Imaging for Drone Safety summary

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Imaging for drone safety

- Human crowd detection
- Multiview crowd detection
- Visual Drone Detection
- Emergency landing site detection

Imaging for drone safety

- **Safety** is an extremely important aspect in drone operations:
  - Protecting the **pilot** and **other people** on the ground
  - Protecting **property** (buildings, cars)
  - Protecting the **drone** or other drones

Imaging for drone safety

- Drone safety has many aspects:
  - Obstacle detection and avoidance
  - Crowd or individual persons detection so as not to fly near or over them (illegal)
  - Drone to drone collision avoidance
  - Drone hardware and communications reliability, fault tolerance
  - Early warning for potentially dangerous faults and situations

Imaging for drone safety

- Assisting the pilot during flight or in emergency situations so as to reduce safety risks due to e.g. human errors:
  - Autonomous or semi-autonomous (assisted) flight modes
  - Emergency landing site detection
  - Automated emergency landing procedures

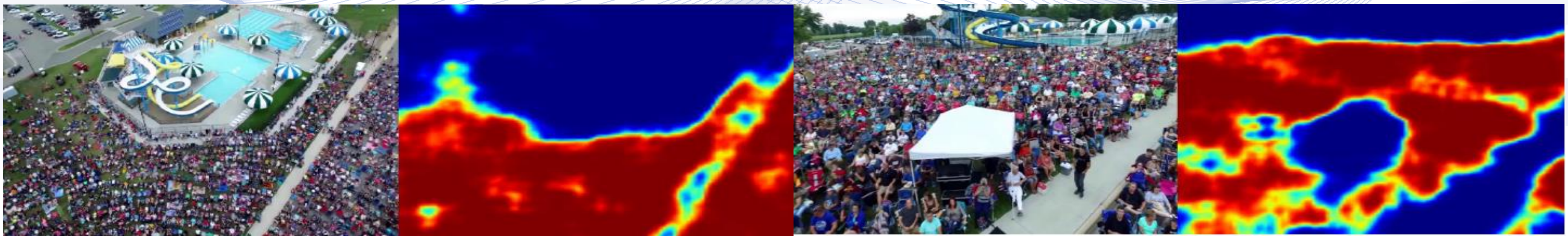
- **Imaging, computer vision, artificial intelligence** can have a crucial role in **drone safety**.

Imaging for drone safety

- **Human crowd detection for safe autonomous drones**
- Visual drone detection for collision avoidance
- Emergency landing site detection.

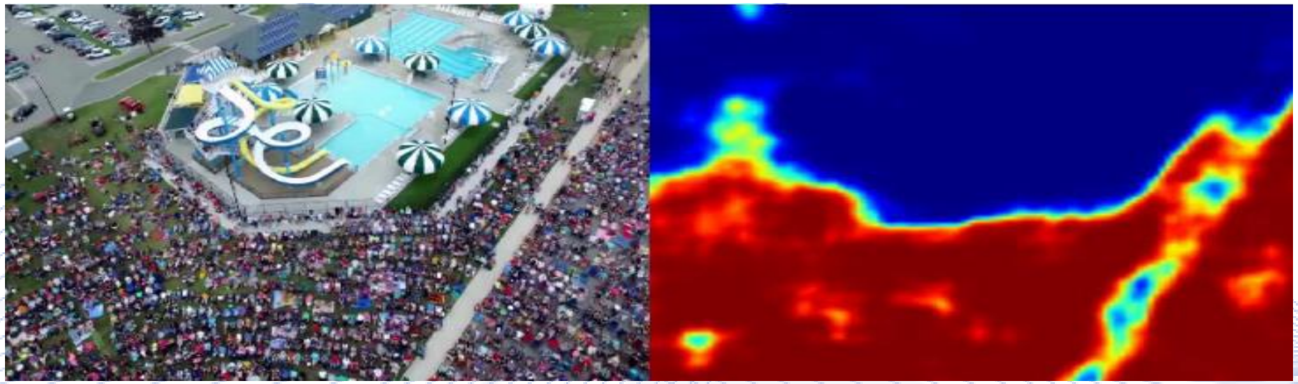
Human crowd detection for safe autonomous drones

- Aim: detect and localize crowds in drone videos.
- Provide **binary crowd maps** or **heatmaps** depicting the **probability of crowd presence** or the **crowd density** in each image location.
- **Challenging task**: occlusions, viewing angle variations, small size of persons, complex background



