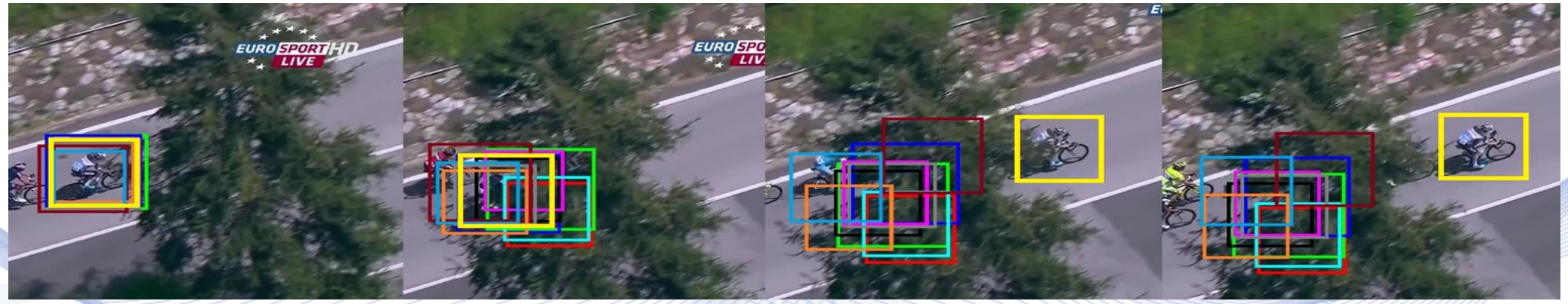


Cognitive inspection functionalities:

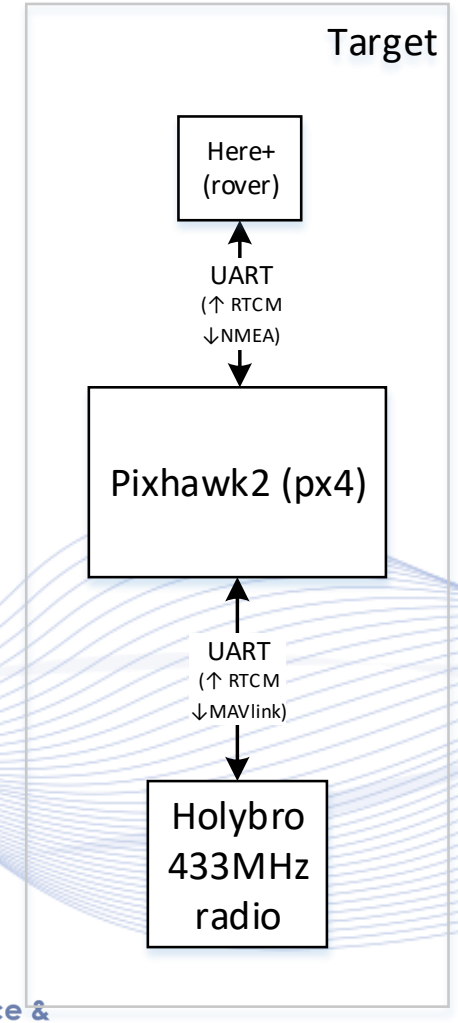
- Detection/localization of electric lines, rods, etc.

