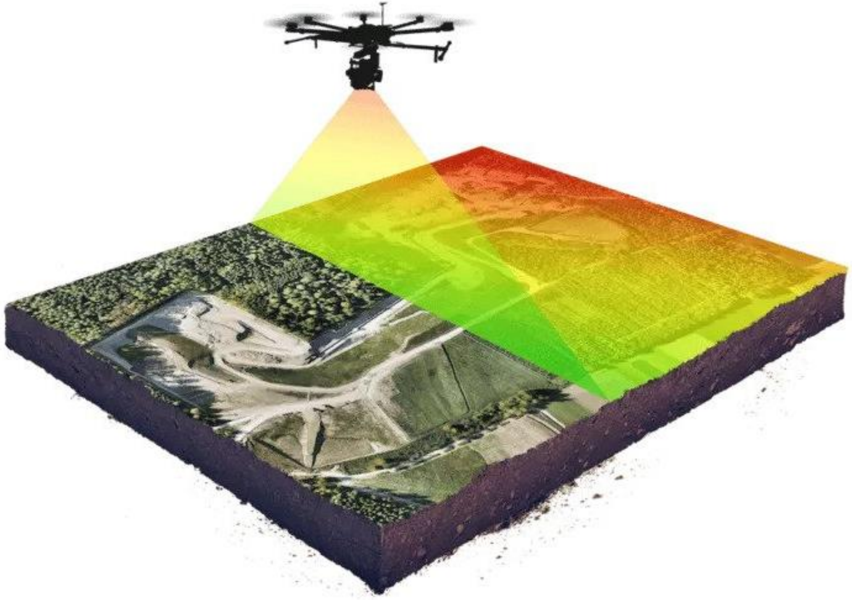
EPFL



Methods of Trajectory Estimation in Challenging Mapping Scenarios

IUGG 2023 Berlin

G05f - Multi-signal positioning, Remote Sensing and Applications

Aurélien Brun

13.07.2023

Motivation

Challenges in LiDAR mapping technology

[Source : Wingtra]

Direct georeferencing & Continuous capture

↓

Trajectory must be accurately determined at all times

Motivation

Challenges in LiDAR mapping technology

Trajectory must be accurately determined at all times

What if we use a drone with low grade navigation sensor ?

What if we lose GNSS signal ?

What if we miscalibrate our system ?

How to improve LiDAR reliability?

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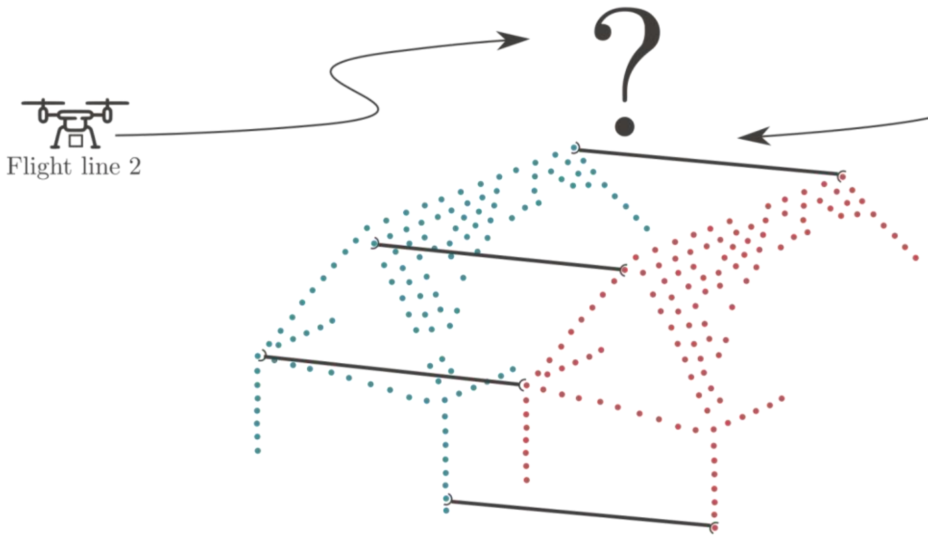
We propose a novel LiDAR based trajectory adjustment procedure:

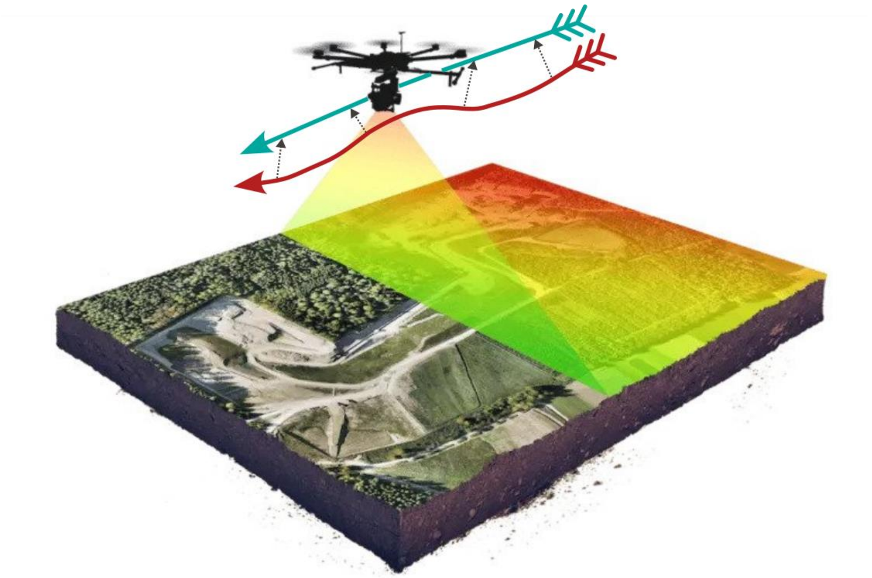
1. Robust pipelines to establish point to point correspondences in point clouds



How to improve LiDAR reliability?

We propose a novel LiDAR based trajectory adjustment procedure:

1. Robust pipelines to establish point to point correspondences in point clouds
2. Adjustment step to refine the entire trajectory, calibrate system mounting



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How to improve LiDAR reliability?

We propose a novel LiDAR based trajectory adjustment procedure:

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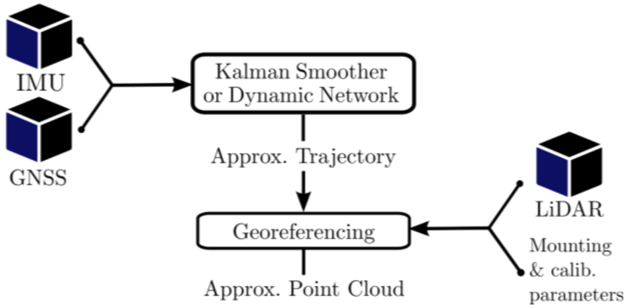
Objectives : allow post processing system calibration & trajectory correction, specifically when GNSS outages occur

Methods
Processing pipeline



[A. Brun et. al., 2022, Lidar point–to–point correspondences for rigorous registration of kinematic scanning in dynamic networks, ISPRS Journal of Photogrammetry and Remote Sensing]

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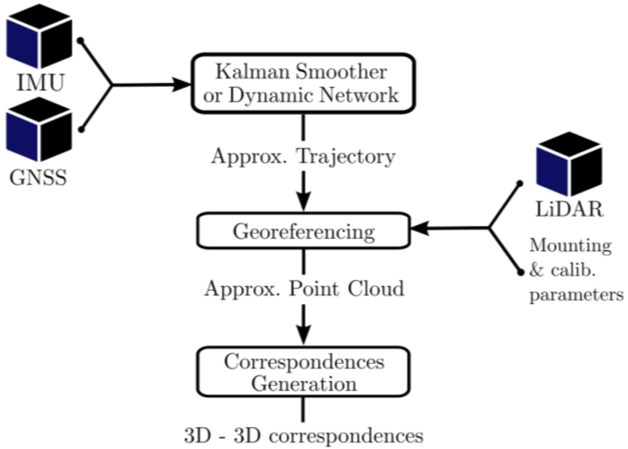

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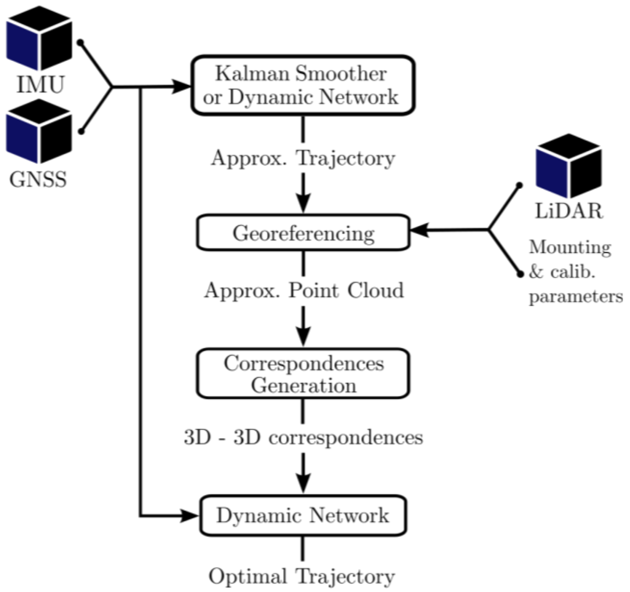

