3D Robot Localization and Mapping summary

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Artificial Intelligence &
Information Analysis Lab

3D Localization and Mapping

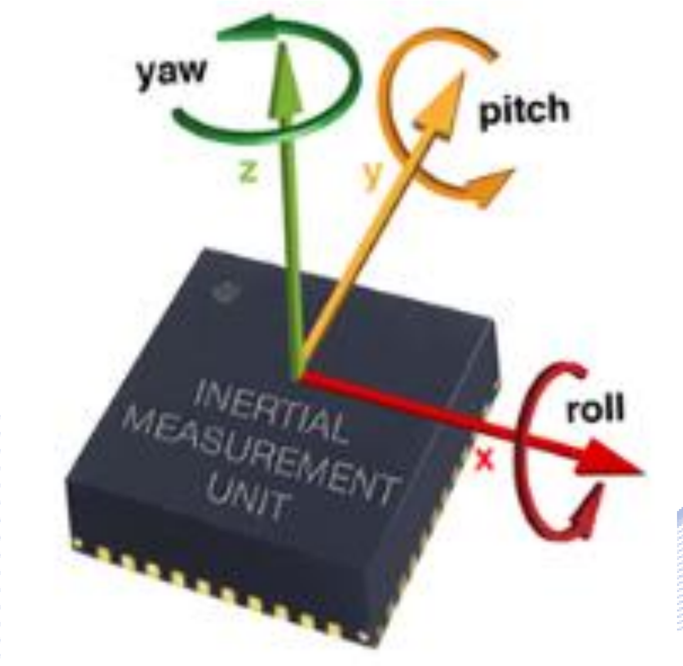
3D scene mapping and vehicle/sensor (primarily camera) localization:

- ***Mapping***: create or get 2D and/or 3D maps.
- ***Localization***: find the 3D location based on sensors.
- ***Simultaneous Localization and Mapping (SLAM)***.
- Information fusion in localization and mapping.

Sensors

- On-vehicle Sensors:
  - Lidar
  - Monocular camera
  - IMU
  - laser altimeter
  - RTK D-GPS.

- Embedded processing units:
  - Intel NUC NUC6i7KYK2 i7-6770HQ
  - Jetson TX2



Visual odometry

Structure from Motion (SfM) recovers:

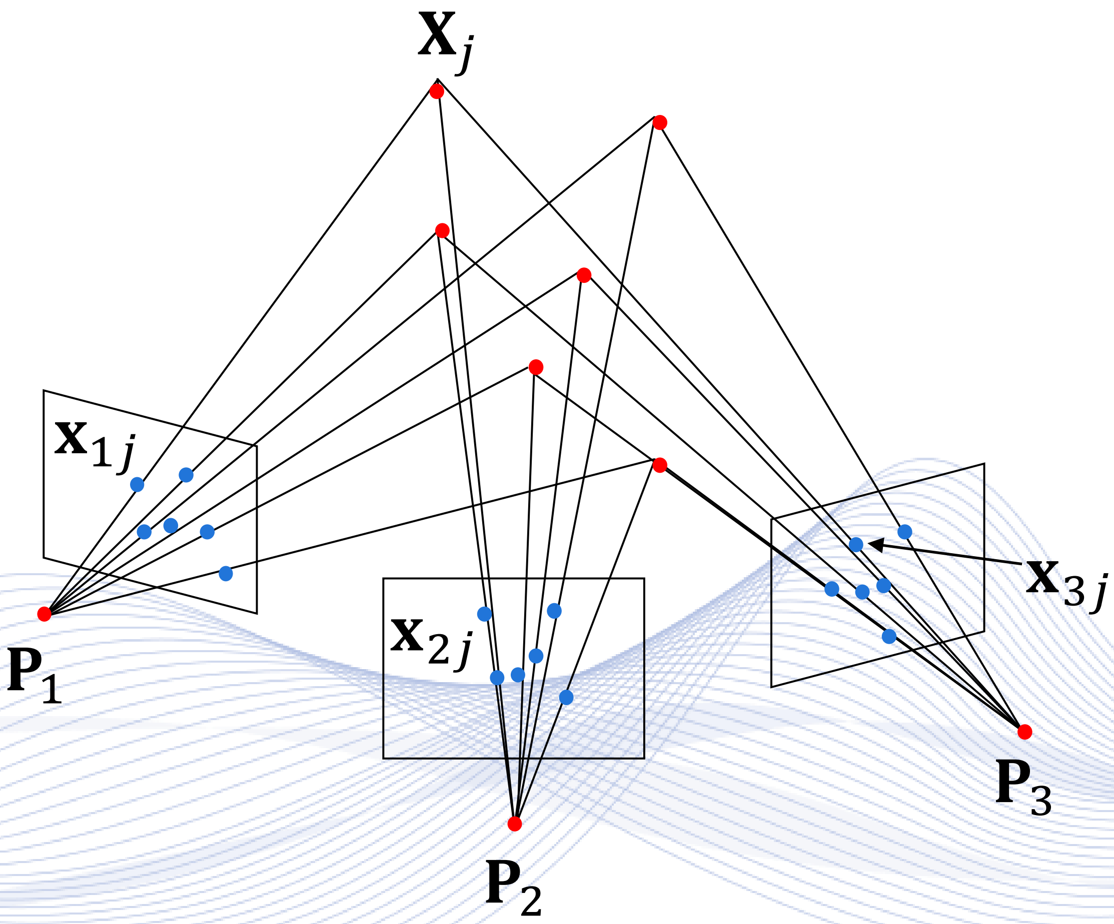
a) the relative camera poses and

b) the three-dimensional (3D) scene structure,

from a set of camera images (calibrated or noncalibrated).

