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LiDAR Mobile Mapping with centimeter accuracy in long tunnels

Jens Kremer

Lausanne, 11.02.2016

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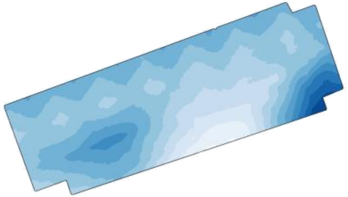
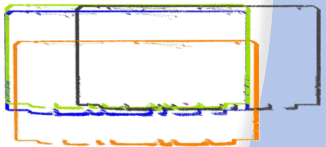
- System layout
- GNSS conditions in Mobile Mapping
- Example FRA - optimal GNSS conditions
- Example SSB - navigation in the absence of GNSS





Modular Sensor Management System

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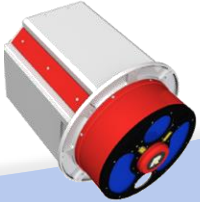
- **Mission planning**
- **Guidance**
- **Georeferencing**
- **Sensor management**
- **Data storage**








AEROcontrol / TERRAcontrol with IMU-IIf / IMU-m

www.igi-systems.com

- Integrated GPS/GLONASS/BEIDOU/QZSS… receiver with *DIA+*
- Dual Antenna & Dual IMU Support
- Fibre Optic Gyros / MEMS Gyros
- Data rate up to 512Hz
- Gyro Drift 0.03°/h (FOG)

  < 2°/h (MEMS)

All IMUs are export free!

Modular Sensor Management System - SMU

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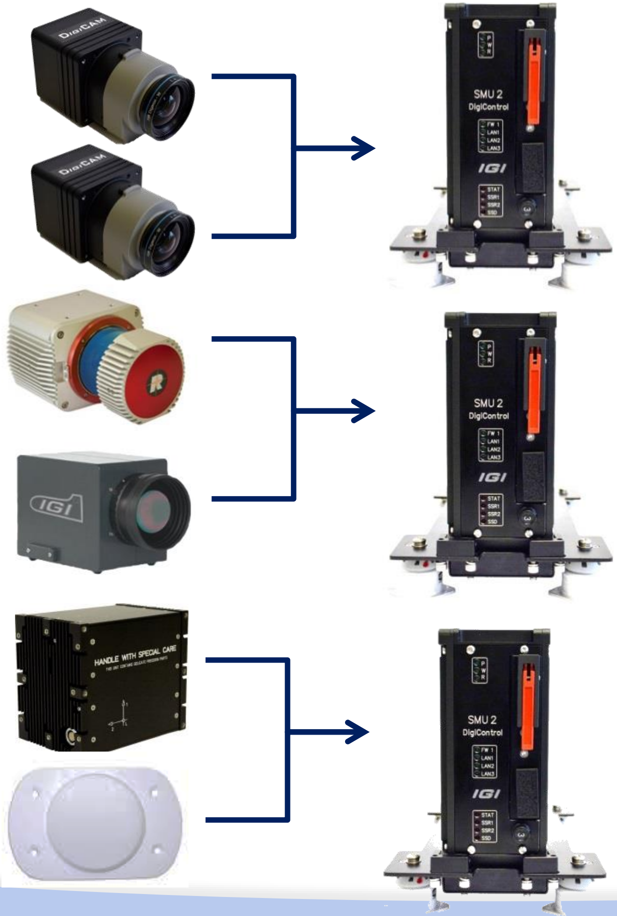


IGI
www.igi-systems.com
FMS
CONTROL PANEL
POWER SUPPLY
STATUS
FUSE
CSM 130
IGI
www.igi-systems.com
Cavalon Aerial Survey

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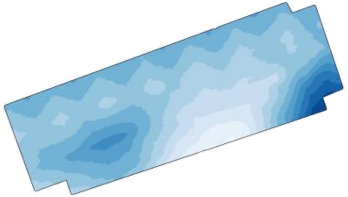
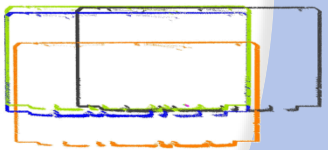
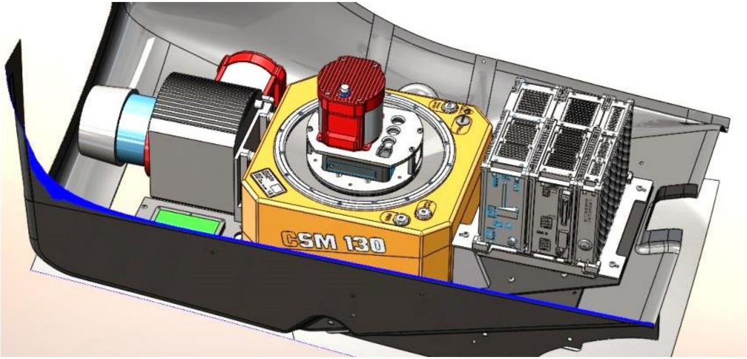




Mobile Mapping & Airborne LiDAR System

LITE MAPPER



STREET MAPPER

GNSS: Air vs. Ground

Airborne LiDAR	optimal GNSS conditions
Mobile LiDAR Mapping	diverse GNSS conditions from “near airborne” to the absence of GNSS in tunnels

