

AeroTraj:

Trajectory Planning for Fast, and Accurate 3D
Reconstruction Using a Drone-based LiDAR

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Eugene Chai, Karthik Sundaresan, and Ramesh Govindan

3D Reconstruction



3D Model

Process of building 3D models

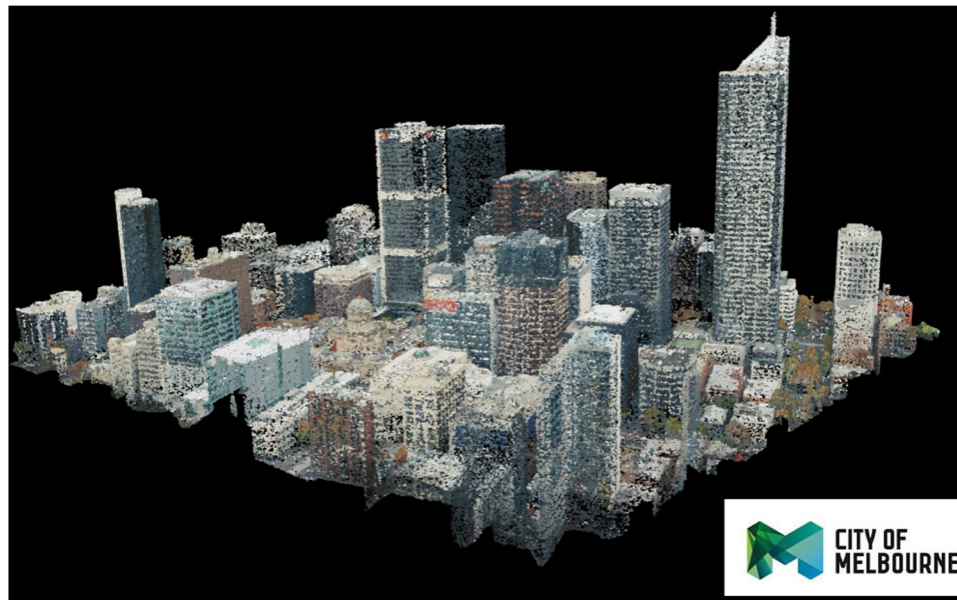
3D representation of the world

3D Model Representations

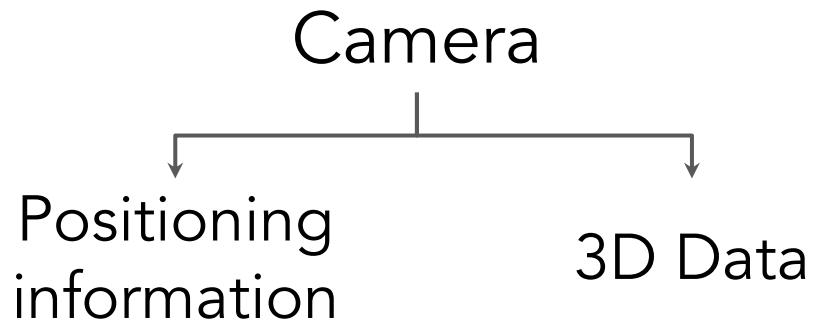
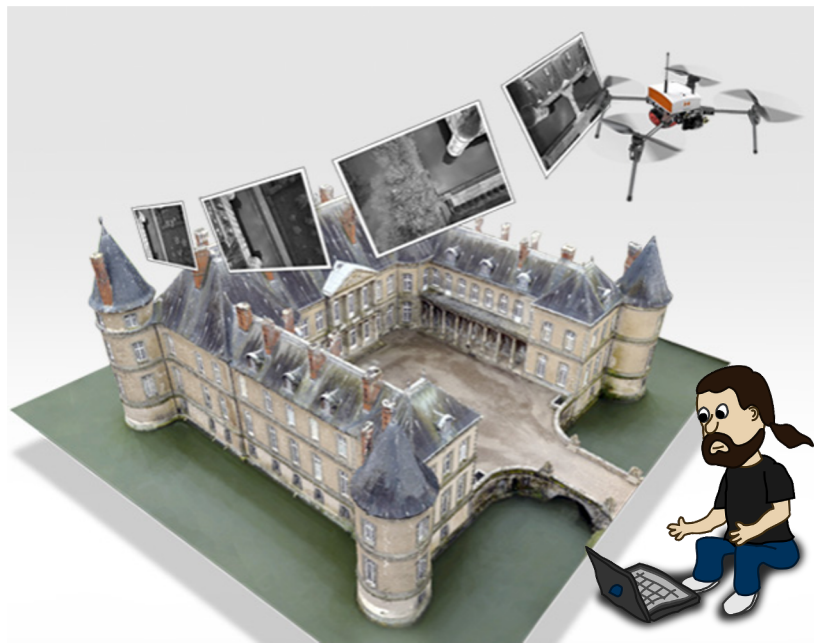
3D Point Cloud

Points:

- 3D position (x, y, and z)
- Intensity
- Color (RGB)



Photogrammetry



* ICRA 2015, CVPR 2016, ICRA 2017, ISPRS 2017

Introduction

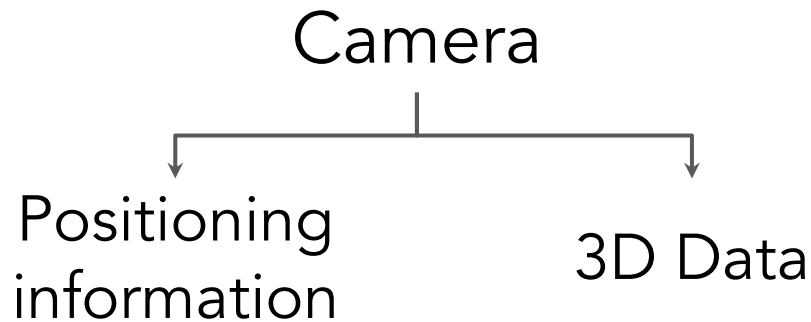
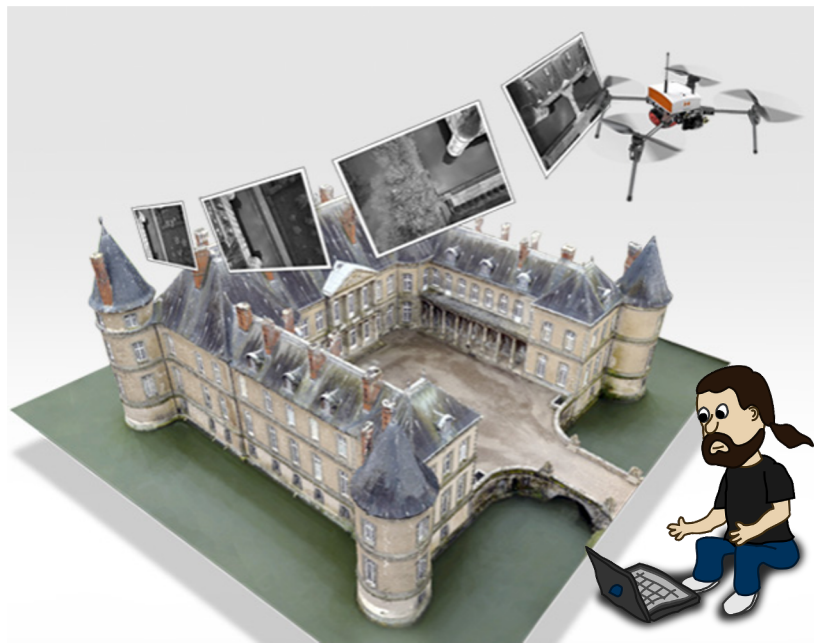
Problem Statement

