Technische Universität Braunschweig

Institute of Flight Guidance

An Automated Rapid Mapping Solution Based on ORB SLAM 2 and Agisoft Photoscan API

Institute of Flight Guidance, TU Braunschweig, Germany

Motivation

Natural disasters substantially change the enviroment.

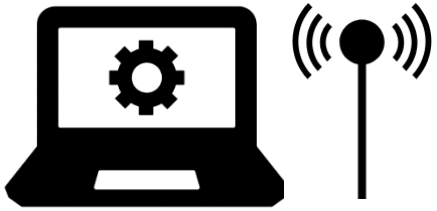
Rescue forces need up-to-date map data immediatelly.

Goal

Prototype mapping drone for disaster responce forces

- Accurate aerial mapping
- Results as fast as possible
- Little training required

Approach

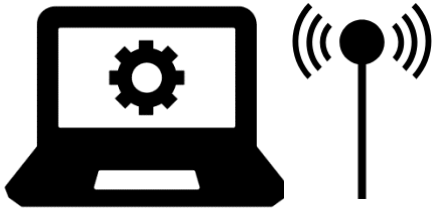


1. Automatic Mission Planning

5. Automated Mapping

2. Flying planned mission
3. Acquire images
4. Send images

Approach



1. Automatic Mission Planning

5. Live Mapping (ORB SLAM 2)
6. Photogrammetry (Agisoft)

2. Flying planned mission
3. Acquire images
4. Send images

Contents

Contents

Hardware Setup - Copter

AirRobot AR200

220cm wingtip distance
3kg payload
12kg take-off weight
25min flight time

Payload

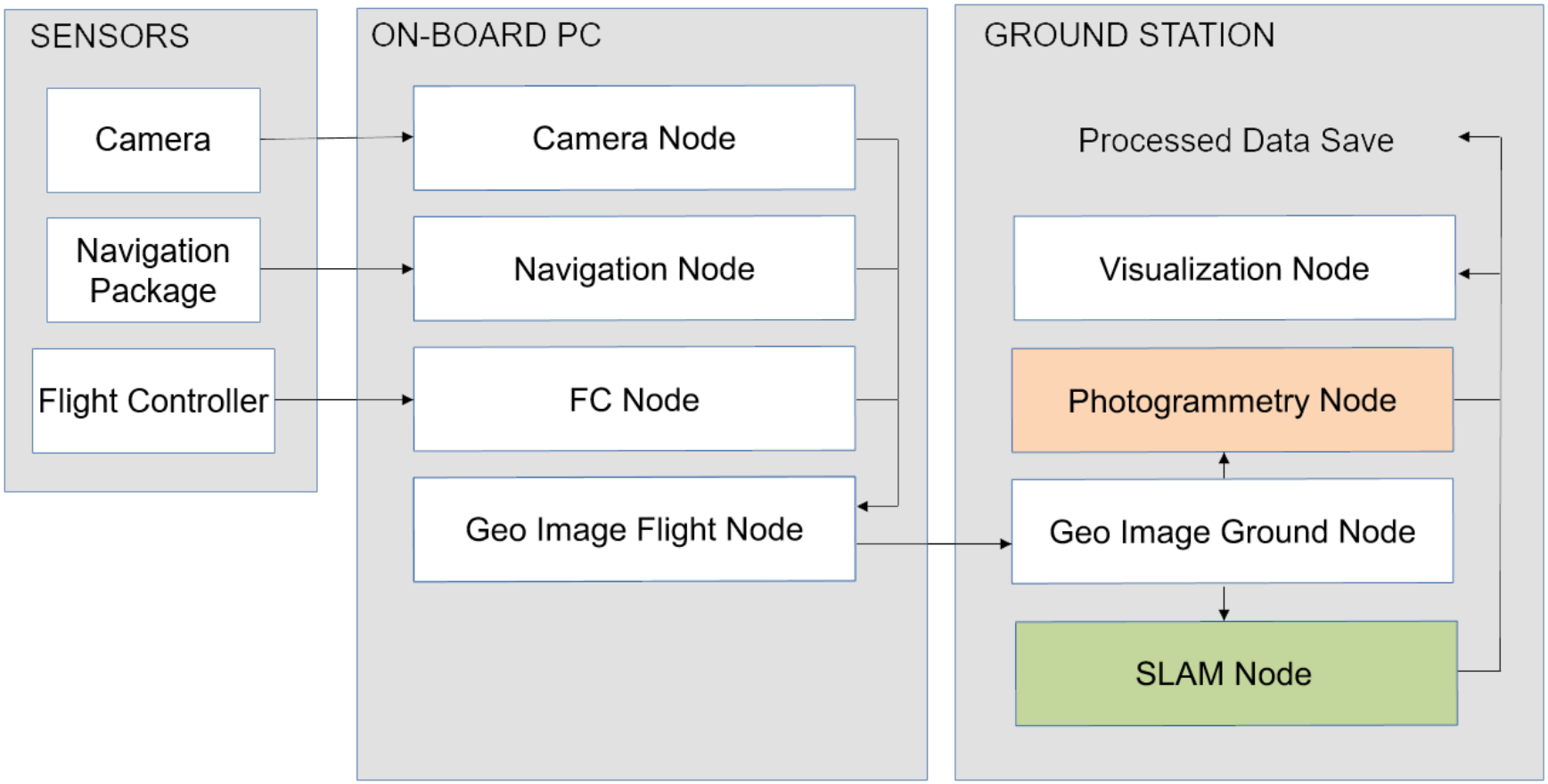
Gateworks GW5520 wifi board
Cortex A9 navigation PC
ADIS16488A IMU + uBlox M8T GPS

Hardware Setup – Payload & Ground Station

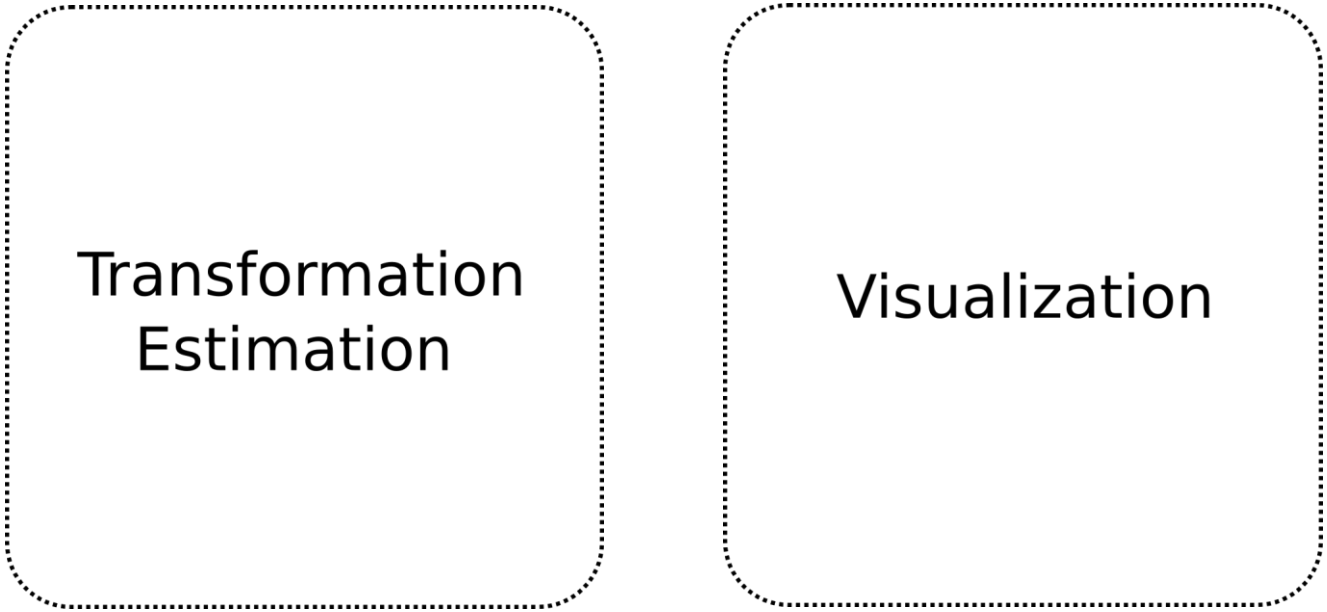
VIS Gimbal
AV Manta 917c 1“ GigE Camera
Cinegon 1.9/10mm lens
Intel NUC i5 PC
ADIS 16488A IMU

Ground Station
Intel i7 CPU
GeForce GTX1080 GPU
Wifi + GPS

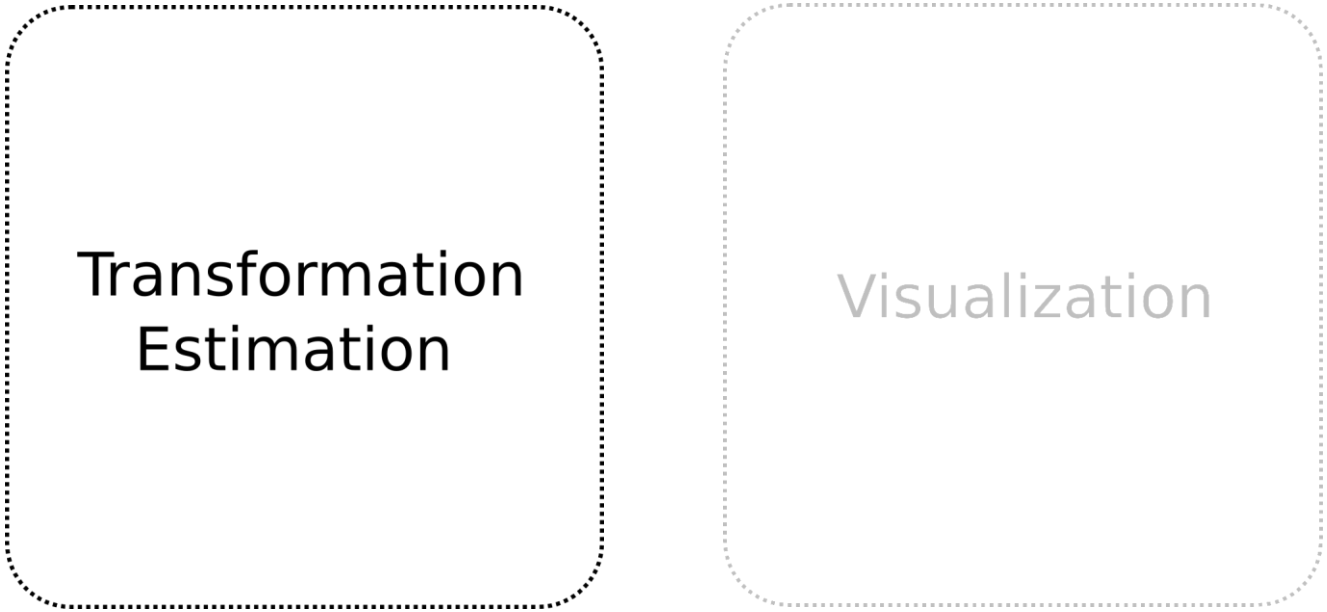
Software Setup – ROS Structure



SLAM - Software Architecture



SLAM - Software Architecture



SLAM - Software Architecture

Main challenges:

- Reconstruct 3D pose from images
- Minimize error propagation
- Meeting real-time requirement
- Robustness

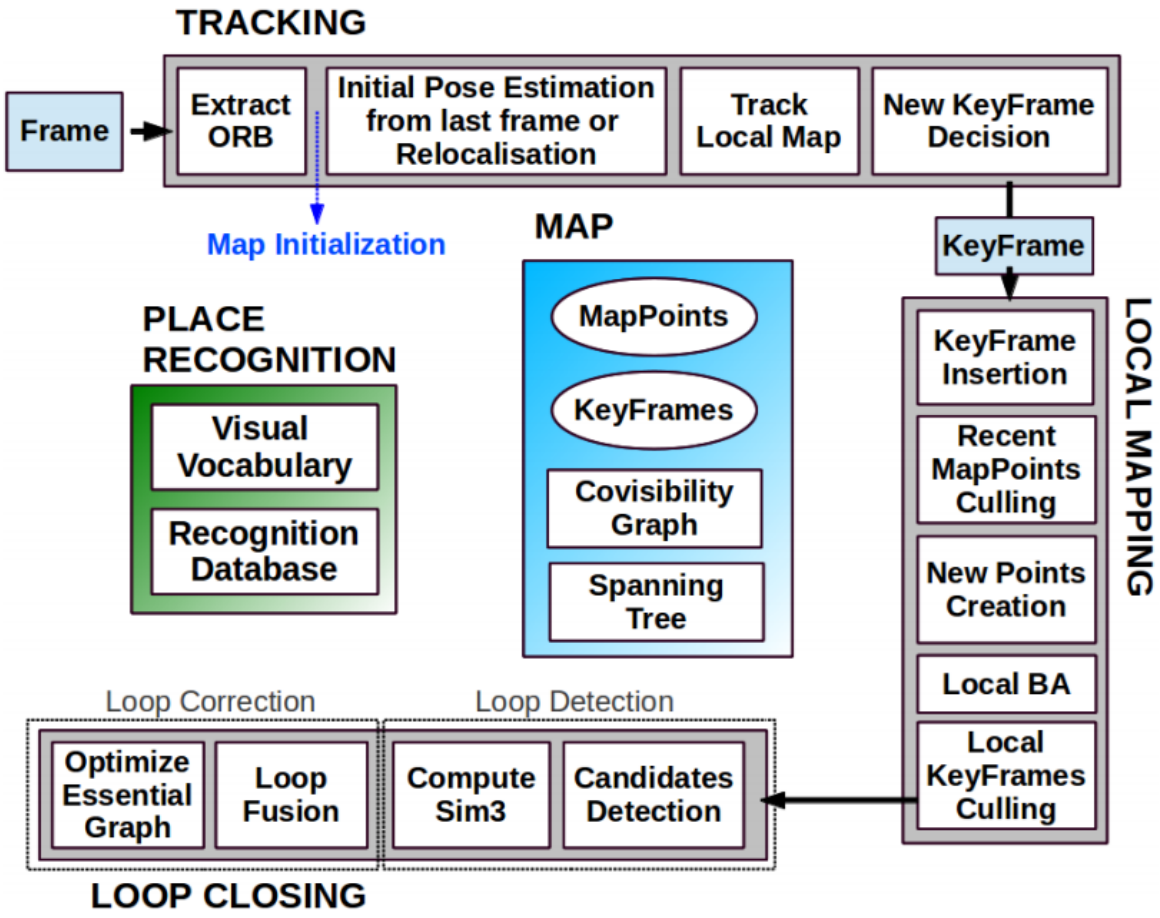
SLAM - Software Architecture

Main challenges:

- Reconstruct 3D pose from images
- Minimize error propagation
- Meeting real-time requirement
- Robustness

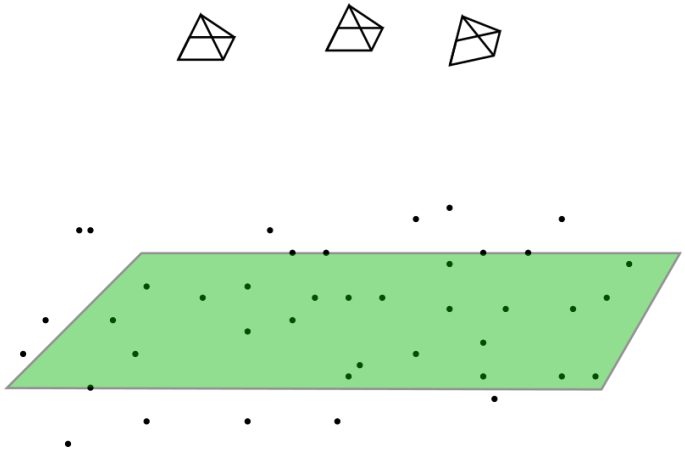
→ Visual SLAM frameworks

SLAM – ORB2 Process



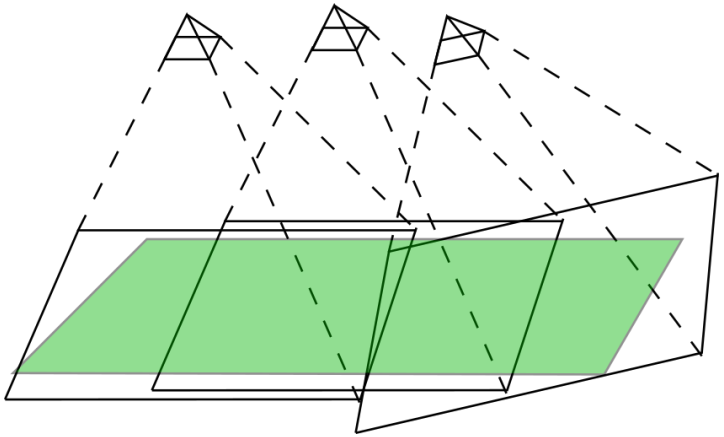
SLAM - Common Reference Plane

Best fit from sparse pointcloud



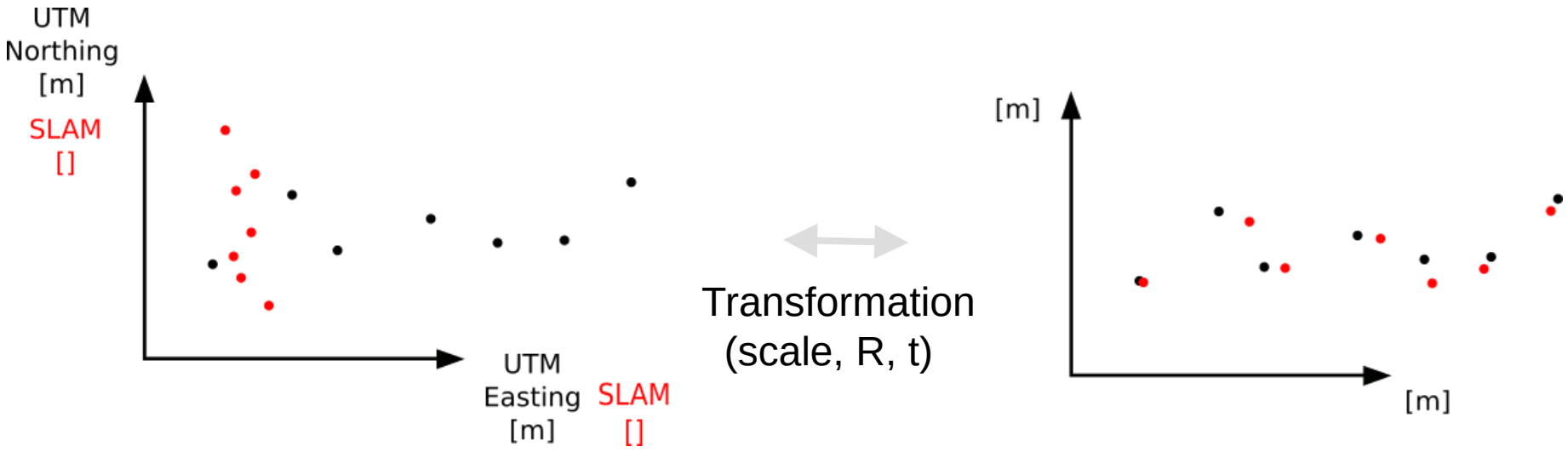
+ Also applicable without down facing camera
- More complicated calculation (outlier removal)
- Sensitive to depth variation of environment

Best fit from fixed depth projection



+ Robust to depth variation of environment
+ Straightforward calculations
- Needs camera face down

SLAM - Georeferencing Pose



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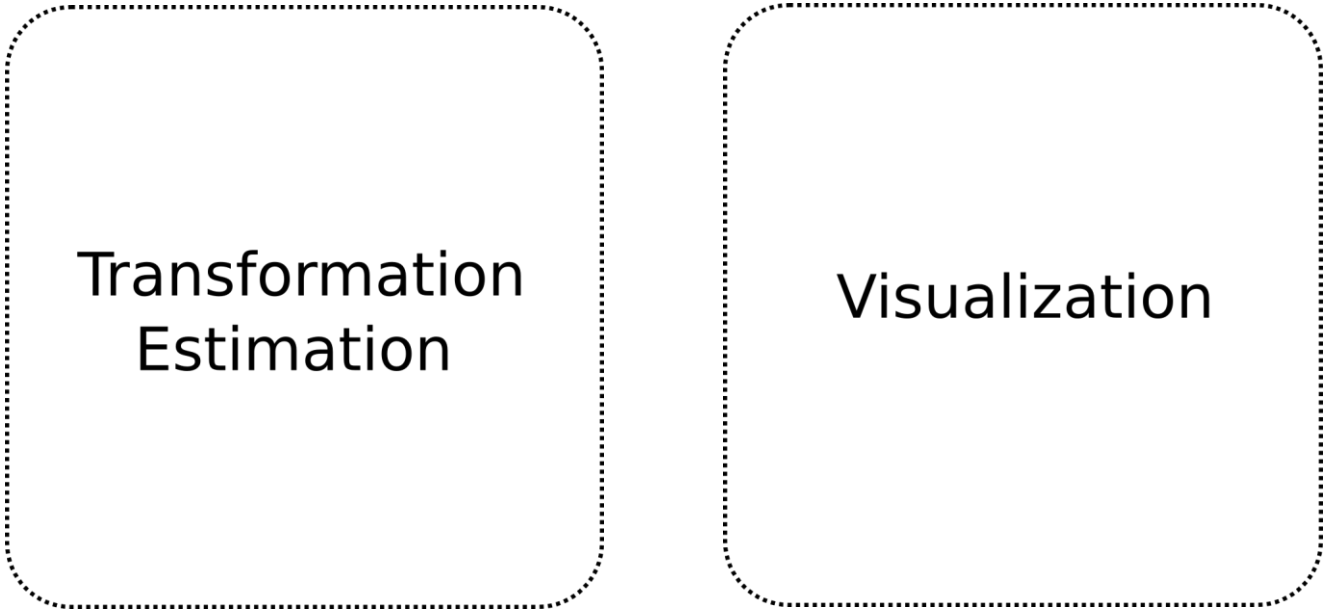

