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Verification and improving planimetric accuracy of ALS with using photogrammetric data

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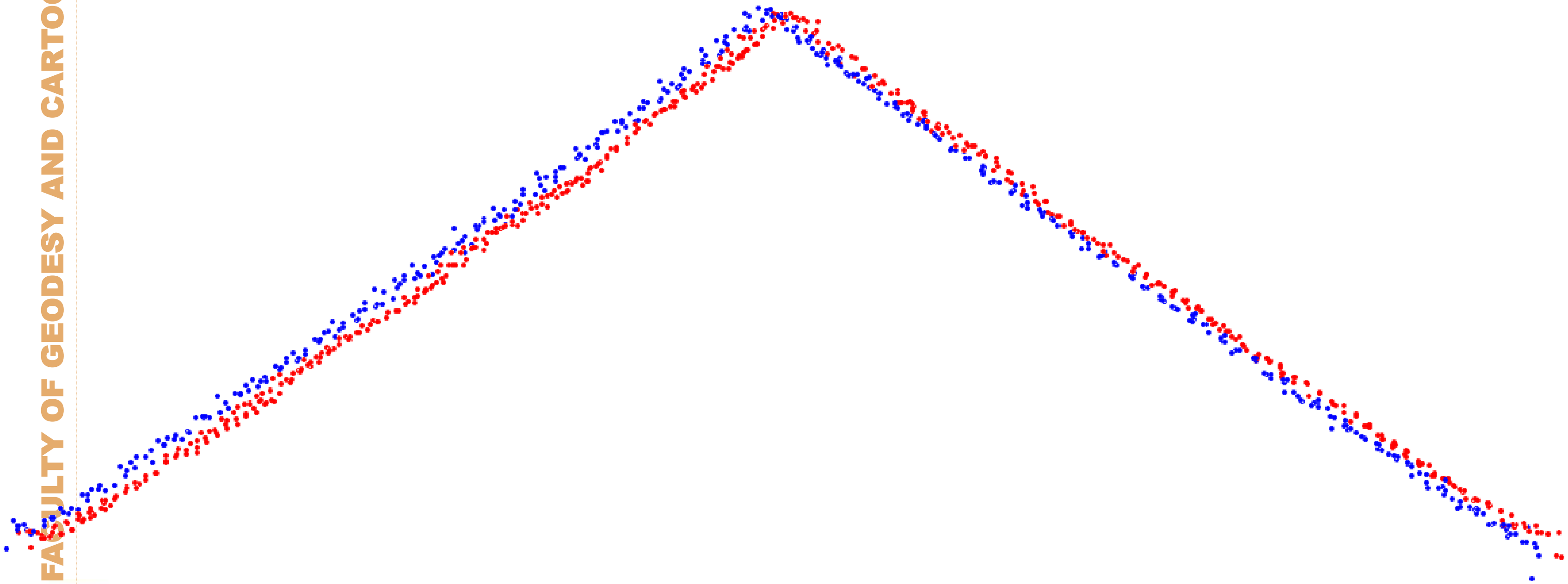
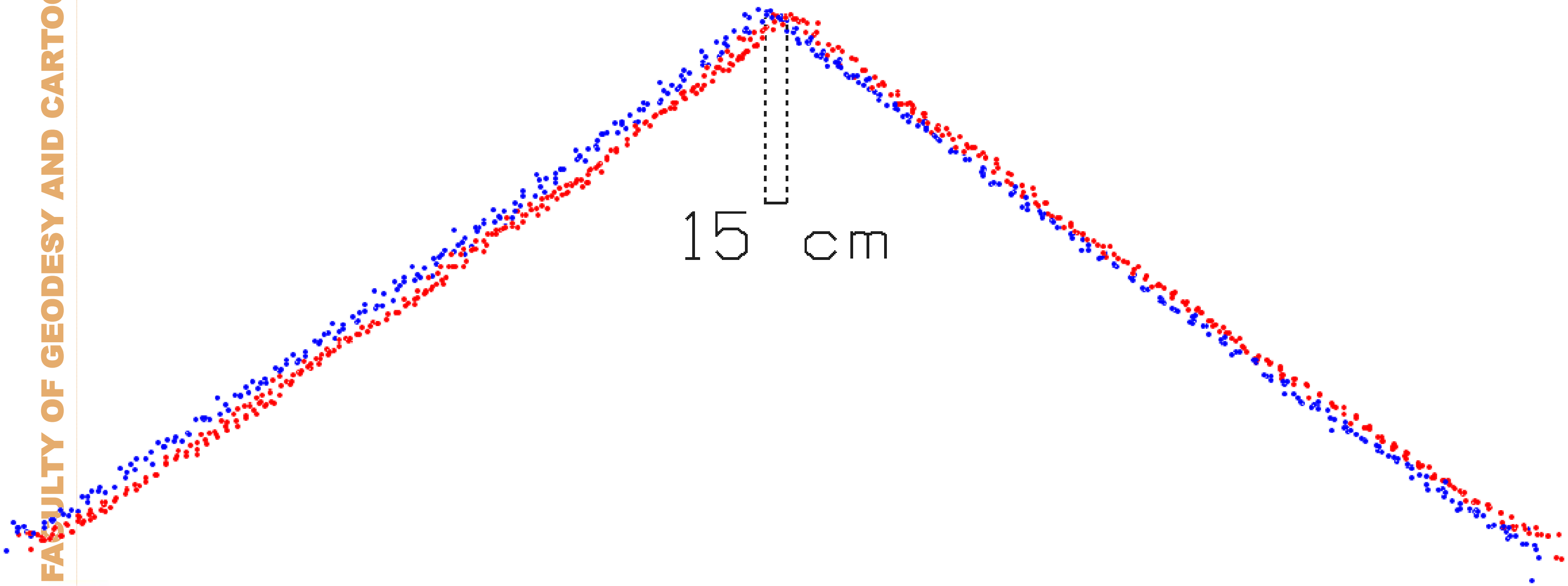
- Sometimes the final product looks like this