Approach

Evaluation

Wrap-up

Photogrammetry: Shortcomings



Slow & offline

Human-in-the-loop

Inaccurate reconstruction

* ICRA 2015, CVPR 2016, ICRA 2017, ISPRS 2017

Introduction

Problem Statement

Approach

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Wrap-up

Our Goal

Automated, Fast, and Accurate 3D Reconstruction

Introduction

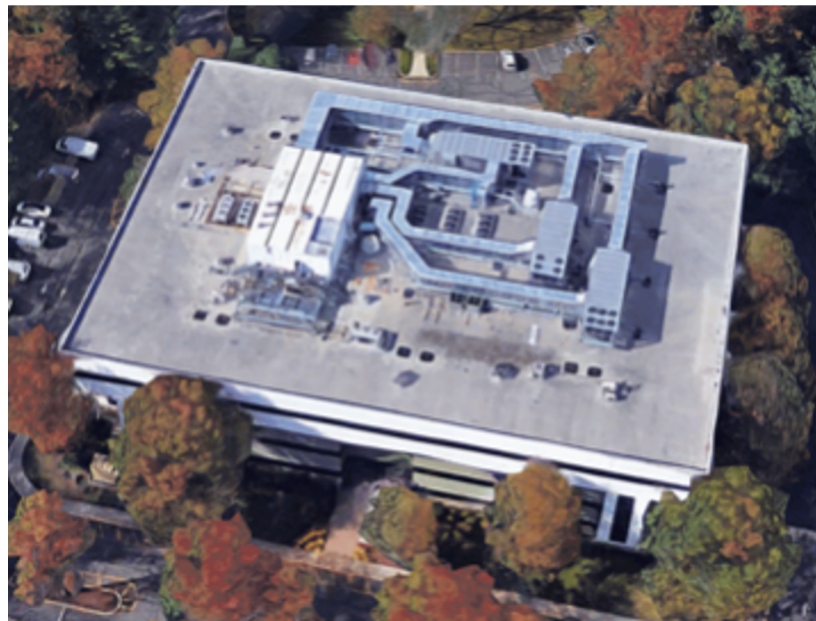
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Fast 3D Reconstruction



Building to reconstruct

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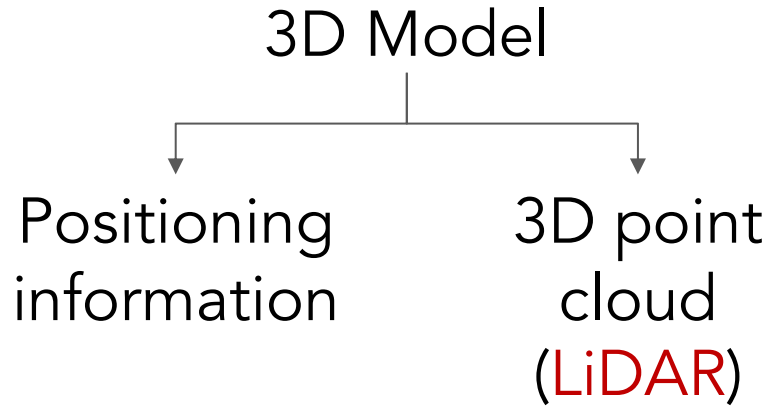
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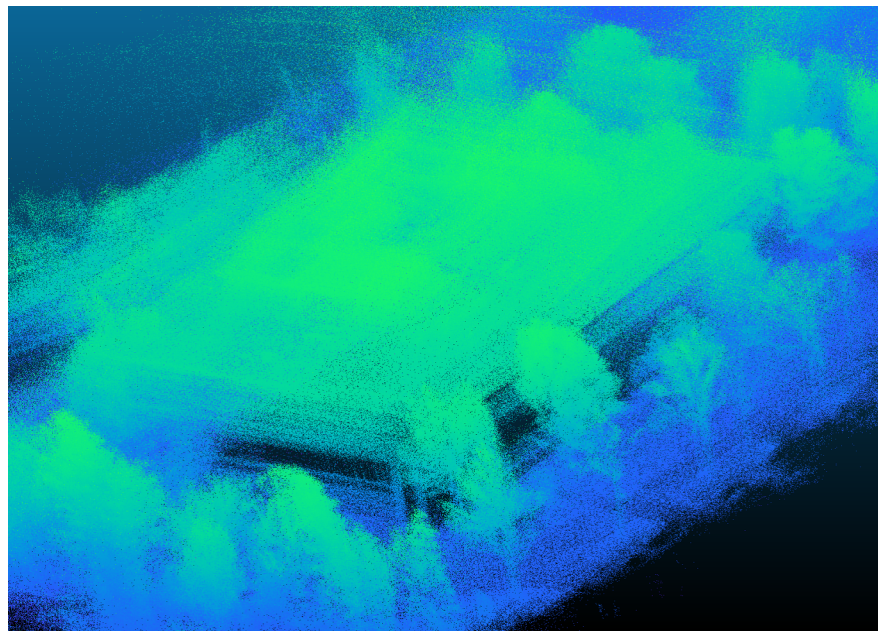
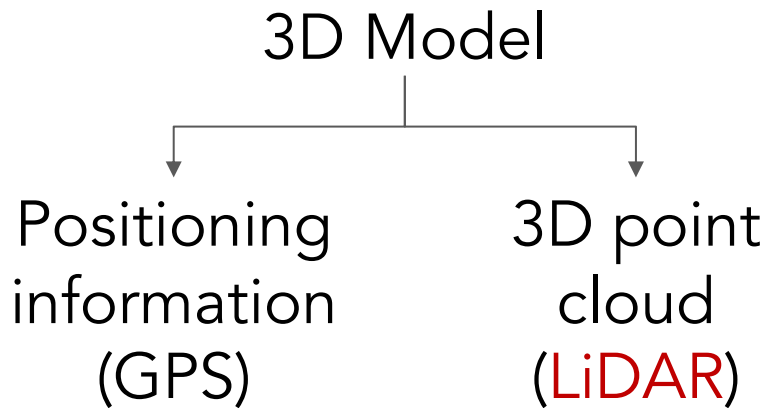
Wrap-up