Navigation in the Absence of GNSS

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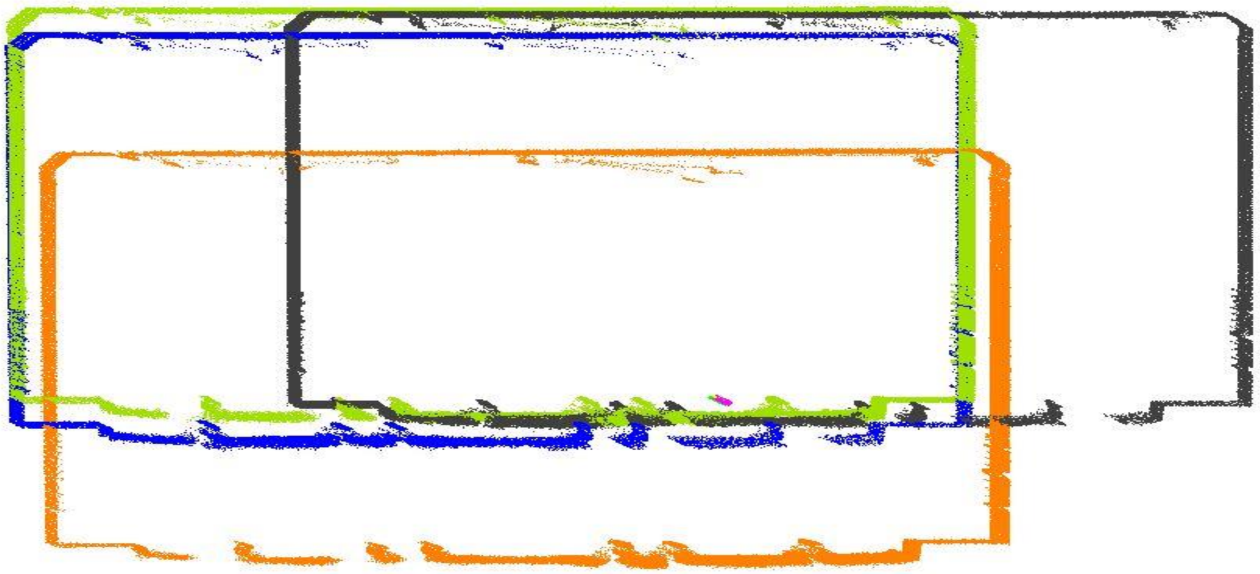
Example: Tunnel profile for the middle of a tram tunnel. Four separate passes, up to 15 min without GNSS aiding.



Processing Mobile GNSS/IMU Data

- Multi Antenna
- ZUPTs
- Odometer
- Different Initialization Methods
- Include extra Position Information

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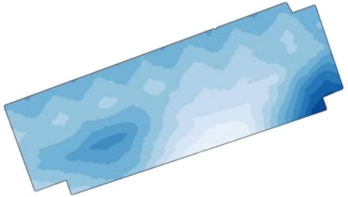
- System layout
- GNSS conditions in Mobile Mapping



- **Example FRA - optimal GNSS conditions**
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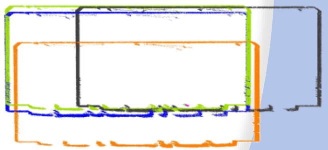


Example FRA - optimal GNSS conditions

ICAO Guidlines:

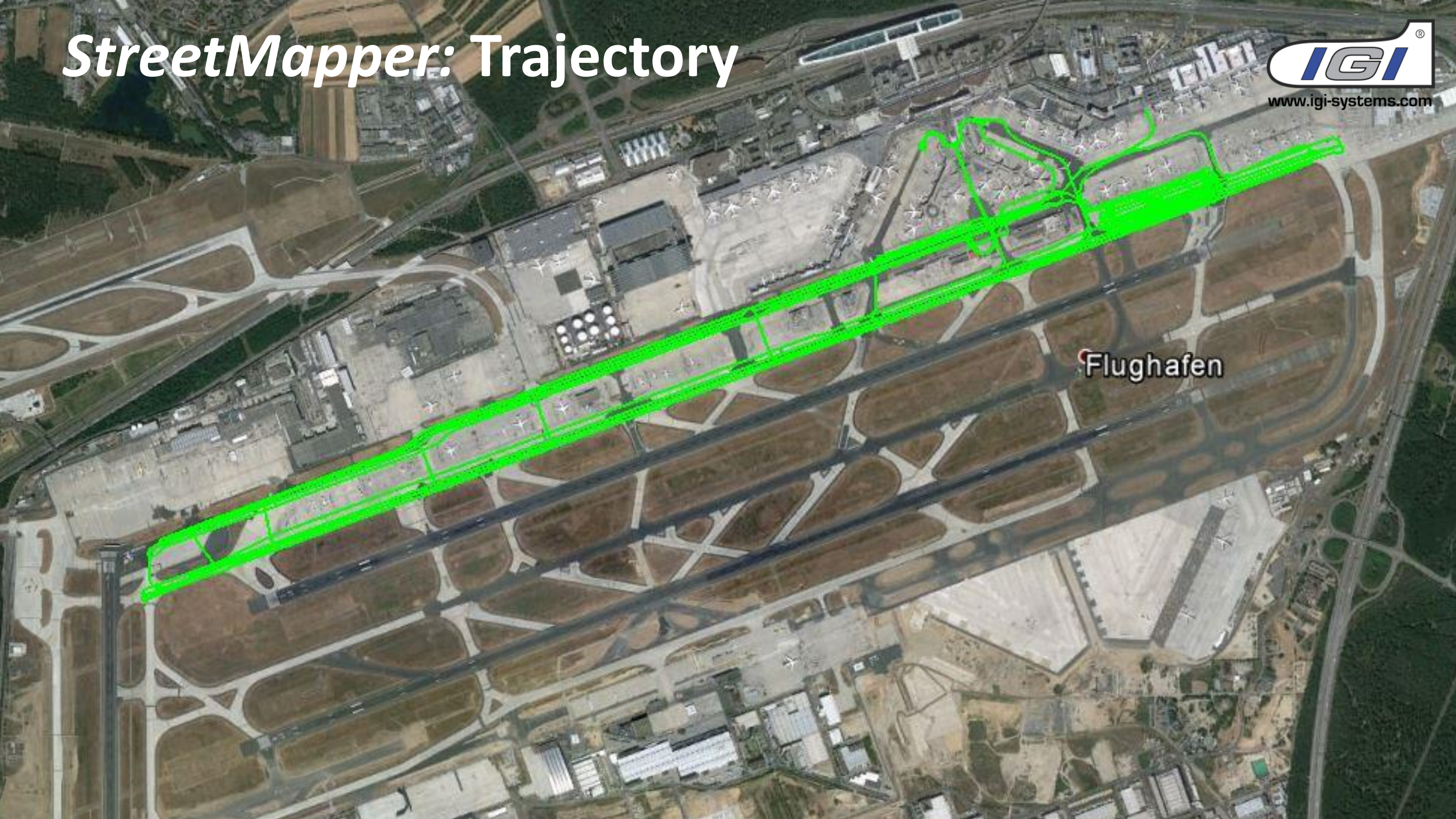
Ensurance of a consistent implementation of international standards.