- Visual Odometry is a particular case of SfM.
- Focuses on estimating the 3D motion of the camera sequentially, as a new frame arrives, in real time.

Visual odometry



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Visual odometry based methods for mapping

Lidar Odometry and Mapping (LOAM):

- It is an odometry estimation and mapping method that calculates the trajectory of the laser, using high-level features based on the properties of rotatory lasers.

- It identifies as data features both corner and surface points.
- It generates a map that contains both of them separately.

Geometrical mapping

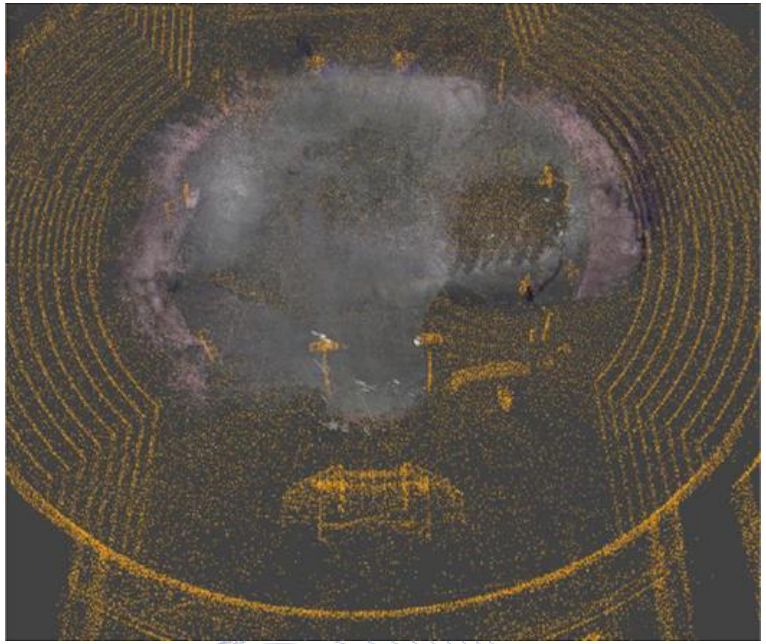
- 3D LIDAR:
  - SLAM-like algorithm based on Prediction-Update Recursions.
  - Extract from the LIDAR measurements: corner and surface points.
  - ***Prediction***: Estimate LIDAR-based odometry from different scans using the ICP algorithm.
  - ***Update***: Matching of the LIDAR scan with the estimated map.
  - Good estimate of robot 6 DoF pose and geometrical map.

- Visual camera:
  - Extraction of features using detectors such as SURF, SIFT or ORB.
  - Estimation of visual odometry.

- Robot odometry is a combination of:
  - LIDAR-based odometry.
  - Visual odometry.
  - IMU.