Fast 3D Reconstruction



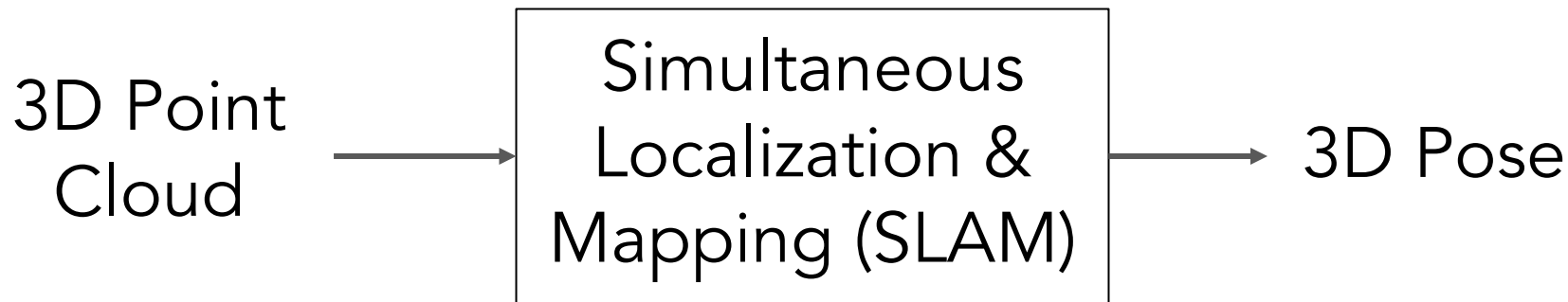
Building to reconstruct

Fast, and *Accurate* 3D Reconstruction

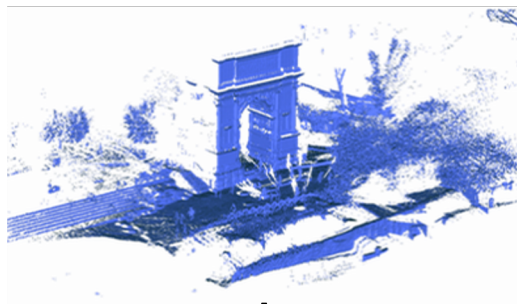


Fuzzed 3D Model with GPS

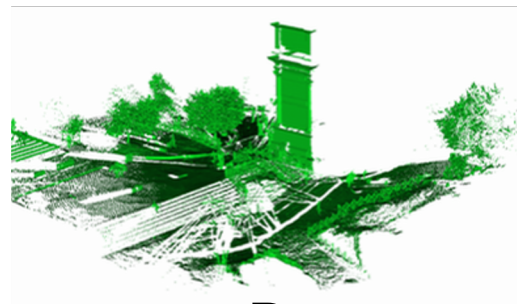
SLAM for Positioning



SLAM for Positioning



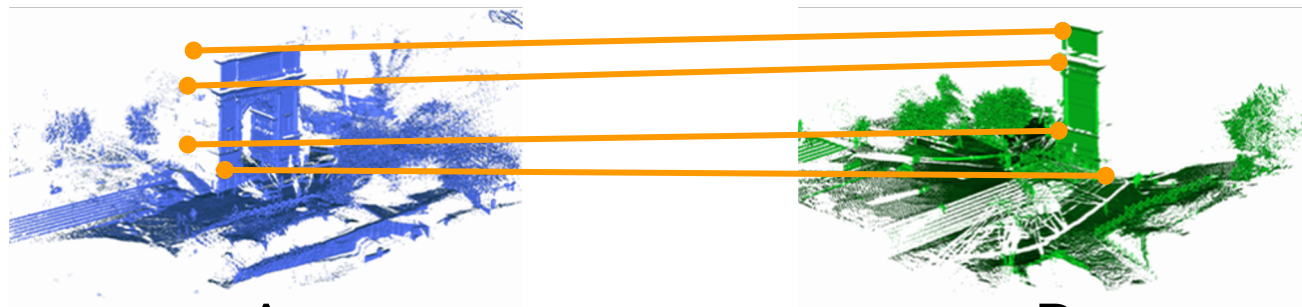
A



B

Aligning 3D point clouds

SLAM for Positioning



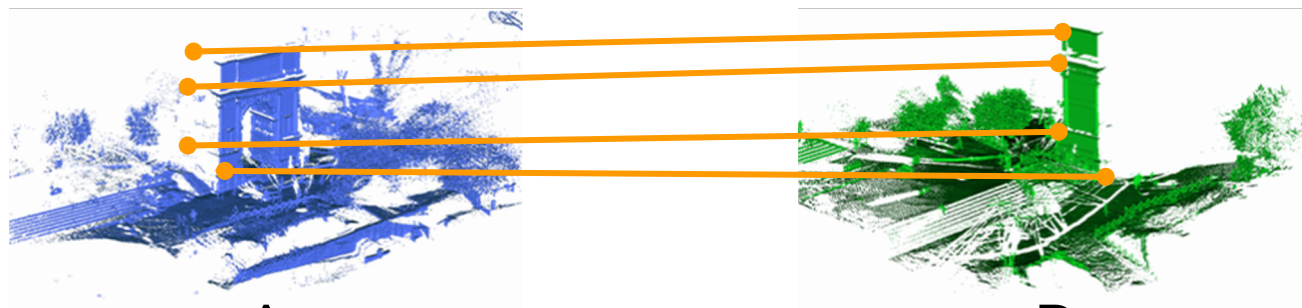
$T_1 = \text{Align}(A, B)$

A

B

Aligning 3D point clouds

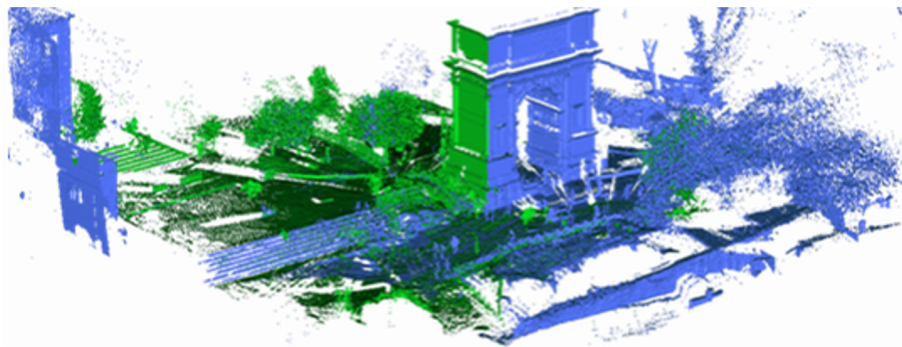
SLAM for Positioning



$T_1 = \text{Align}(A, B)$

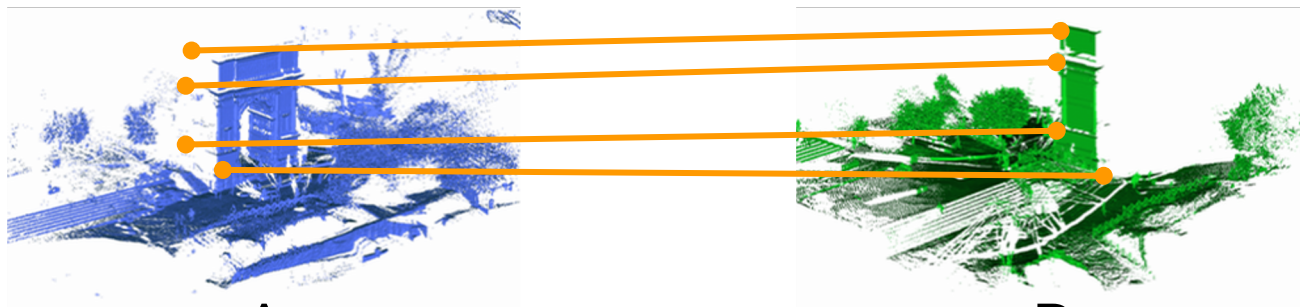
A

B



$$Z = A + T_1 * B$$

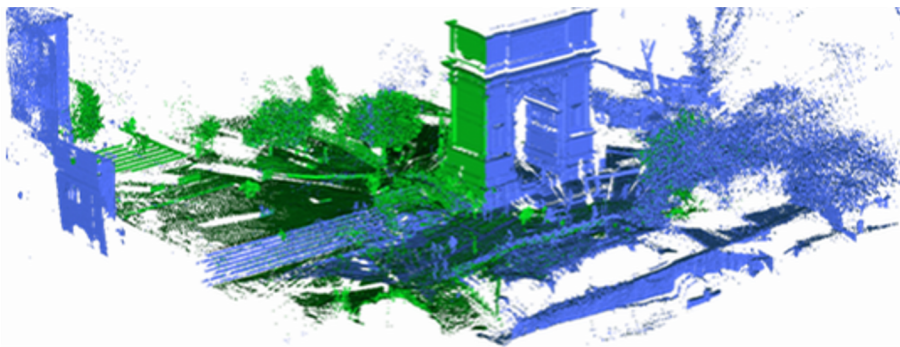
SLAM for Positioning



$T_1 = \text{Align}(A, B)$

A

B



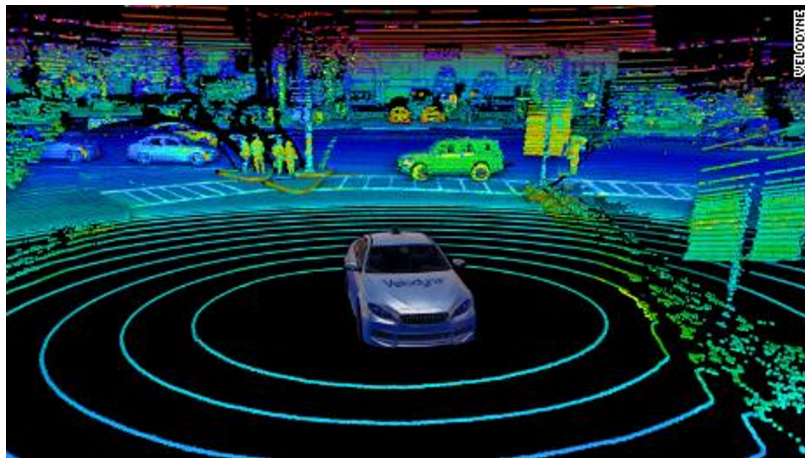
$$Z = A + T_1 * B + T_2 * C + T_3 * D$$