Is there anything more we can do?

- Sometimes the final product looks like this



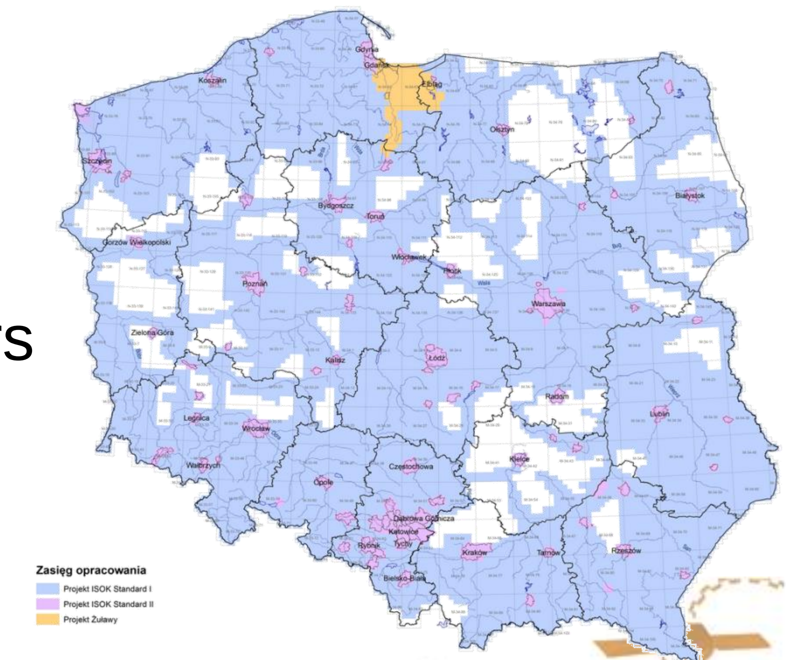
Is there anything more we can do?

Agenda

- Genesis of the problem – ALS in Poland
- ALS data georeference – problem of plannimetric accuracy
- Experiments
  - Data used
  - Methods
  - Results
- Conclusion

ISOK – airborne laser scanning in Poland

- **ISOK** – IT System for Country Protection against extraordinary hazards
- Purpose – Flood Directive
- Range of 80% of Poland
  255 000 km^2
- Extremely short time – 3 years
- Products:
  - DTM (1 m)
  - DSM (0.5 or 1 m)
  - classified, coloured point cloud



ISOK – airborne laser scanning in Poland

- Products accuracy

Standard	Density	Area	Absolute accuracy tolerances
I	4 p. / m^2	182 403 km^2	Z RMS < 0.15 m **XY RMS < 0.5 m**
	6 p. / m^2	8 148 km^2	
II (94 cities)	12 p. / m^2	13 769 km^2	Z RMS < 0.10 m **XY RMS < 0.4 m**

ISOK – perspective of ISOK products application

- Typical application of ALS is elevation models usage
  - DTMs are applied in country-wide system of hydraulic modelling (1D and 2D)
  - Huge interest of archeologists, geomorphologist – 30% Poland is covered by forests
- Country-wide project of 3D city modelling seems to be next task.

ISOK – perspective of ISOK products application

- In many other application higher planimetric accuracy is required – not only vertical is a priority
- Is broader application of ALS is possible?
- If the absolute planimetric accuracy would be improved, can ALS be used in surveying applications such as 3D cadaster, automatic extraction many object measured by surveyours in various databases creation/menagement?

