One step mobile mapping laser and camera data orientation and calibration

E. Angelats, I. Colomina

Centre Tecnològic Telecomunicacions Catalunya (CTTC)

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Agenda

- Introduction
- Proposed approach
- Modelling
- Concept validation
- Conclusions
- Further research

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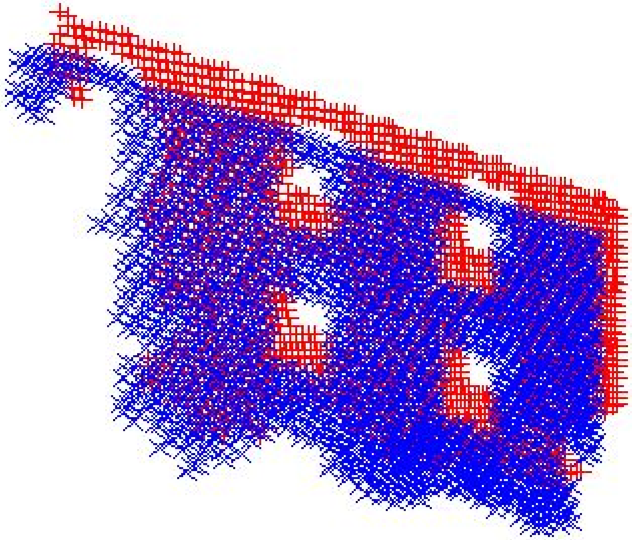
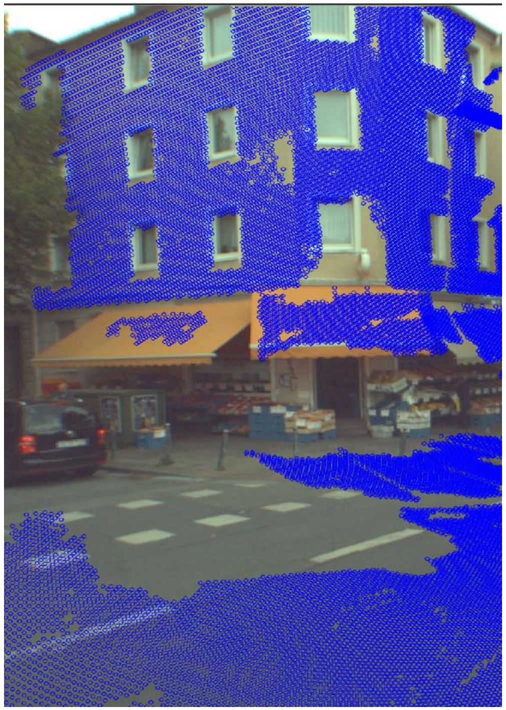
Introduction





Introduction

- Standard approach includes several steps: system calibration, point cloud generation and laser to laser and camera to laser co-registration.
- The platform trajectory is estimated using INS, DGNSS and odometer observations, in a tight coupling scheme, using Kalman Filter.
- The trajectory is post-processed using forward, backward and smoothing.

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Proposed approach

- A single network adjustment (**one step)** to solve **orientation** and **calibration** of laser and camera data, is proposed
- Same idea succesfully applied fo co-registration of airborne laser scanner and photogrammetric data.