Challenges

Challenge	Mechanism
Limited compute	
Limited battery	
SLAM positioning	

SLAM Positioning: A Drone's Perspective

Vehicle LiDAR SLAM



Whole point cloud

SLAM Positioning: A Drone's Perspective

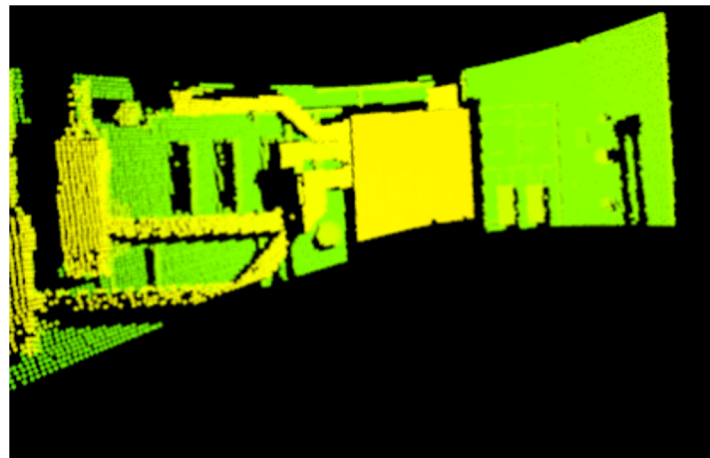
Challenging to align sparse point clouds

Vehicle LiDAR SLAM



Whole point cloud

Drone LiDAR SLAM



9% of the point cloud

AeroTraj: Fast, and Accurate 3D Reconstruction

Input	Area of Interest Reconstruction LoD
Output	3D Model at LoD

*LoD (Level of Detail)

Contributions

Challenge	Mechanism
Limited compute	
Limited battery	
SLAM positioning	Trajectory optimization & In-flight feedback

Introduction

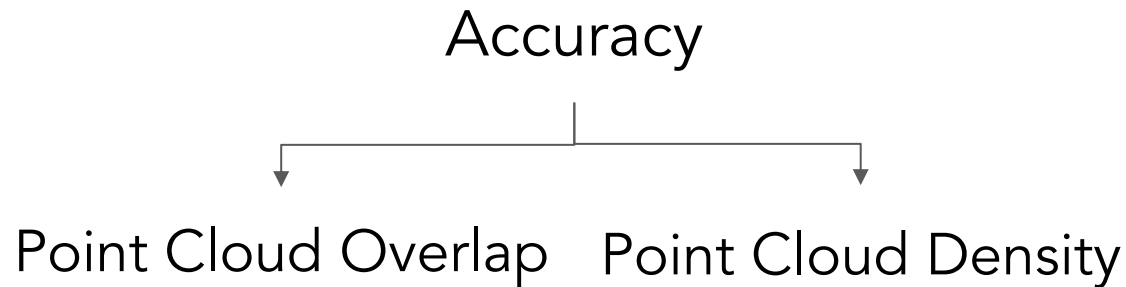
Problem Statement

Approach

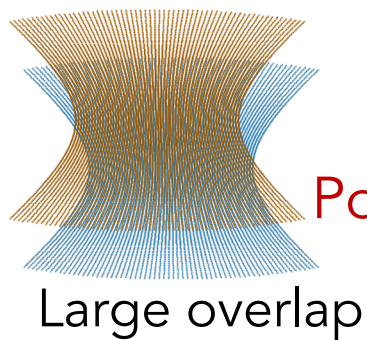
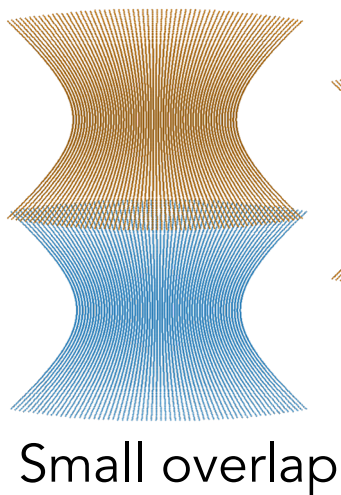
Evaluation