Geometrical mapping

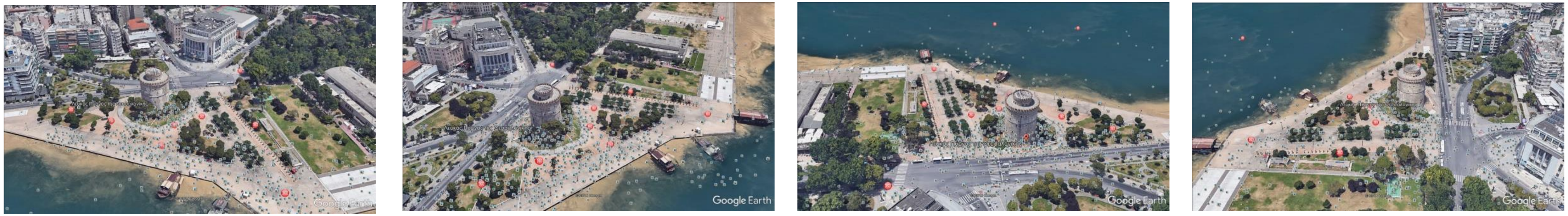
Experiments



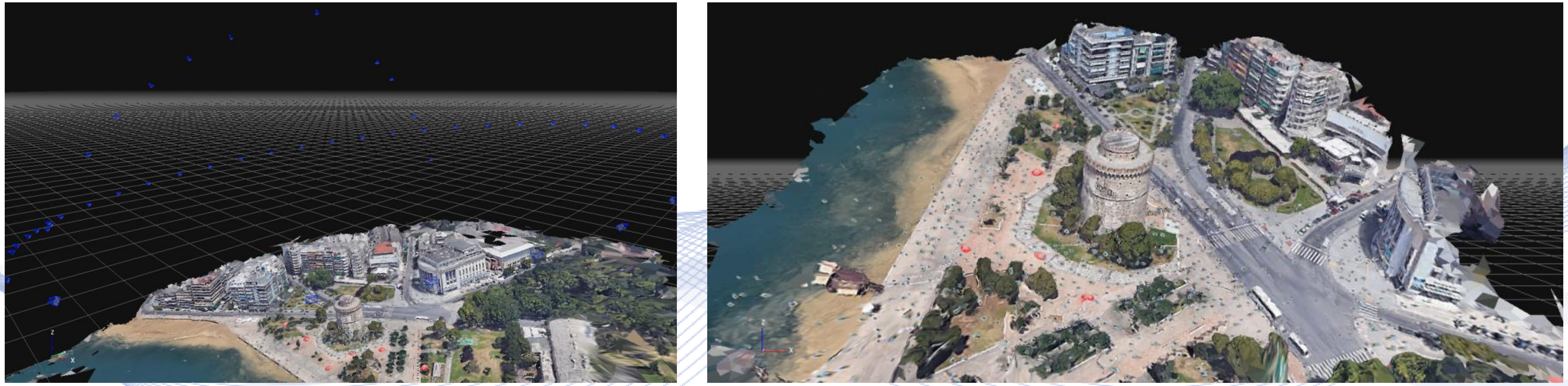
Repeatibility

Dataset	Mean Error (m)	Median Error (m)	Min Error (m)
1	0,1377	0,1073	0,00098
2	0,1053	0,0769	0,00045
3	0,0847	0,0578	0,00083
4	0,1074	0,0792	0,00078
5	0,1722	0,1560	0,00130

3D Scene mapping from multiple uncalibrated images



Images obtained from Google Earth.

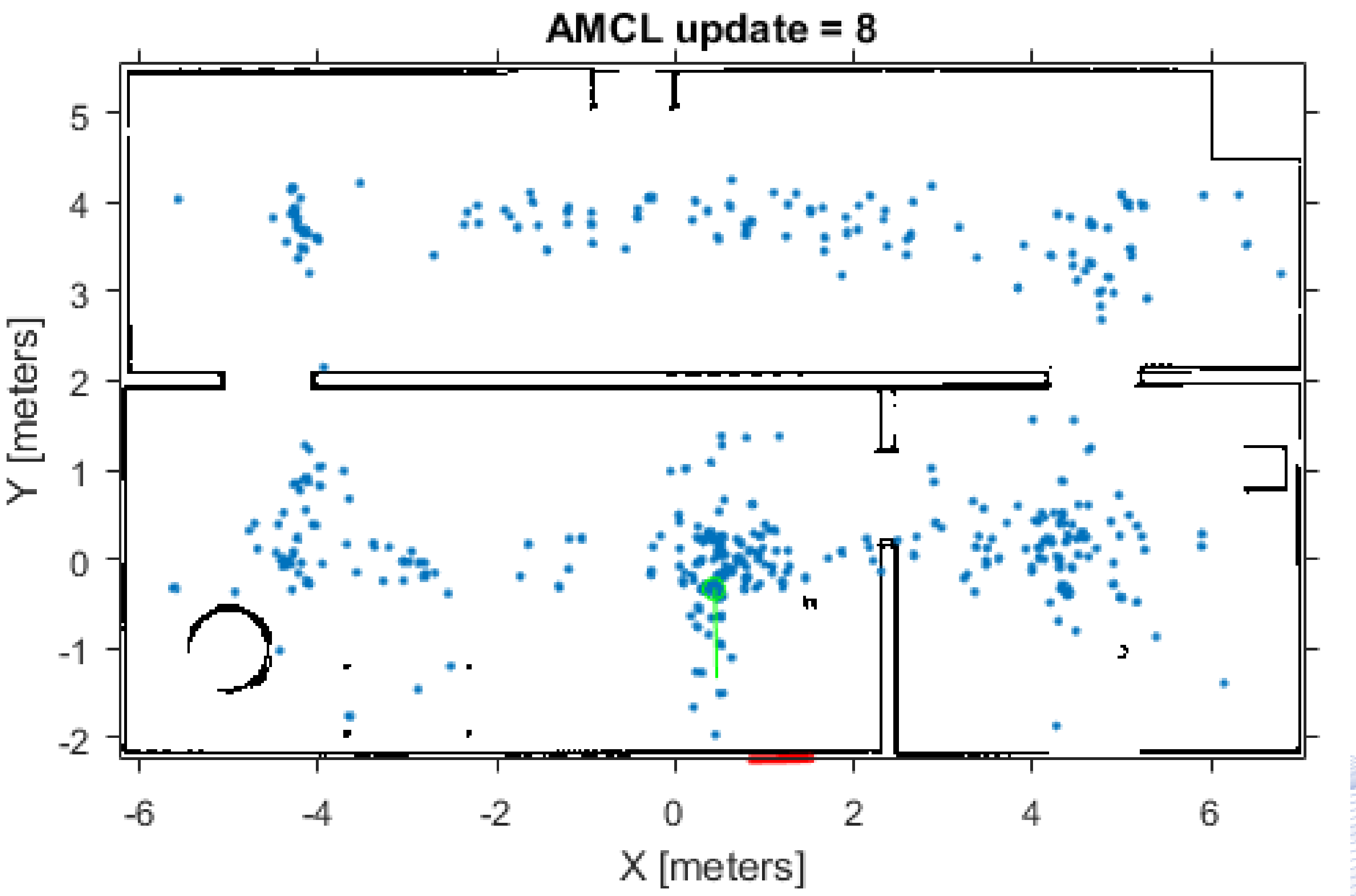


3D models reconstructed using 50 images from Google Earth.