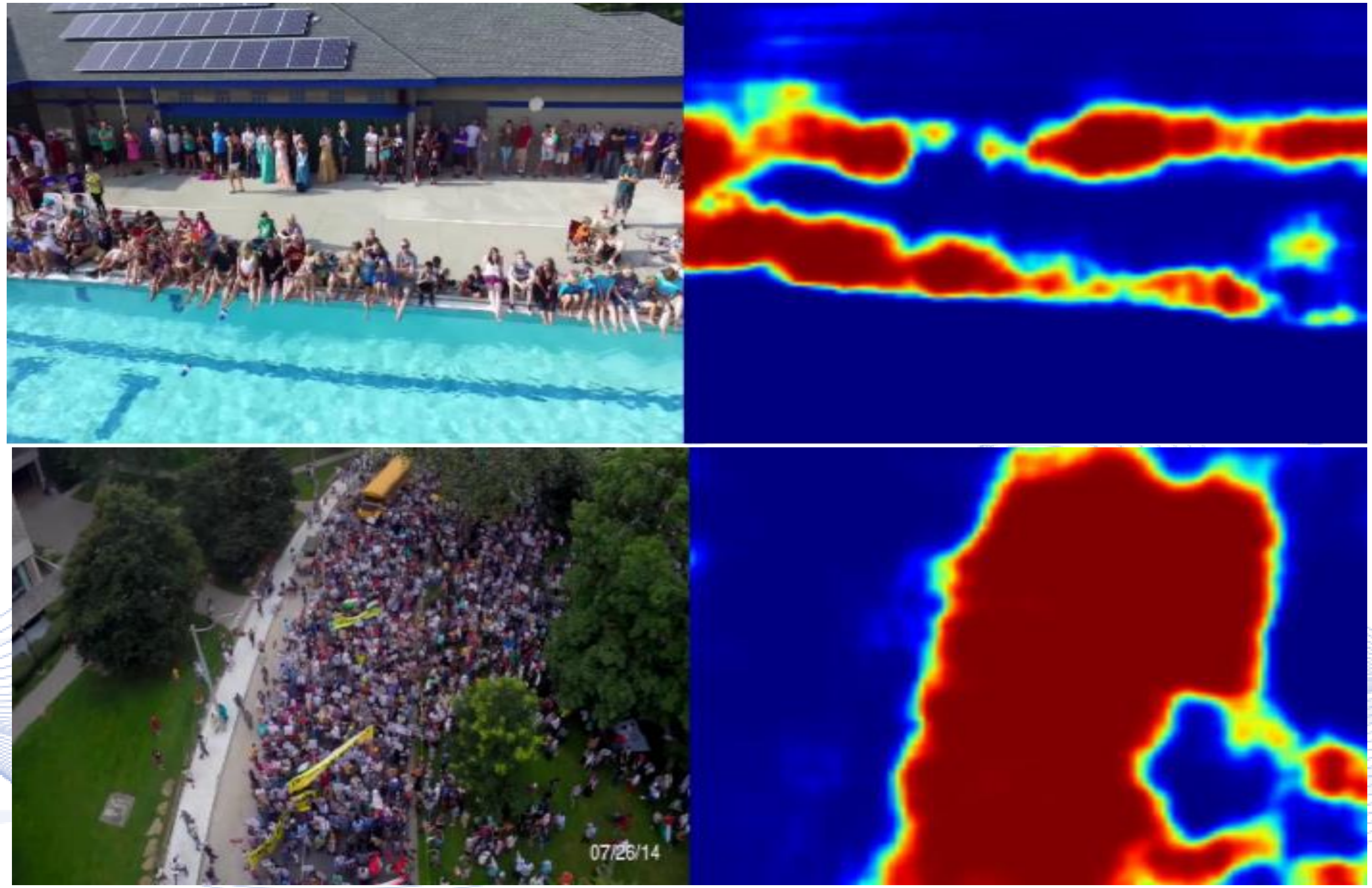
Human crowd detection for safe autonomous drones

- In [4] a **Fully Convolutional Model** for crowd detection in drone videos is proposed
- The output of the method is a heatmap denoting the estimated probability of crowd existence in each frame location

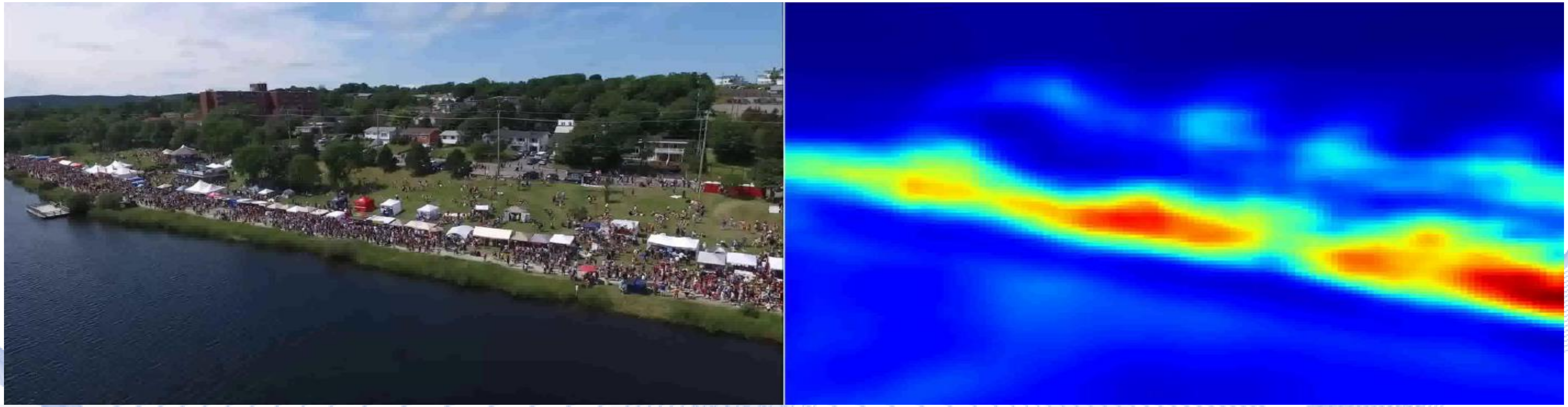


[4] M. Tzelepi, A. Tefas, "Human Crowd Detection for Drone Flight Safety Using Convolutional Neural Networks." in European Signal Processing Conference (EUSIPCO), Kos, Greece, 2017.