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SLAM Positioning: Accuracy



SLAM Positioning: Point Cloud Overlap



Point Cloud Overlap

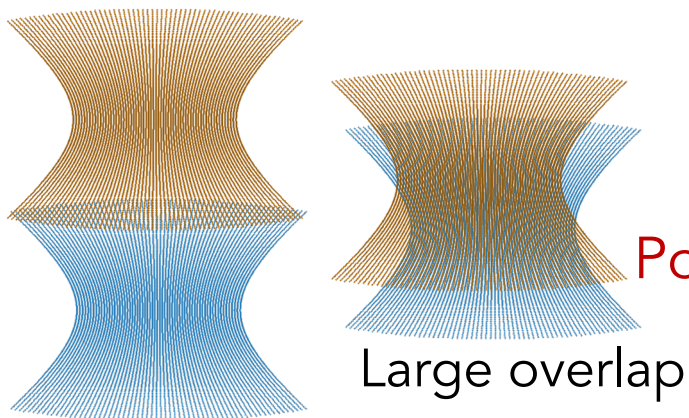
Accuracy



Point Cloud Density

Common area between
point clouds

SLAM Positioning: Point Cloud Overlap



Small overlap

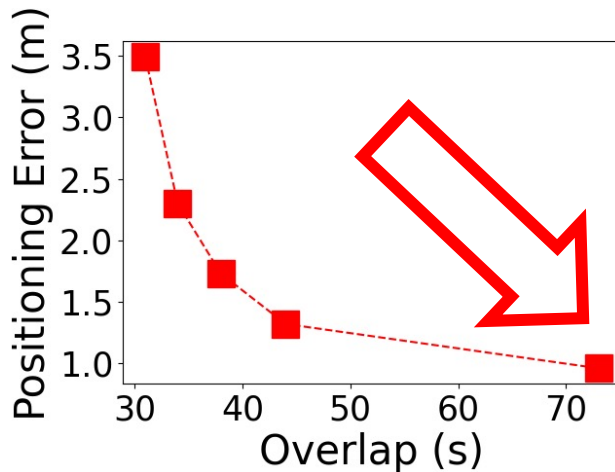
Large overlap

Common area between point clouds

Point Cloud Overlap

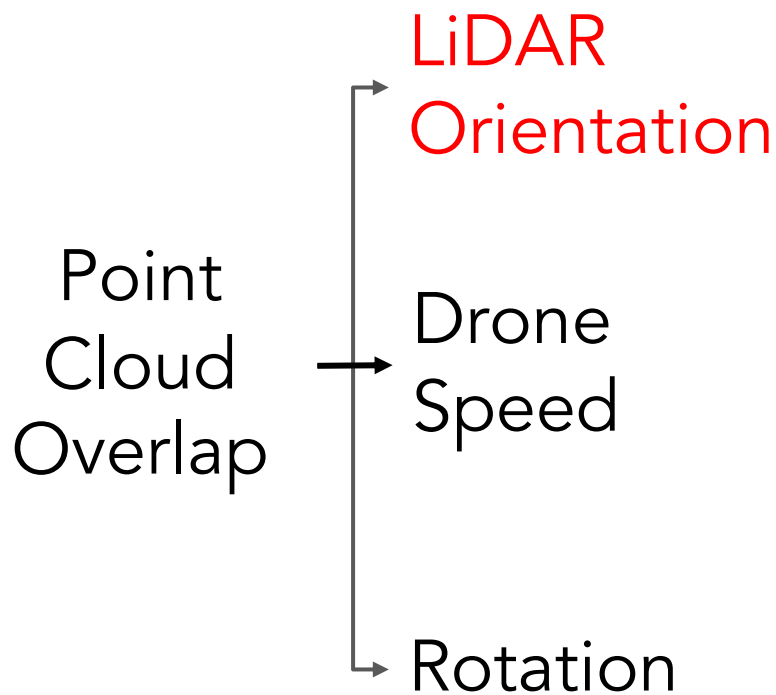
Point Cloud Density

Accuracy

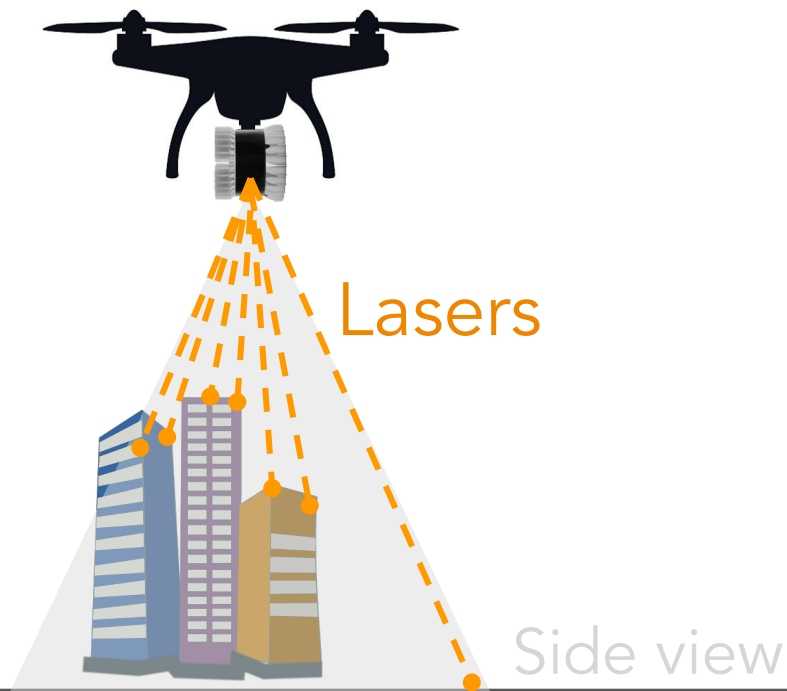


Higher overlap is better!

Controlling Point Cloud Overlap: LiDAR Orientation



Controlling Point Cloud Overlap: LiDAR Orientation



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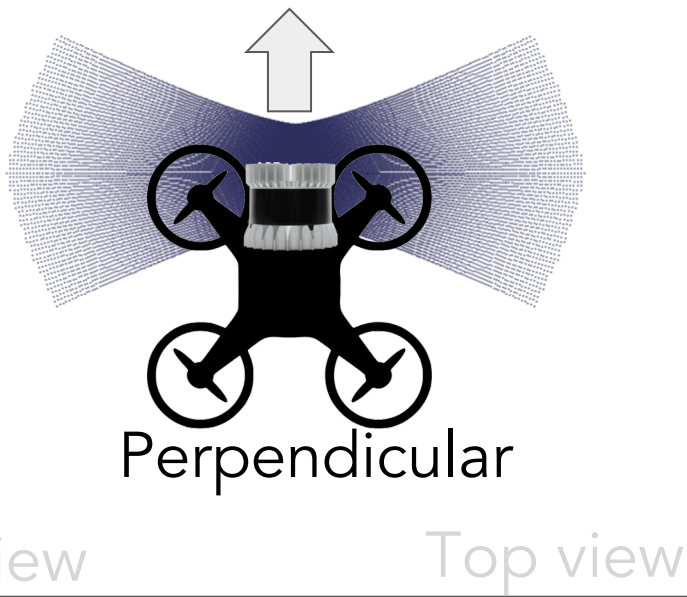
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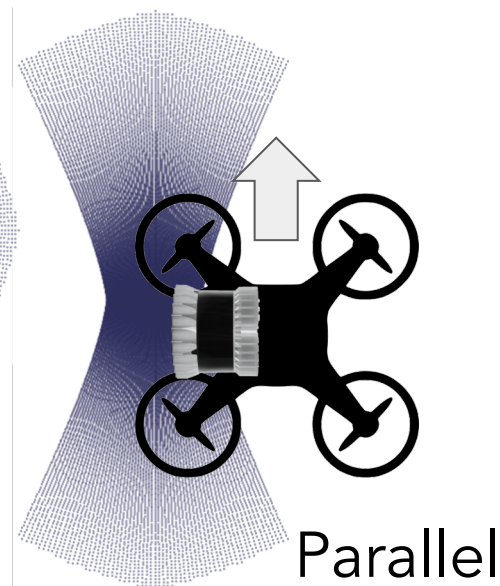
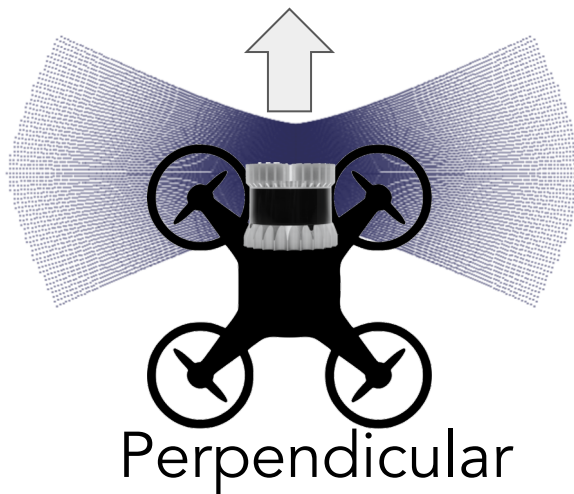
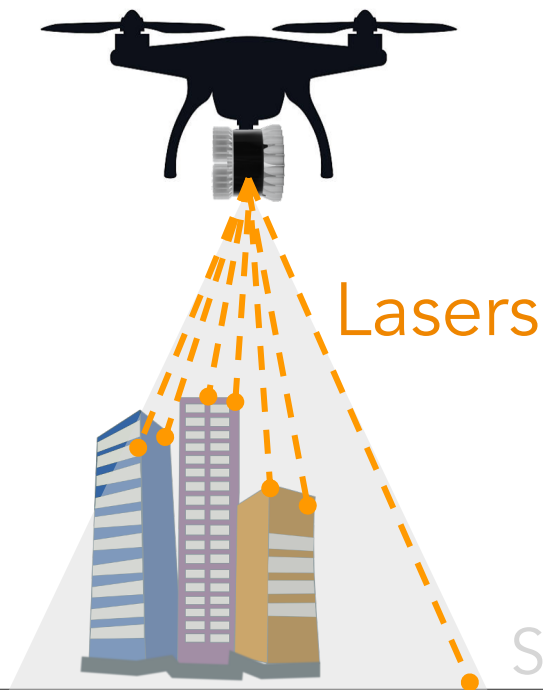
Controlling Point Cloud Overlap: LiDAR Orientation