ALS - georeferencing

- GPS/IMU postprocessing gives the trajectory and orientation of the scanner
- tie object (planes, points) between individual strips are found
- Adjustment based on tie objects gives corrections to the trajectories of individual strips
- Transformation to local projected coordinate system

ALS - georeferencing

- Additional steps to enhance the absolute accuracy of the entire block:
  - Control planes
  - Control points
- Typical planimetric accuracy possibilities
  - Relative accuracy 2-3 cm
  - Absolute accuracy 10-15 cm

ALS – problem of planimmetric accuracy

- Is there a possibility to improve locally the absolute planimetric accuracy of ALS data?
- A few methods were already tried:
  - GPS RTK measurement of features identified on ALS intensity image (Toth *et al*. 2007)
  - Specially designed targets (Csanyi & Toth 2007)
  - Back projection of linear features from ALS data to stereo images (Schenk *et al.* 2001)
  - Digitization of road markings on orthoimage (Ray & Graham 2008)
- Would new types of photogrammetric products based on dense image matching be good as reference data?

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Experiments

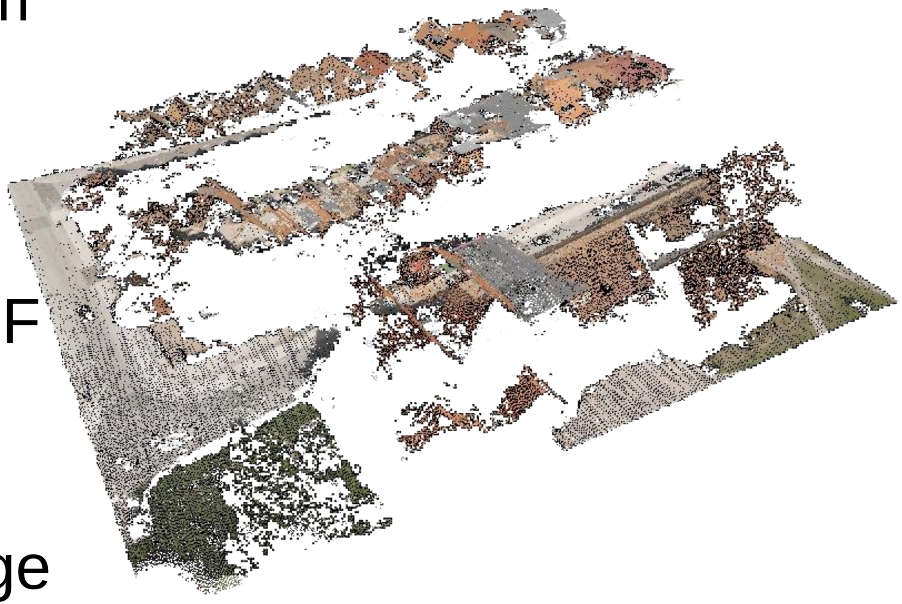
- Reference data
- Data tested
- 1st method description
- 2nd method description
- Results
- Methods comparison
- Methods assessment

Experiments – reference data

- flight missions involving the whole city of Elbląg, Poland in March 2011
- As a test area for the experiments a fragment of block (approximately 0.5 km^2)
- Aerial images acquired by Intergraph DMC II 230
- 80% overlap and 40% sidelap
- 5 cm GSD.
- A block of 2243 images was adjusted with the use of 86 GCPs
- RMSE of 2.9 cm (X (E)), 3.8 cm (Y (N)), 4.5 cm (Z) estimated on the basis of 96 check points

Experiments – reference data

- Point clouds resulting from Semi-Global Matching algorithm were used as reference
- SURE application from IPF Stuttgart was used (Rothermel et al., 2012)
- Point clouds from 18 image pairs were generated covering the test field



Experiments – reference data

- The coloured point cloud resulting from Semi-Global Matching visualized orthogonally gives a true-ortho with obscured areas visible

„SGM true-ortho”