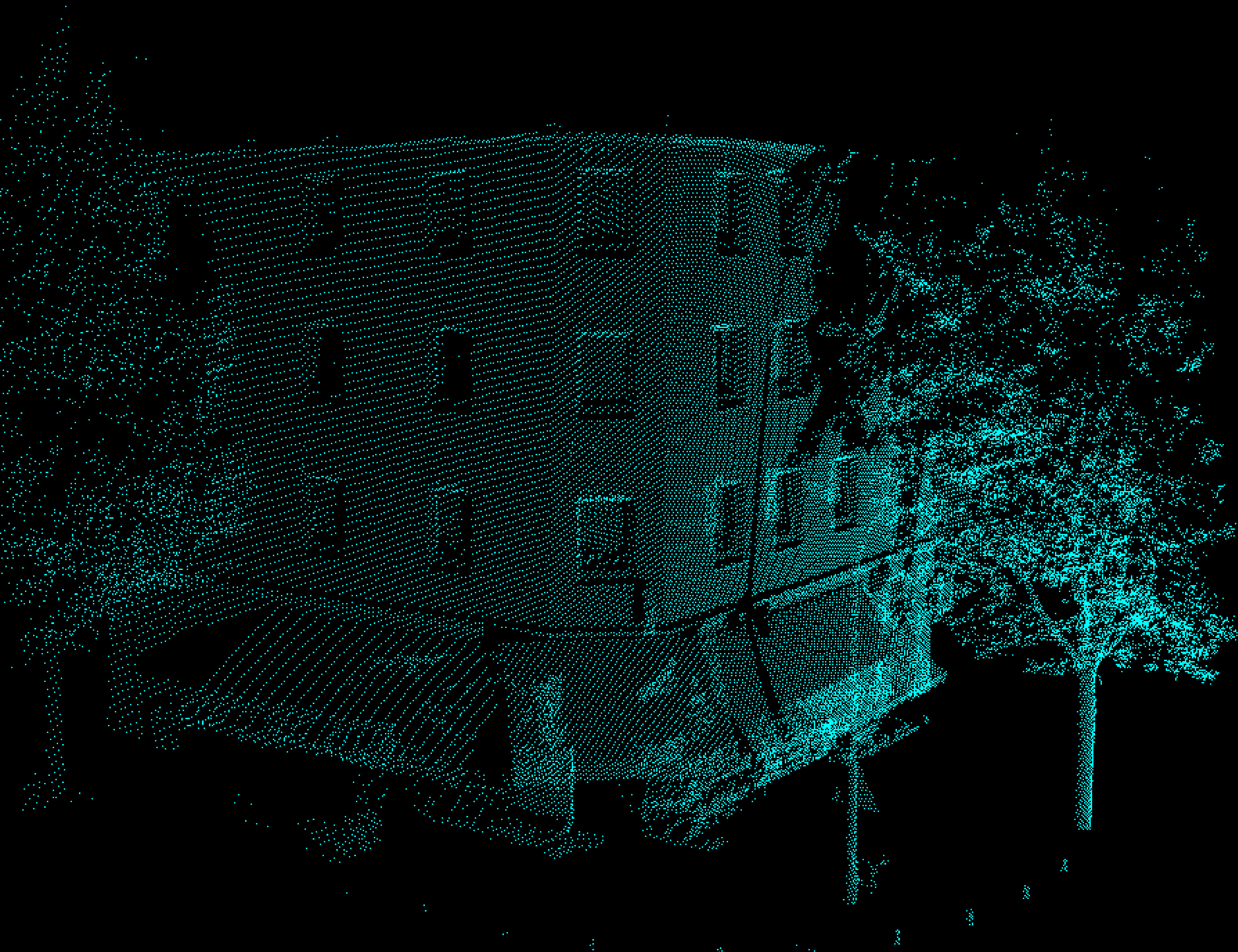
Angelats, E., Blázquez, M. and Colomina, I., 2012. *"Simultaneous orientation and calibration of images and laser point clouds with straight segments"*. In: International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 39(B1), Melbourne, Australia, pp. 91–96.