Direction of motion

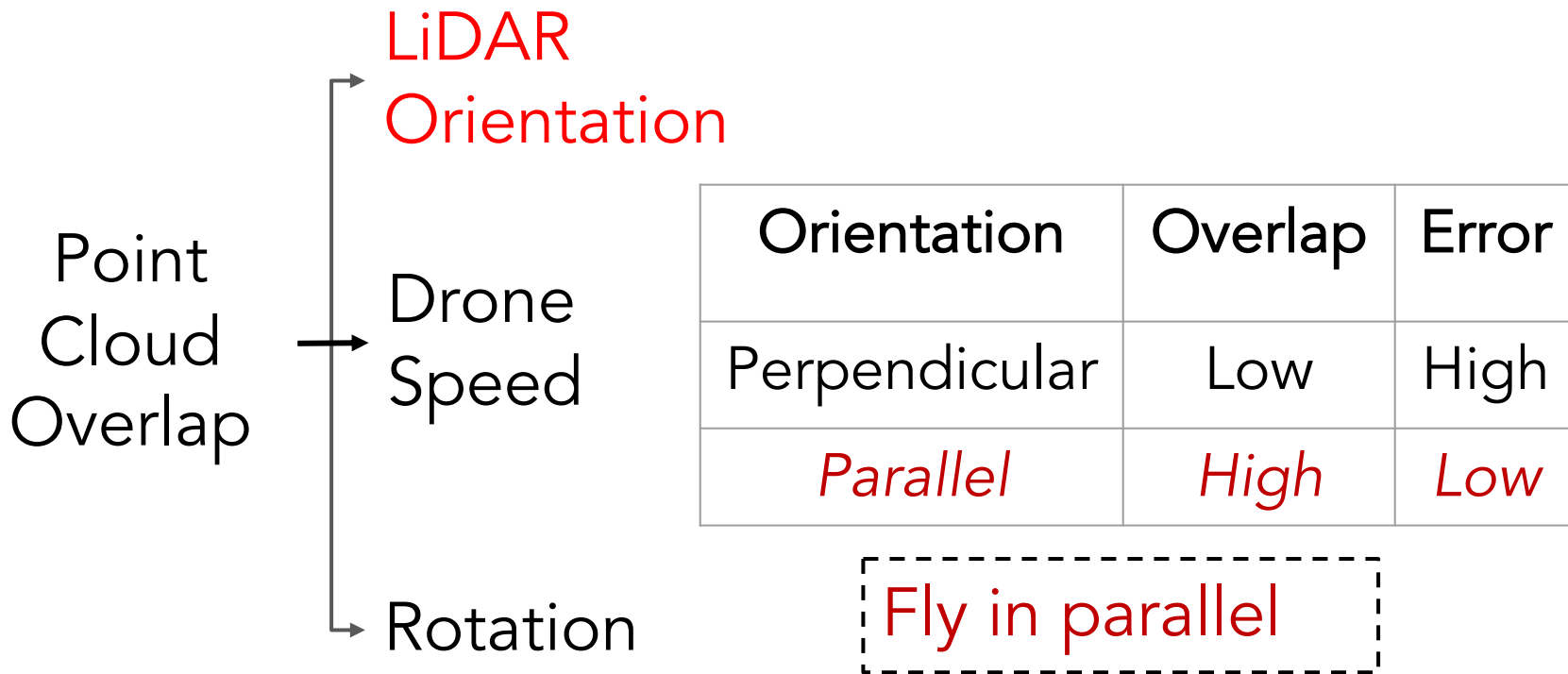


Controlling Point Cloud Overlap: LiDAR Orientation

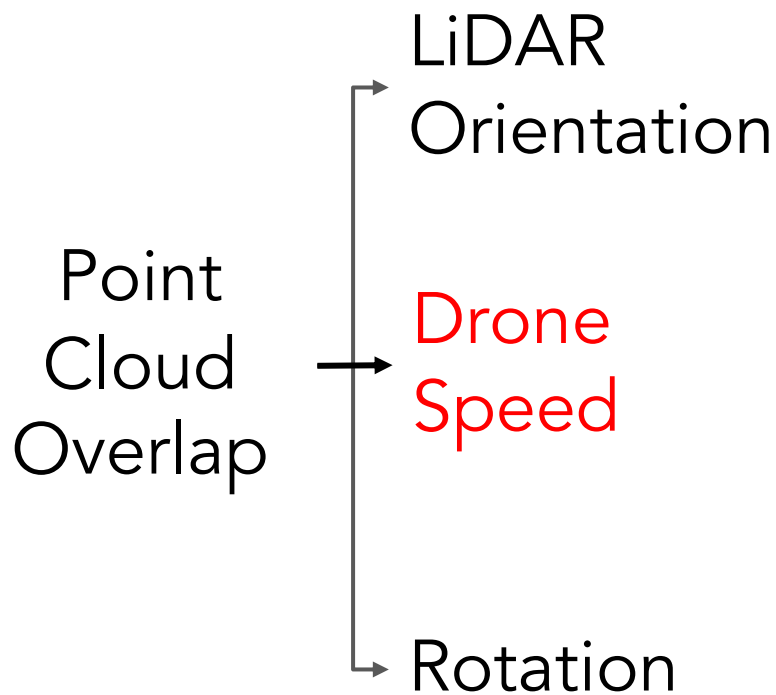
Direction of motion



Controlling Point Cloud Overlap: LiDAR Orientation



Controlling Point Cloud Overlap: Drone Speed



Introduction

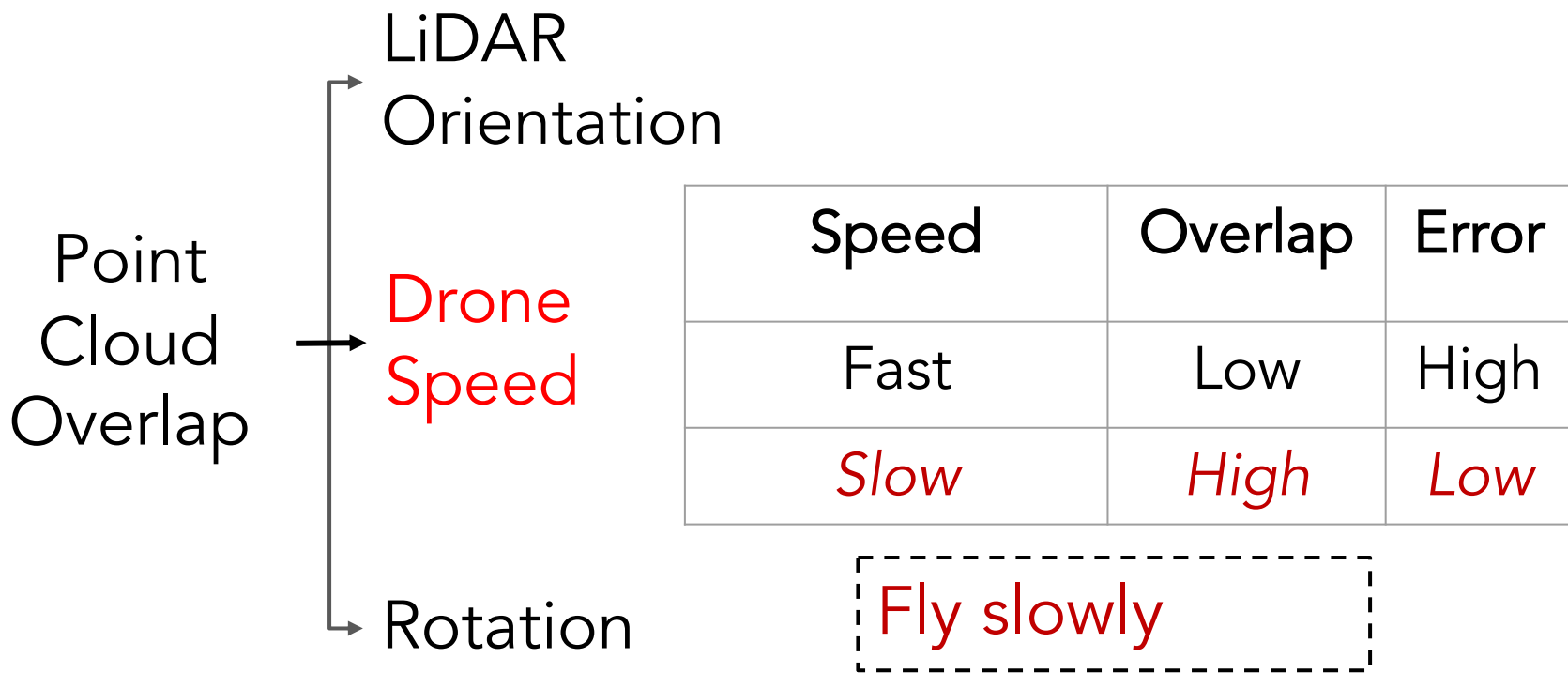
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Approach