Experiments – reference data

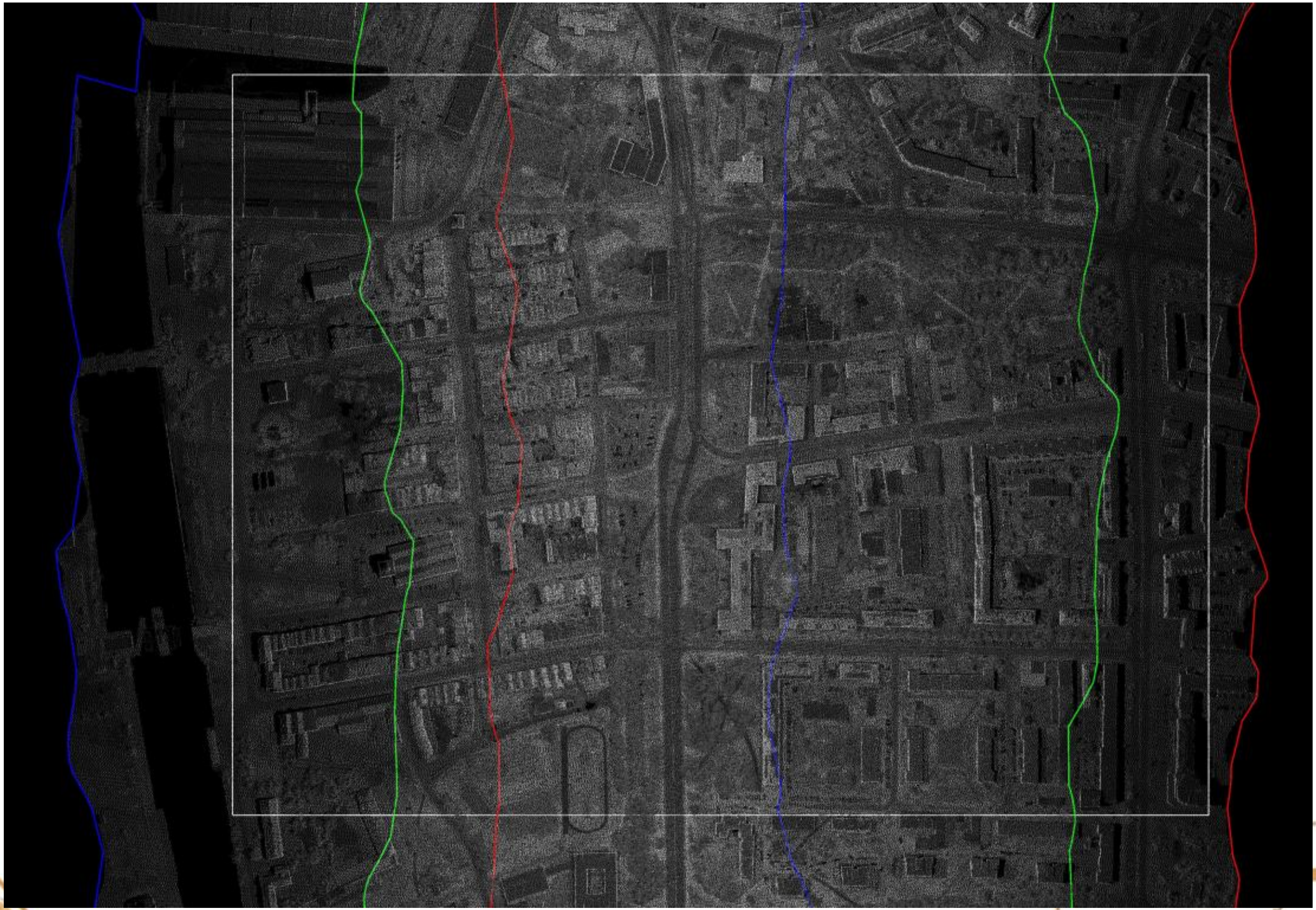
The absolute accuracy of the „SGM true-ortho” mosaic was verified using 21 check points

Parameter	X (Easting) [m]	Y (Northing) [m]
average residual	-0.001	0.014
RMSE	0.038	0.034
STD	0.038	0.031

Experiments – data tested

- LIDAR data was acquired with Riegl LMS-Q680i
- 70 strips – parts of 3 were tested
- average density of point cloud - 10 pt./m^2
- roofs of buildings in 5 locations as the reference planes; in each location two roof planes oriented perpendicularly were surveyed
- global shift of 4.4 cm (X), 6.0 cm (Y) and 2.8 cm (Z)

- intensity images with resolution of 15 cm generated
- 3D city model (LoD2) prepared automatically



Experiments – 1st method Intensity-based

- based on measurement of corresponding points on true-ortho and intensity of ALS reflection
- points mostly associated with road markings, manholes and pavements surface - high contrast on intensity images (ground points)
- middles of lines and centres of visible small pavement figures were frequently a subject of manual measurement
- huge redudancy guaranting well true value of error estimation - 550 points measured totally