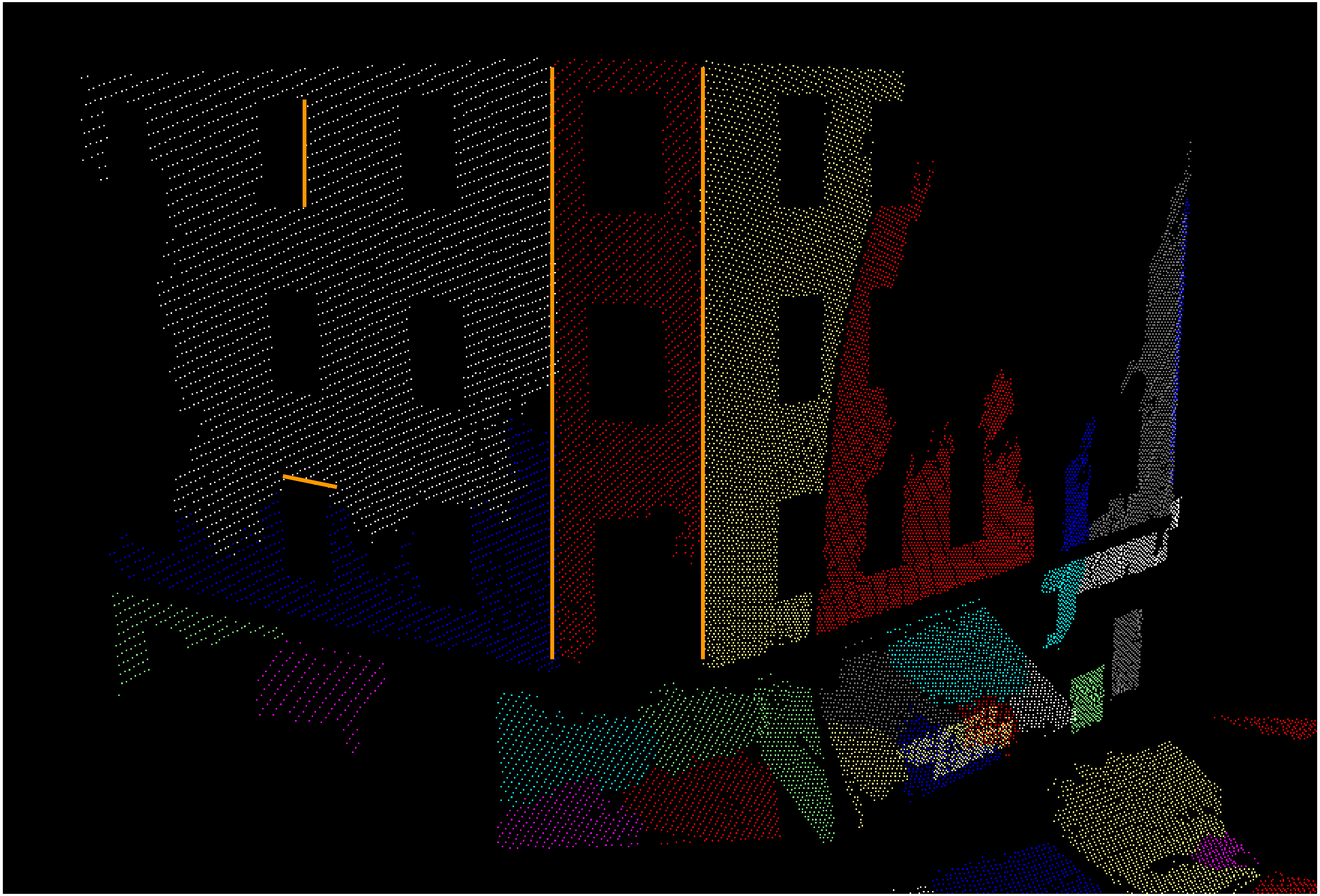
- Is the approach still valid for mobile mapping data
- … and the modelling

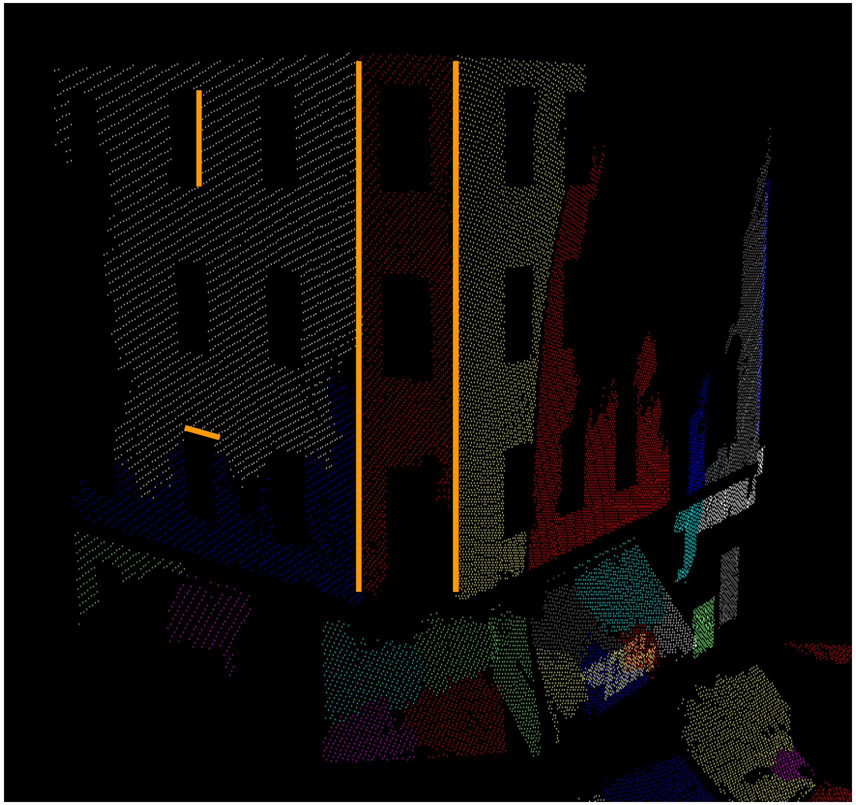
Proposed approach

Benefits:

- Co-registration, implicity solved.
- The use of laser and photogrammetric measurements, allows to avoid point cloud based camera to LiDAR registration.
- The redundancy of the adjustment is increased and the geometry improved.
- Overall accuracy can also be improved adding photogrammetric and LiDAR ground control information.







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Proposed approach

	Observations	Tie features	Parameters
Camera ISO	Image coordinates (cam images) Ground control points (GCP) Platform time-position-attitude (tPA)	Points (TP)	TP parameters Exterior orientation (EOs) Self-calibration parameters tPA linear shift
Laser ISO	Range and scan-angle (MMS scenes) Platform tPA	Planes (TPL)	TPL parameters MMS self-calibration tPA linear shift
Cam-laser ISO		Lines (TL)	TL parameters

Modelling

Camera point collinearity

- Relates the camera image coordinate observations with the EO, tie point and self-calibration parameters.

Camera line coplanarity

- Relates the parameters of a 3D line, the EO parameters of an image, and the image observations (x; y) of a point of the line.

MMS plane

- Enforces a laser point to belong to a planar surface through a direct georeferencing implicit step.

Line-in-plane

- Relates the camera tie lines and the MMS tie planes.

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Concept validation

- An experimental "model toolbox" with the models discussed before was developed at CTTC that runs on the Geonumerics' generic network (bundle) adjustment platform GENA (Colomina et al., 2012).

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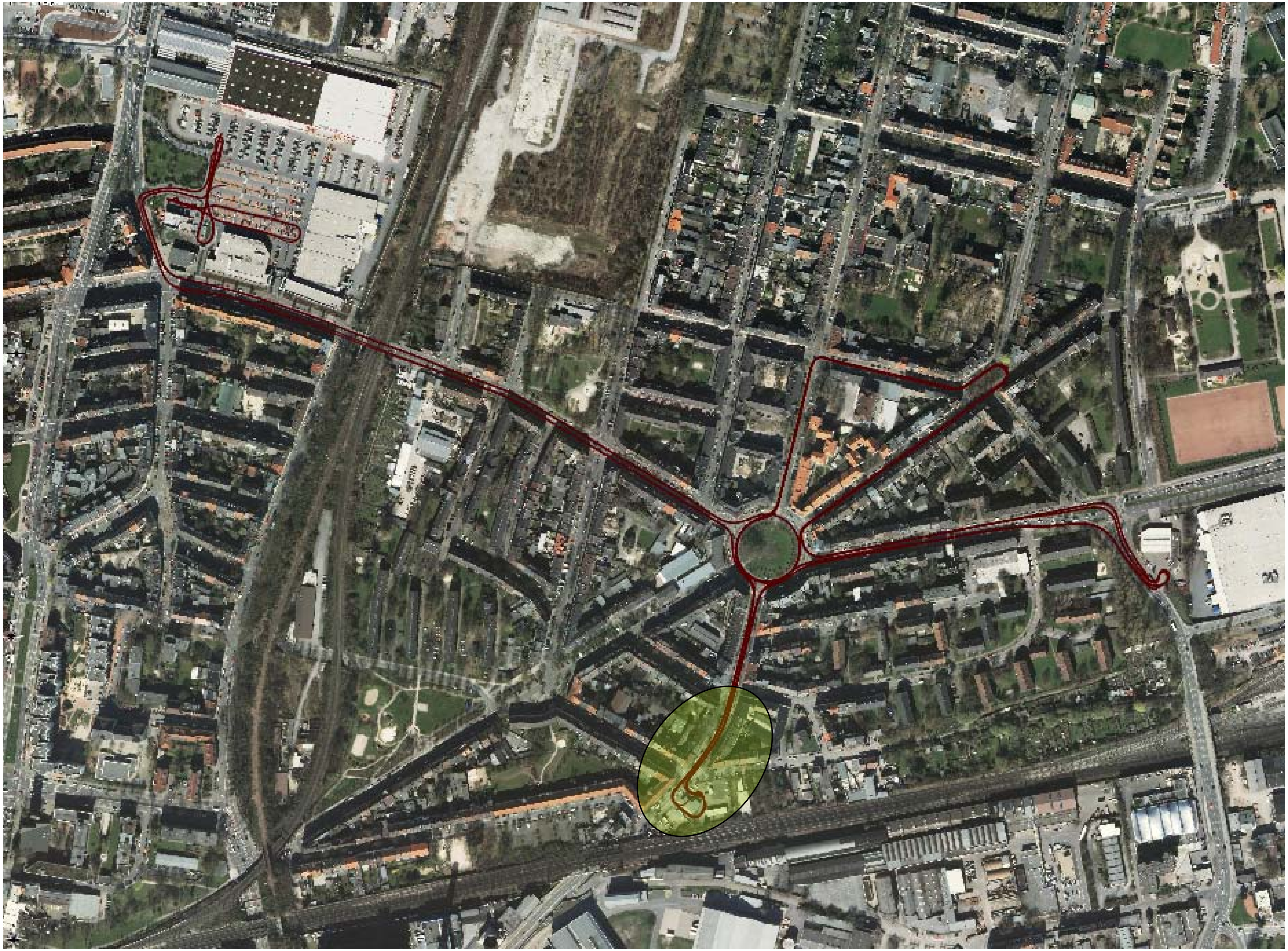
Concept validation