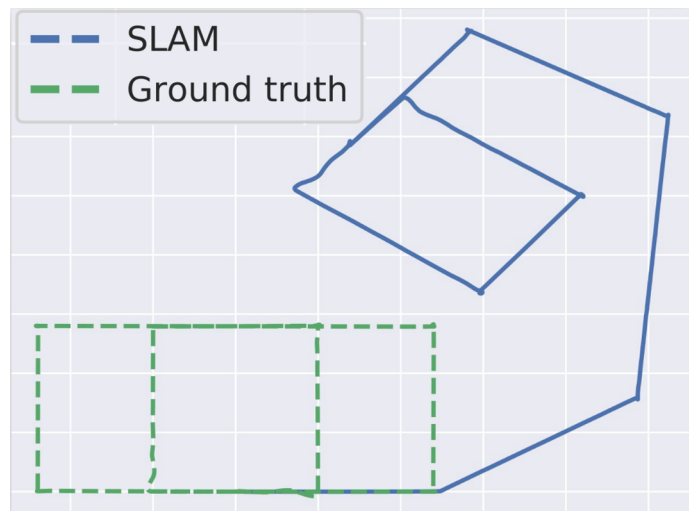
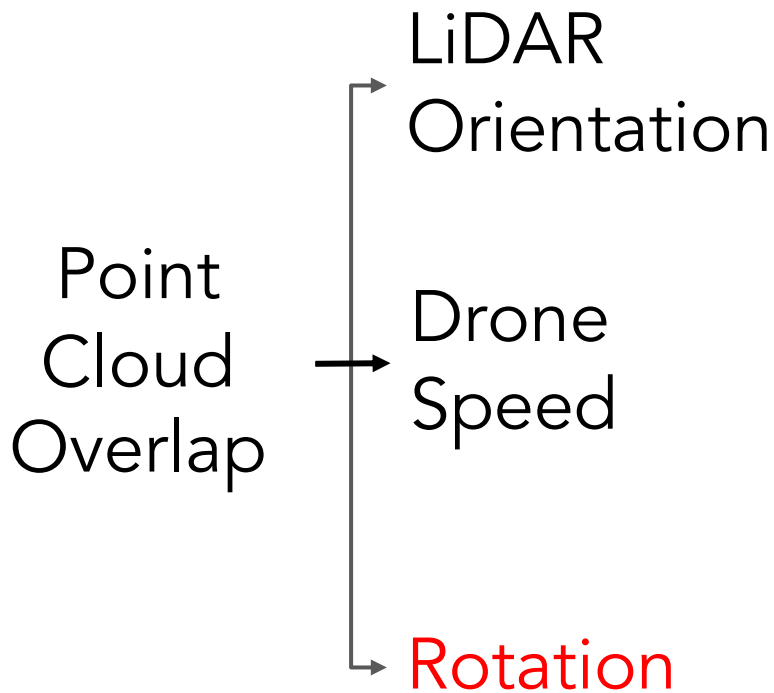
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Controlling Point Cloud Overlap: Drone Speed



Controlling Point Cloud Overlap: Rotation

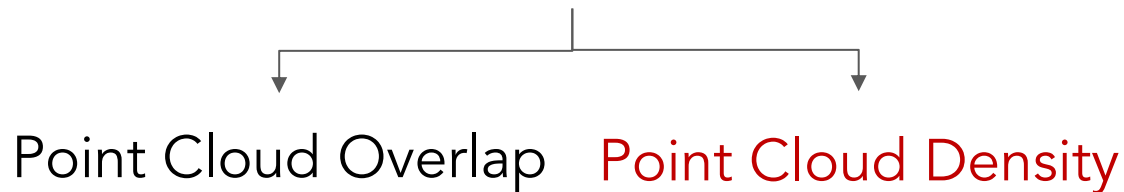


Avoid rotations

The text 'Avoid rotations' is written in red and enclosed in a dashed black rectangular box.