-> Slopes of taxiways and runways ±1.5%

http://www.icao.int/safety/Implementation/Pages/Home.aspx

http://www.icao.int/safety/Pages/default.aspx

StreetMapper: Trajectory



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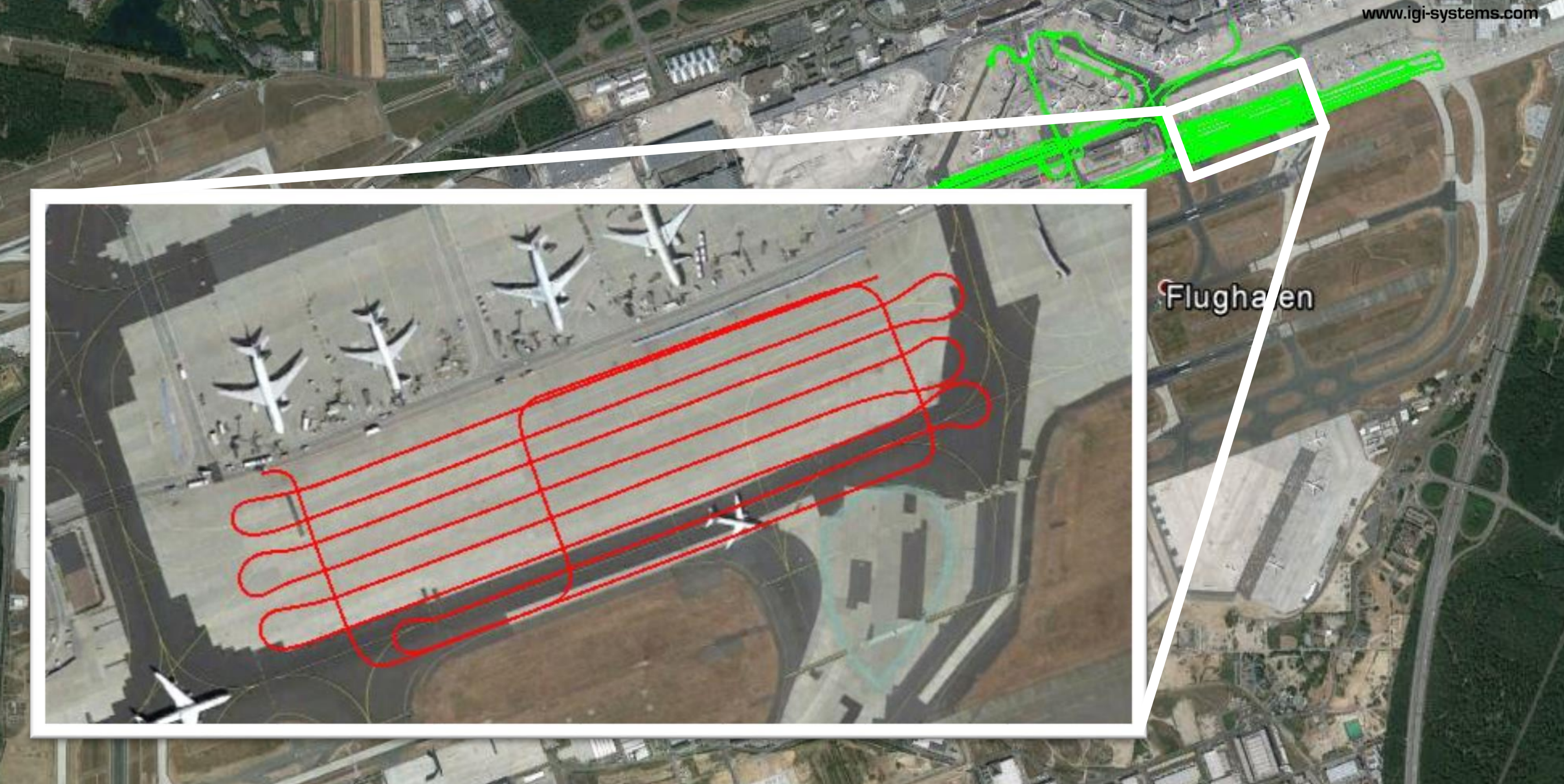
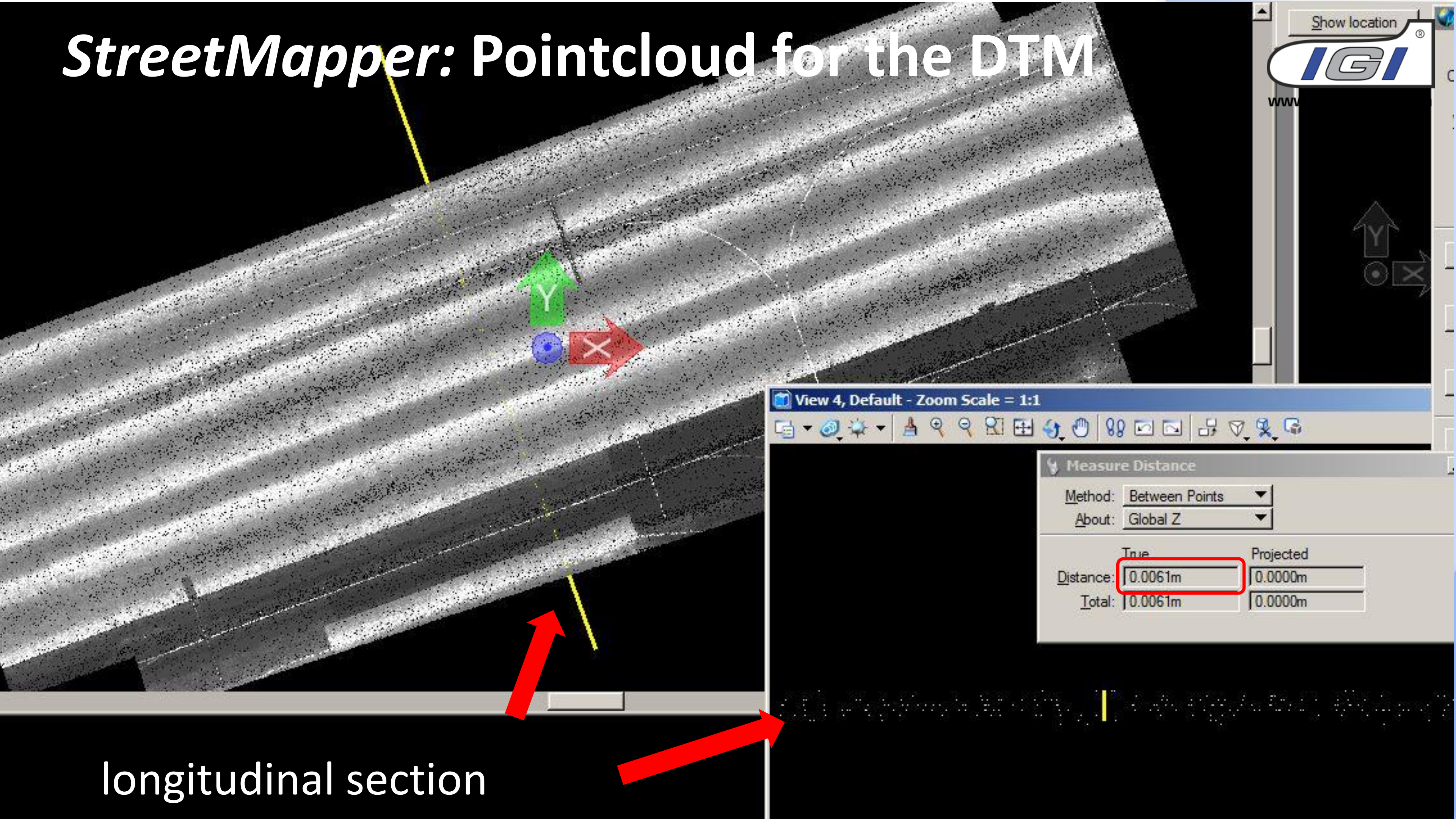
StreetMapper: Trajectory Detail