Deep crowd detectors



Deep crowd detectors



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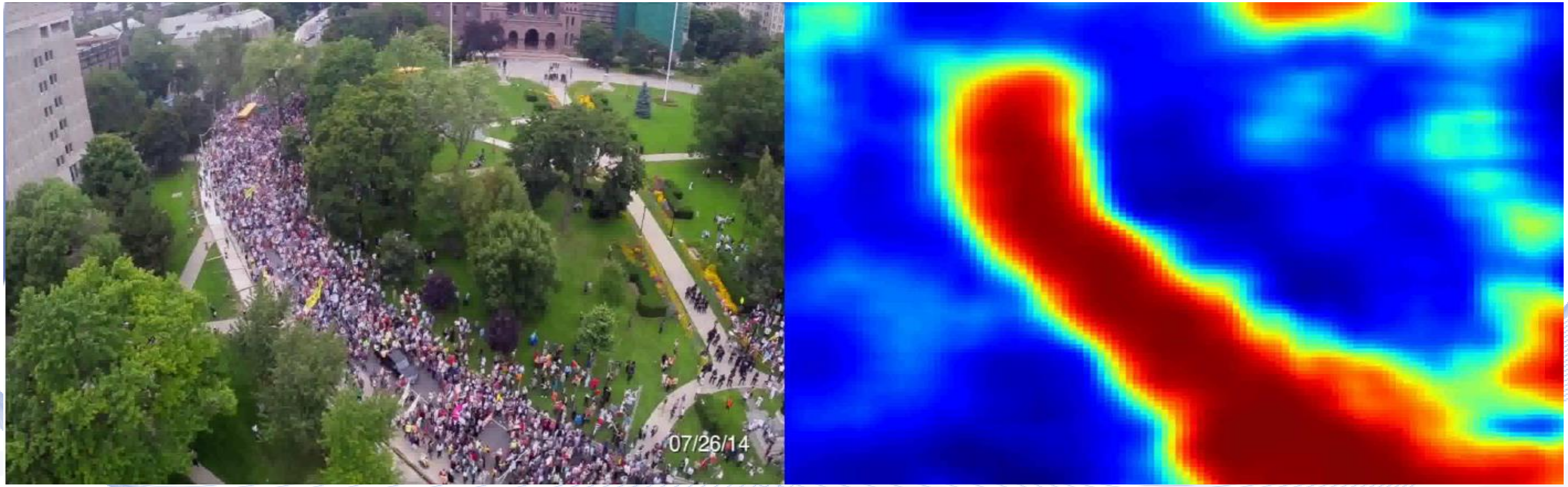
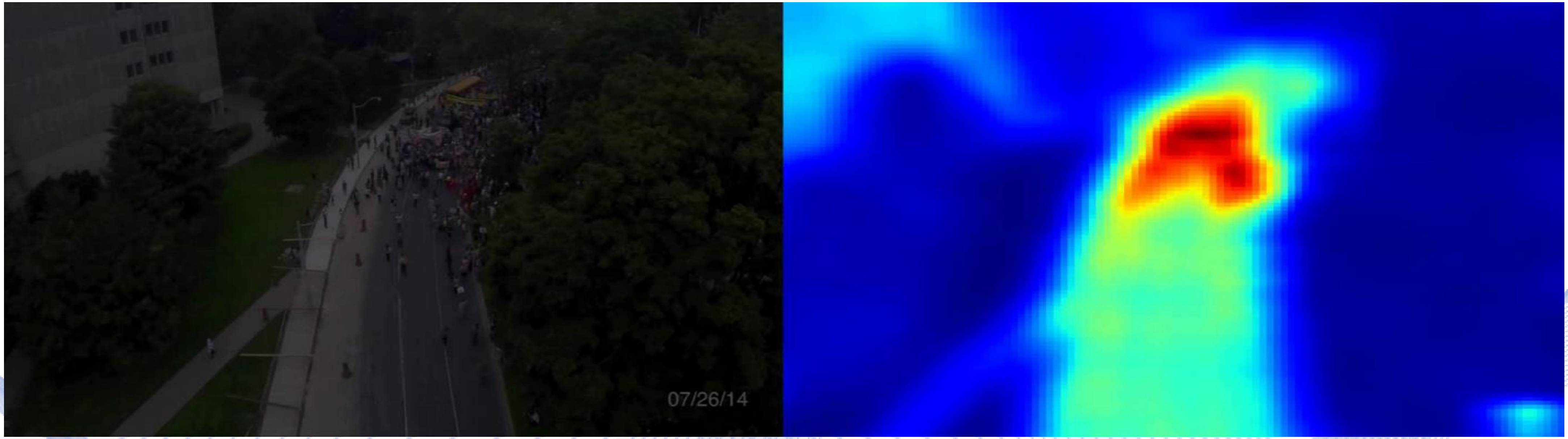
Deep crowd detectors