Localization

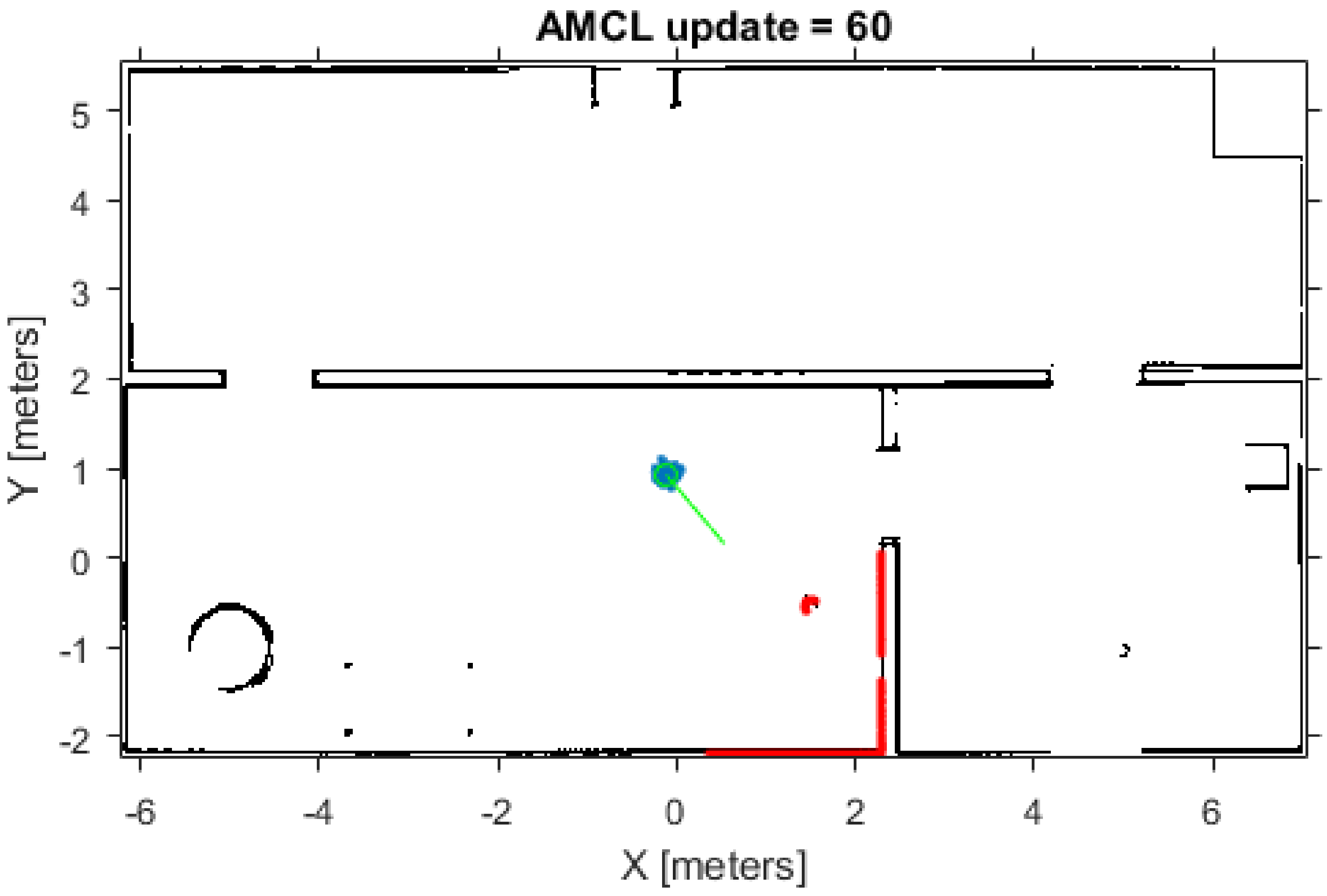
- Not an easy task.
- ***Unconstrained nature of robot/drone movements*** → use of high-fidelity algorithms and sensors that do not reply on them.
- Many methods used for Mapping, are also used for Localization.
- Localization methods can be used as an alternative, in case of GPS failure.