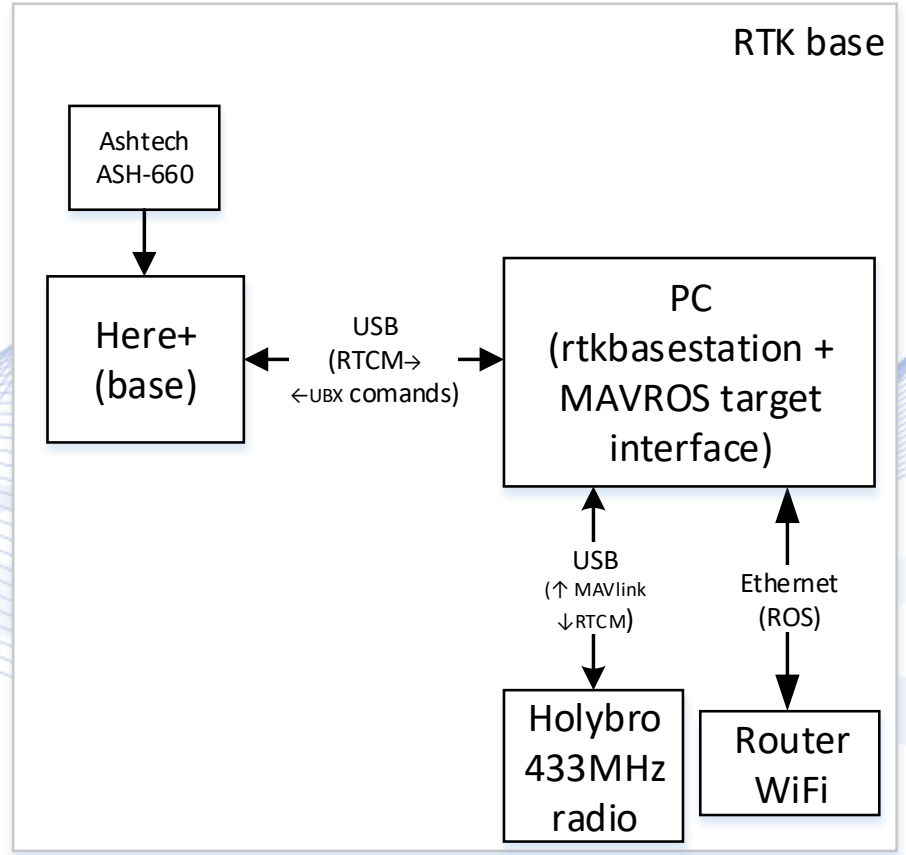
Joint Detection & Tracking

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



Target RTK GPS





UAV Shot Type Simulation

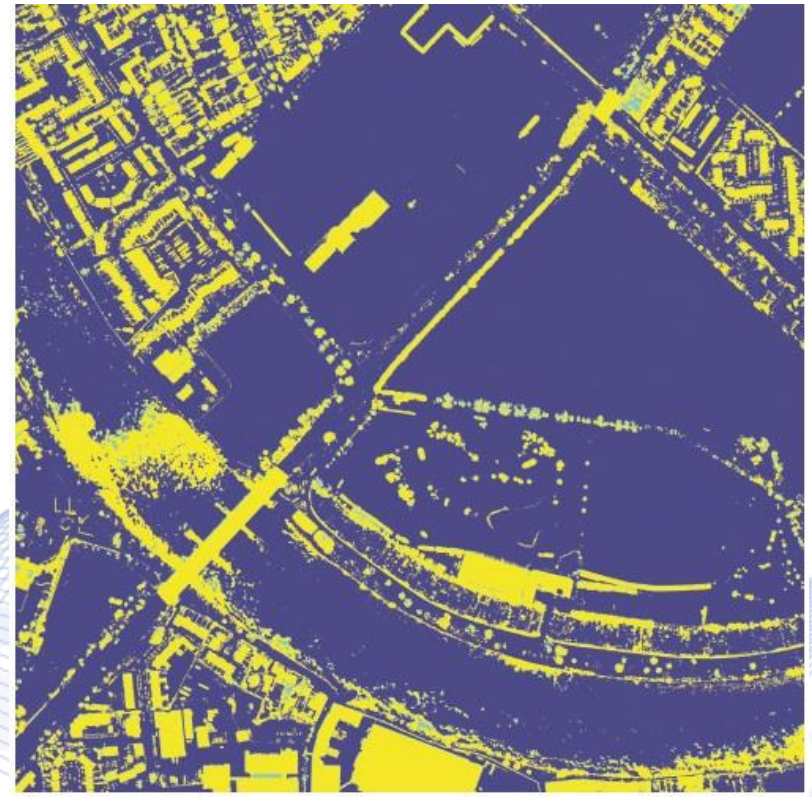
- Example: CHASE

Drone vision for Safety Functionalities

1. **Visual and perception data analysis for safety and security:**
    1. Obstacle detection.
    2. Event detection.
    3. **Privacy protection.**
    4. **Emergency landing site detection.**
    5. **Crowd detection.**
    6. **Semantic 3D map annotation.**