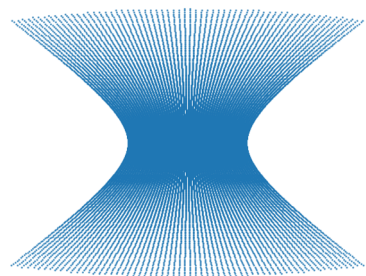
SLAM Positioning: Point Cloud Density

Accuracy

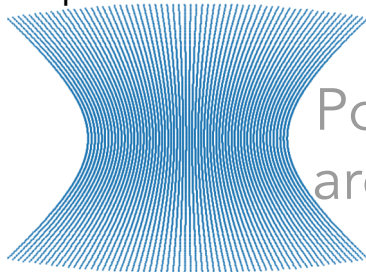


Points per unit
area (pts/m²)

SLAM Positioning: Point Cloud Density



High density
point cloud



Low density
point cloud

Points per unit
area (pts/m²)

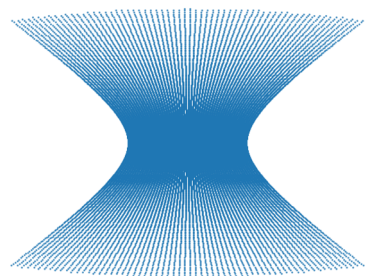
Accuracy



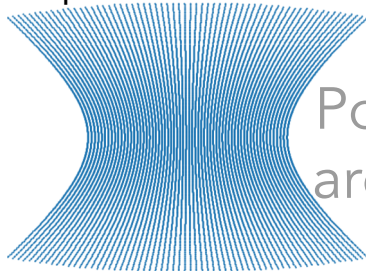
Point Cloud Overlap

Point Cloud Density

SLAM Positioning: Point Cloud Density



High density
point cloud

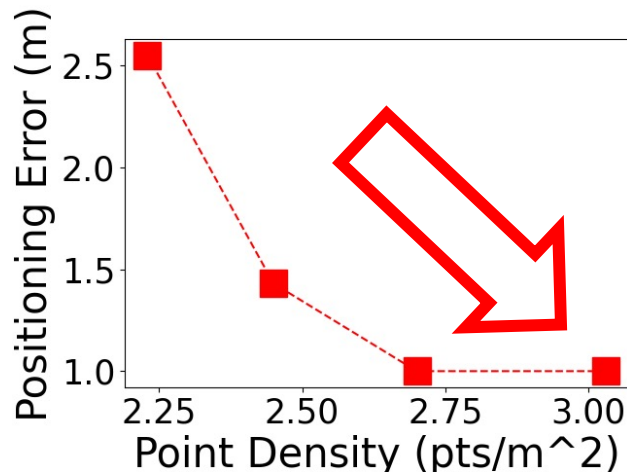


Low density
point cloud

Points per unit
area (pts/m^2)

Accuracy

Point Cloud Overlap Point Cloud Density



Higher density
is better!

Controlling Point Cloud Density: Distance

Accuracy



Point Cloud Overlap

Point Cloud Density

Height	Density	Error
Far	Low	High
<i>Close</i>	<i>High</i>	<i>Low</i>

Fly close to surface

Optimized Trajectory Generation

Goal: Minimize trajectory length

Accuracy constraints

LoD constraints

Building geometry

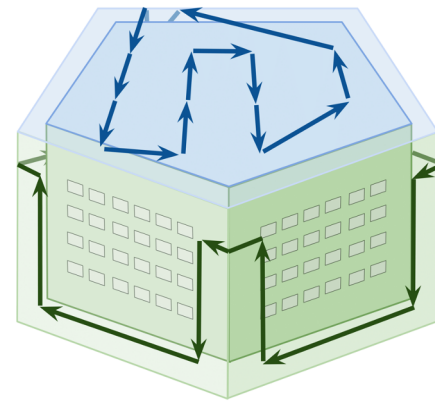
Optimized Trajectory Generation

Goal: Minimize trajectory length

Accuracy constraints

LoD constraints

Building geometry



Contributions

Challenge	Mechanism
Limited compute	
Limited battery	
Model accuracy	Trajectory generation & In-flight feedback

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Drift Detection and Re-calibration

Detection: Trajectory comparison with GPS

Mitigation: Loop closure

AeroTraj: Evaluation

3D Model Reconstruction

Performance Evaluation

Ablation Study

Data Collection

Boundary Estimation

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AeroTraj 3D Reconstruction Accuracy

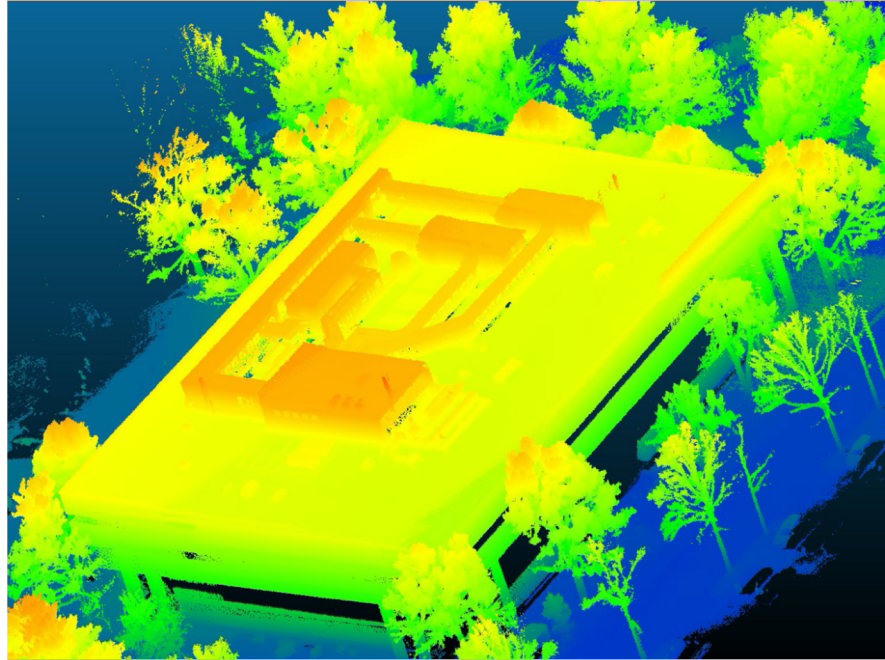
Scheme	Accuracy (m)	Completeness (m)	Reconstruction Time (s)
Large building (100m x 50m x 20m)			
ColMap			
AeroTraj			

AeroTraj 3D Reconstruction Accuracy

Scheme	Accuracy (m)	Completeness (m)	Reconstruction Time (s)
Large building (100m x 50m x 20m)			
ColMap	0.16	0.75	31600
AeroTraj	0.09	0.05	<i>in-flight</i>

AeroTraj can do fast and high-quality 3D reconstructions

AeroTraj: Fast, Accurate, and Automated 3D Reconstruction



3D model of large building complex built using AeroTraj