AMCL algorithm



https://www.mathworks.com/help/search.html?qdoc=amcl&submitsearch=

AMCL algorithm



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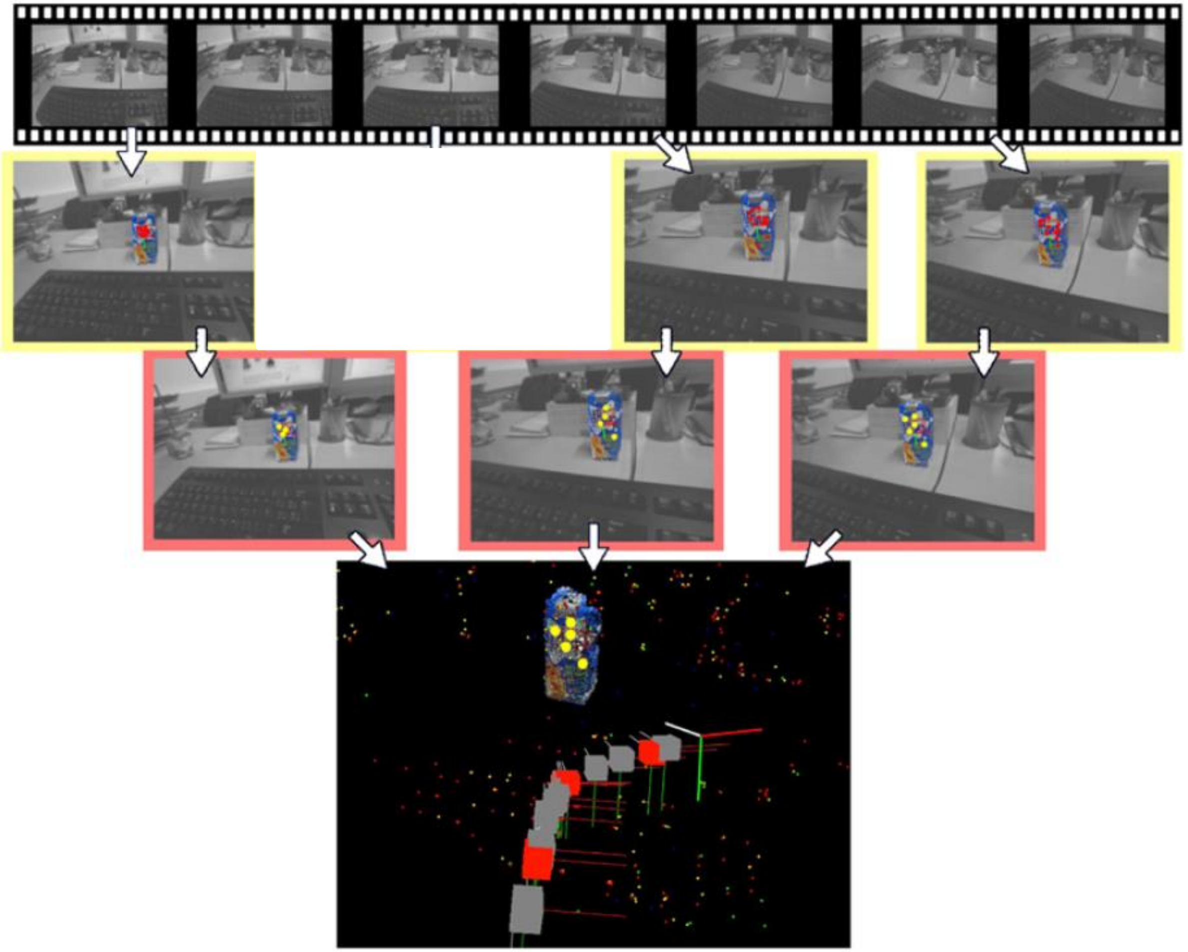
ORB-SLAM

- Among top performers in sparse features VSLAM.
- ***Robust, real-time, large scale operation***.
- Able to operate in general scenes.
- Prototype ORB-SLAM system ready to use.