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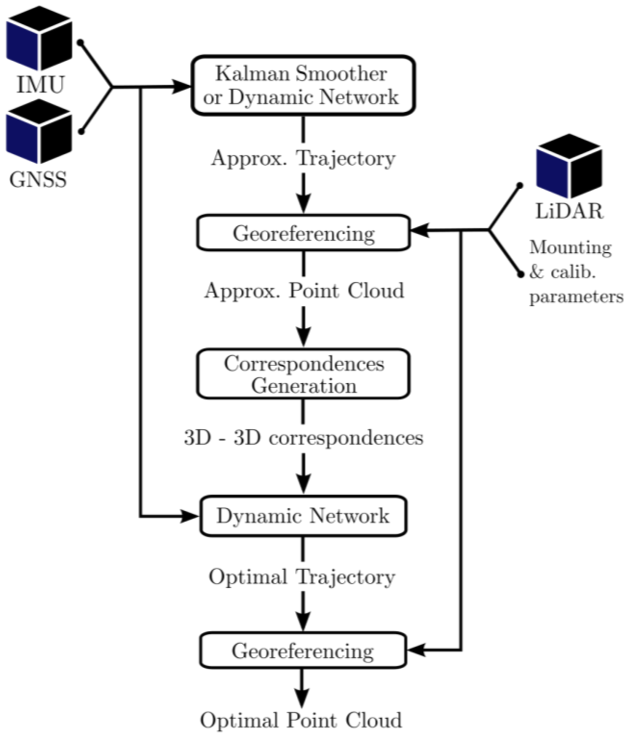

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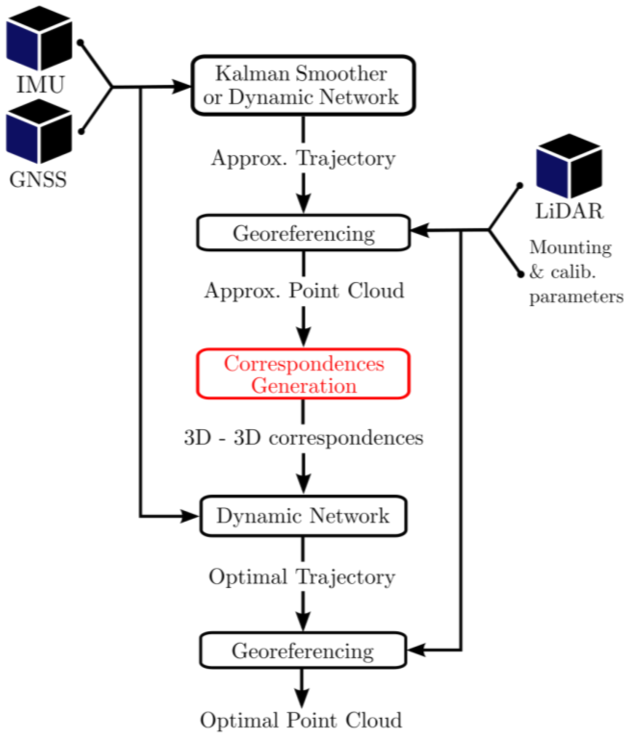
Point to point correspondences generation



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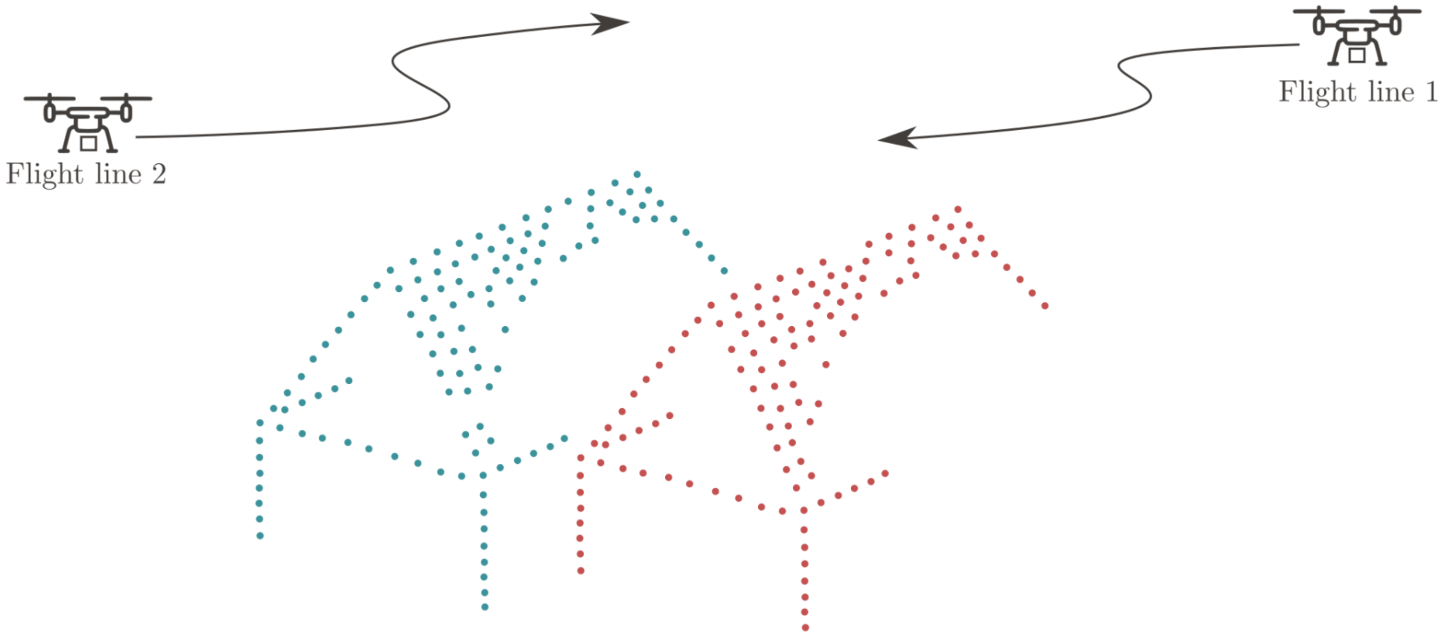

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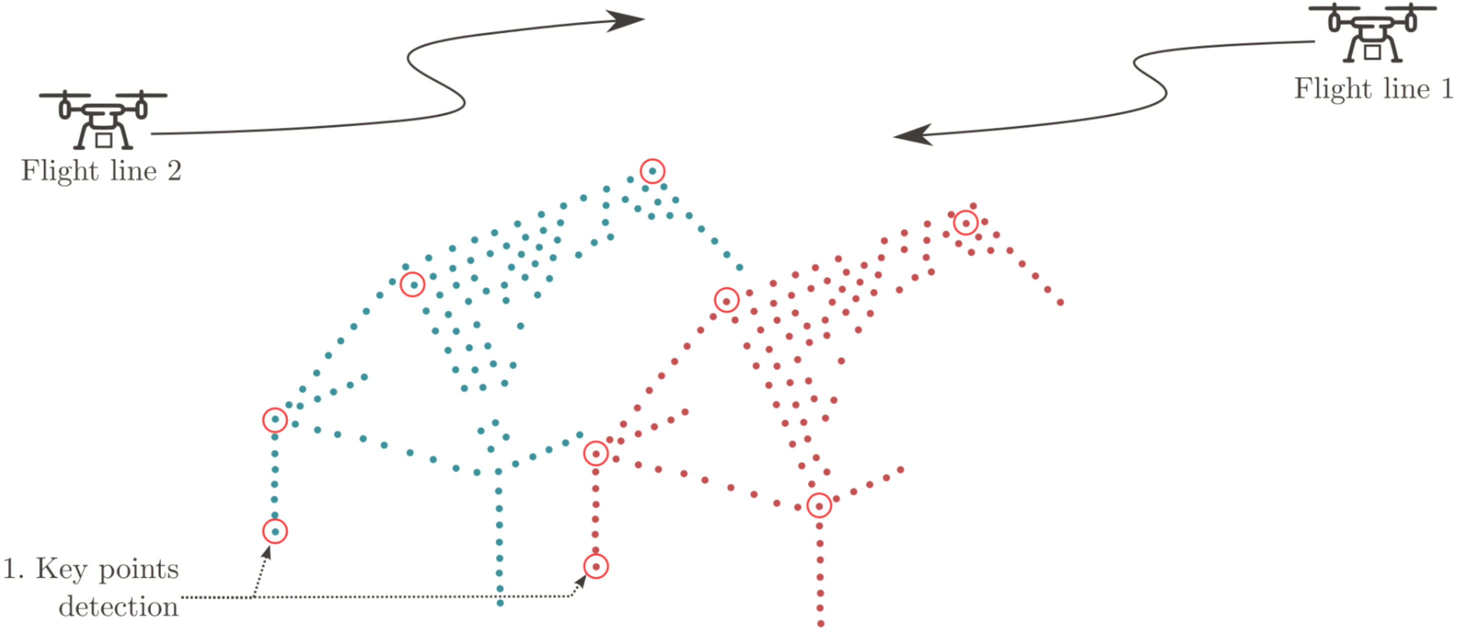