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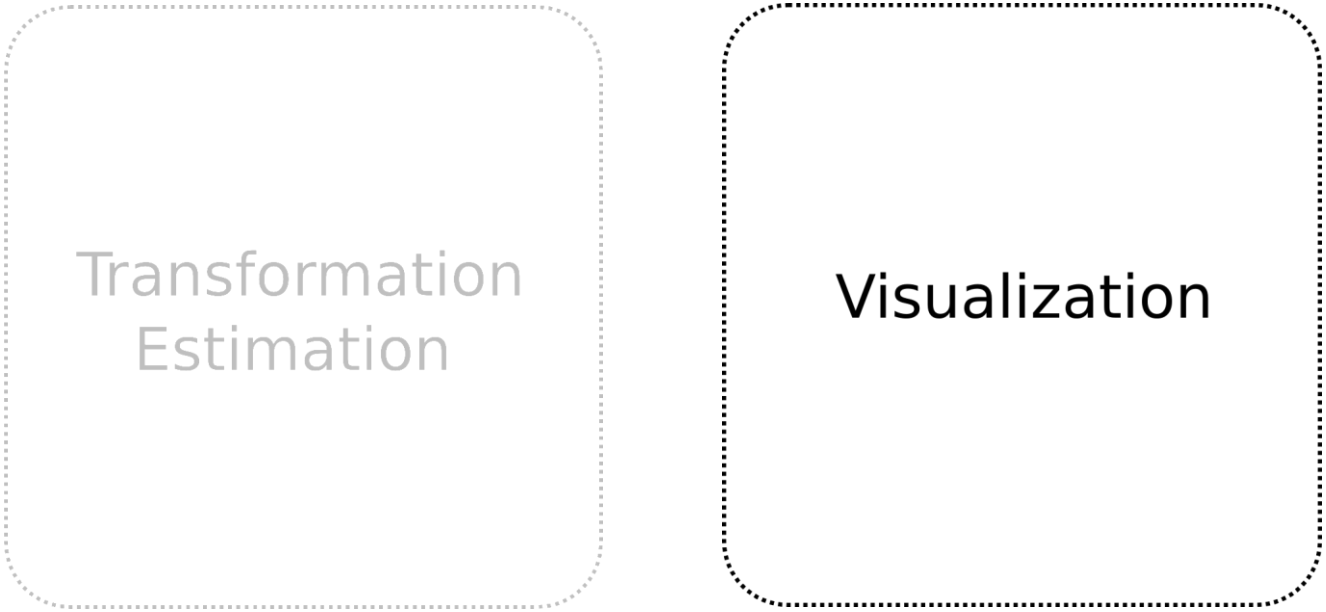
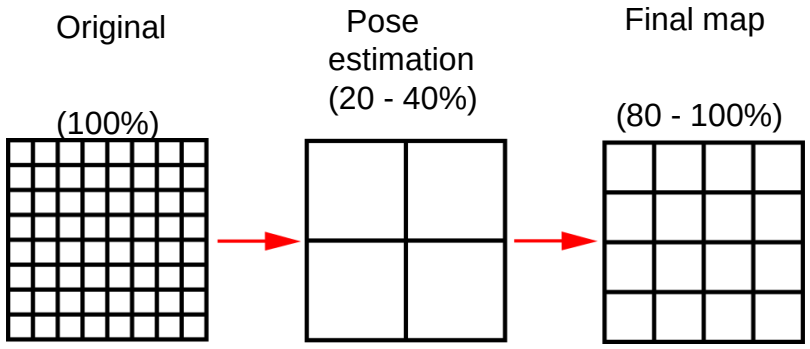


SLAM - Visualization strategies

① Vary image resolution



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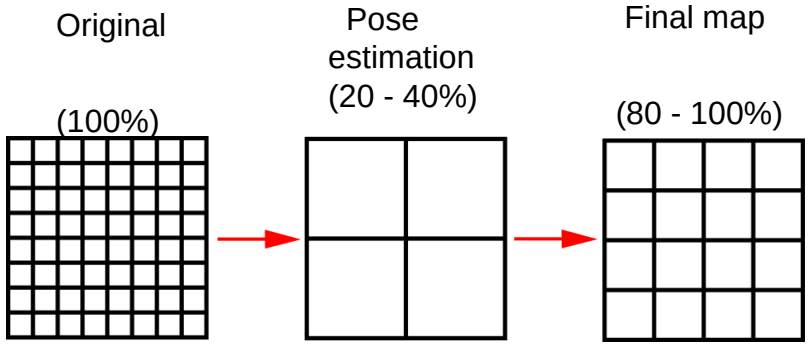
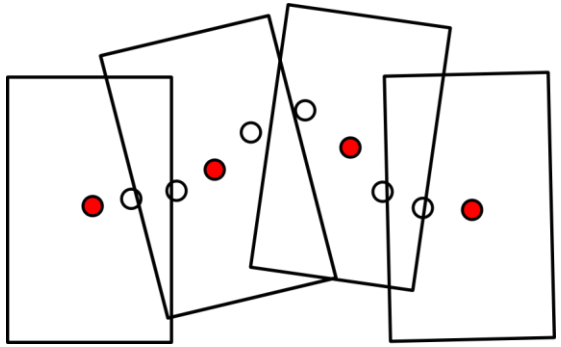


② Visualize keyframes only



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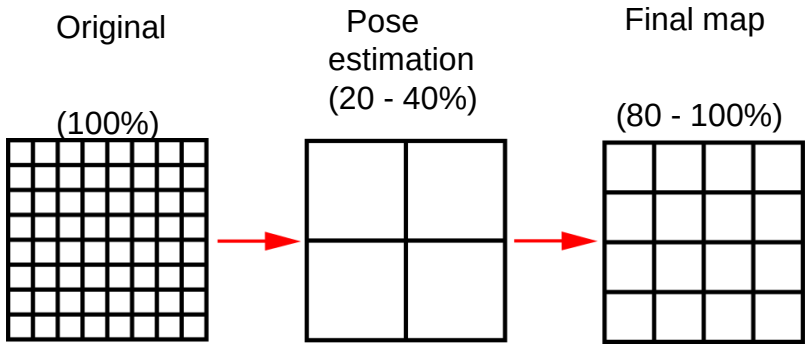

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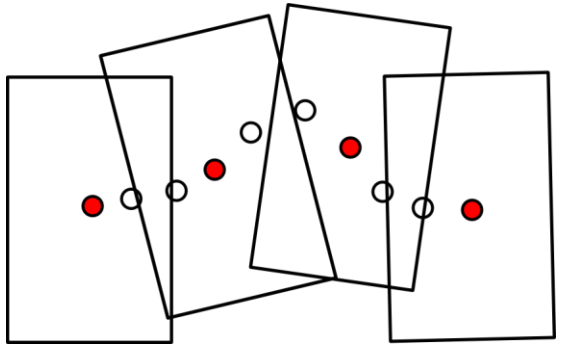
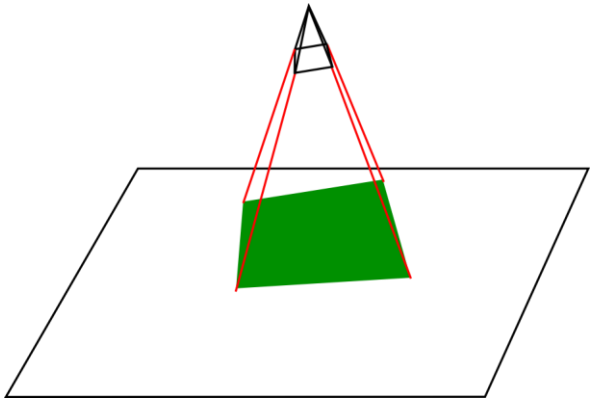
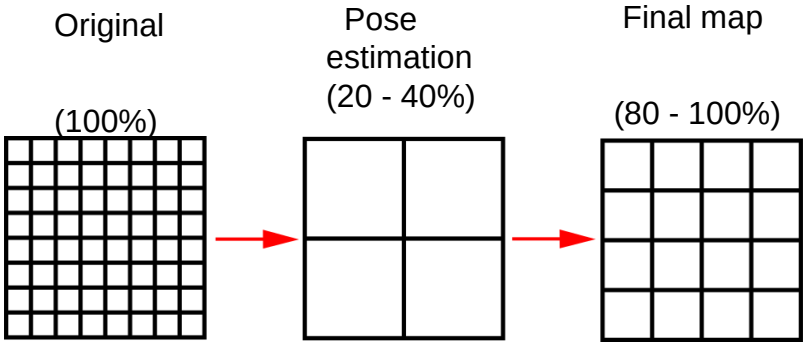


③ Visualize area of interest only



SLAM - Visualization strategies

① Vary image resolution



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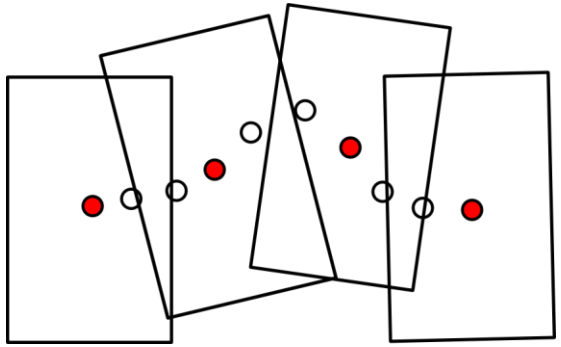