Face de-detection/de-identification

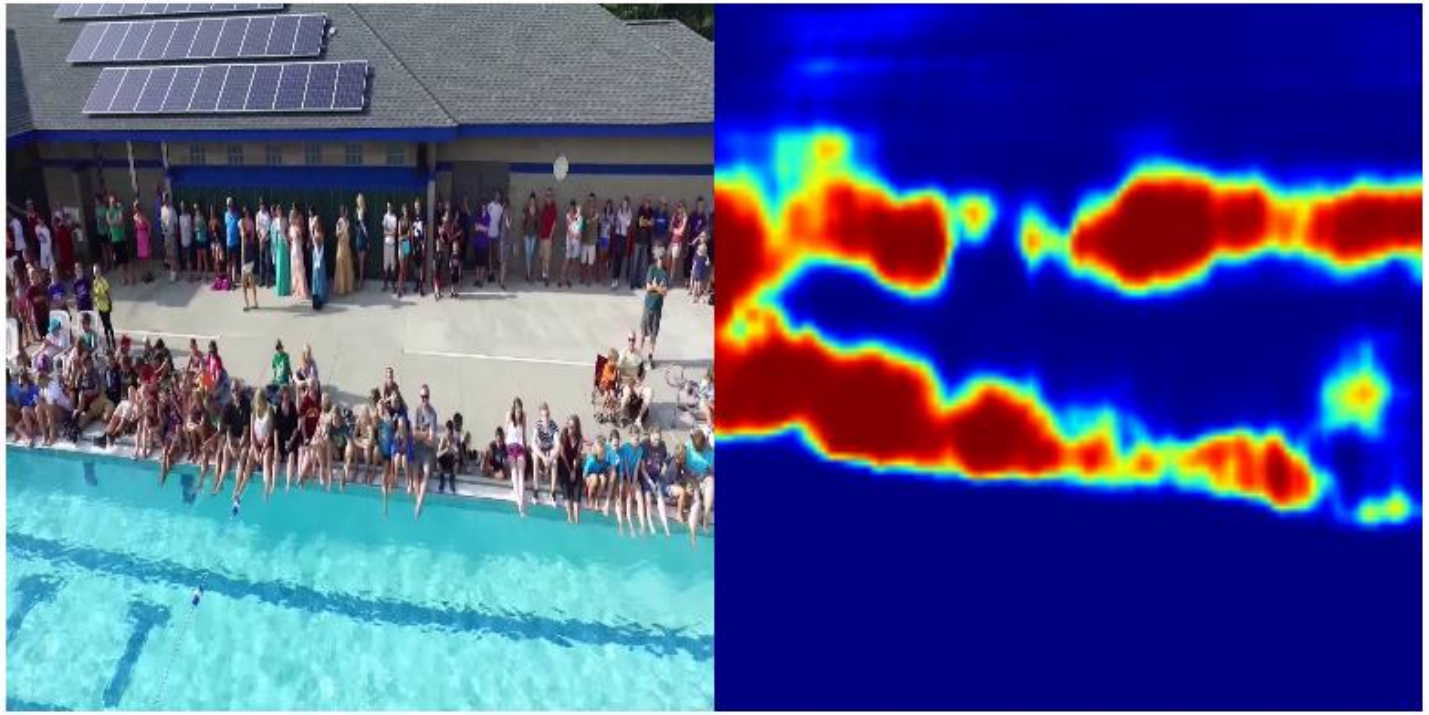
Landing site detection