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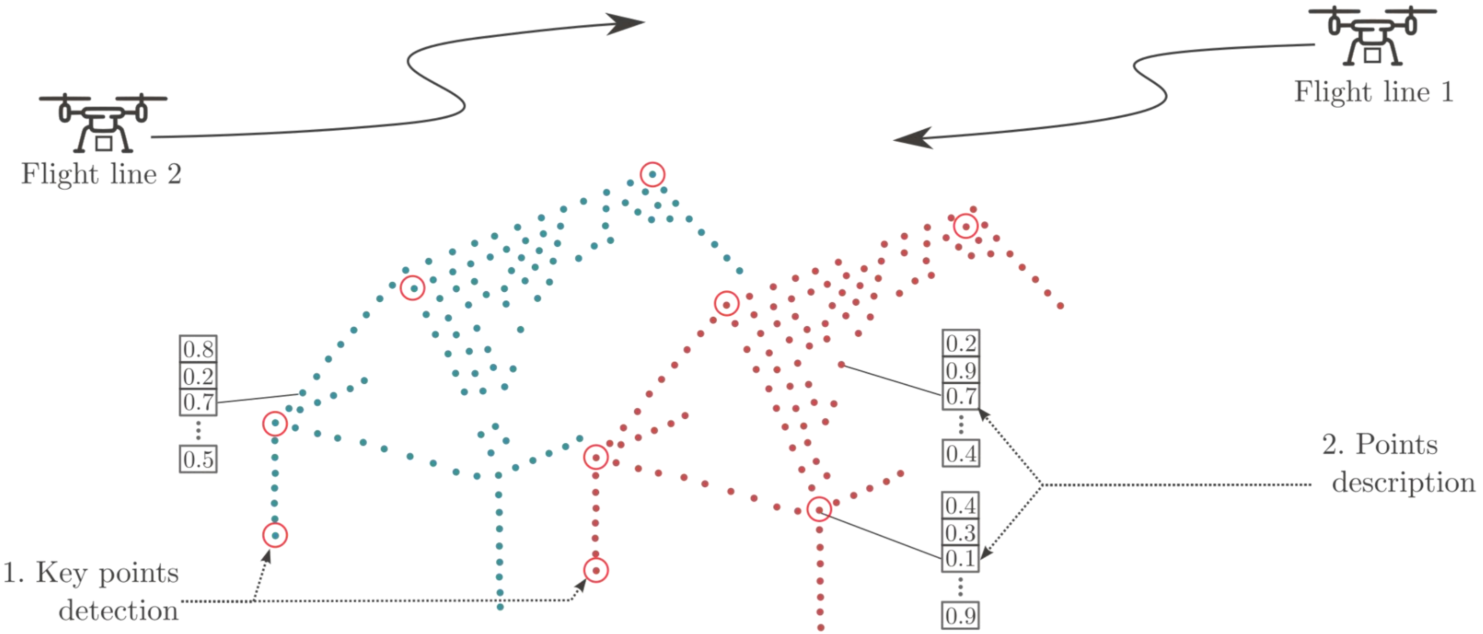

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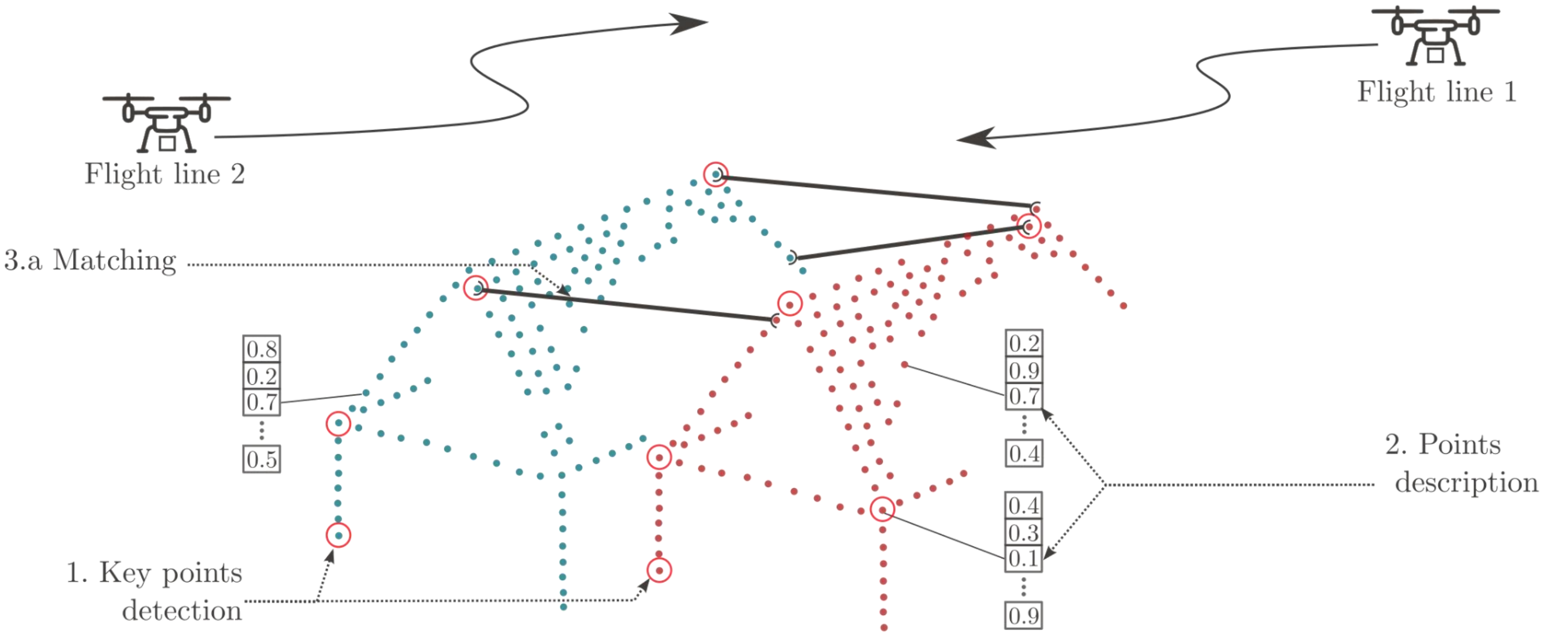

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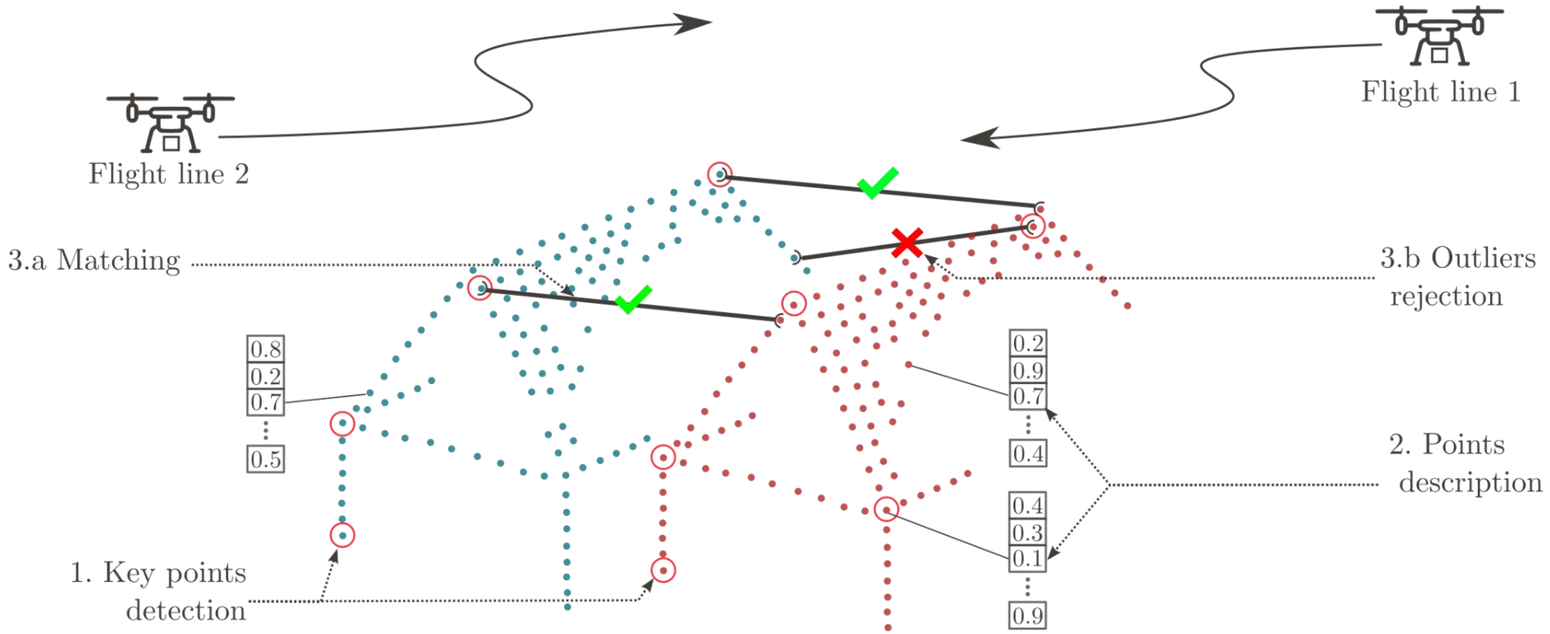

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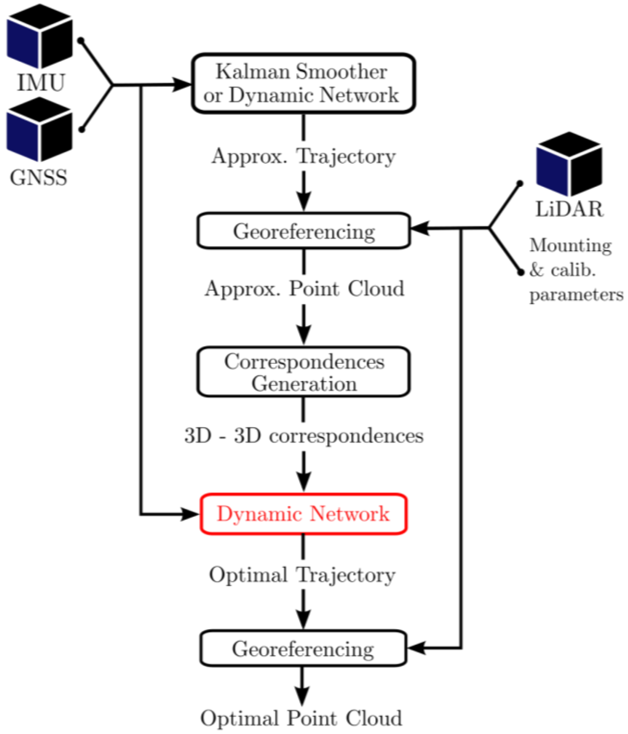
Methods
Dynamic Network