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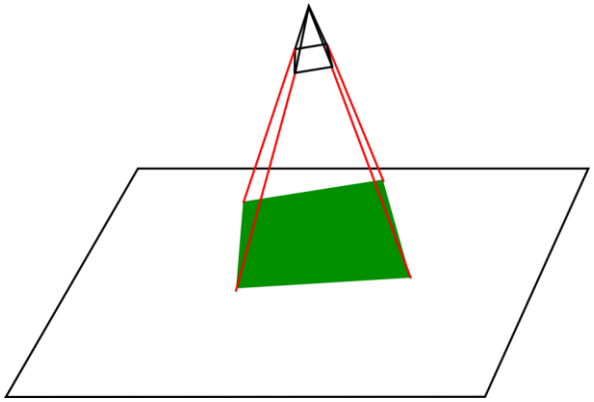
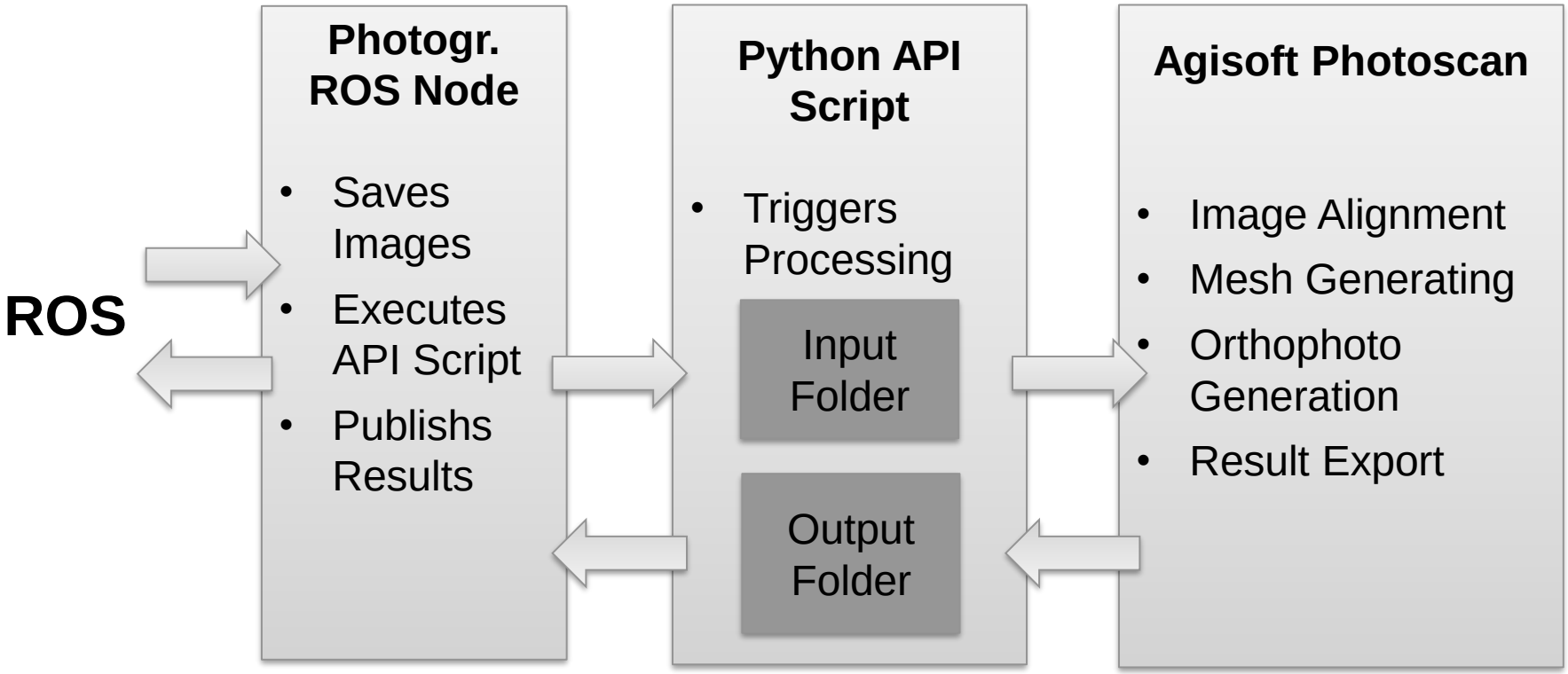


④ Optional:

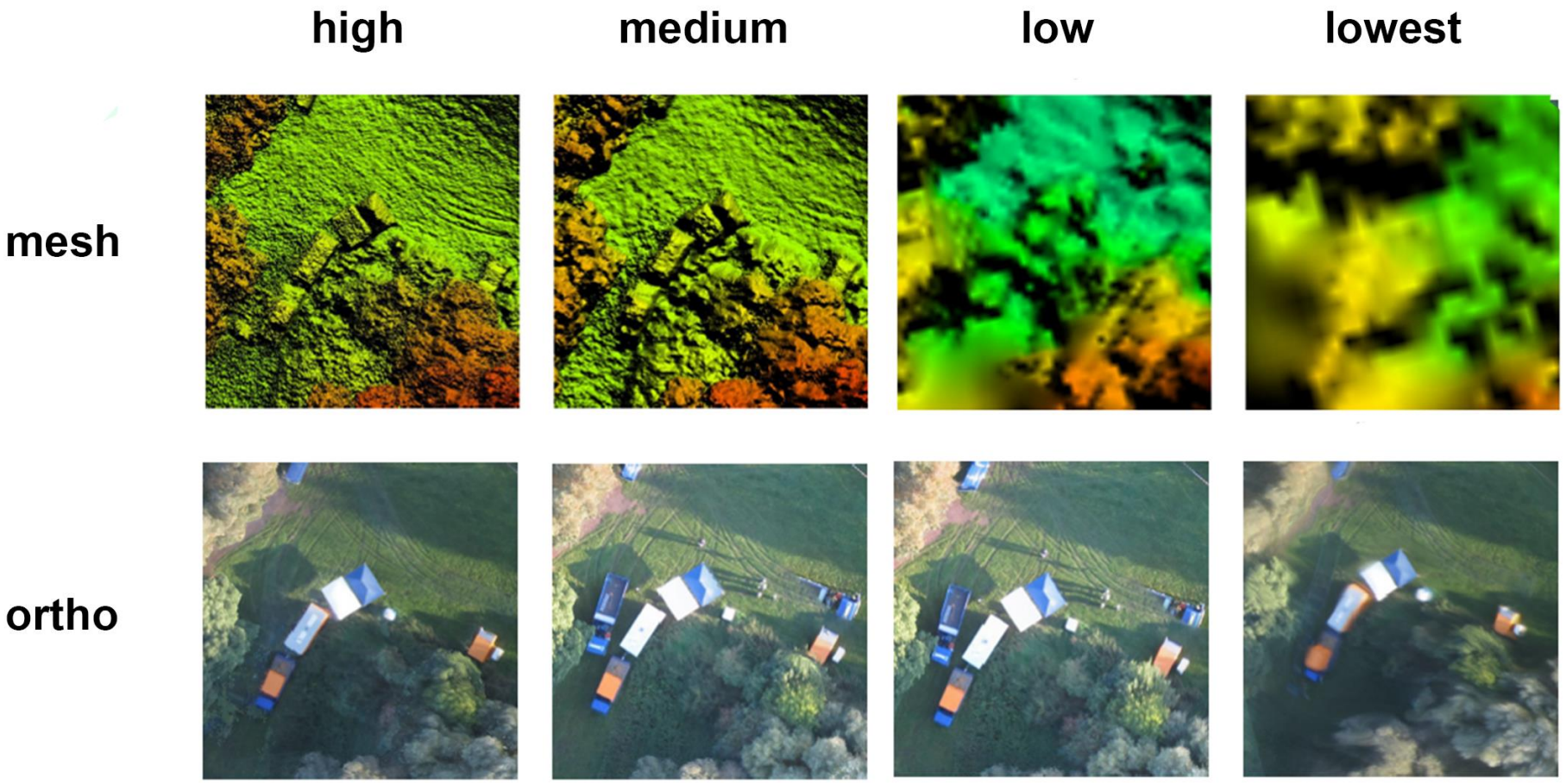
Pose estimation onboard

Visualization offboard

Photogrammetry



Photogrammetry profiles



Evaluation

Mapping Flight

100m alt

75% Sidelap

3min

SLAM

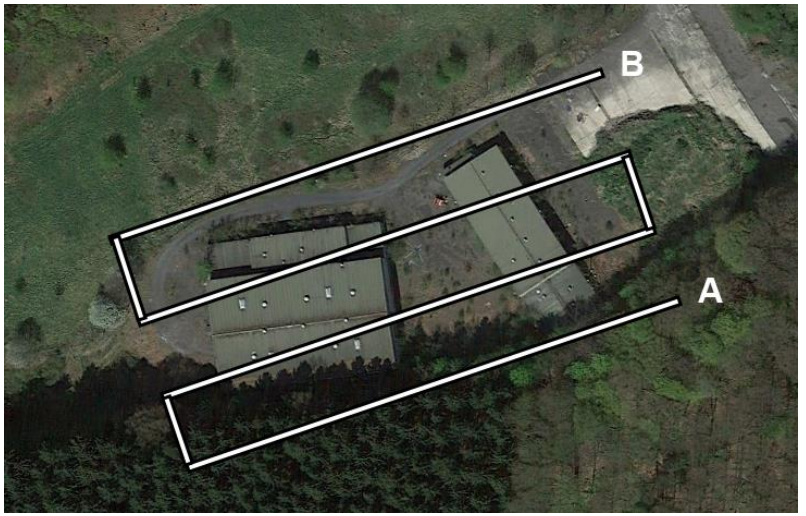
99% Overlap ⇨ 4.0Hz

864 images

Photogrammetry

75% Overlap ⇨ 0.3Hz

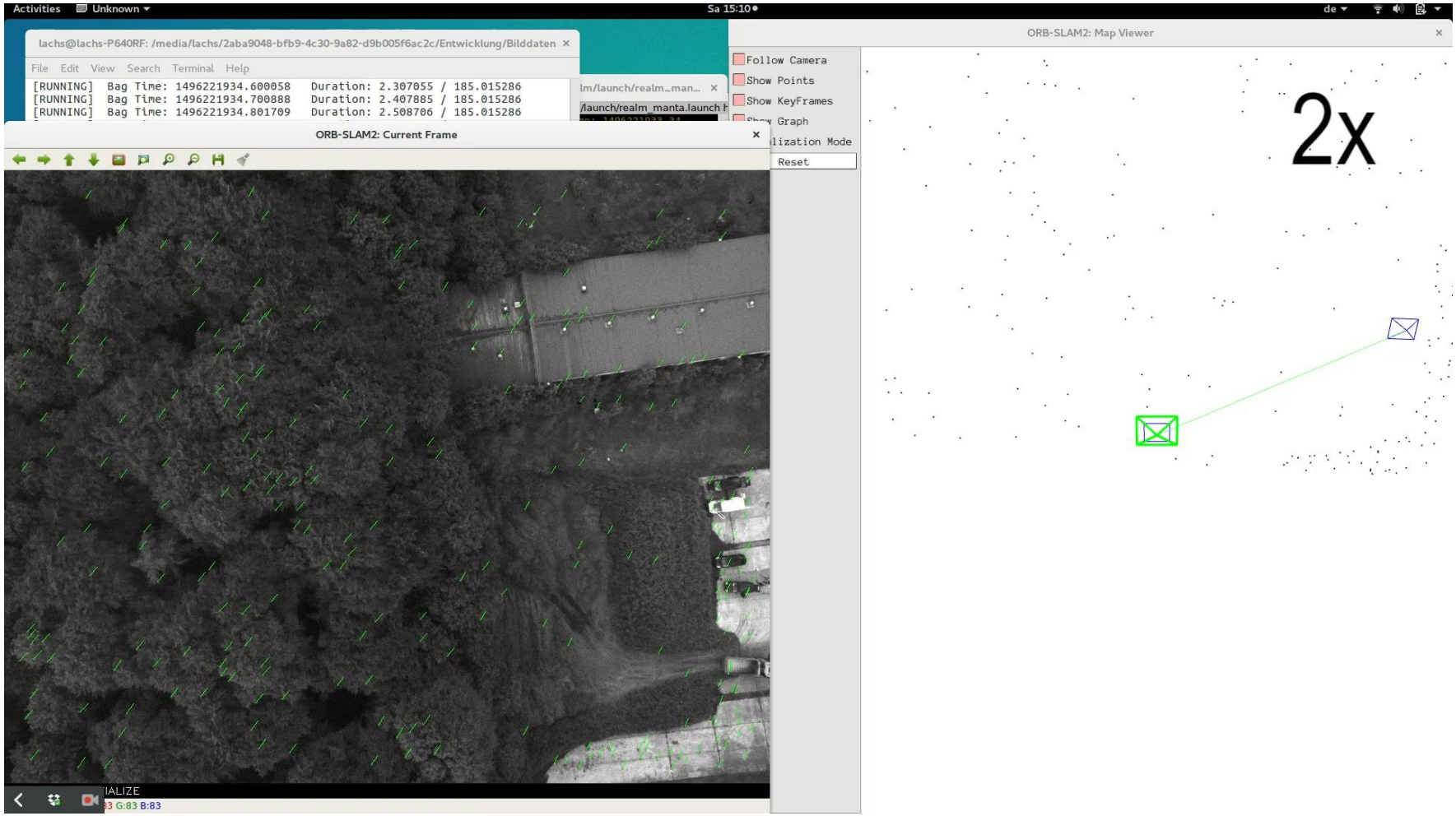
47 images



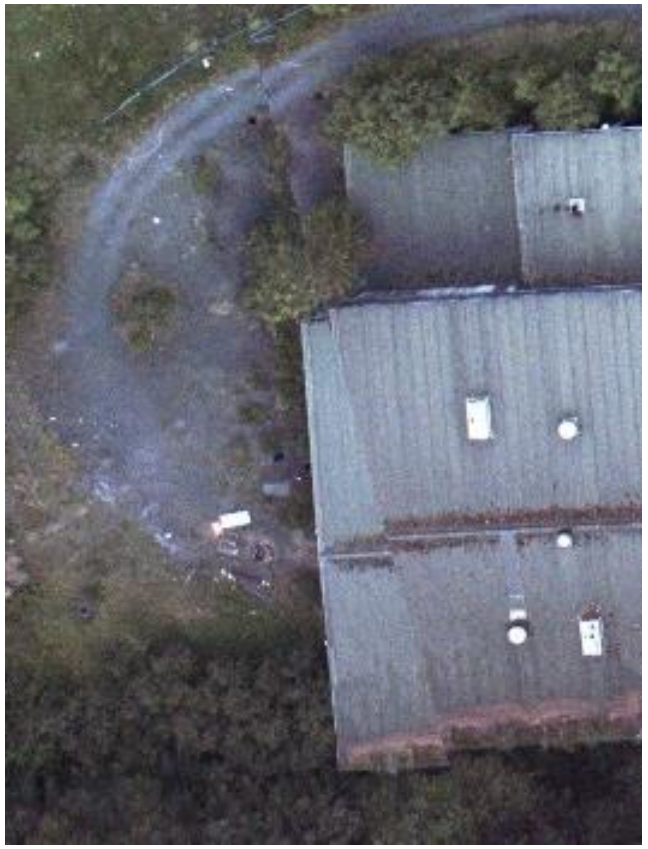
Area: 150x100m

Ground Reference Points

Evaluation SLAM



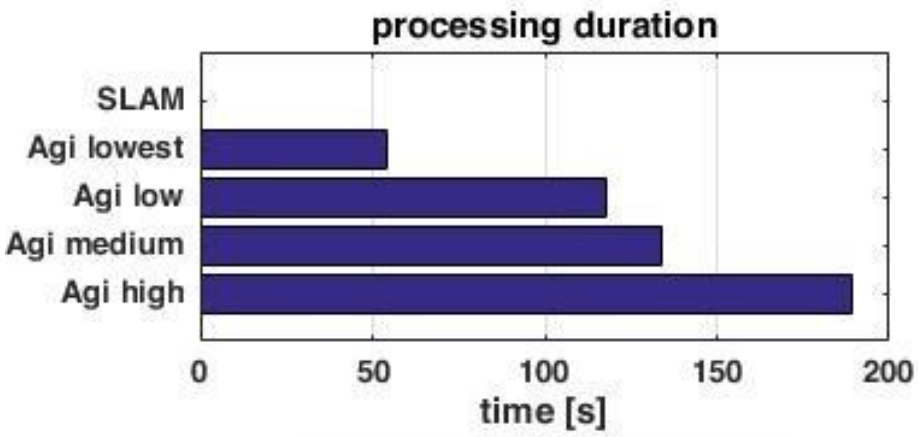
Evaluation SLAM

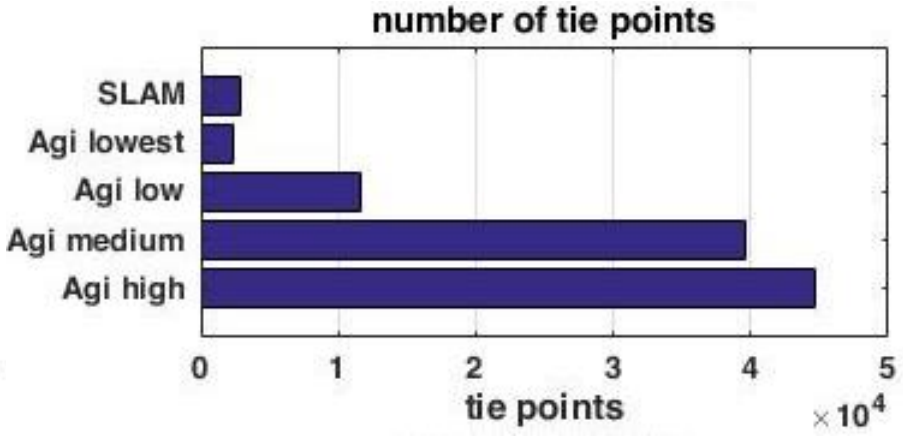


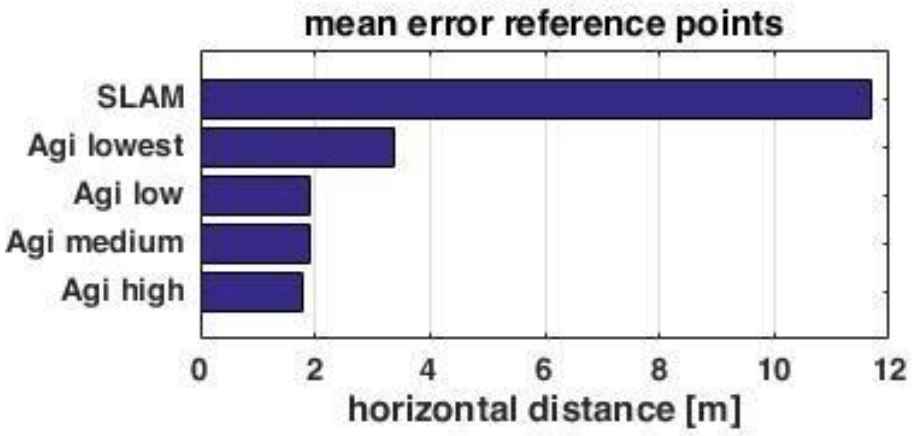
Evaluation Photogrammetry

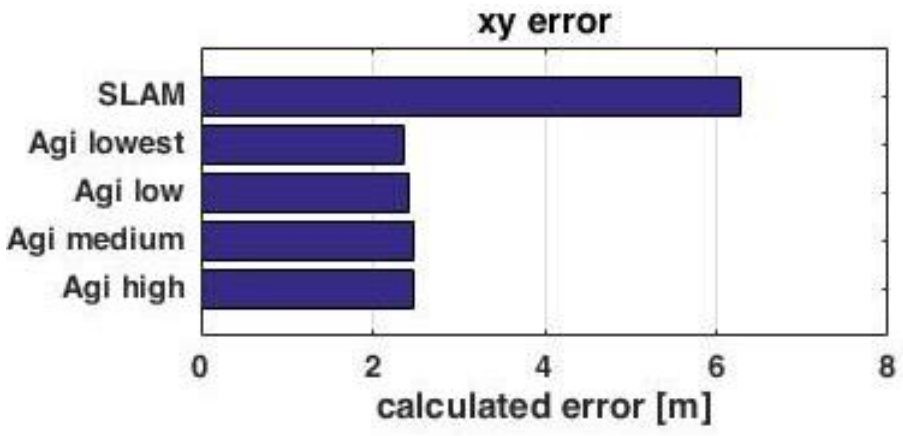
Agi lowest

Evaluation SLAM VS Photogrammetry

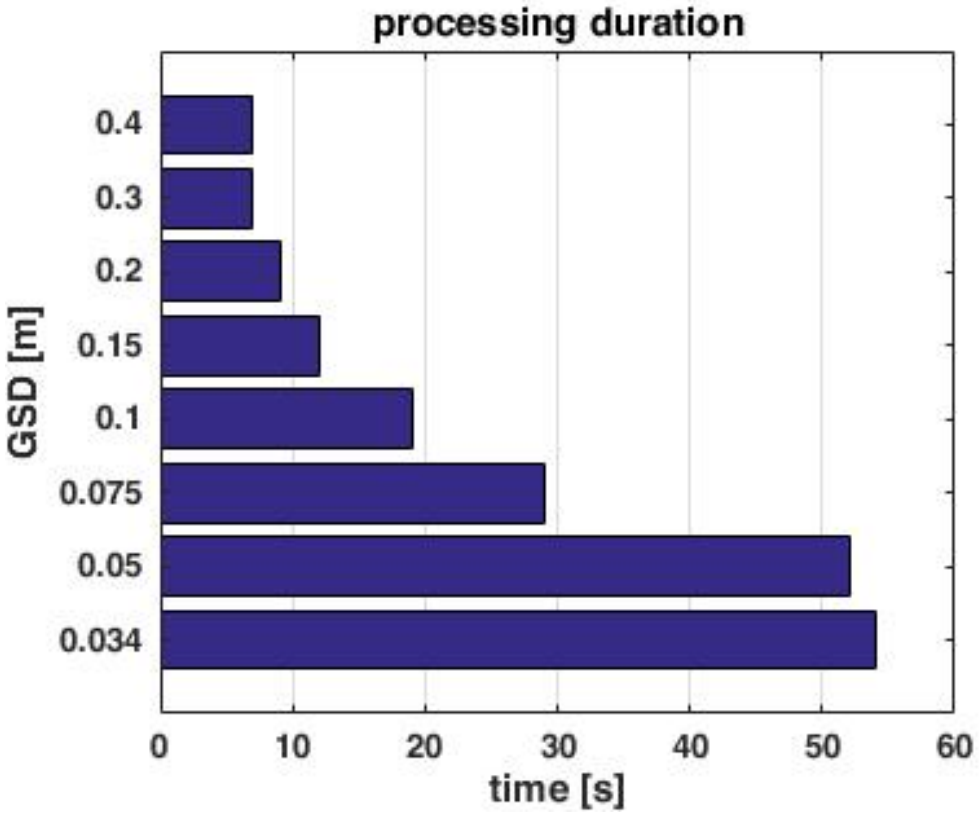








Processing Time depending on GSD



- Orthophoto creation takes up most time
- Can be reduced using smaller GSD
- Processing times under 10s possible