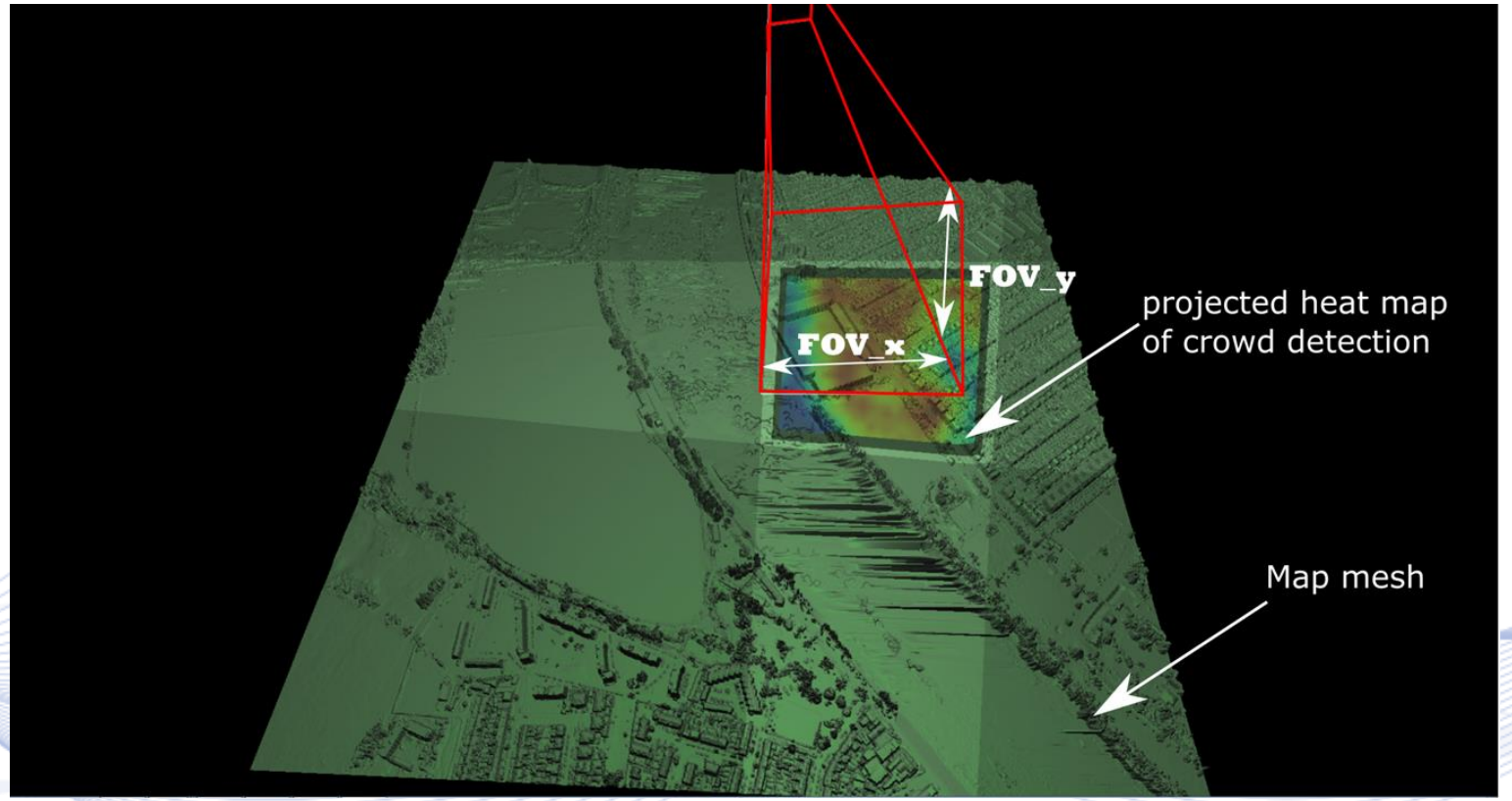
Landing site detection results. Blue pixels correspond to landing zones.