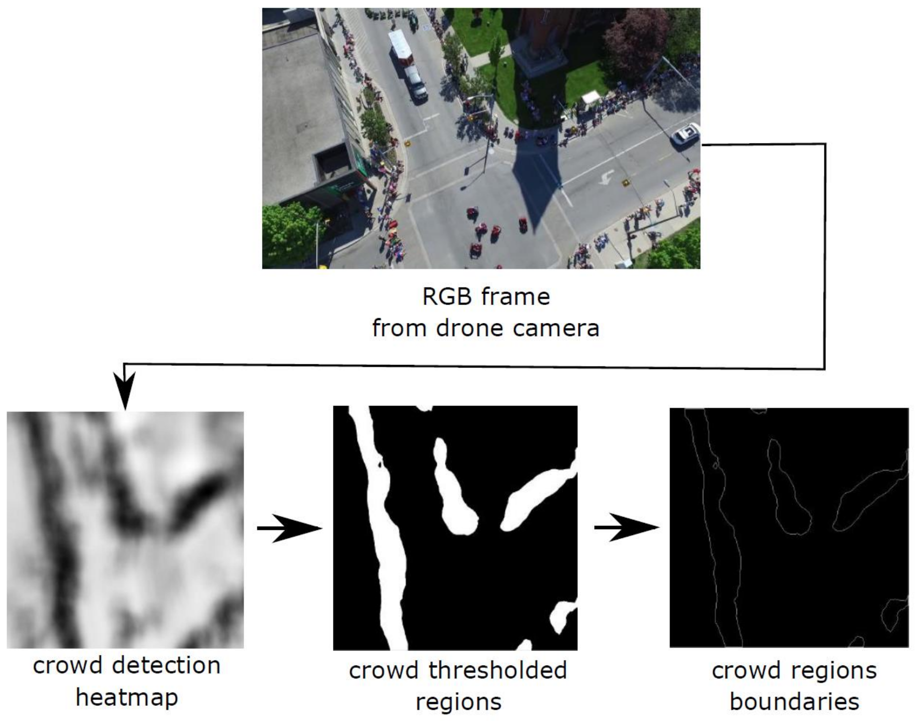


Deep crowd detectors



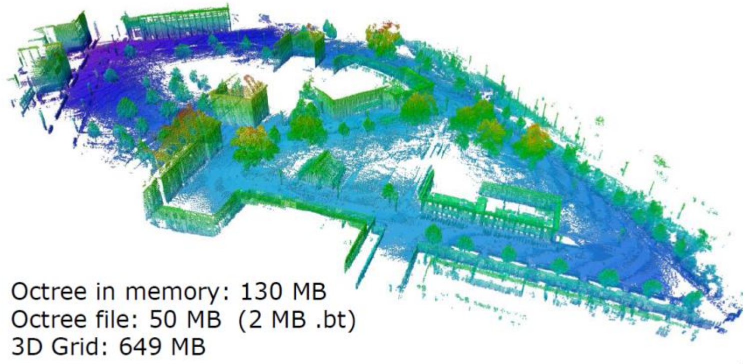
Crowd Projection onto a 3D map

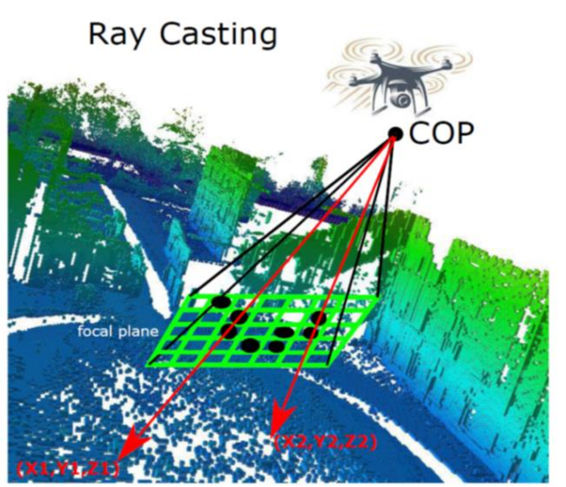
- The **2D heatmap** with crowd existence probabilities can be **projected on a 3D map of the flight environment** to localize the crowds on the map
- The heatmap is thresholded to obtain a binary image
- Contour following is performed to find the crowd region boundaries