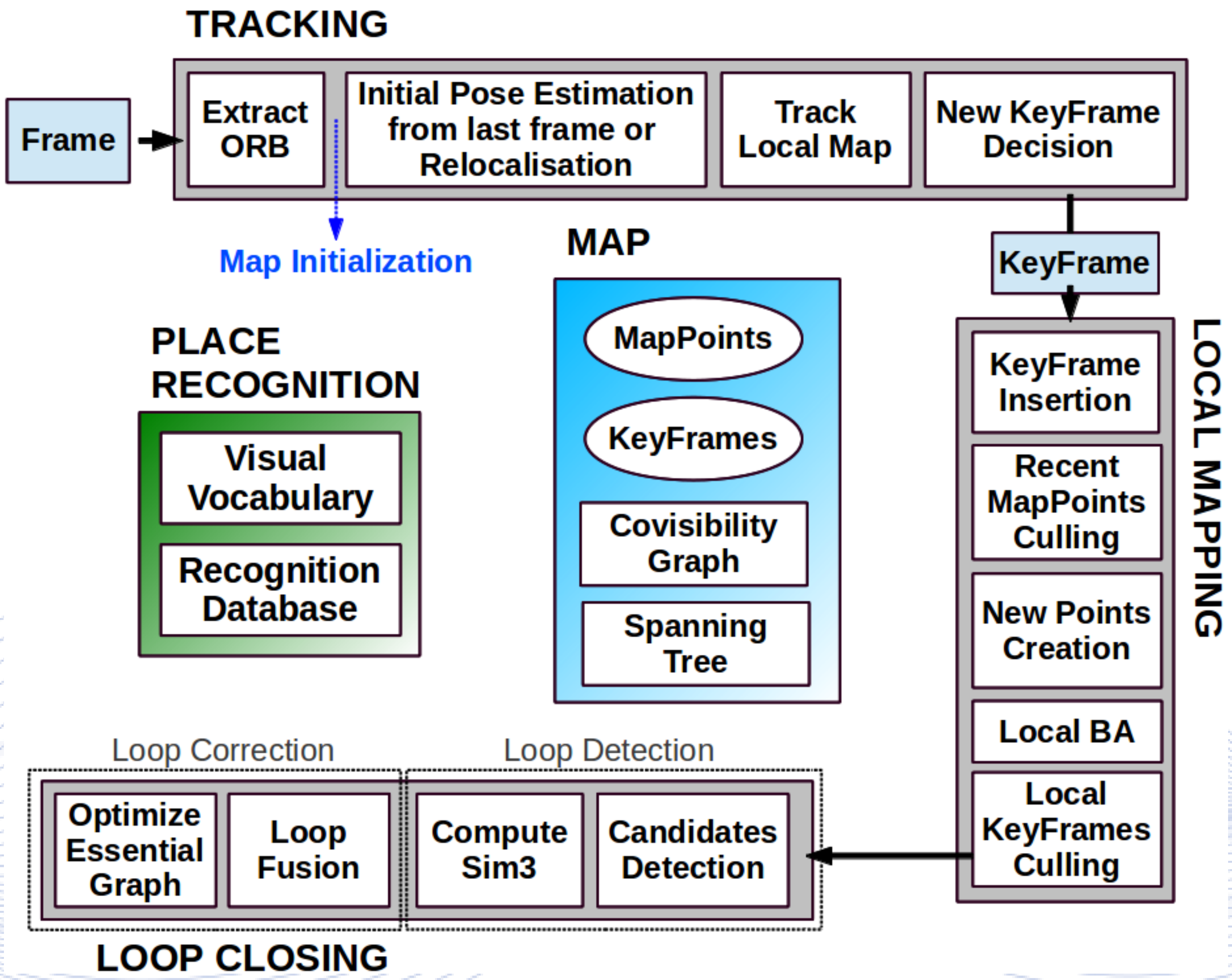
Frame / keyframe



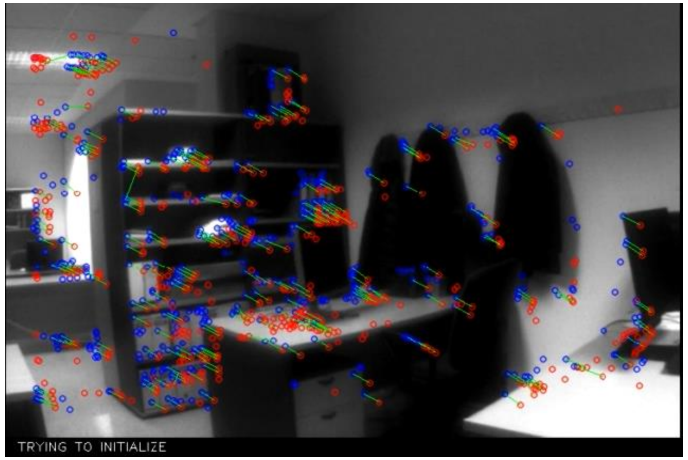
G. Klein and D. Murray . Parallel tracking and mapping for small AR workspaces. (ISMAR), November 2007

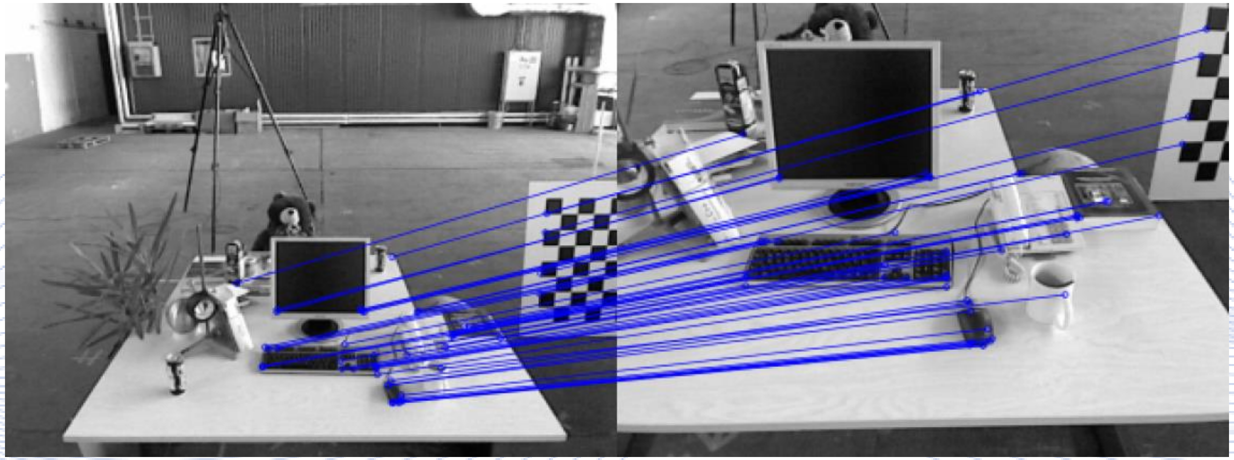
- Local Map.
- Keyframe-based systems:
- Localization and Mapping are separated into two steps:
- Full BundleAdjustment:
  - KeyFrames and map points.
- Regular video frames:
  - Only camera pose is computed.