Methods

Dynamic Network

An extension of conventional geodetic networks:

1. Optimal solving of all trajectory parameters and their derivatives at once (e.g. specific forces + angular velocities) → ~300k parameters to solve per minute of trajectory[1]

1. D. A. Cucci et. al., 2017. Bundle adjustment with raw inertial observations in UAV applications, ISPRS Journal of Photogrammetry and Remote Sensing

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3. Target the source of the errors (e.g. IMU biases) rather than the consequences (i.e. their projection on the orientation)

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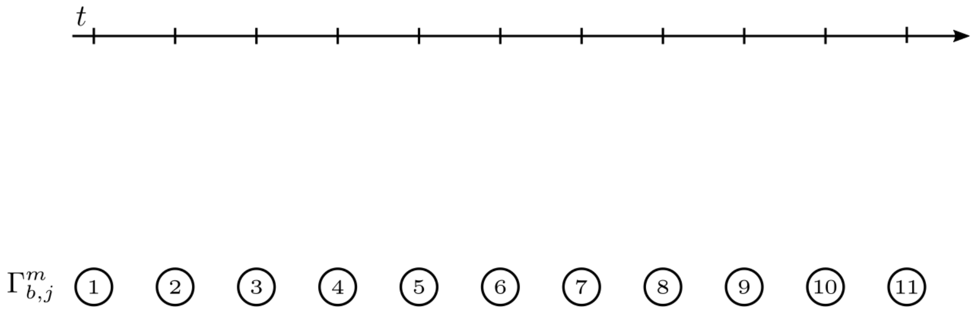

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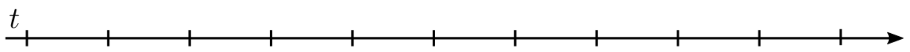

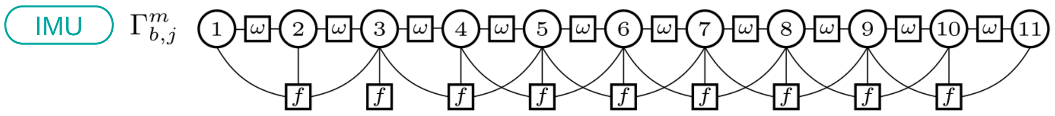

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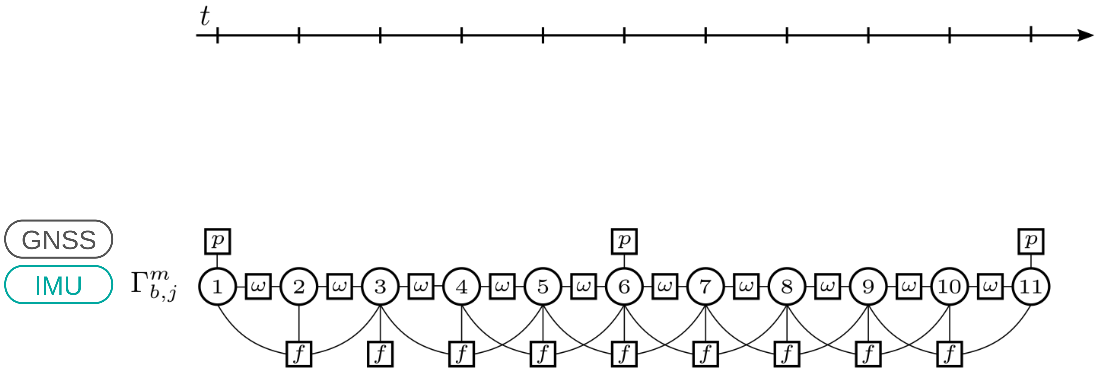
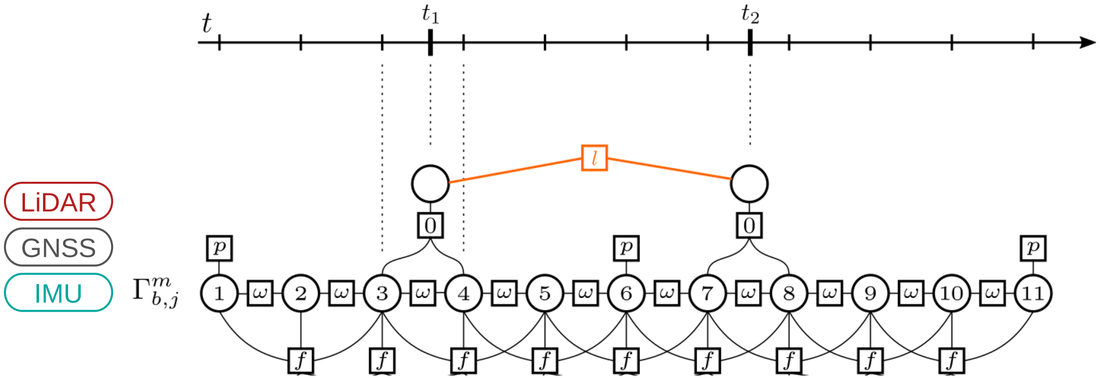