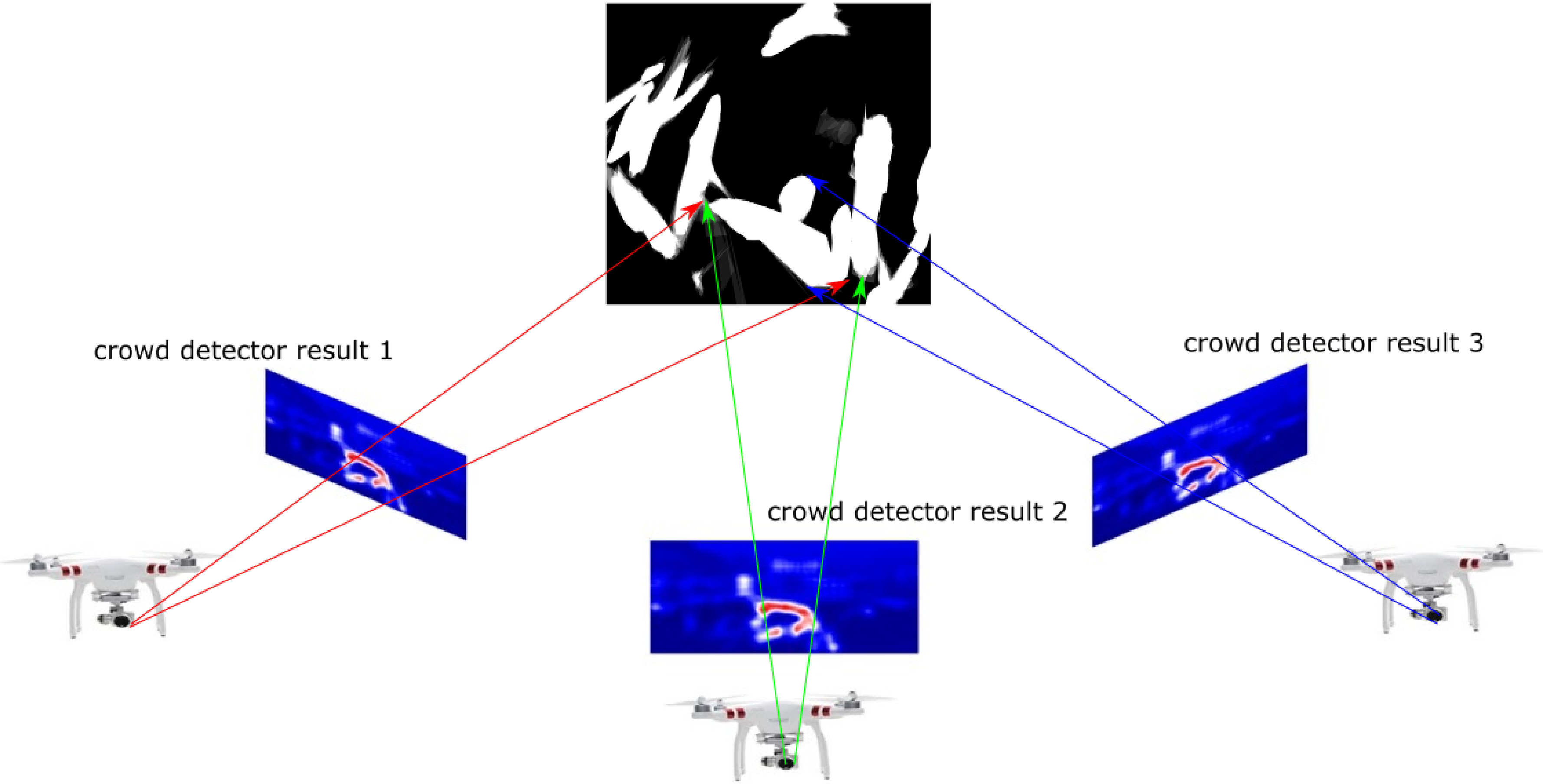
Crowd Projection onto a 3D map

- Assuming that **drone position, camera intrinsic parameters** (e.g., focal length) and **camera orientation** are known, the crowd contours (boundaries) can be **projected from the image onto the 3D map** (octomap)
- A ray is cast from each of the image contour points towards the octomap.
- A series of voxels defining the points of the crowd contour on the octomap is found
- Crowd contours generated as the drone flies are **merged** using OR operator
- Tests were performed on synthetic and real data





Multi-view Crowd Heatmap Fusion



Multi-view Crowd Heatmap Fusion

- ***Real world Dataset:*** Multiple drones (2) are seeing a crowd existing in a flat terrain

- Multi-view video sequences are derived.

Imaging for drone safety

- Human crowd detection for safe autonomous drones
- **Visual drone detection**
- Emergency landing site detection.

Visual Drone Detection

- The widespread use of drones raises concerns regarding **drone-to-drone collision** or collision with other aerial vehicles

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Radar-based Drone Detection

- **Radars** are typically designed to detect big and speedy vehicles
- Radars designed for **UAV detection** are usually **bulky, costly** and targeted towards **ground usage** by governments, commercial venues, airports, etc.

Visual Drone Detection

- **Lightweight radars for on-drone usage** have recently emerged but are not yet broadly used or available
- **Thermal /IR cameras** mounted on **drones** can also be used to detect other drones in certain circumstances
  - + can operate during night or in low light conditions.
  - - affected by noise and other thermal sources

Fortem TrueView radar, 650g, 32W, 2018

DJI Zenmuse XT thermal camera

Visual Drone Detection

- **Visible light cameras** can be also used for drone detection
  - +All drones are equipped with such cameras
- However, visual drone detection is a difficult task
  - At long distances drones appear **very**
  - **small** in the frame
  - Easy to **confuse** them with other aerial
  - objects, such as distant **planes** or even
  - **birds**
  - They may be hard to distinguish from the **background**, especially in urban areas

Imaging for drone safety

- Human crowd detection for safe autonomous drones
- Visual drone detection
- **Emergency landing site detection.**

UAV Landing site detection

- **Automatic detection of landing sites** is important for drone **safety**
- Detected landing sites can be used for **normal** or **emergency landing**
- A landing site detection algorithm shall **preferably run onboard the drone** to ensure that it can be used in emergency situations.
  - Drone might have lost contact with the ground
- Data used for landing site detection:
  - Videos, images
  - Lidar (Light Detection And Ranging) data / point clouds
  - 3D terrain data, e.g. Digital Elevation Models (DEM)