Summery

ROS based System for Aerial Survey and Image Transport

ORB SLAM 2 implementation for gereferenced image stitching

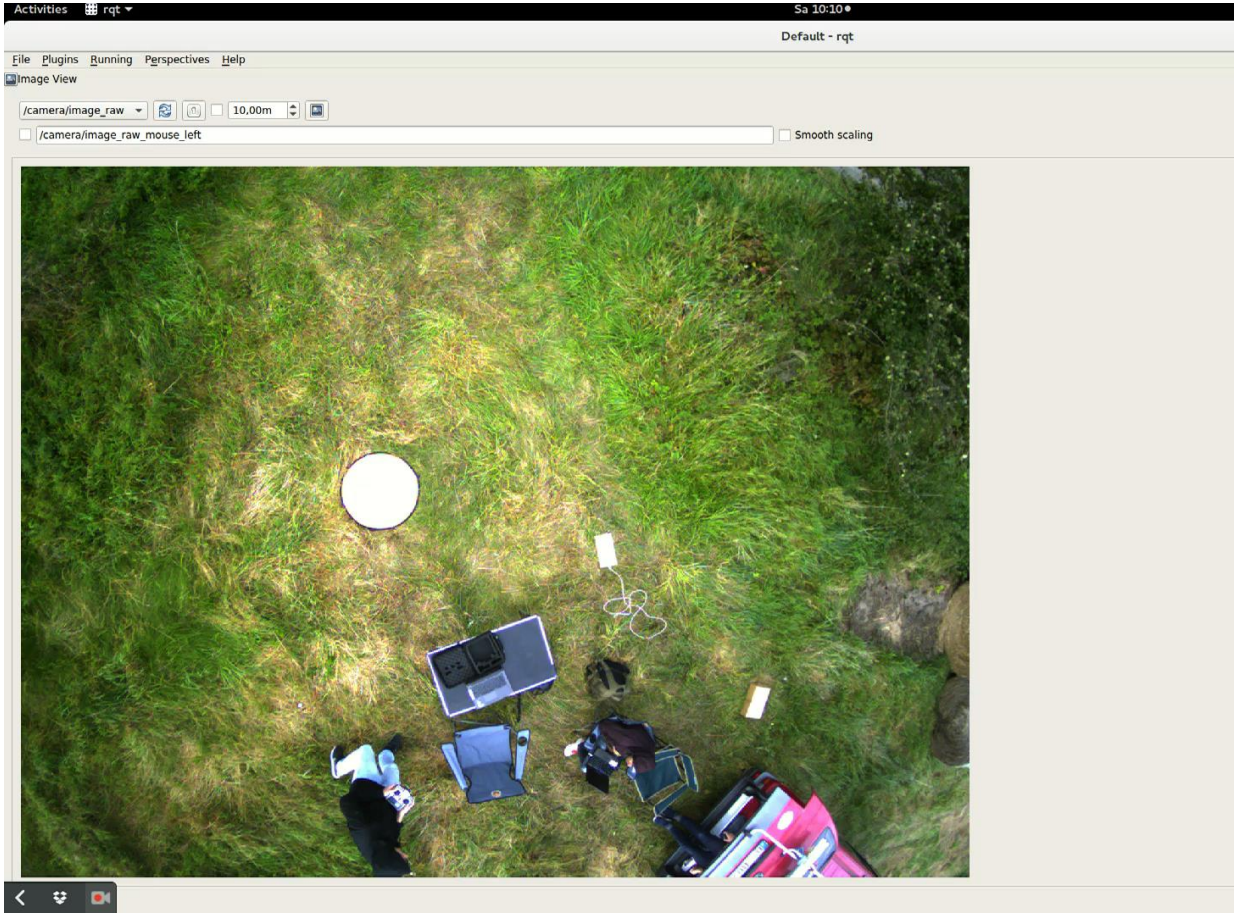
Photogrammetry ROS Node using Agisoft Photoscan

SLAM 2-3 times less accurate than Photogrammetry

Questions?

Appendix

IMAV2017 Competition



Feature Based Mapping

high overlap required
not so robust
not so fast

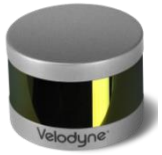
Pose Based Mapping

no overlap required
very robust
Very fast

Introduction – System-Design

Ground Station

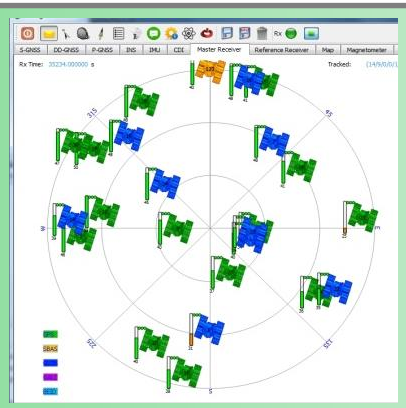
Basic-Nav. & Comm.



	UAV 1 Hrafnas	UAV 2 Hugin	UAV 3 Mugin	UGV 1 Geri	UGV 2 Freki
GNSS	X	X	X	X	X
IMU	X	X	X	X	X
Comm.	X	X	X	X	X
LiDAR	X			X	X
RGB-Camera		X			
IR-Camera			X		X

Introduction – Software and Frameworks

IFF-Navigation-Framework

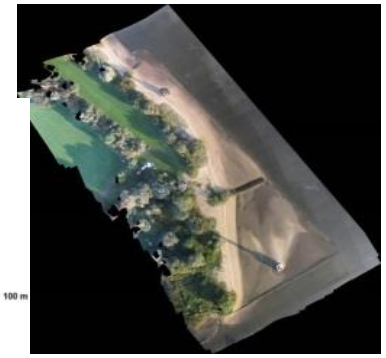


Position
(multi-constellation)

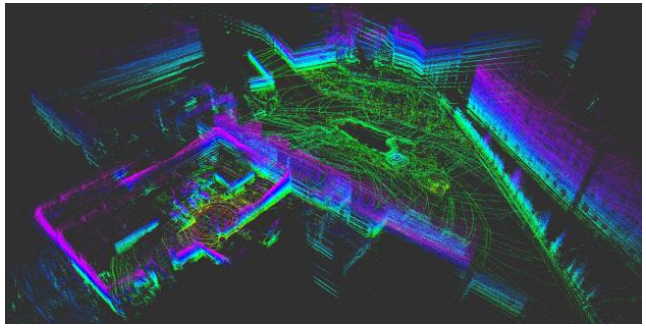
State-Vector
(IMU/GNSS-Fusion)

ROS-Framework

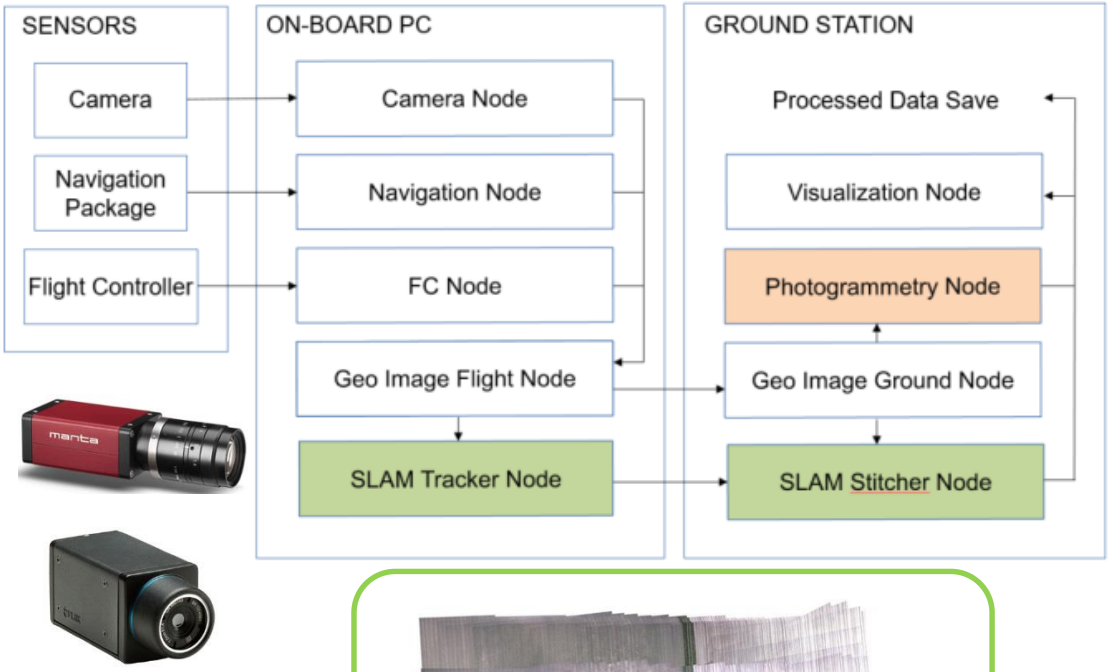
2D-/3D-mapping
(RGB/IR-camera)