Methods
Dynamic Network



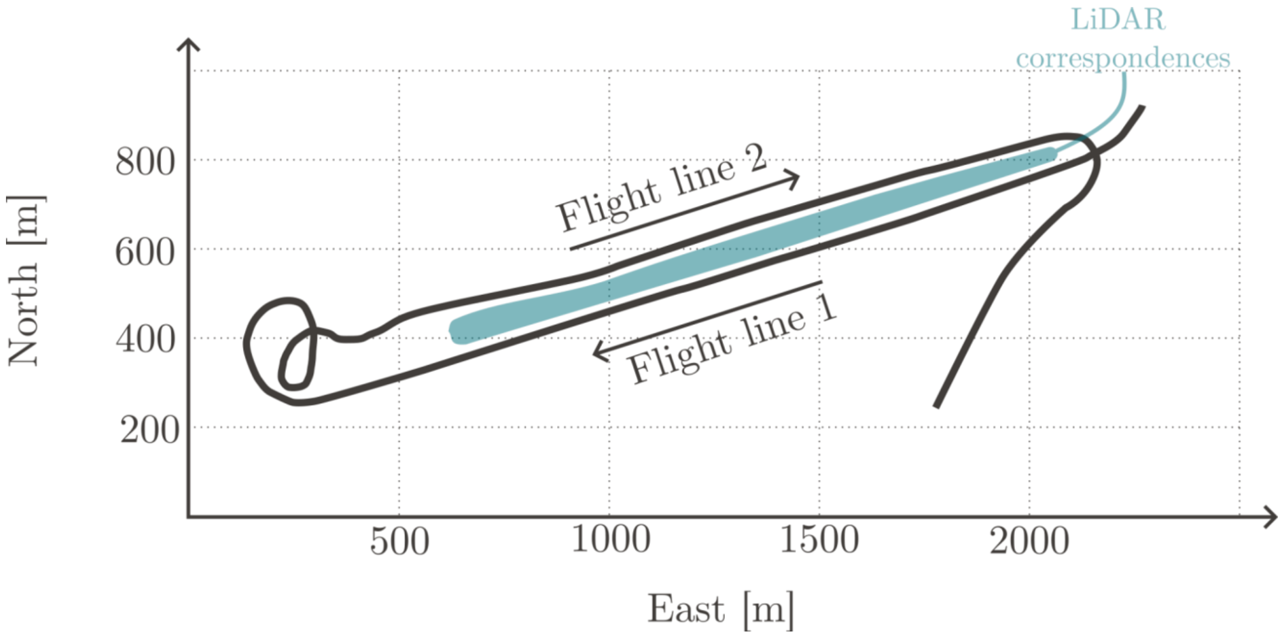
Setup

Aerial - Nominal Scenario

Trajectory. 1 GNSS IMU

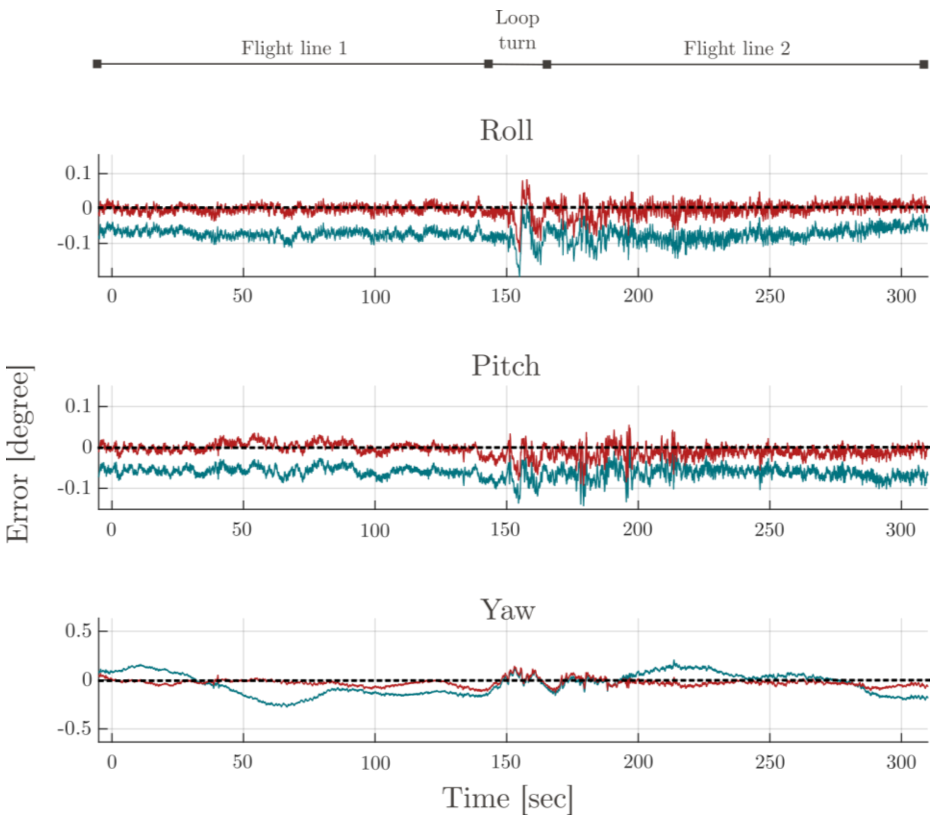
Trajectory. 2 GNSS IMU LiDAR

- Flight duration ~ 5 minutes
- Precise laser & UAV grade IMU → large attitude errors
- Navigation grade (~ ground truth) trajectory available



Results

Aerial - Nominal Scenario



Trajectory. 1 GNSS IMU

T. 1 attitude error

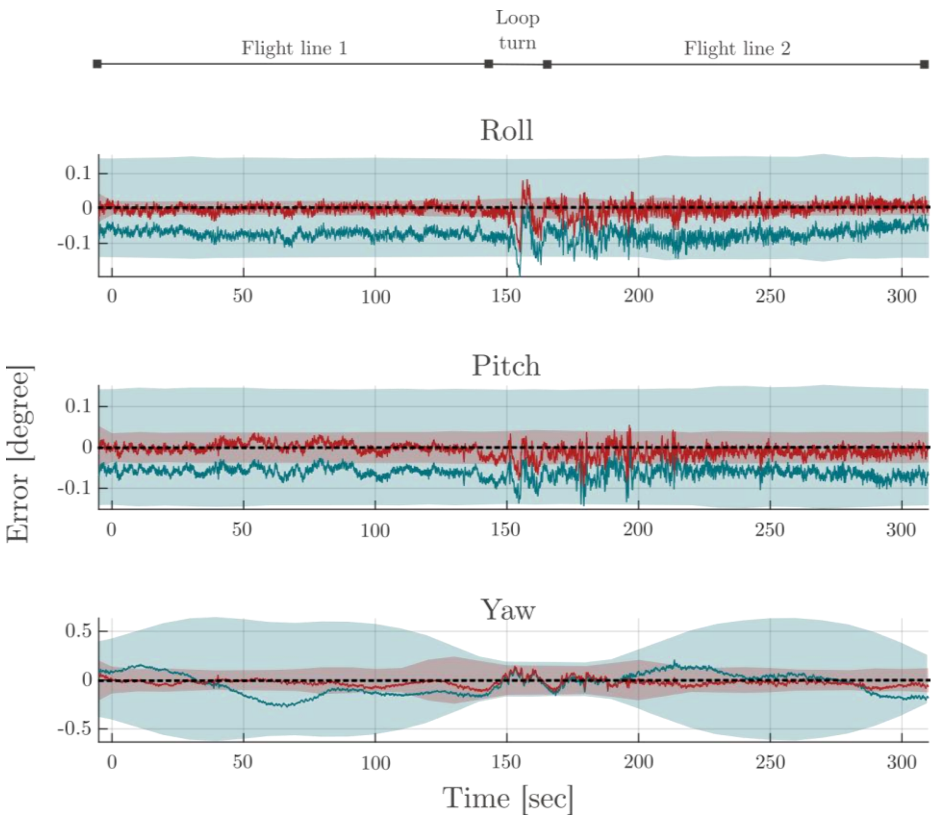
Trajectory. 2 GNSS IMU LiDAR

T. 2 attitude error

- Errors reduced by a factor 3→5 (attitude and subsequent point cloud)

Results

Aerial - Nominal Scenario



Trajectory. 1 (GNSS) (IMU)

T. 1 attitude error

T. 1 3σ confidence interval

Trajectory. 2 (GNSS) (IMU) (LiDAR)

T. 2 attitude error

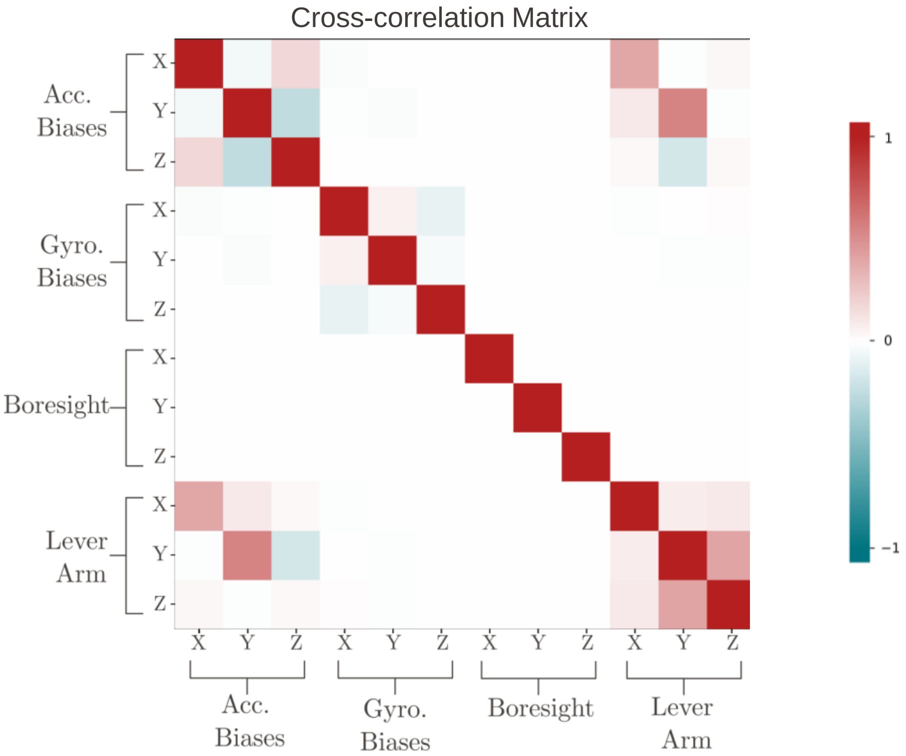
T. 2 3σ confidence interval

- Errors reduced by a factor 3→5 (attitude and subsequent point cloud)
- A posteriori confidence largely improved