Experiments – 1st method Intensity-based

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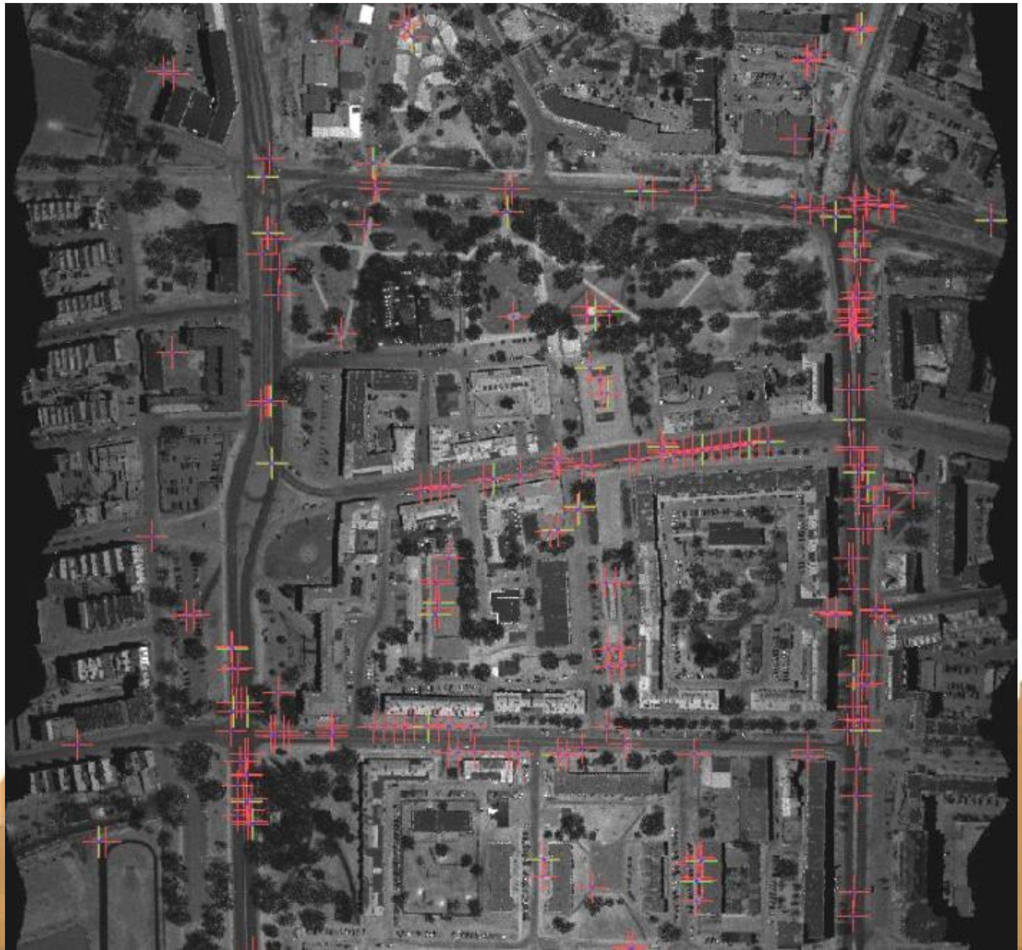
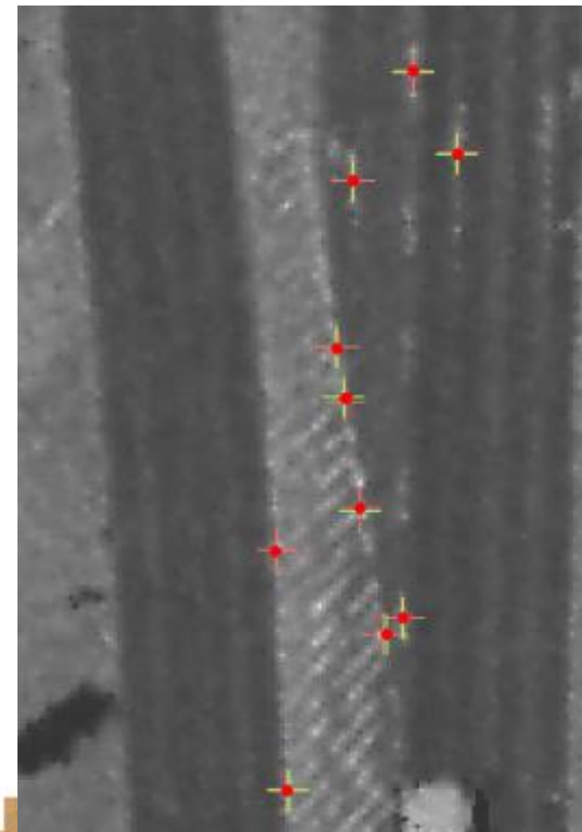
Spatial distribution of points measured on intensity image and true-ortho