- The proposed concept was tested and validated using real data from a high-end mobile mapping campaign in Dortmund (Germany).

System: 2 laser scanners and 2 cameras	Optech LYNX with
Measurement frequency:	100 kHz each
Pulses (echos): (1st, 2nd, 3rd and last)	Up to 4 simultaneously
Field of view:	360
Range:	Up to 100 m
Distance between spots:	Up to 1 cm at 100 km/h
Measurement accuracy: (standard deviation)	Up to 0.7 cm
Absolute accuracy: (standard deviation)	Up to 5 cm
Eye safety:	IEC/CDRH Class 1

(provided by TopScan GmbH.)



Concept validation

Dortmund test configuration

Camera sub-block	
Equipment	Optech Lynx camera Applanix POS LV420
Image size	5.684 x 4.326 mm
Pixel size	3.5 μm
Camera constant (f)	3.866 mm
No. of strips	1
No. of images	4
No. of ground control points (GCPs)	1
No. of tie points (TPs)	37
No. of tie lines (TLs)	4
Horizontal Overlap ≈	60%

MMS sub-block	
Equipment	Optech Lynx laser Applanix POS LV420
Density (points/m^2) (≈)	NA
No. of strips	3
No. of control planes (GCPLs)	4
No. of tie planes (TPLs)	12
Average no. of points per plane	1700
No. of tie lines (TLs)	2

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Concept validation

Tests configuration

Test	camera ic	GCPs	TPs	camera TLs	MMS rs	TPLs	GCPLs	MMS TLs
cam_TP	YES	1	YES	NO	NO	NO	NO	NO
cam_TL	YES	1	YES	YES	NO	NO	NO	NO
MMS	NO	0	NO	NO	YES	YES	YES	NO
ALL	YES	1	YES	YES	YES	YES	YES	YES

ic: camera image coordinates.
rs: MMS range and scan angle.

Concept validation

Precision of observations

Observable	Precision (σ)	Units
Camera ic of TPs	$\sigma_{x,y} = 7$	μm
Camera ic of TLs	$\sigma_{x,y} = 10$	μm
GCPs	$\sigma_{e,n} = 3,\ \sigma_u = 5$	cm
Camera EO position	$\sigma_{e,n,h} = 20$	cm
Camera EO attitude	$\sigma_{\omega,\kappa} = 100,\ \sigma_\varphi = 200$	mdeg
MSS tPA position	$\sigma_{e,n} = 15,\ \sigma_u = 15$	cm
MMS tPA attitude	$\sigma_{pi,ro} = 5,\ \sigma_{he} = 8$	mdeg
MMS range	$\sigma_r = 0.05$	cm
MMS scan angle	$\sigma_\theta = 250$	μdeg

ic: image coordinates

Concept validation

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Estimated parameters

	camera					MMS	
Test	EOs	TPs	BC	Shift	TLs	$(\Delta r, \Delta\theta, S_\theta)$	TPLs
cam_TP	YES	YES	NO	NO	NO	NO	NO
cam_TL	YES	YES	NO	NO	YES	NO	NO
MMS	NO	NO	NO	YES	NO	NO	YES
ALL	YES	YES	YES	YES	YES	NO	YES

BC: IMU-to-camera boresight matrix calibration.