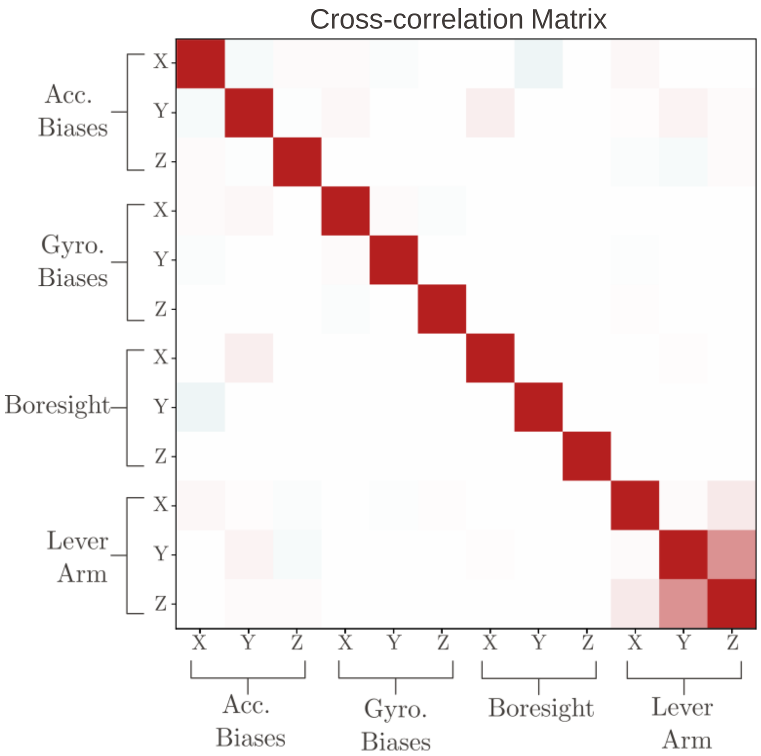
Results

Aerial - Nominal Scenario

Trajectory. 1 GNSS IMU



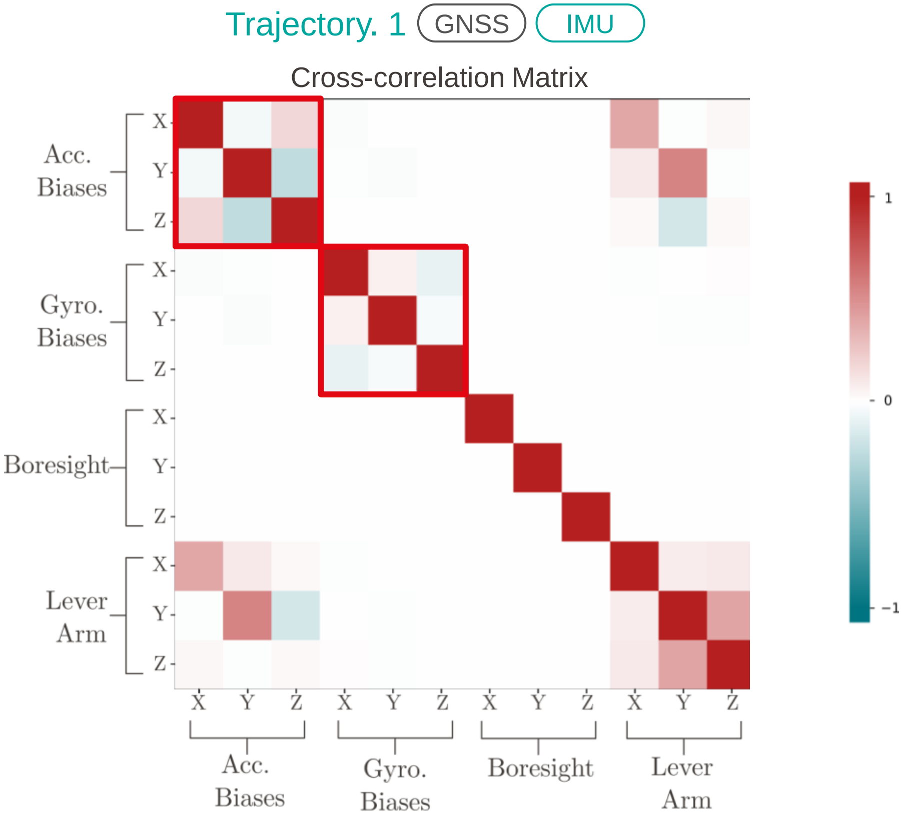
Trajectory. 2 GNSS IMU LiDAR

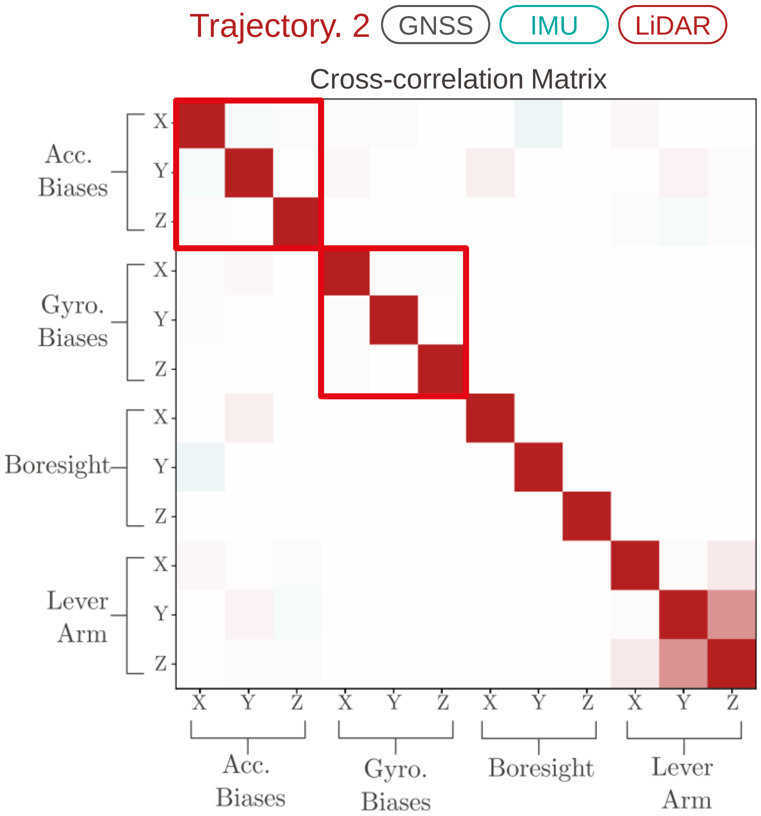


EPFL

Results

Aerial - Nominal Scenario





Results

Aerial - Nominal Scenario

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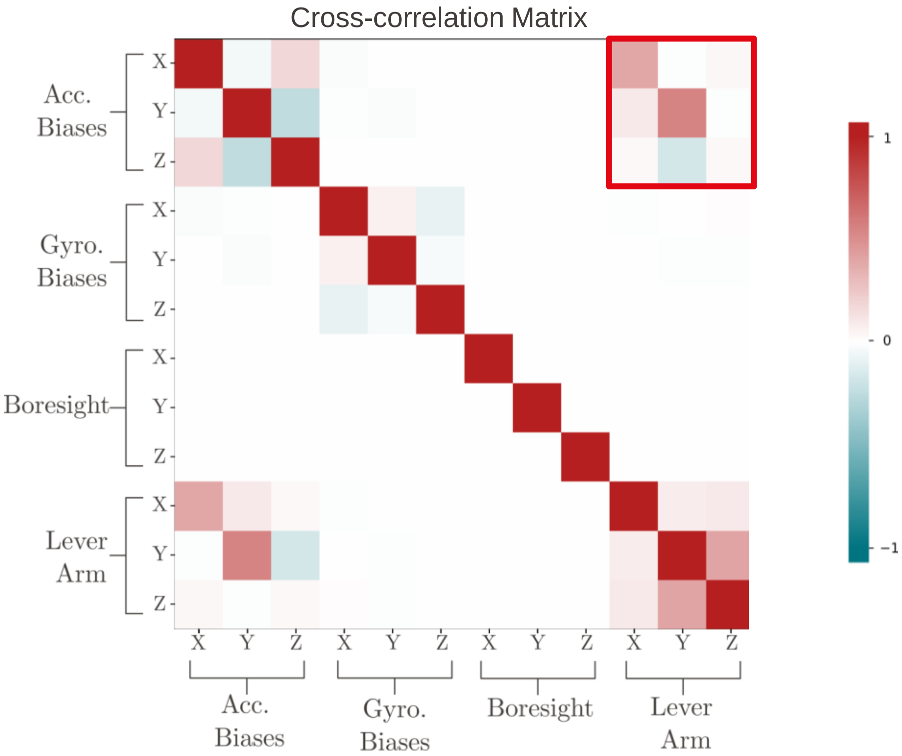
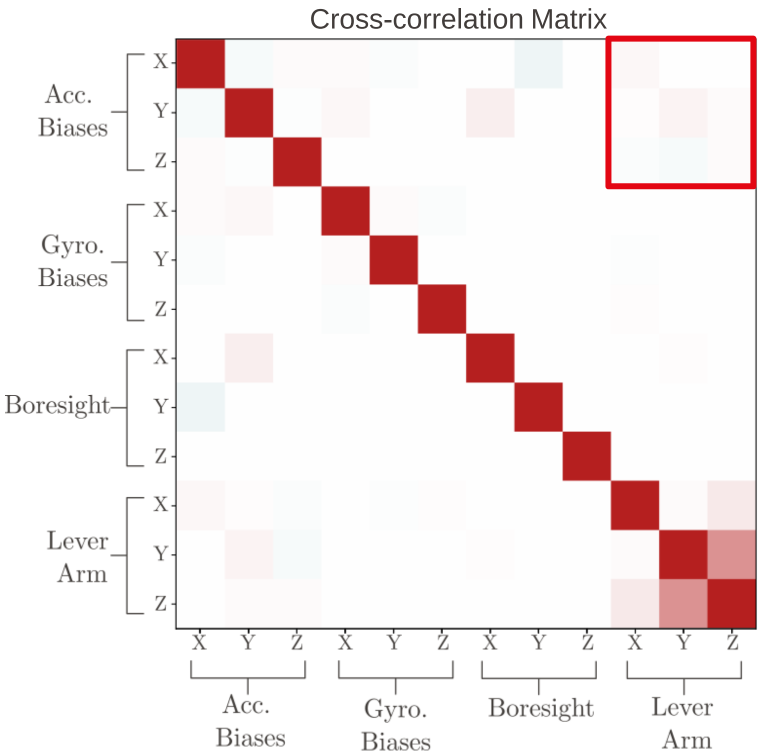