UAV Landing Site Detection

- The algorithm labels pixels as:
  - below roof top,
  - on roof top but unsafe,
  - insufficient space
  - safe landing area.
- A confidence map is also constructed
- Both the “landing” and the confidence map are updated over time
- An algorithm for defining a **landing trajectory** in the most suitable landing site is also proposed

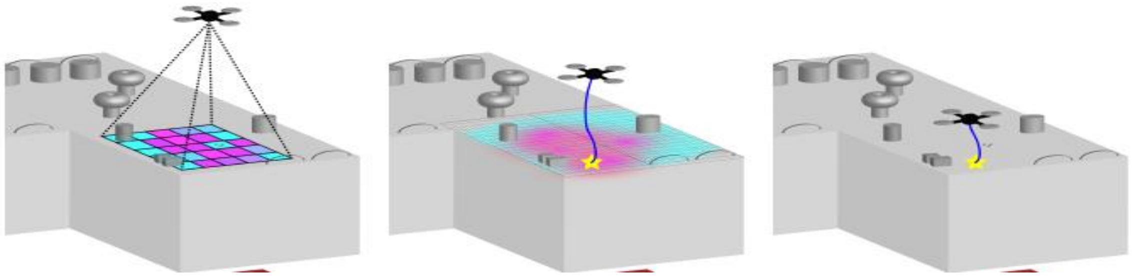
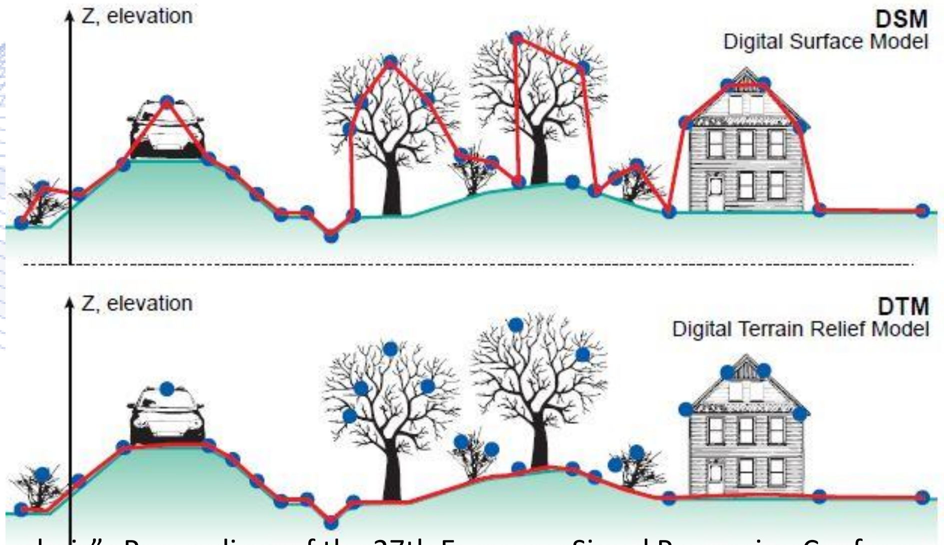


Figure: Methodology overview [10]

UAV Landing Site Detection

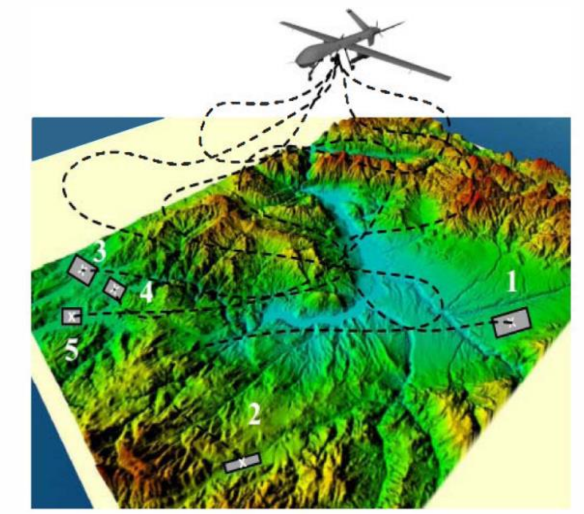
- 3D terrain information in the form of **Digital Elevation Models (DEM)** can be used for landing site detection :
  - Raster DEMs: images where the pixel value denotes the elevation
  - **Digital Surface Models (DSM)** include information for both the ground and the manmade structures or vegetation
  - **Digital Terrain Models (DTM)** include bare ground information, without any man-made structures or vegetation.