Shift: tPA linear shift.

Concept validation

Camera results

	RMSE TP (mm)			EO (mm, mdeg)					
Test	e	n	u	e	n	u	ω	ϕ	κ
cam_TP	48.8	220.0	58.7	45.8	66.8	57.4	44.4	89.3	44.2
cam_TL	47.5	211.7	57.8	45.2	66.4	57.3	43.3	87.1	43.4
MMS	-	-	-	-	-	-	-	-	-
ALL	47.6	211.9	57.8	45.0	66.4	57.3	43.5	87.0	43.2

Concept validation

LiDAR results

Test	Strip	Estimated Shift (mm)			C_{xx} (mm)		
		e	n	u	e	n	u
MMS	1	4.1	-3.0	92.8	1.9	1.1	164.6
	2	-280.2	559.4	410.3	2.4	1.3	164.6
	3	-56.7	159.6	277.0	2.0	1.2	164.6
ALL	1	4.8	-2.8	311.9	1.9	1.2	162.6
	2	-281.7	559.5	629.3	2.4	1.3	162.6
	3	-56.4	159.6	495.3	2.0	1.25	162.6

Concept validation

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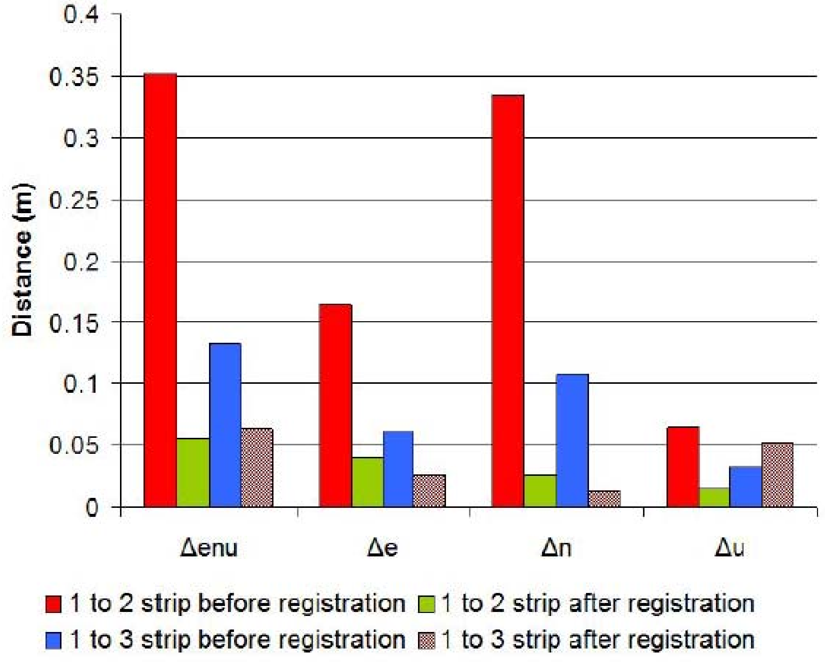
Point cloud comparison



Results obtained using CloudCompare SW, (Giradeau-Montaut, 2014)

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Conclusions

- A method where camera and MMS ISO were performed in one step has been presented.

- Points (camera), planes (MMS) and lines (camera-MMS) are used as tie features.

- Photogrammetry results show that with this combined camera, MMS, and camera-MMS, concept, the performance in terms of precision, is at least maintained.

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Conclusions

- The platform trajectory can be improved with a linear shift.
- With this trajectory improvement, the co-registration between overlapping point clouds, is improved.
- With this approach, a single or several camera and laser data from different or same systems, can be integrated and so, co-registered.

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Further research

- Validate the concept with a larger data set.
- Explore additional models than linear shift for trajectory error modelling.
- Not only the precision, but also the accuracy of the one step approach, must be measured.
- Required number of GCP and planes, to explore if this number can be reduced due to one step approach.

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Thank you for your attention!!