ORB-SLAM system overview



Features





Why is place recognition difficult

Likely algorithm answer:

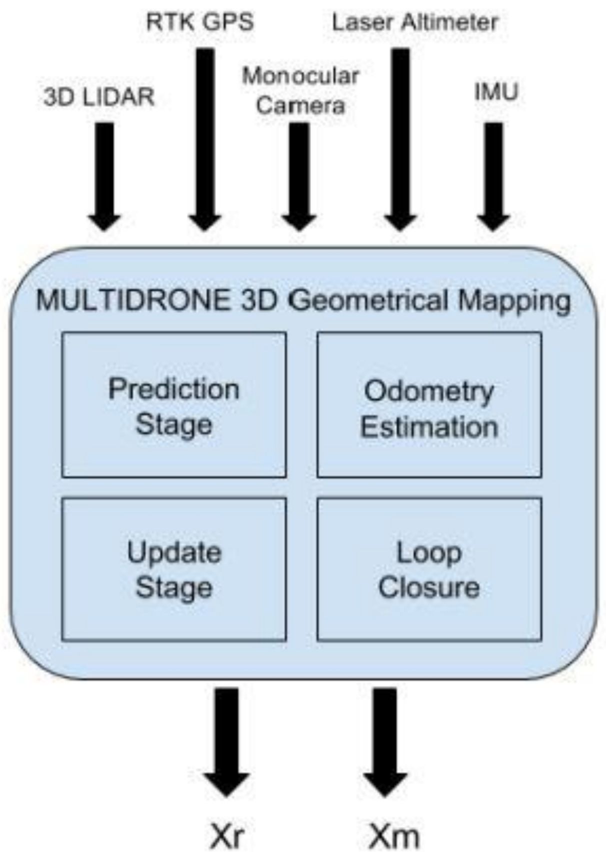
NO **YES** **FALSE POSITIVE**

Perceptual aliasing is common in indoor scenarios

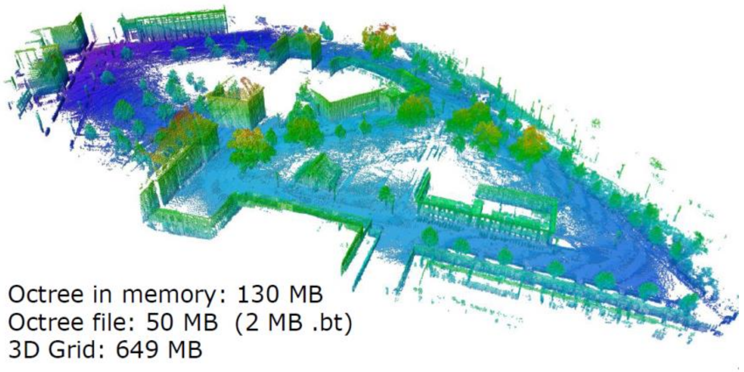
SLAM in dynamic scenes

Data fusion in drone localization

- INPUT: measurements from multiple sensors.
- OUTPUT: 3D geometrical map X_m and the 3D drone pose estimation X_r.