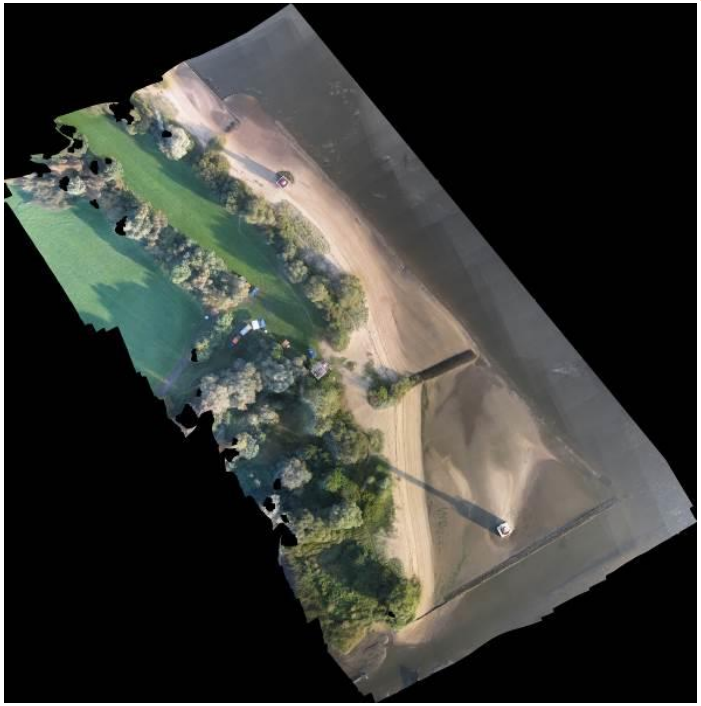


LiDAR-mapping

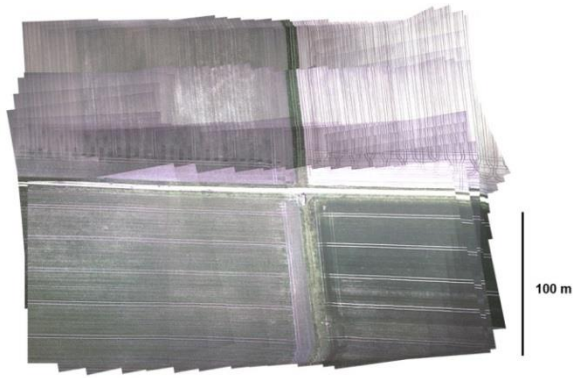


Introduction – Mapping





3D-Photogrammetry

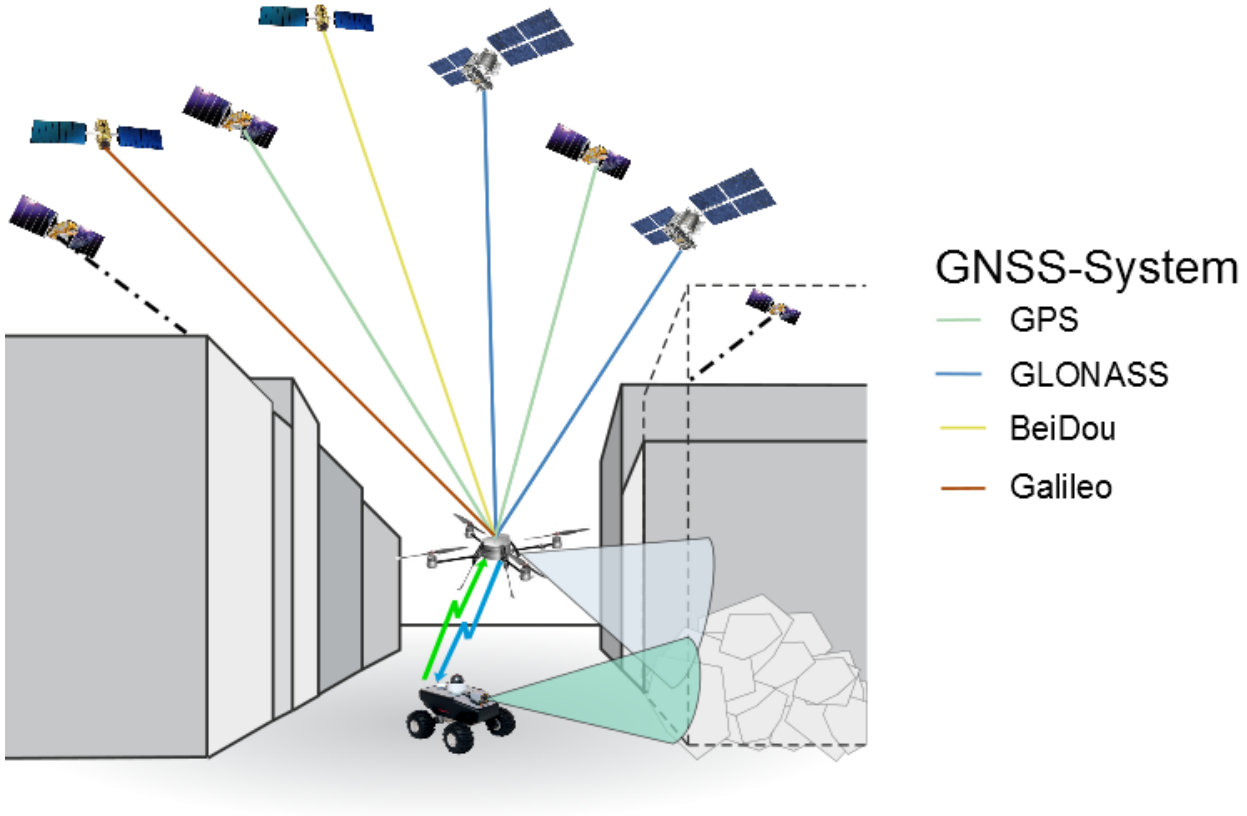


2D-Live-Stitching

Robust positioning for image-georeferencing and initializing

Multi-Constellation – Availability

Increasing availability by using different GNSS-Systems at the same time



➡ provides advantages in areas of degraded GNSS-reception (e.g. urban scenarios)

Multi-Constellation – Software implementation

IFF-Navigation-Framework

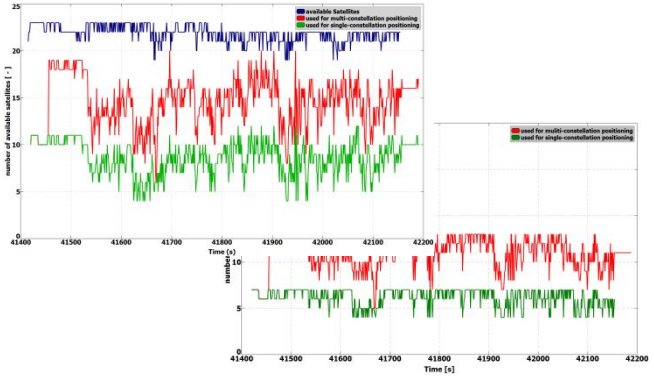
Software-Implementation:

- Decoding of the navigation-raw-messages (u-blox protocol)
- Taking different Reference-Frames in account (geodetic and time)
  - WGS84 (GPS), PZ-90 (GLONASS), GTRF (Galileo), CGCS2000 (BeiDou)
  - Extension of the state vector to represent the different Time-References and resultant extension of the Coupling-Filter (EKF)

$$\vec{x} = (x\ y\ z\ \Delta t_{GPS} \Delta t_{GLO} \Delta t_{GAL} \Delta t_{BDS})^T$$

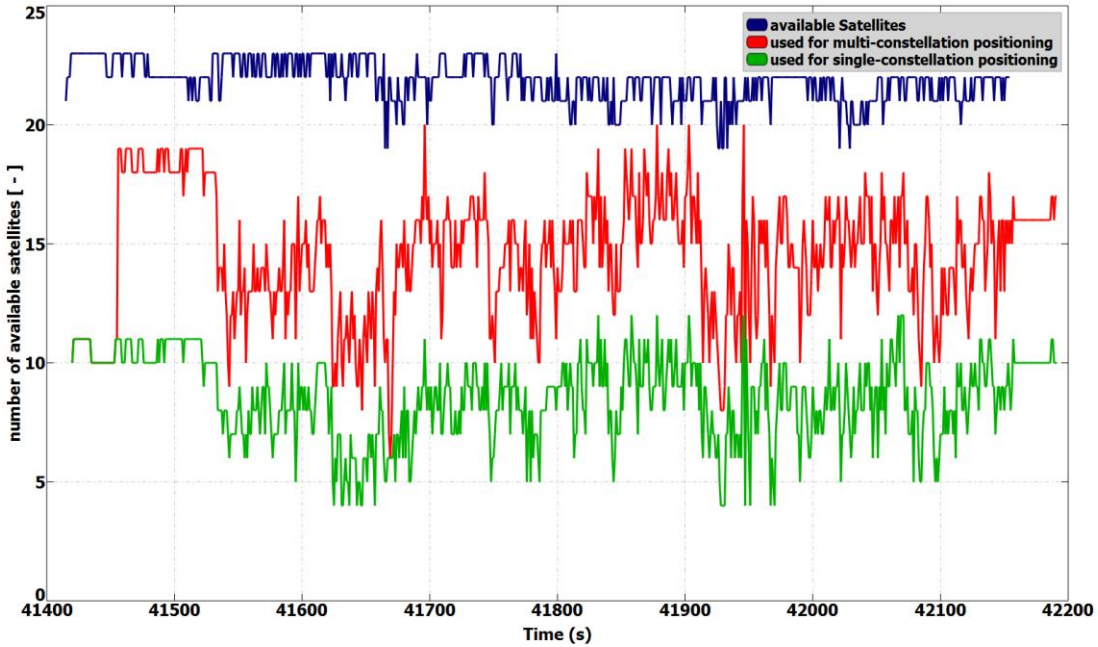
Real-Time-Processing

Post-Processing



Multi-Constellation – Results

Availability (no shadowing effects)

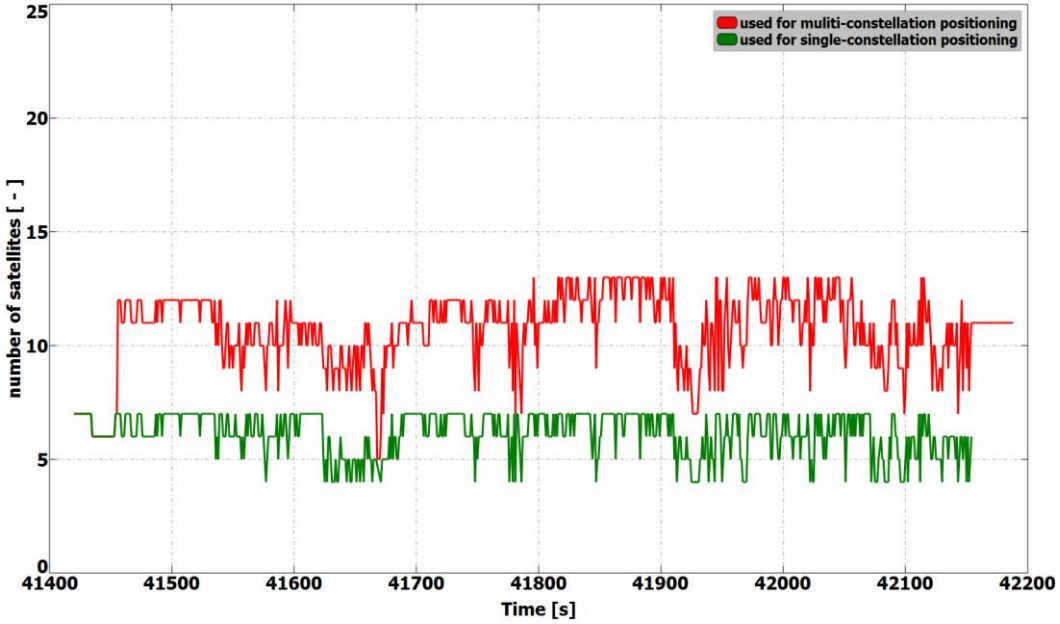


– Test Area near Peine

- Cut-off elevation: 5° (common value for GNSS-Positioning)
- Number of satellites used in single-constellation case: 11 or less
- Number of satellites used in multi-constellation-case: 17 or less
- Number of received satellites: 21 to 23

Multi-Constellation – Results

Availability (mean shadowing effects)

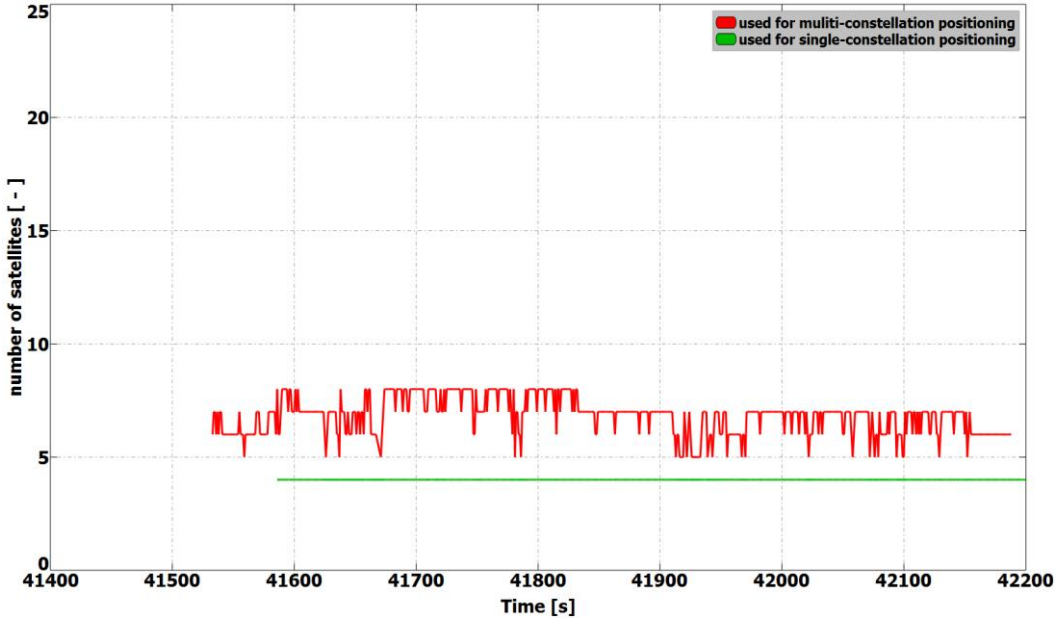


– comparable to a flight near flat obstacles (e.g. nearby buildings)