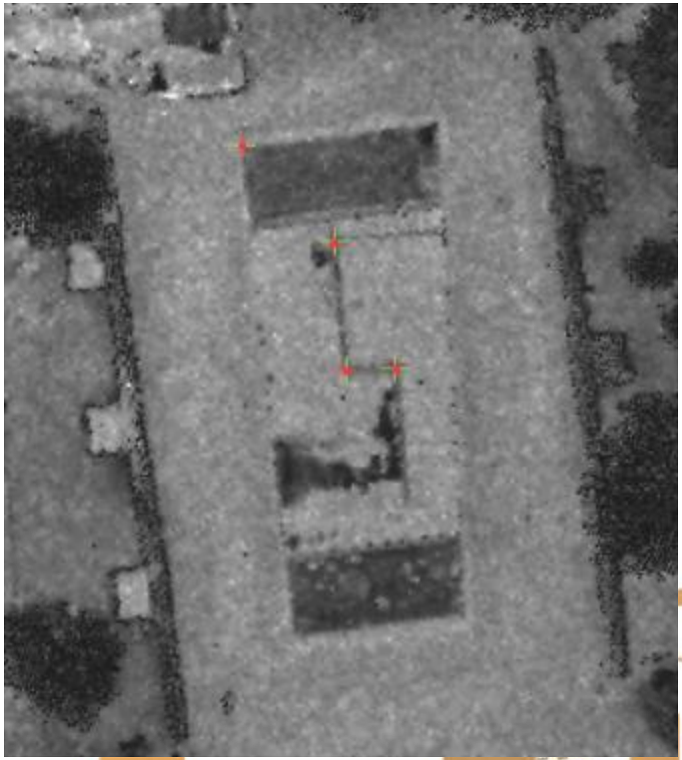
Experiments – 1st method Intensity-based

Examples of points measured on intensity image and true-ortho



Experiments – 1st method Intensity-based

Examples of points measured on intensity image and true-ortho



Experiments – 2nd method Ridge-based

- Building models were generated automatically from ALS data (Terrascan vectorize buildings function)
- Roof ridges were vectorized independantly on the base of „SGM true-ortho”
- Normal distances between roof ridges resulting from two sources were measured
- About 100 roof ridges for each strip were used (totally 323 roof ridges)
- The translation vectors between ALS and true-ortho roof ridges were found for each strip

Experiments – 2nd method Ridge-based

Examples of automatically generated 3D models of buildings with true-ortho from aerial images in a background.

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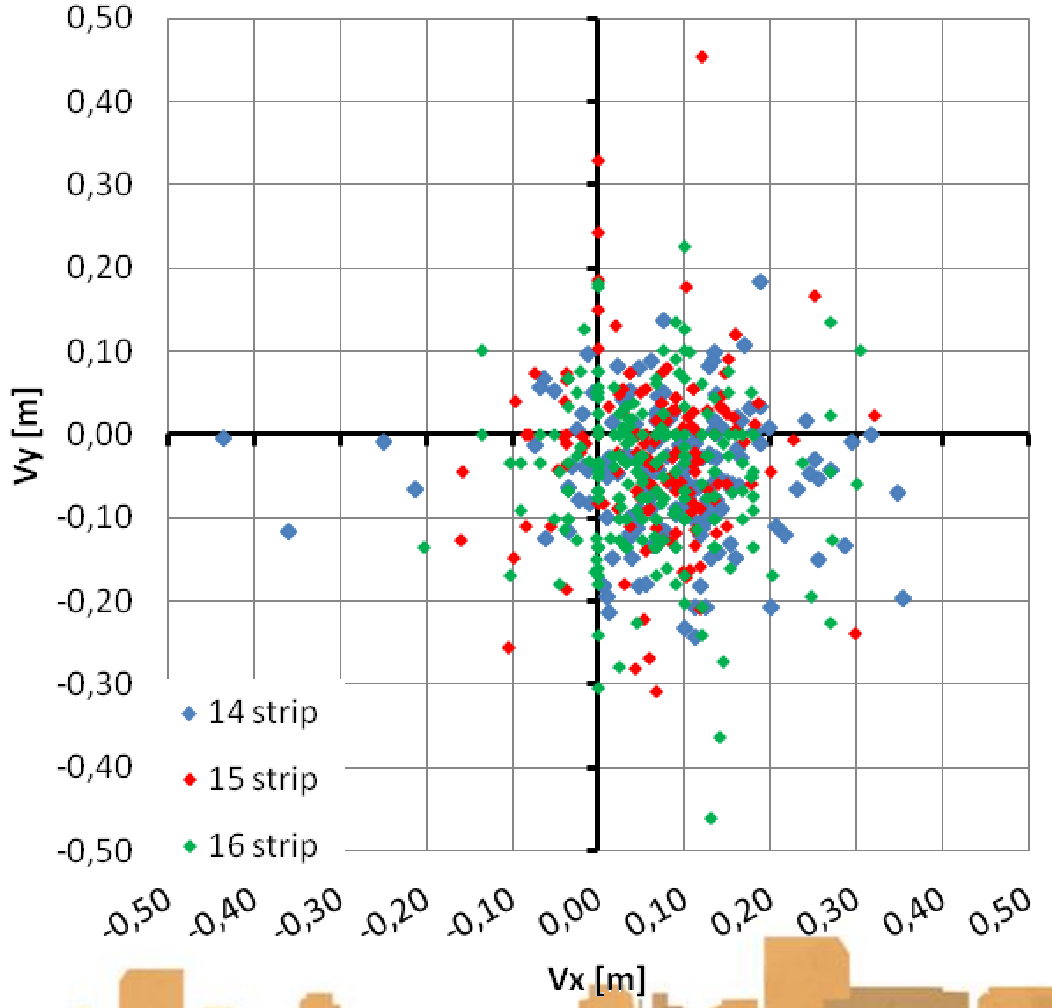
Experiments – 2nd method Ridge-based

- Examples of automatically generated 3D models of buildings with true-ortho from aerial images in a background.