www.igi-systems.com

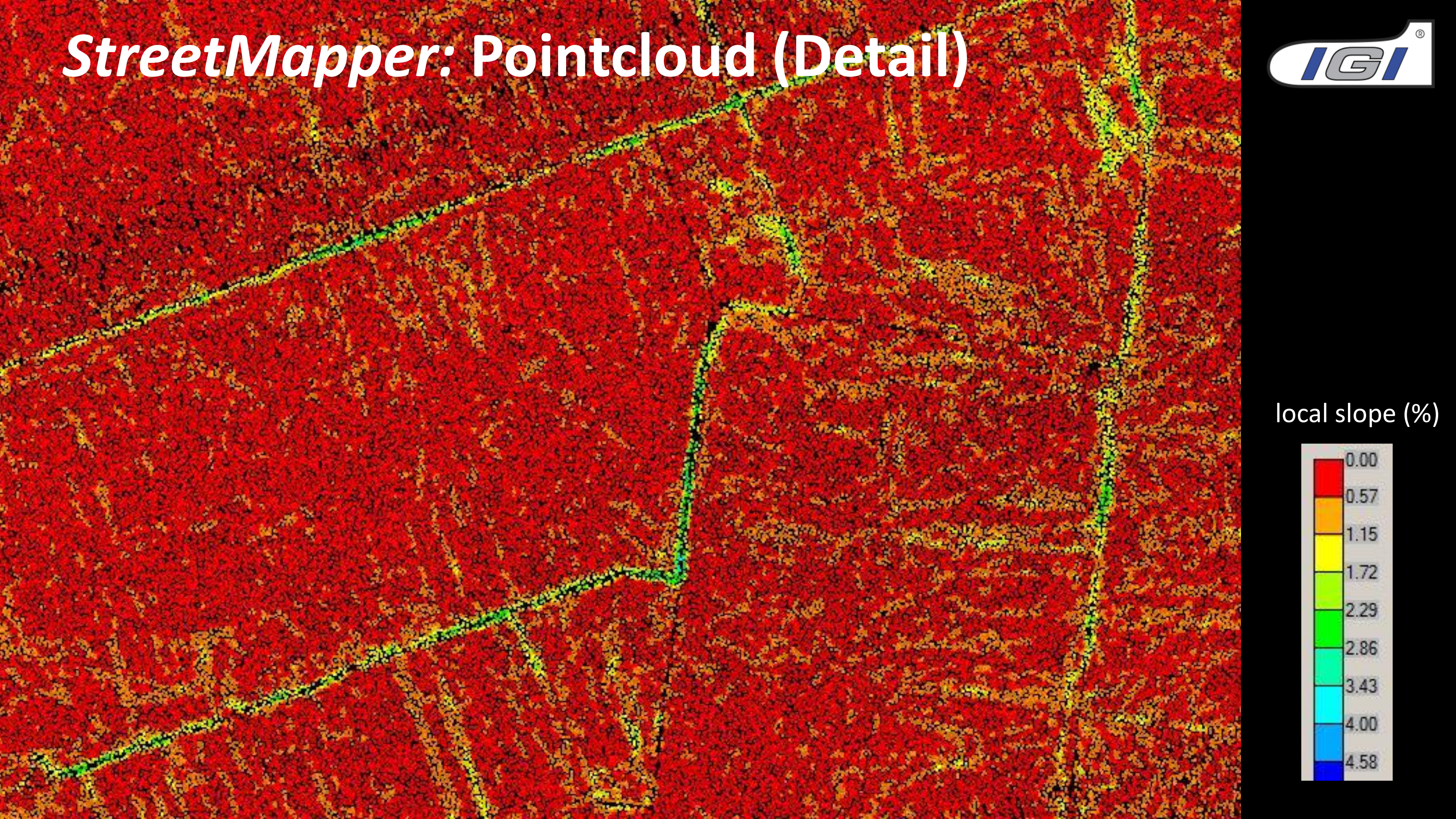


StreetMapper: Pointcloud for the DTM



longitudinal section

StreetMapper: Pointcloud (Detail)



StreetMapper: Trajectory

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- System layout
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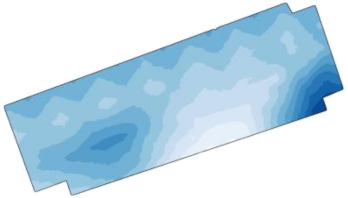