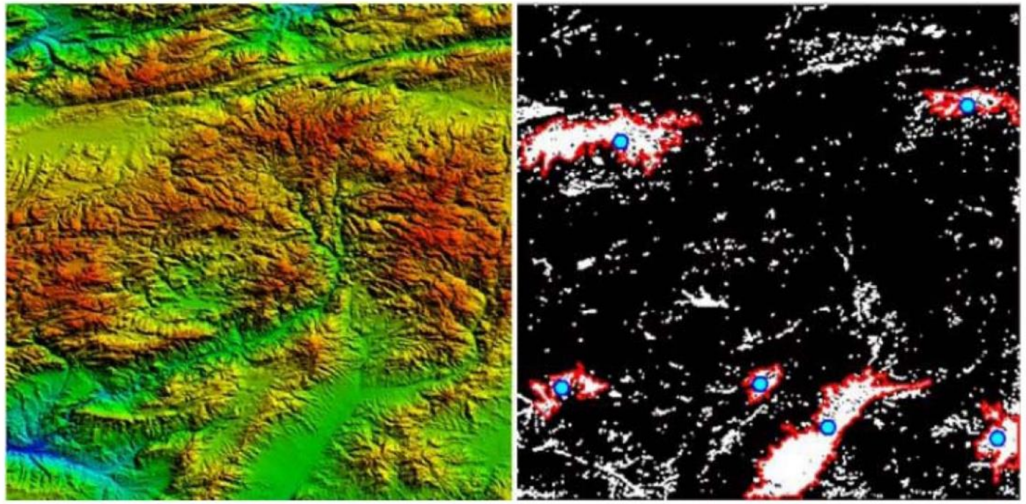


[14] Kakaletsis, E., Nikolaidis, N. "Potential UAV Landing Sites Detection through Digital Elevation Models Analysis", Proceedings of the 27th European Signal Processing Conference (EUSIPCO), Satellite Workshop: Signal Processing, Computer Vision and Deep Learning for Autonomous Systems, A Coruna, Spain, September 2-6, 2019.

UAV Landing Site Detection

- In [2] surface fitting on coarse elevation models using Least Squares Error is performed.
- The slope of the fitted surface is used to specify landing areas.
  - Low slope areas are selected



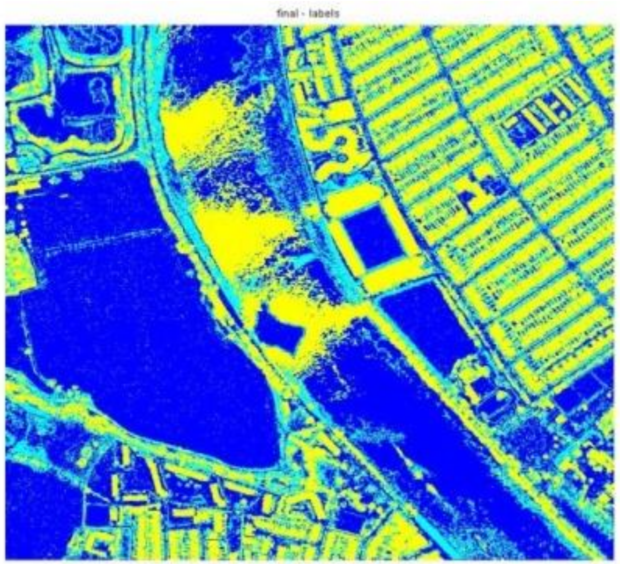


[16] Aydin, Musa, and Emin Kugu, *"Finding smoothness area on the topographic maps for the unmanned aerial vehicle's landing site estimation."*, Sixth International Conference on Digital Information and Communication Technology and its Applications (DICTAP), IEEE, 2016.

POTENTIAL LANDING SITE DETECTION ALGORITHM

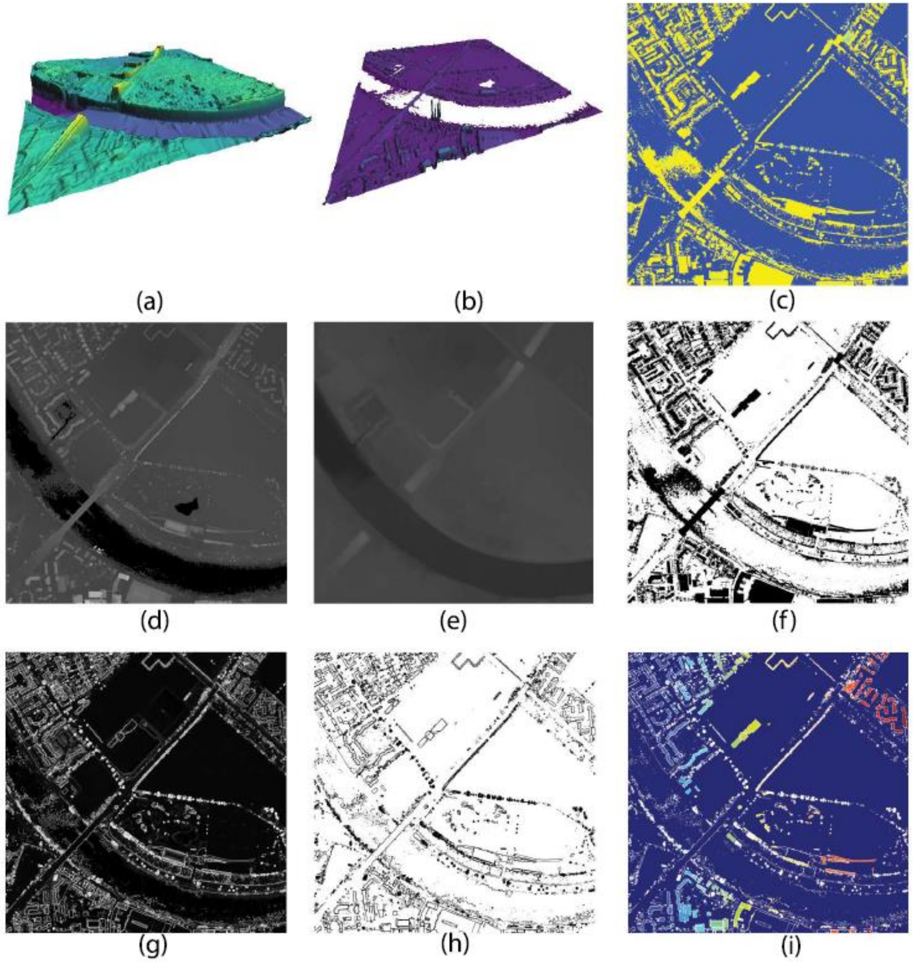
- 5) Creation of the final map
  - we remove from the large low slope areas found in the previous step those parts that overlap with buildings and vegetation found in step 1.