Trajectory. 2 GNSS IMU LiDAR



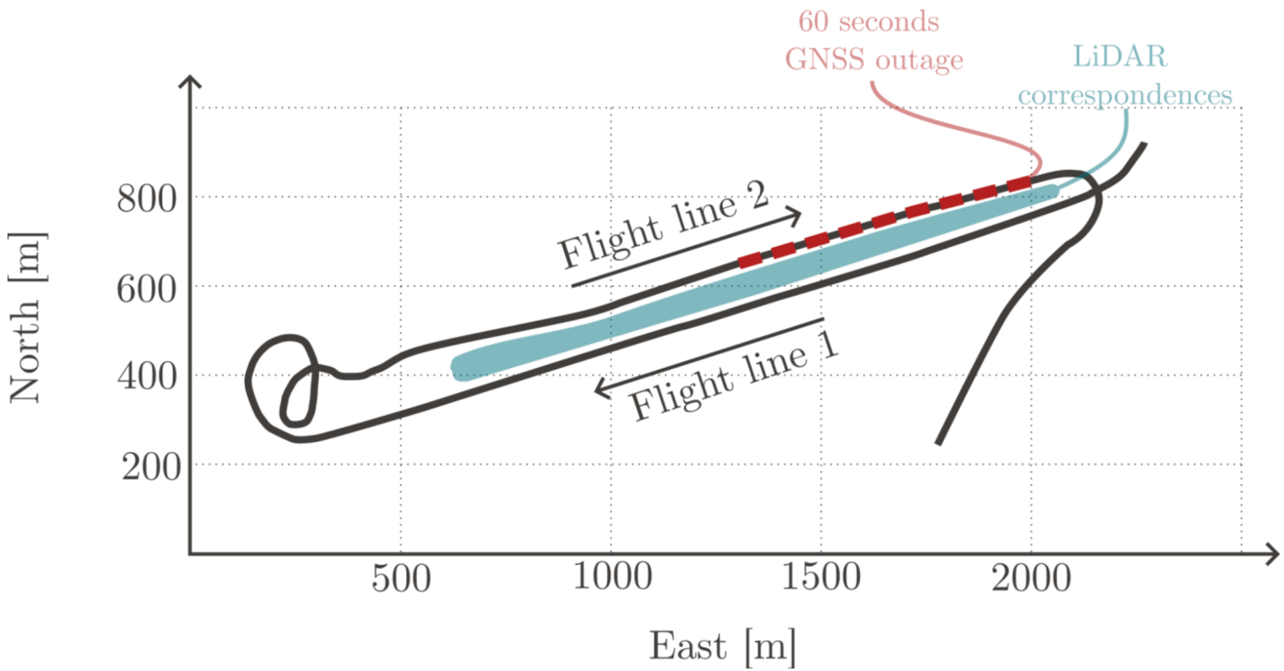
Setup

Aerial - GNSS Outage

Trajectory. 1 (GNSS) (IMU)

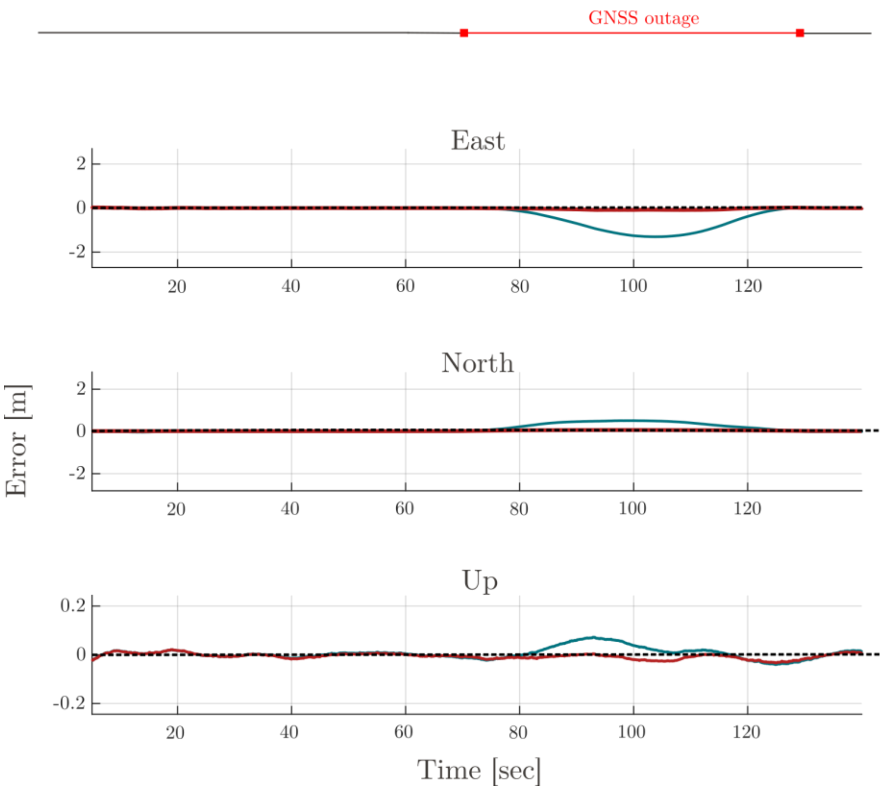
Trajectory. 2 (GNSS) (IMU) (LiDAR)

- Flight duration ~ 5 minutes
- GNSS Outage → large position errors
- Navigation grade (~ ground truth) trajectory available



Results

Aerial - GNSS Outage



Trajectory. 1 [GNSS] IMU

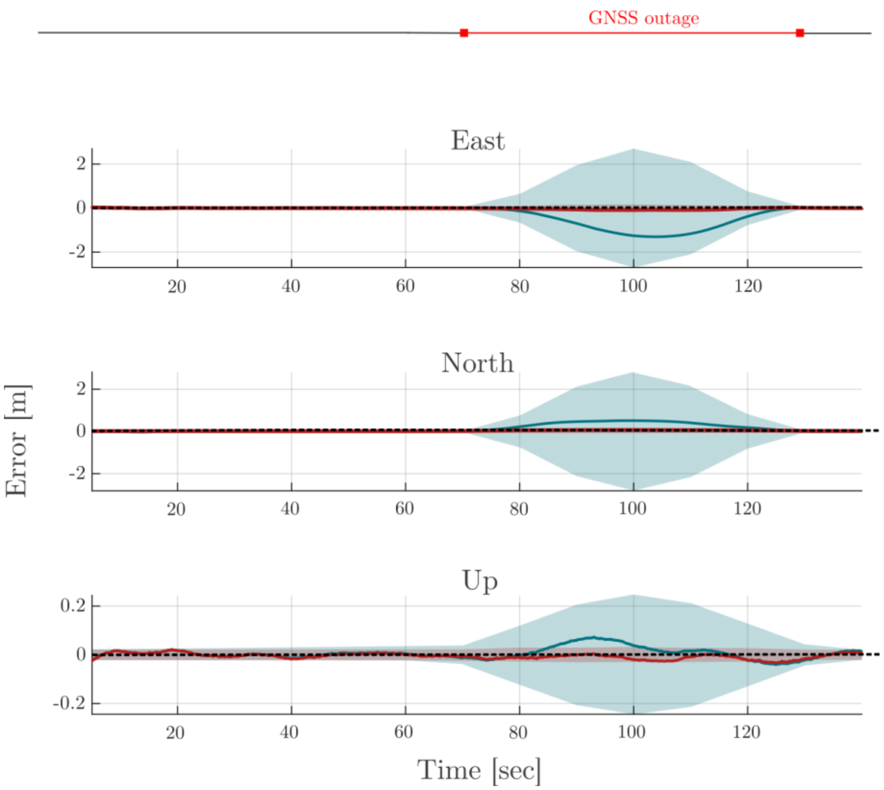
T. 1 position error

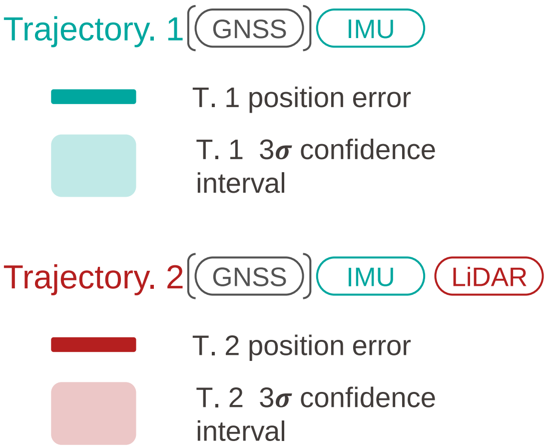
Trajectory. 2 [GNSS] IMU LiDAR

T. 2 position error

- Max. errors reduced by a factor 10→15 (position and subsequent point cloud)

Results
Aerial - GNSS Outage

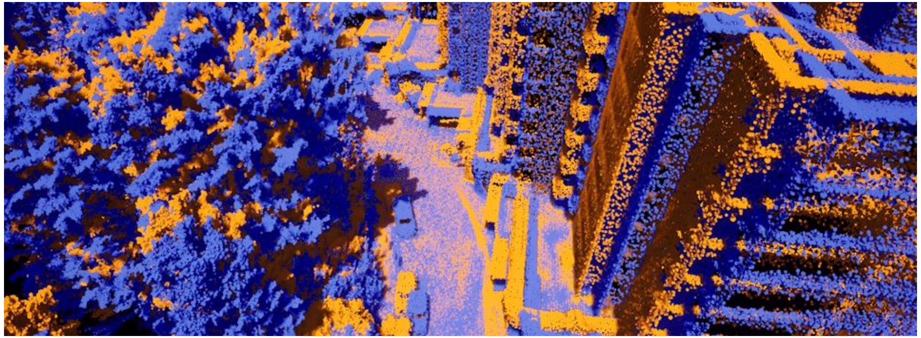




- Max. errors reduced by a factor 10→15 (position and subsequent point cloud)
- Quality and confidence inside the outage maintained comparable to outside of it

Conclusion

- Point to point correspondences in Dynamic Network improve significantly trajectory estimation
- Allow estimating unknown mounting parameters (i.e. lever-arm + boresight) up to certain accuracy
- Application to other navigation scenarios, e.g. indoor SLAM …