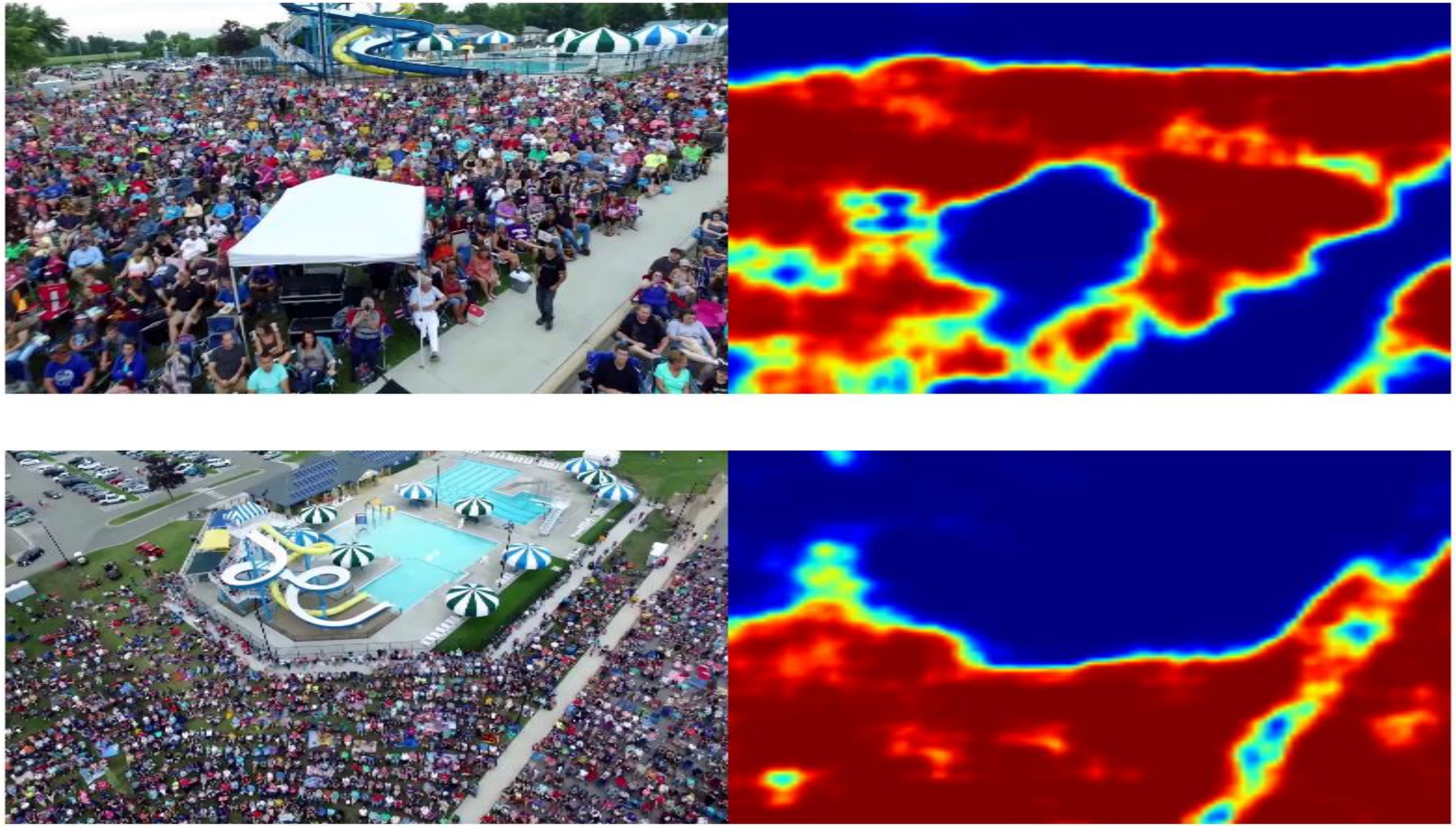


Final result: 3D maps

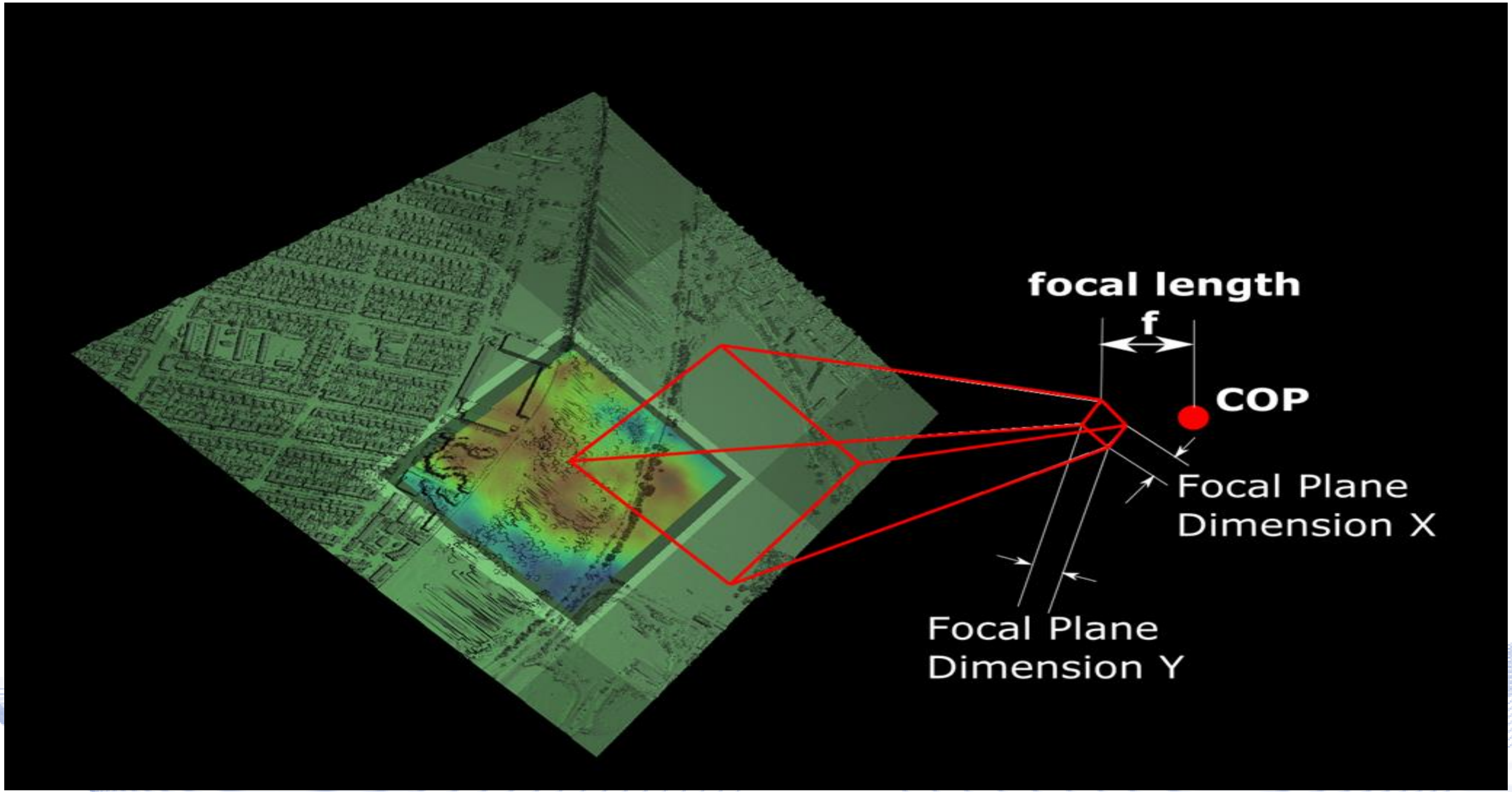


- Formats:
    - 3D triangle mesh.
    - 3D Octomap.
- Octomap :
    - The Octomap is a fully 3D model representing the 3D environment, where the UAV navigates.
    - It provides a volumetric representation of space, namely of the occupied, free and unknown areas.
    - It is based on octrees and using probabilistic occupancy estimation.

Projection of crowd location onto the 3D map



Semantic 3D Mesh Map Annotation



Q & A

Thank you very much for your attention!

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