- **Blue pixels**: landing zone i.e. small slope and enough pixels
- **Light blue pixels:** no landing zone, i.e. large slope or very few pixels
- **Yellow pixels:** no landing zones due to buildings and vegetation



EXPERIMENTAL EVALUATION: Real world Dataset

- 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



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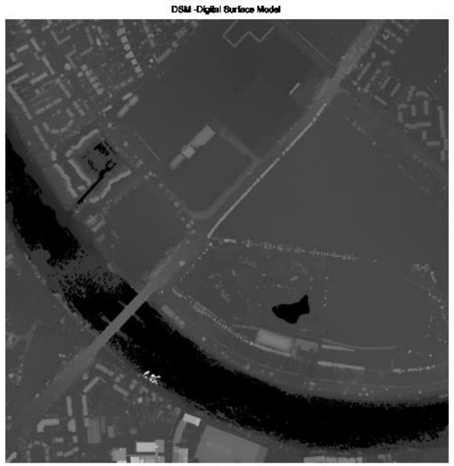
EXPERIMENTAL EVALUATION:
Ground Truth

- For the areas in the real world dataset:
  - Ground truth (potential landing sites, areas not suitable for landing) was manually constructed by the authors through visual inspection of the DEMs and satellite images (the latter were obtained by Google Maps).
- In the case of the synthetic dataset,
  - The ground truth for the vegetation was created automatically, since the locations where vegetation was inserted were known.
  - The synthetic nature of the terrain allowed us to calculate local slope information and use it to mark areas with low slope as being appropriate for landing. Small such areas were excluded.

DSM

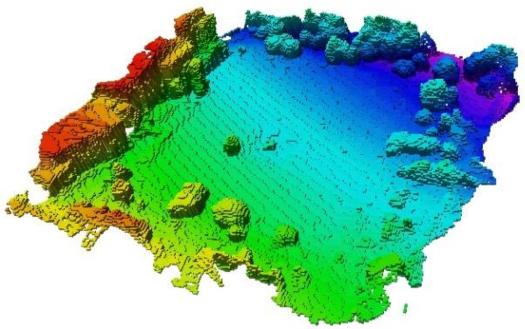


Ground Truth

Computation complexity (execution time)

- It shall be noted that the algorithm in [15] does not take into account man-made structures and vegetation a fact which contributes in it having inferior performance but smaller execution time.
- Moreover, the level of granularity of the DTM and DSM obviously affects the execution time: large resolutions increase the execution time of the algorithm.

method\dataset	real world dataset	synthetic dataset
proposed	48.5957	1.4563
[15]	6.4702	1.3845


3D projection of DSM

OUTPUT : Safe Landing Areas

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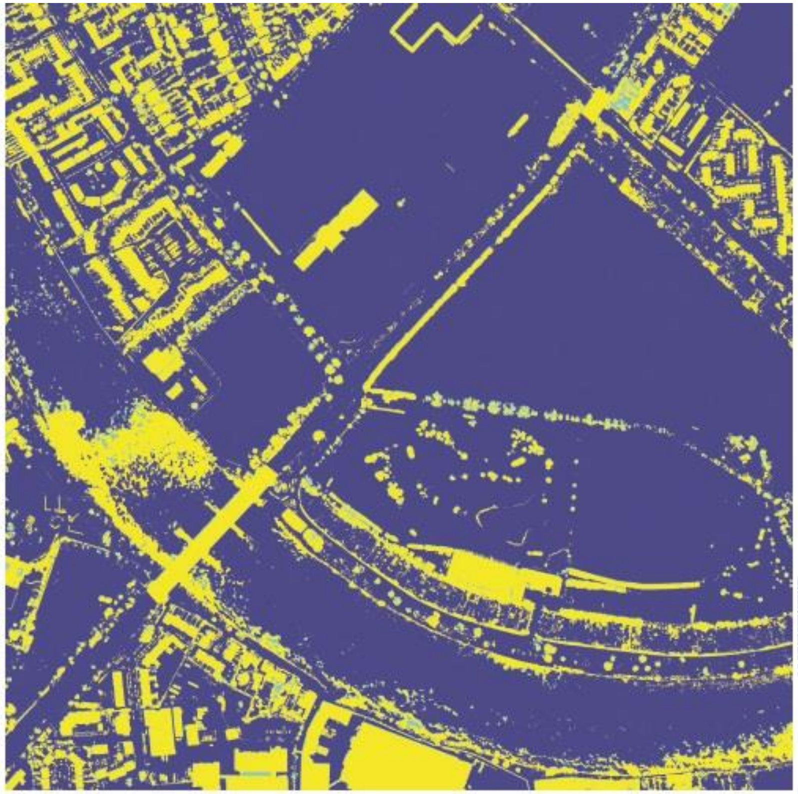
Semantic segmentation for landing site detection



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

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Q & A

Thank you very much for your attention!

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