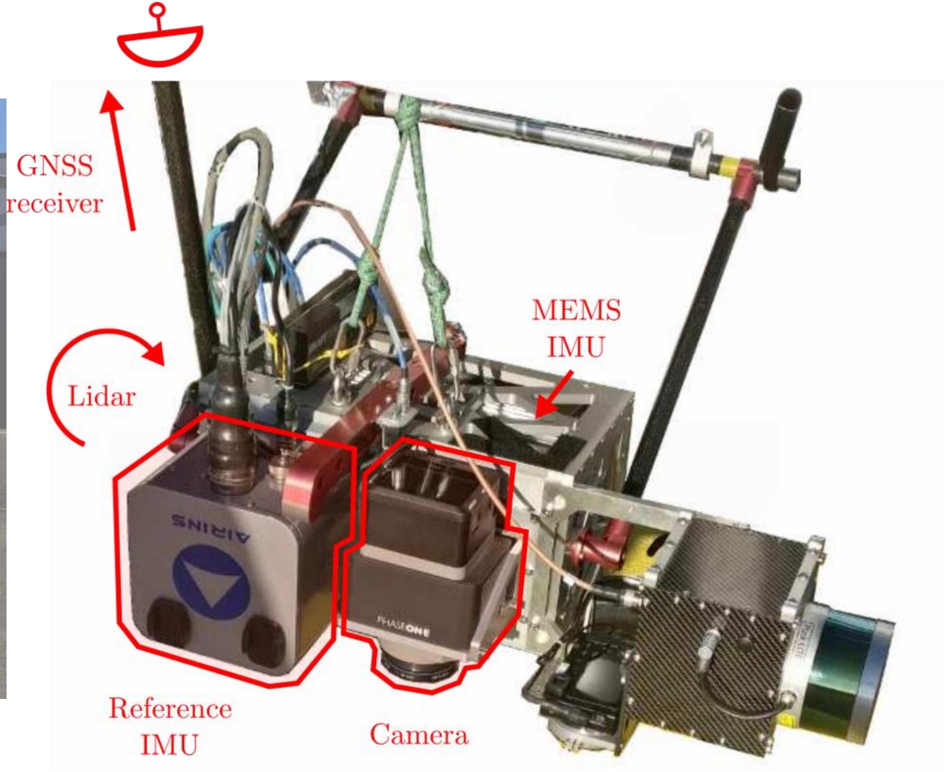


1. A. Brun et. al., 2022, Lidar point–to–point correspondences for rigorous registration of kinematic scanning in dynamic networks, ISPRS Journal of Photogrammetry and Remote Sensing

Supplementary slides

Setup


HELILAUSANNE


GNSS
receiver
Lidar
MEMS
IMU
Reference
IMU
Camera
AIRINS
PHASEONE

EPFL

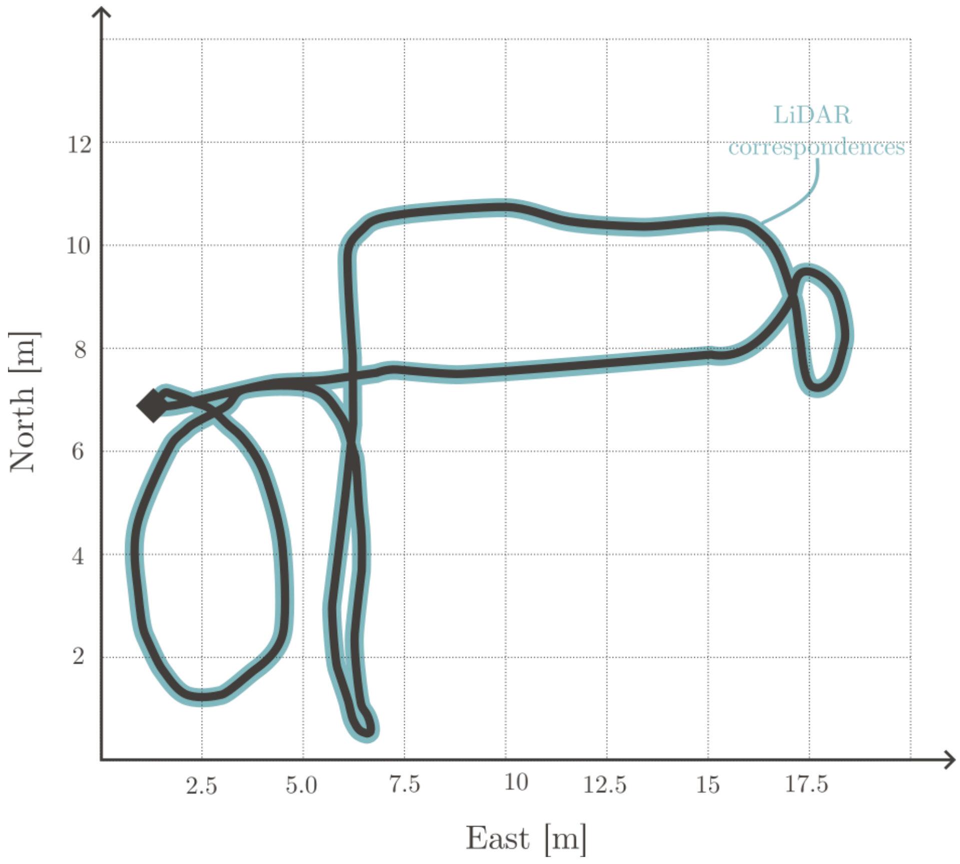
Setup

Indoor (on-going)

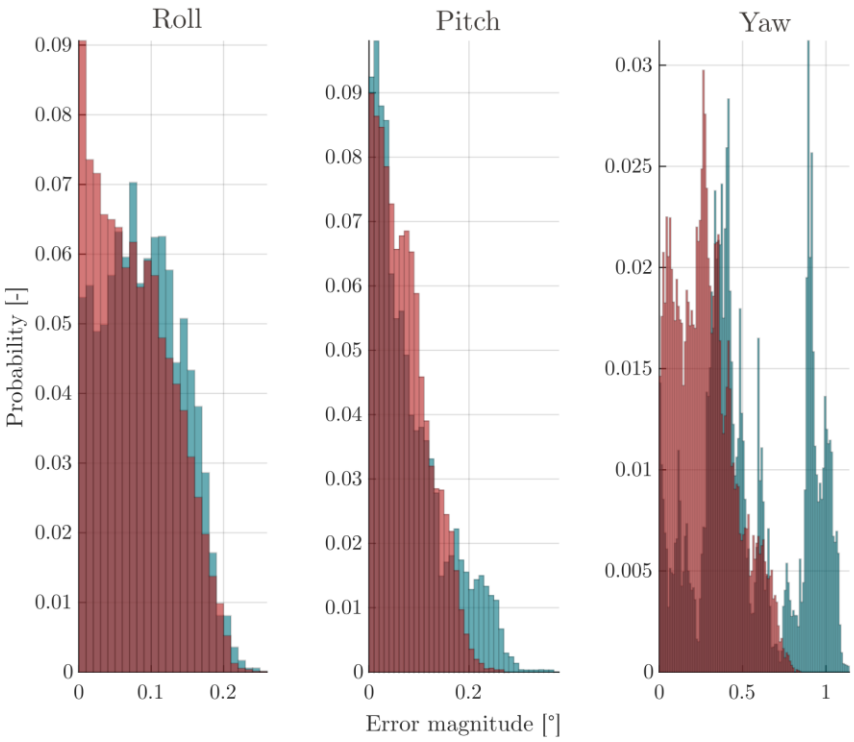
Trajectory 1 IMU RGB

Trajectory 2 IMU RGB LiDAR

Scan duration ~2.2 minutes



Results
Indoor- GNSS denied



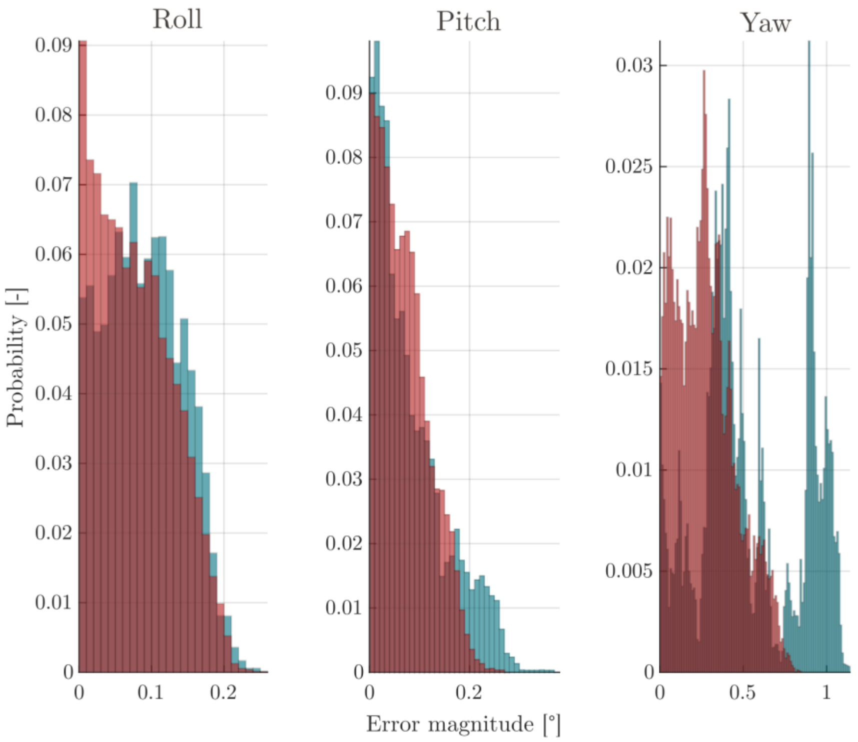
Trajectory. 1 IMU RGB

T. 1 attitude error

Trajectory. 2 IMU RGB LiDAR

T. 2 attitude error

Results
Indoor- GNSS denied



Trajectory. 1 IMU RGB

T. 1 attitude error

Trajectory. 2 IMU RGB LiDAR

T. 2 attitude error

- Attitude error reduced by 10%, 20% and 50% in roll, pitch and yaw
- Similar potential for system calibration as in aerial setup

Supplementary

LiDAR Soft constraint