Crowd Detection

- A CNN can be trained for Crowd Detection.
- The result is a heatmap.



Semantic 3D Mesh Map Annotation



Drone mission simulations

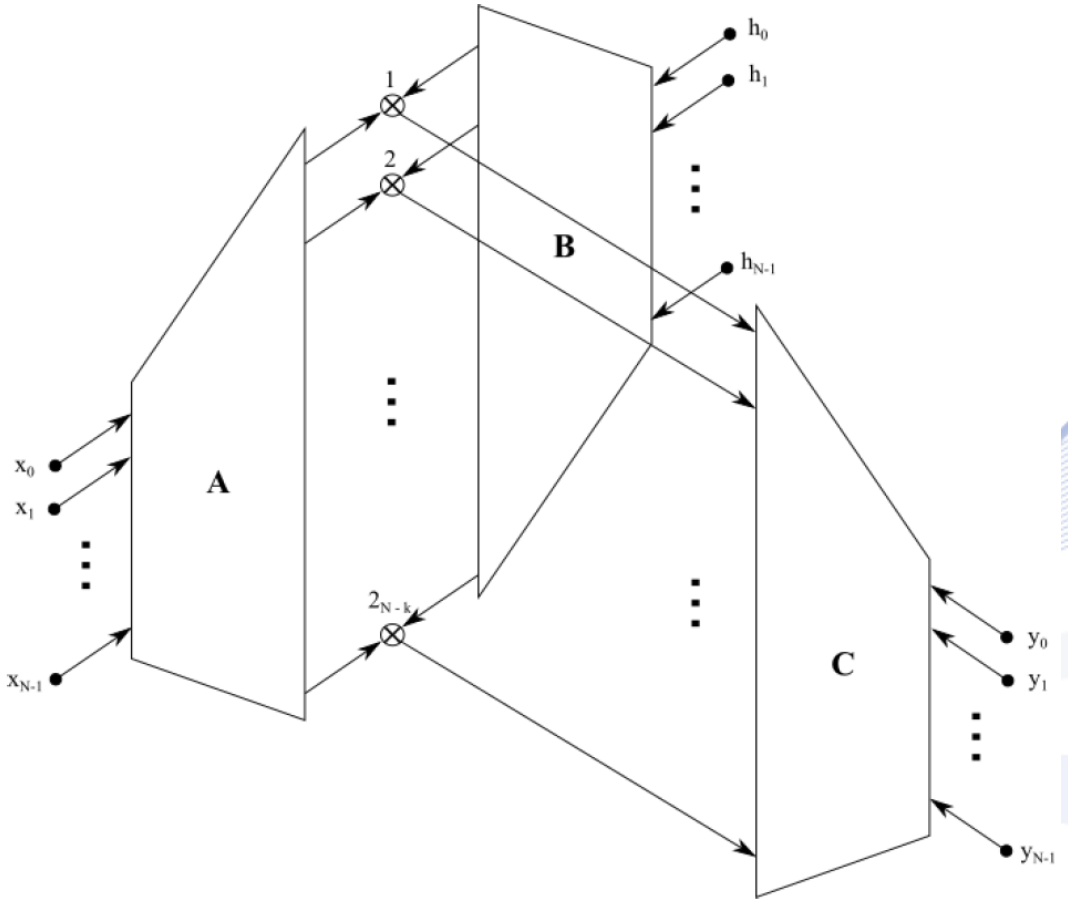
- **Subjective Evaluation on Viewing Experience of Drone Videos**
- Simulations for training data generation
- Simulations in Gazebo

Fast 1D convolution algorithms with minimal computational complexity

- Winograd convolution algorithms

$$Y = C(\mathbf{Ax} \otimes \mathbf{Bh})$$

- Require only $2N - v$ multiplications in their middle vector product, thus having minimal multiplicative complexity



Experimental media productions

- **High level multiple drone system integration.**

Q & A

Thank you very much for your attention!

Contact: Prof. I. Pitas
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