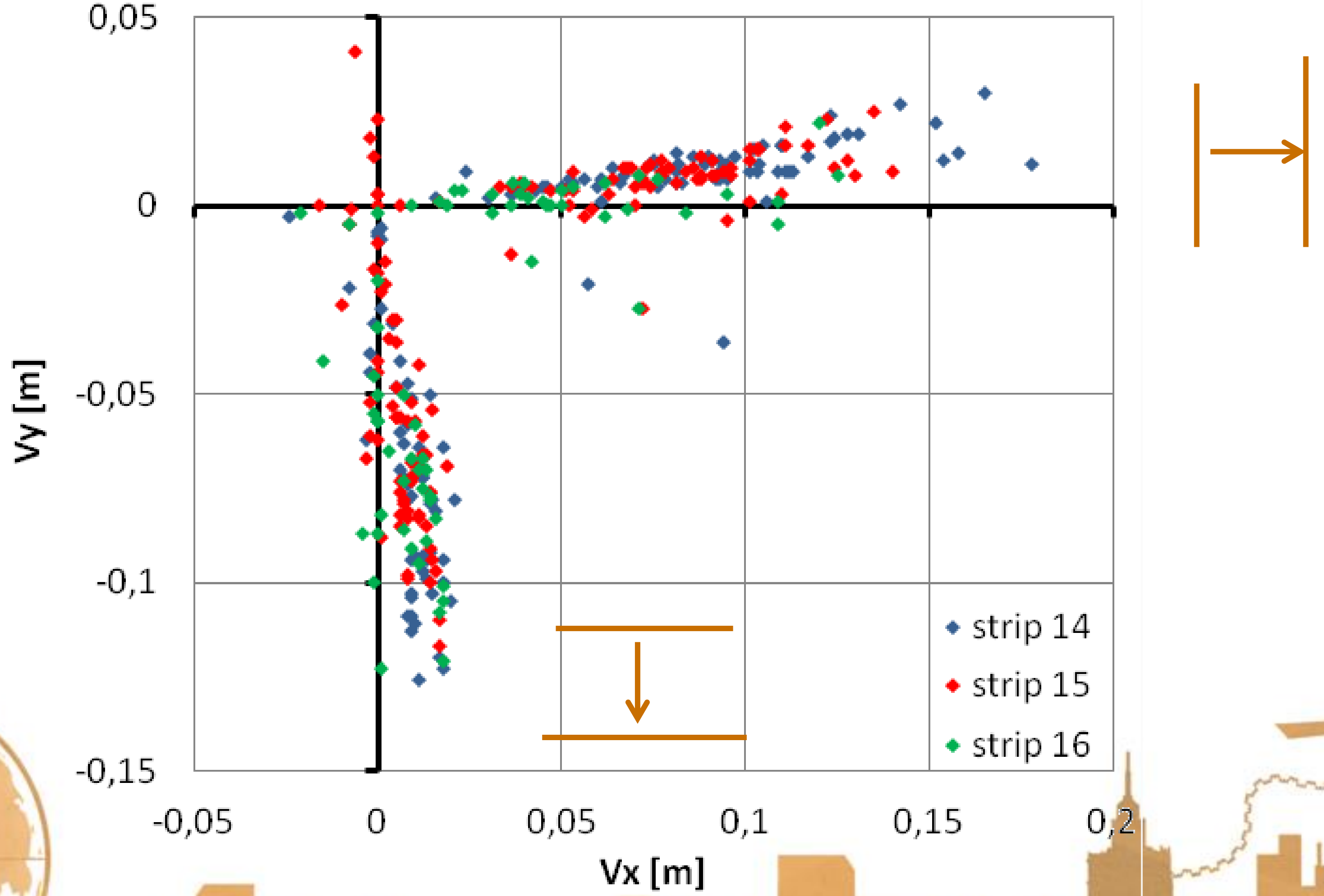
Experiments - results

- predicted planimetric absolute accuracy – few centimetres
- independence of two tested methods
  - different reference data (ground points, roof ridges)
  - different method of systematic error estimation
- estimated corrections can be implemented to the point cloud or products of its processing

Experiments – results of Intensity-based method



Experiments – results of Ridge-based method



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Experiments – methods comparison