- Example FRA - optimal GNSS conditions
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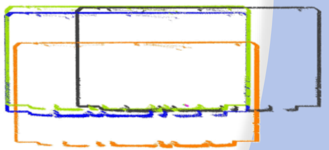
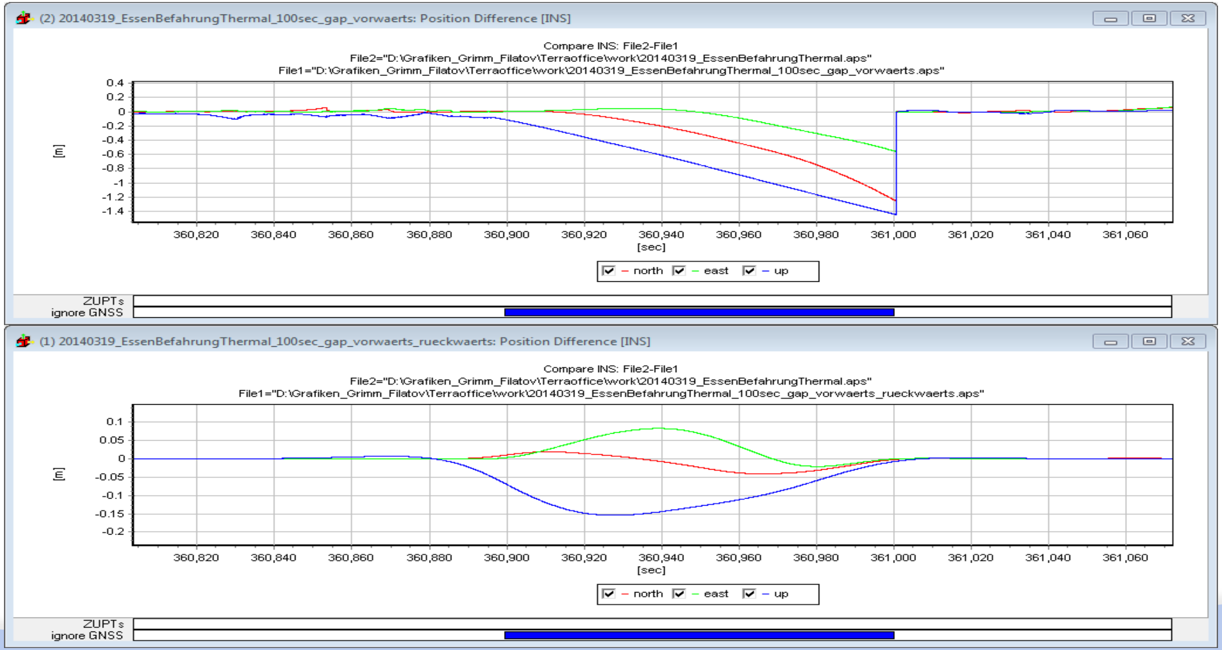


Navigation in the Absence of GNSS

Without aiding, the positon error of inertial navigation rises with (at least) t^2. Forward – reverse smoothing improves the situation, but with increasing times, we still get a problem:



Difference between a solution with an artificial 100sec GNSS gap and a solution with continuous GNSS.

top: forward solution

bottom: smoothed solution

Navigation in the Absence of GNSS

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Standard way of mobile laser data adjustment:

Step 1: GNSS/IMU processing; export of a trajectory

Step 2: Adjustment of the trajectory to fit GCPs or to create a relative match of different passes. The trajectory is deformed to give a better match.

- Correlations between the position and the orientation are not taken into account. Offsets and drifts may not reflect the correct physical situation.
- The information from the IMU and from the GCPs is not fully exploited. The required number of GCPs might be higher than necessary.
- Information about the source of the mismatches is lost (gross errors are difficult to detect).

Navigation in the Absence of GNSS

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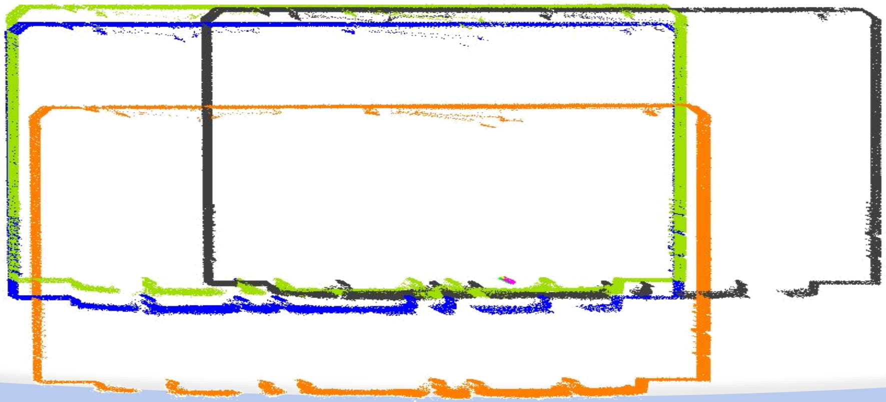
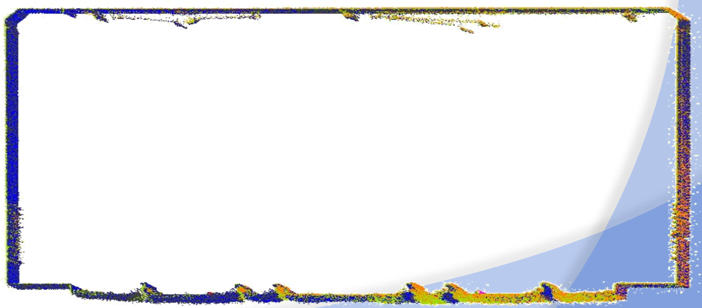
Workflow implemented in *TERRAoffice*:

Step 1: GNSS/IMU processing; export of a trajectory

Step 2: Measure the Ground Control Points in the pointcloud

Step 3: GNSS/IMU processing, taking into account the additional position measurement at the GCP positions.





Example: Stuttgarter Straßenbahn

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A part of the underground network of the Stuttgarter Straßenbahnen (SSB) was scanned with an *IGI RailMapper*, equipped with two Z+F 9012.

Example: Stuttgarter Straßenbahn

www.igi-systems.com

The tunnel was scanned four times:

Forward / reverse with about 50 km/h and

Forward / reverse with 20 km/h.

3.6 km tunnel length.