- Cut-off elevation: 20°
- Number of satellites used in single-constellation case: 7 or less
- Number of satellites used in multi-constellation-case: 12 or less

Multi-Constellation – Results

Availability (shadowing effects)



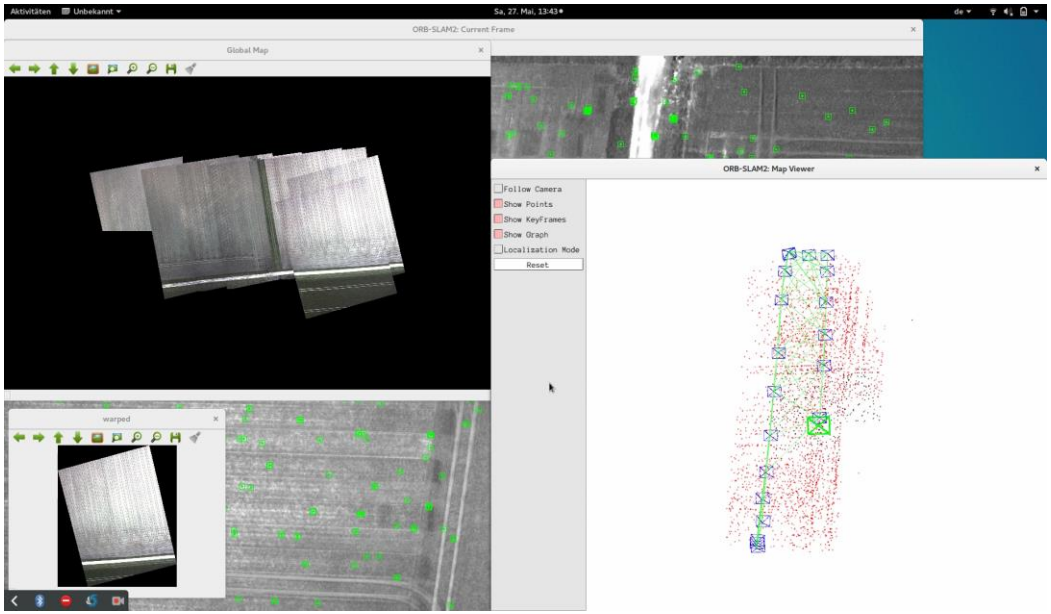
- comparable to a flight near obstacles
  (e.g. urban scenario)
- in most cases enviromental conditions for UGV

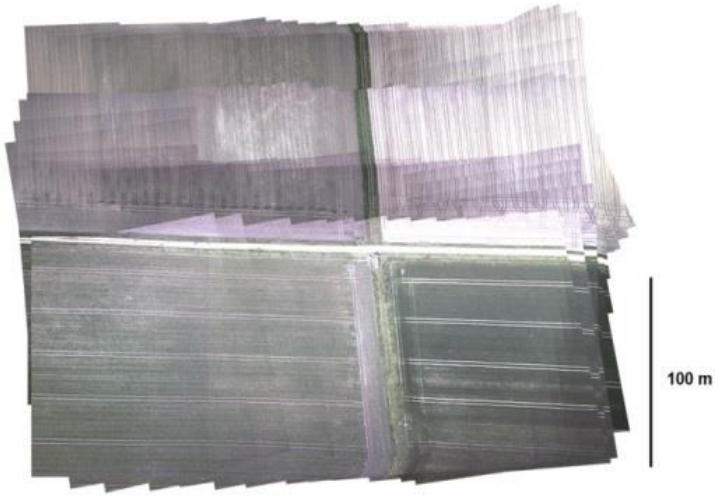
- Cut-off elevation: 35°
- Number of satellites used in single-constellation case: 4 (minimum for positioning)
- Number of satellites used in multi-constellation-case: 7-8

Mapping – Approaches

Approach 1: 2D-„live“-stitching (ORB-SLAM2 based)

- fast overview of the scenario
- good situational awareness
- information for further mission-planning



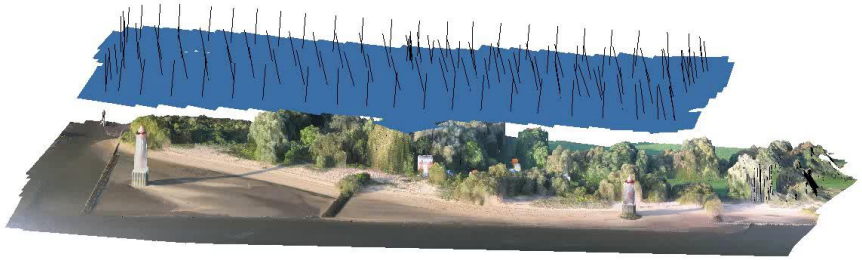


Mapping – 3D-Photogrammetry (RGB-Camera)

Approach 2: 3D-Photogrammetry

Processing-Time ⟷ Image-Quality

- off-the-shelf photogrammetric processing software (Agisoft Photoscan API)
- detailed information of the scenario
- triggered automatically when mission is completed



Mapping – 3D-Photogrammetry (Thermal-Camera)

Thermal-Camera (FLIR A65)

Conclusion and Outlook

Conclusion

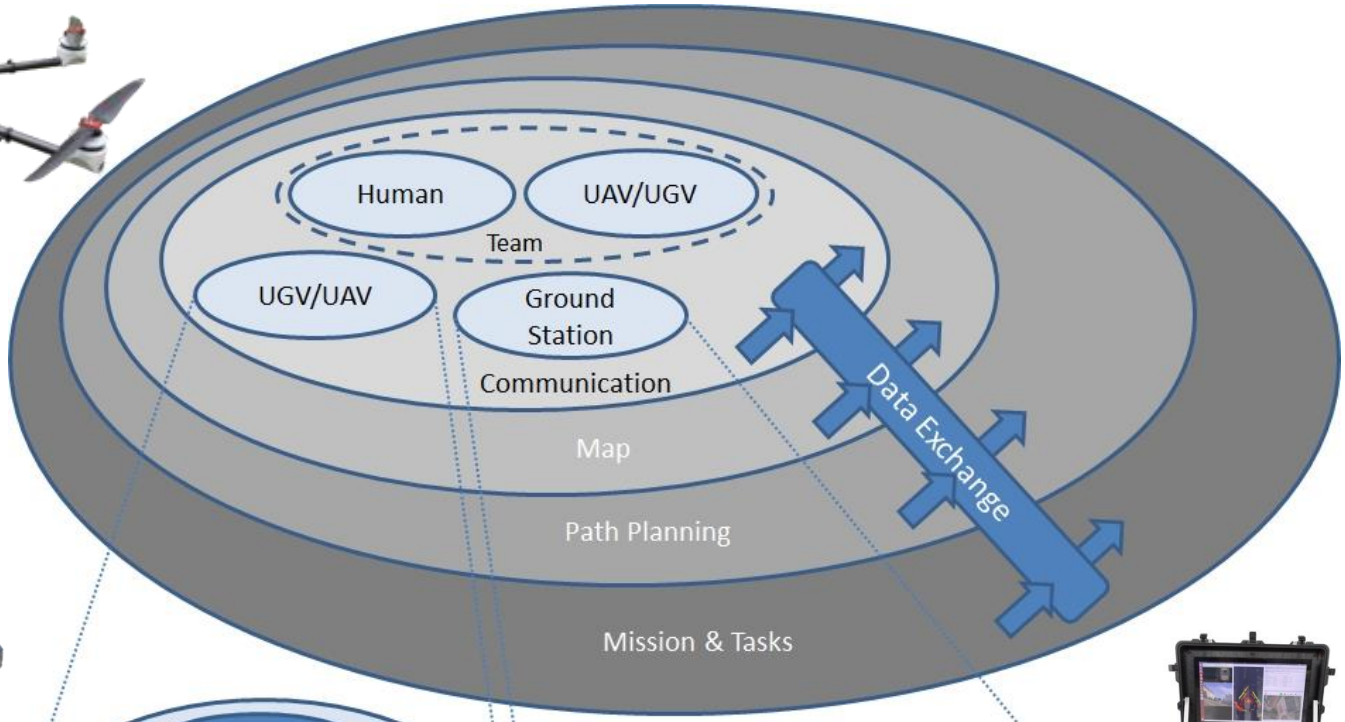
- Overview of the joint research project *ANKommEn*
- Benefit of using a multi-constellation based positioning
- adaption of the software-framework
- different approaches of mapping-processing

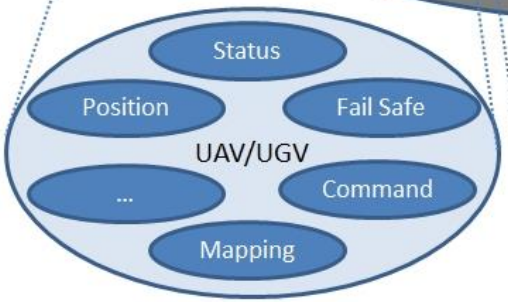
Outlook

- further optimization of the user interface (Ground Station)
- increasing the robustness of processes
- increasing the level of automation


Thank you for your attention!
Questions?

Introduction – Systemdesign





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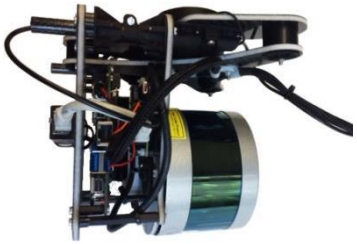
Hardware – Vehicle, Sensors and Processing-Units

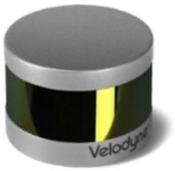
UAV/UGV and Payloads

3x

2x



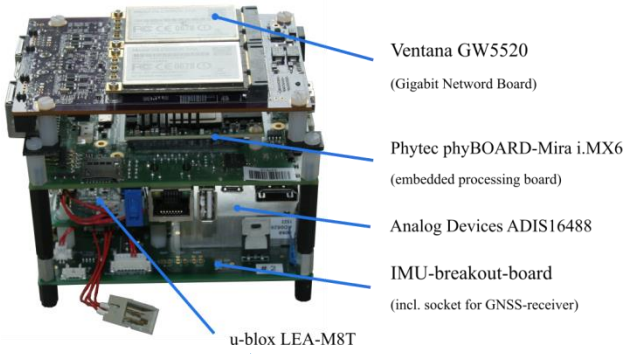
Sensors



Processing-Units

Multi-Constellation – Hardware

Hardware



u-blox LEA M8T	
GNSS-Systems	GPS, Galileo, GLONASS, BeiDou
Features	Carrier Phase Output, 2x PPS
Data-Output: • NMEA-Data for NTP-Server (Phytec Board) • Time-Synchronisation of the Overall-System (Data-Processor, Sensors etc.) • ubx-messages for Positioning (Raw-Data)	
Analog Devices ADIS-IMU-16488	
integrated IMU-breakout-board (custom-designed)	
integrated magnetometer (heading)	

Mapping – Approaches

Approach 1: 2D-„live“-stitching (ORB-SLAM2 based)

- fast overview of the scenario
- good situational awareness
- information for further mission-planning