Intensity-based method

Scanning strip	Parameter	X (m)	Y (m)
14 150 points	median	0.10	-0.05
	RMSE	0.14	0.09
15 150 points	median	0.07	-0.01
	RMSE	0.10	0.11
16 250 points	median	0.07	-0.05
	RMSE	0.08	0.08
all 3 strips 550 points	Median	**0.07**	**-0.04**
	RMSE	0.11	0.10

Ridge-based method

Scanning strip	Parameter	X (m)	Y (m)
14 126 ridges	Shift	0.09	-0.06
	RMSE	0.10	0.07
15 130 ridges	Shift	0.08	-0.05
	RMSE	0.09	0.06
16 67 ridges	Shift	0.05	-0.07
	RMSE	0.06	0.08
all 3 strips 323 ridges	Shift	**0.08**	**-0.06**
	RMSE	0.09	0.07

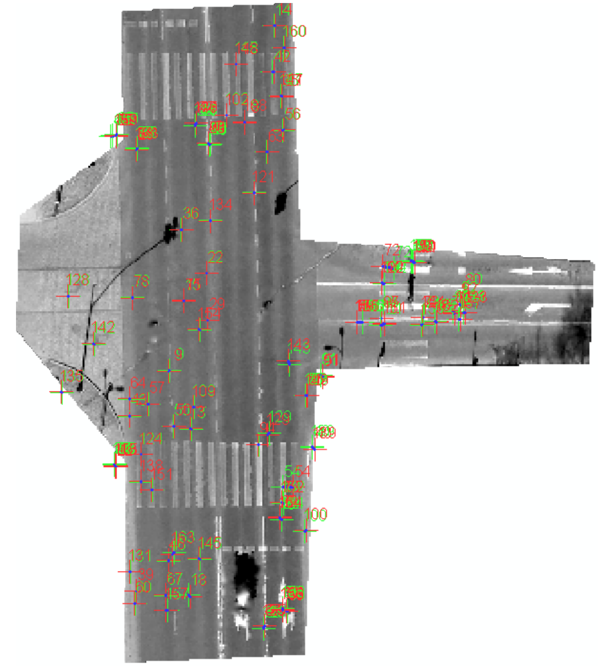
Experiments – methods assessment

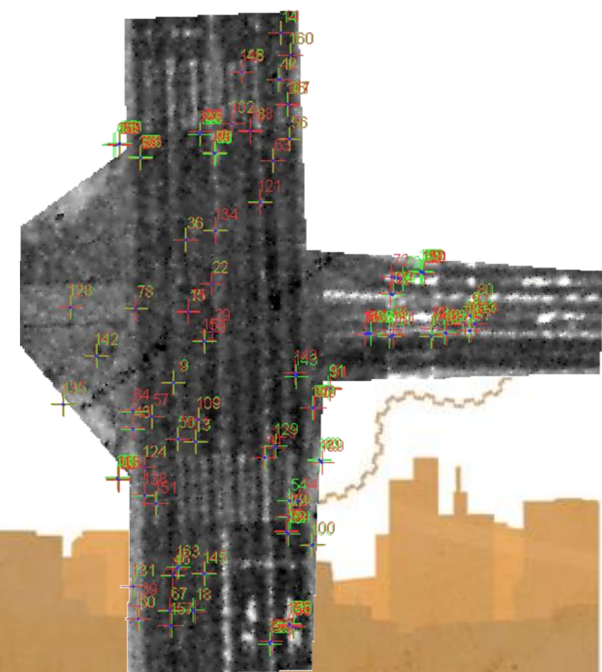
- Both methods resulted in similar values of planimetric error for the analyzed area.
- Statistical analysis indicates that method based on roof ridges of buildings was more accurate but also more labour-intensive and difficult to automate
- Both methods will ensure the best results for urban areas - suitable topography of the area is required:
  - an occurrence of the relevant details in the area (Intensity-based method)
  - an appropriate number of roof ridges oriented in different directions (Ridge-based method)

Conclusion

- Photogrammetric data (aerial images) used as reference data, allow calculating the planimetric error of LIDAR in few centimetre level
- Redundancy of observations gives the opportunity to find the expected value of the planimetric shift of ALS data without gross errors influence
- Detected errors seems to have sub-block character
- Effectiveness of methods can be only guaranteed by automatic techniques of corresponding features matching (points, lines)

- Area-Based matching algorithms, with true-ortho as reference, can be difficult due to different characteristics of both data source:
  - geometry of the data
  - source (spectral characteristics of reflactance)
  - flight mission (obscure areas, shadows distribution)
- Solution:
  - fragments with no obscure areas in small pieces subjected to matching procedure.





Future work

- larger and less fallible participation of automatic matching techniques
- larger test area to prove local distribution of planimetric corrections
- methods should be also tested on lower quality data and less urban test area

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Thank you for your attention

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