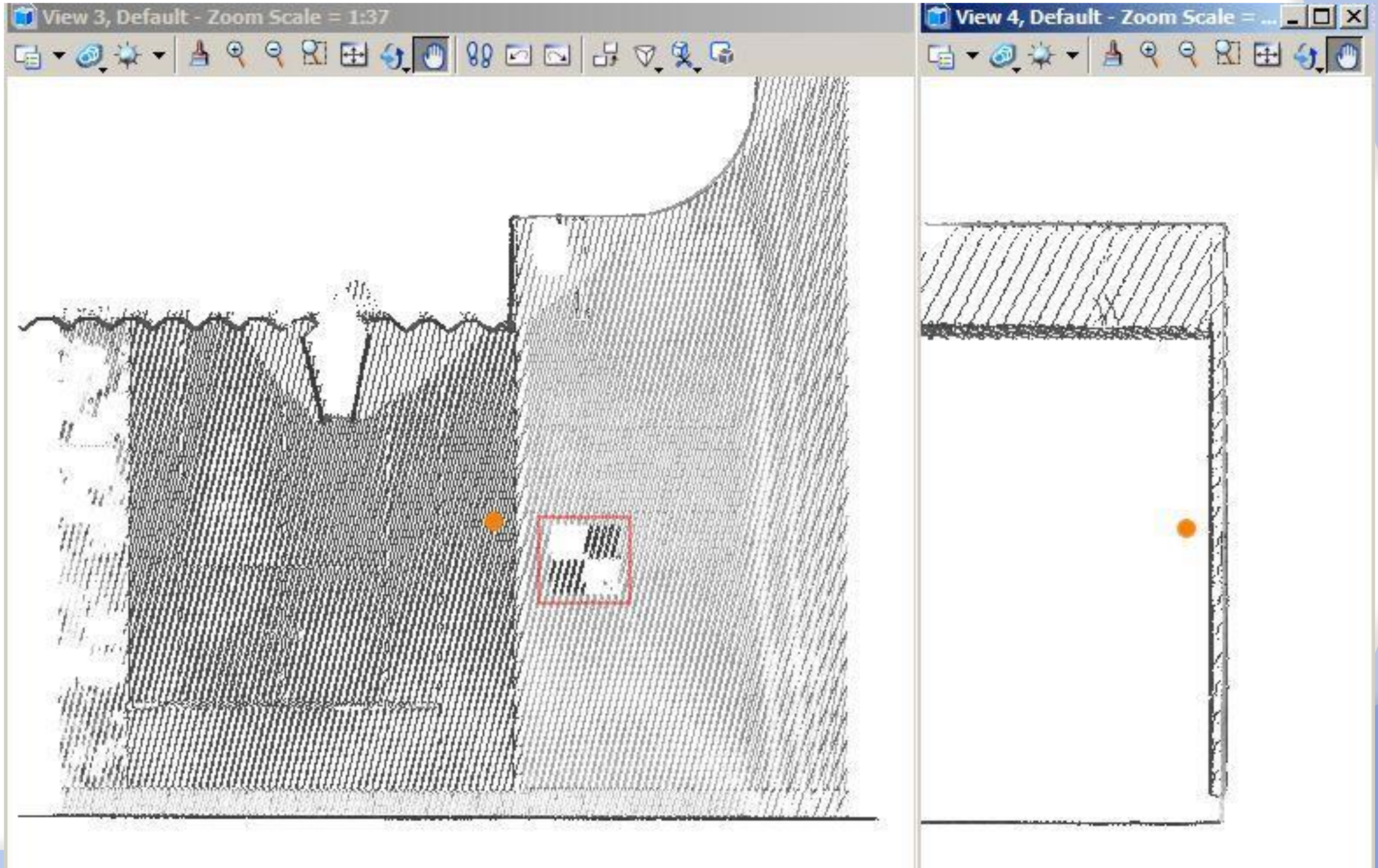
61 marked GCPs.

Track #	Max. Speed [km/h]	Duration [sec]
1	50	335
2	50	361
3	20	762*
4	20	666

* incl. a 61 sec stop

Example: Stuttgarter Straßenbahn

GCPs:



Example: Stuttgarter Straßenbahn

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Track 2:

Track #	Max. Speed [km/h]	Duration [sec]	Used GCPs	Avg. GCP dist. [m]	Average time between GCP [sec]
2	50	361	27	141	14
2	50	361	10	351	36
2	50	361	0	3600	361

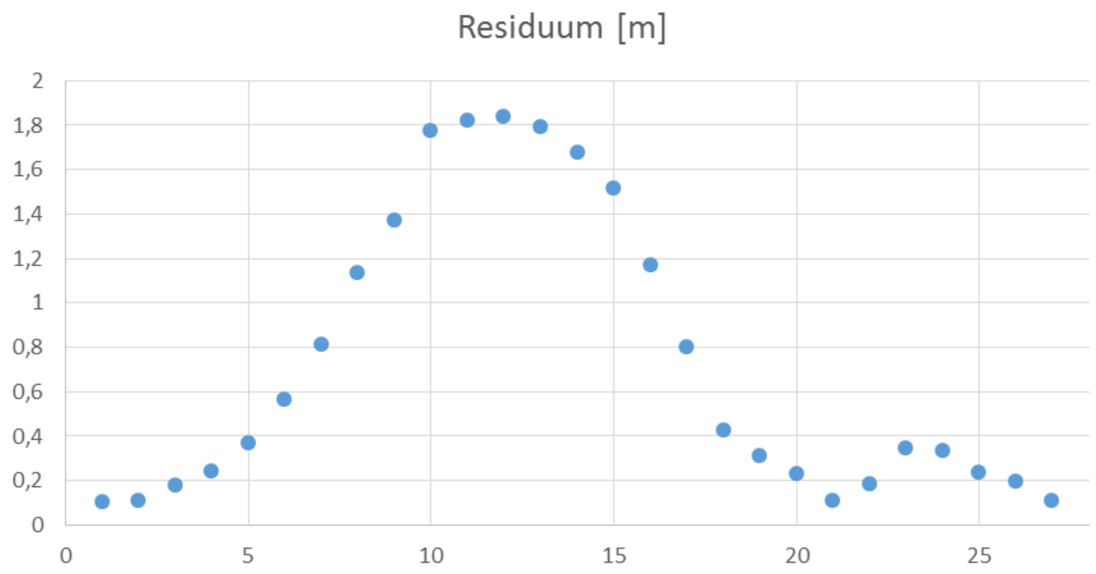
- Determination of the position offset at the 10 or 27 used GCPs, respectively.
- Introduction of the GCP measurements at the related times.
- Re-processing of the trajectory with the newly determined position measurements.
- New georeferencing of the laser points.

Example: Stuttgarter Straßenbahn

0 GCP/
27 Check

Example: Stuttgarter Straßenbahn

Track 2: Residual at the independent check points. (0 GCPs/ 27 checkpoints)



Mean error:

98 cm

Example: Stuttgarter Straßenbahn

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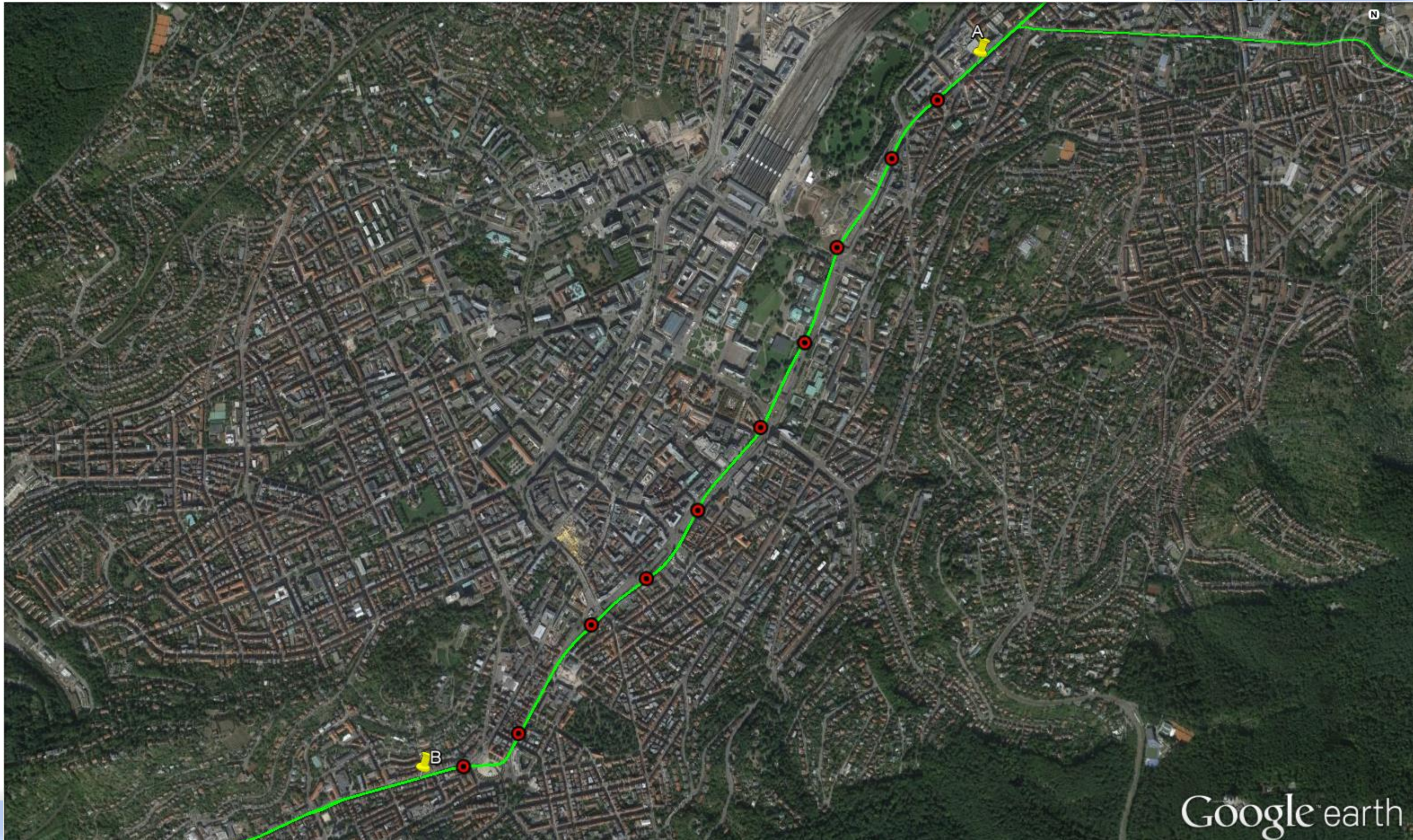
10 GCP/
50 Check



Example: Stuttgarter Straßenbahn

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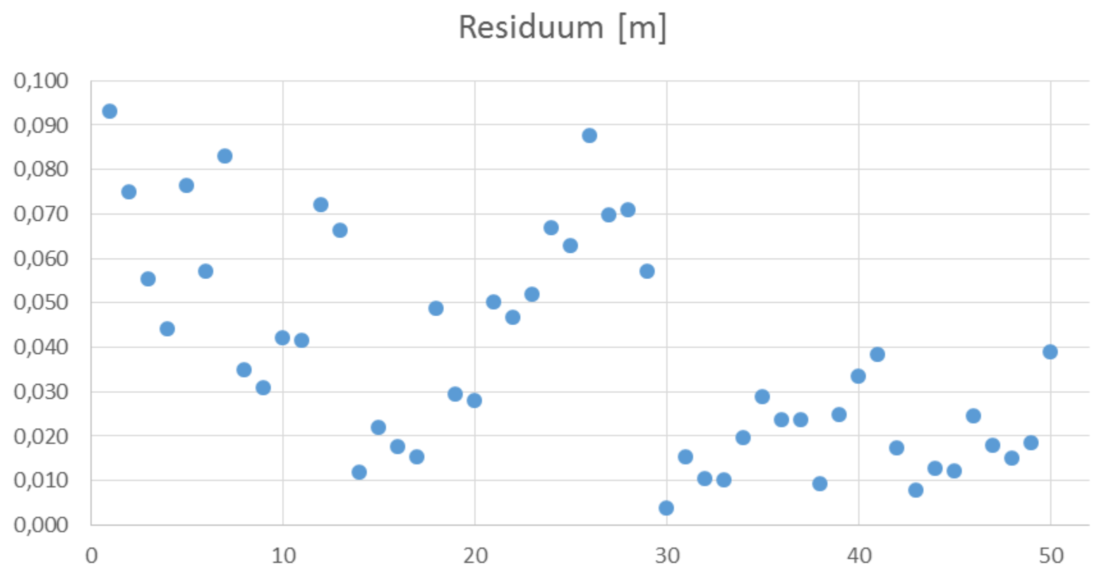
Track 2: Residual at the independent check points. (10 GCPs/ 50 checkpoints)



Mean error:

4.5 cm

Example: Stuttgarter Straßenbahn

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27 GCP/
34 Check

Example: Stuttgarter Straßenbahn

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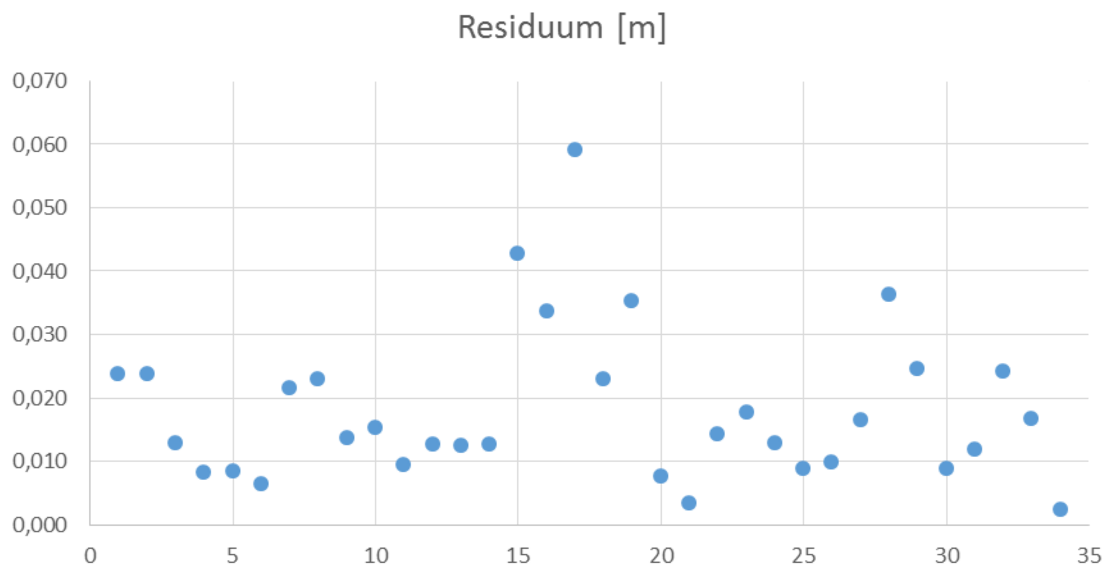
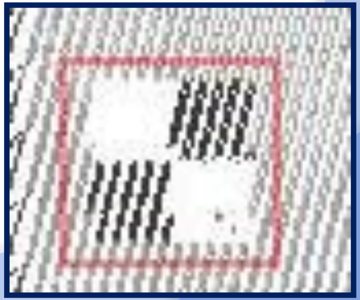
Track 2: Residual at the independent check points. (27 GCPs/ 34 checkpoints)



Mean error:

2.2 cm



Example: Stuttgarter Straßenbahn

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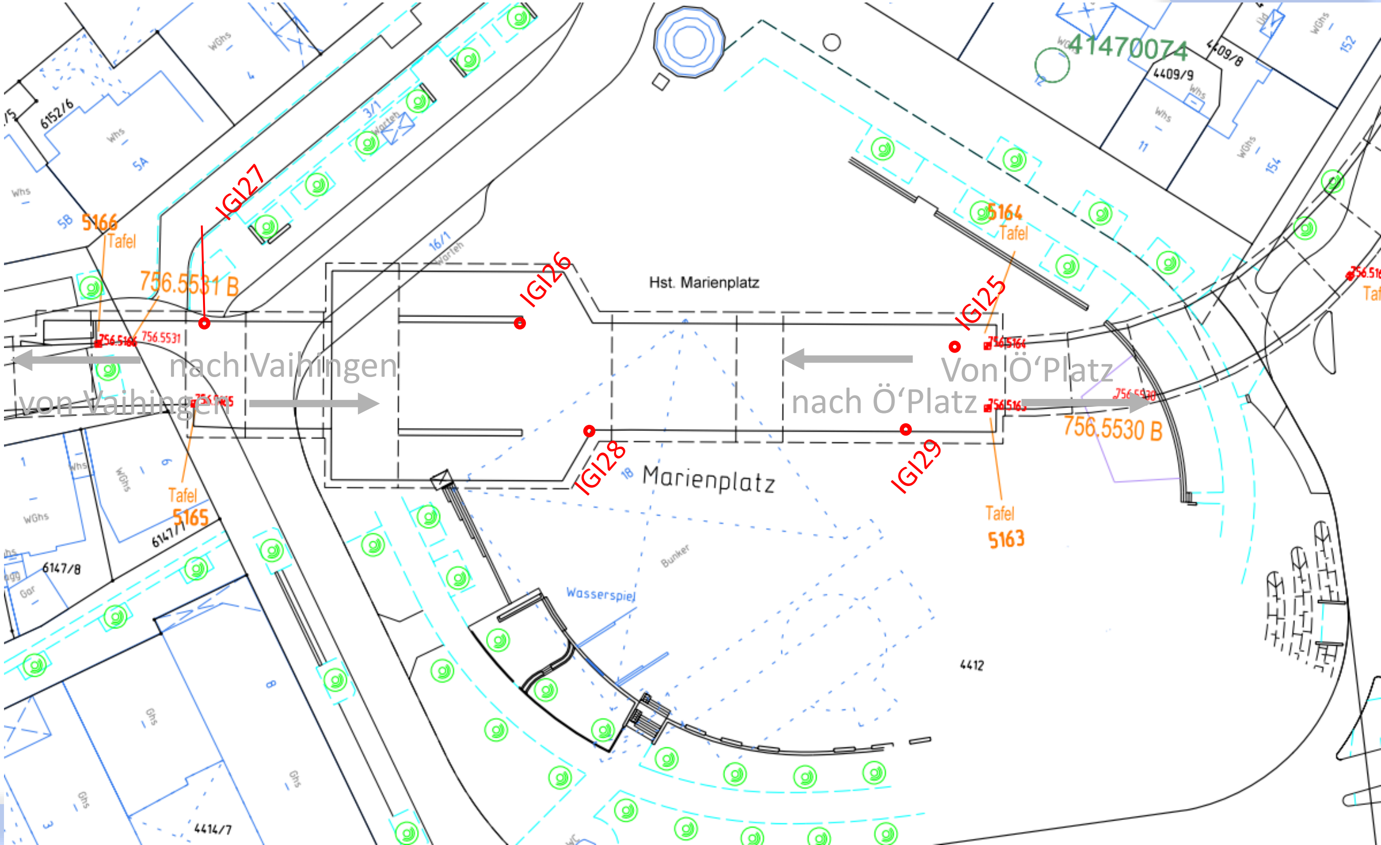
Supplementary measurement of unmarked features in the station “Marienplatz”

by ifp, Univ. Stuttgart



IGI27 – Stationsschild Marienplatz (i-Punkt)
IGI29 – Stationsschild Marienplatz (i-Punkt)
IGI26 – Mauerecke (Fußbodenniveau)
IGI28 – Mauerecke (Fußbodenniveau)
IGI25 – Bahnsteigkante

Example: Stuttgarter Straßenbahn

Example: Stuttgarter Straßenbahn

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Track #	Max. Speed [km/h]	Duration [sec]	Number of Points	RMS east [cm]	RMS north [cm]	RMS height [cm]
1	50	335	11	2.4	1.7	1.0
2	50	361	12	2.7	1.6	2.6
3	20	762	12	2.6	1.2	2.3
4	20	666	12	2.2	1.2	1.3

Conclusion

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- The use of GCP measurements directly inside the GNSS/IMU navigation process leads to an optimal utilization of the information.
- The improvements are usable for all georeferenced sensors, like optical or thermal cameras.
- It minimizes the required number of (expensive) points to a minimum and it extends the usability of GNNS/IMU based Mobile Mapping Systems to long tunnels and tunnel-systems.