UNIVERSITY OF TWENTE.

POINT CLOUDS AND DERIVATIVES FOR NATIONWIDE GEOSPATIAL INFORMATION

GEORGE VOSSELMAN

ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

OVERVIEW

- Point cloud generation and quality control
- New lidar technologies
- Dense matching
- Updating nationwide point clouds
- 3D landscape and building modelling

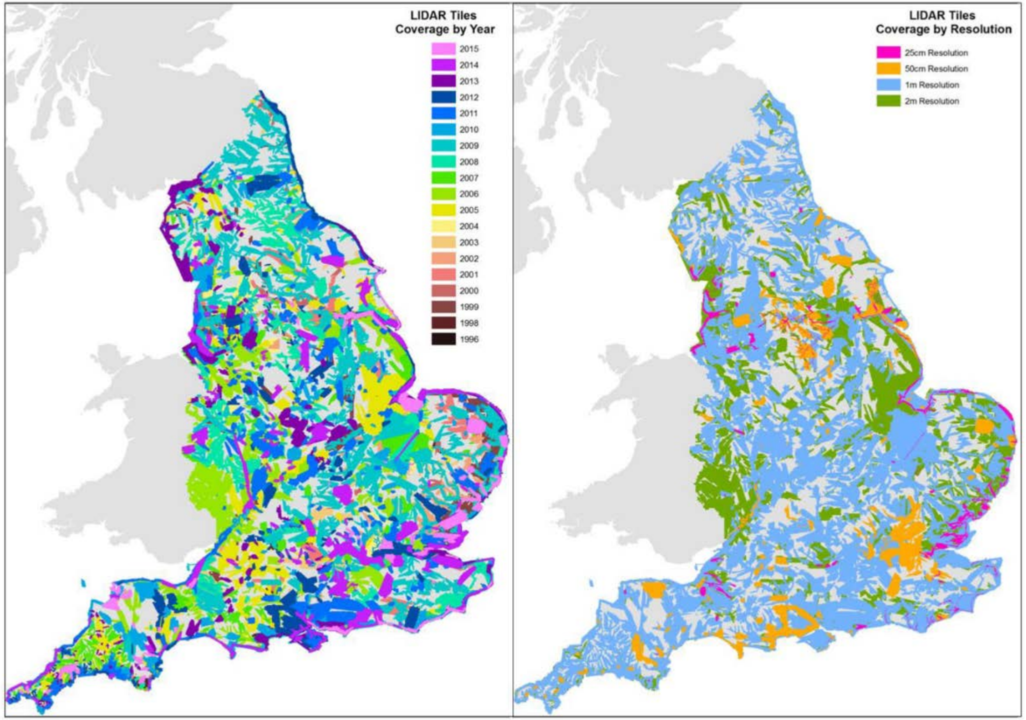
NATION WIDE POINT CLOUD ACQUISITION

Environmental Agency – complete England by 2020

Varying point densities

Height RMSE improving from <15 cm to <5 cm

Planimetric accuracy: altitude / 5500 (manufacturer specs)



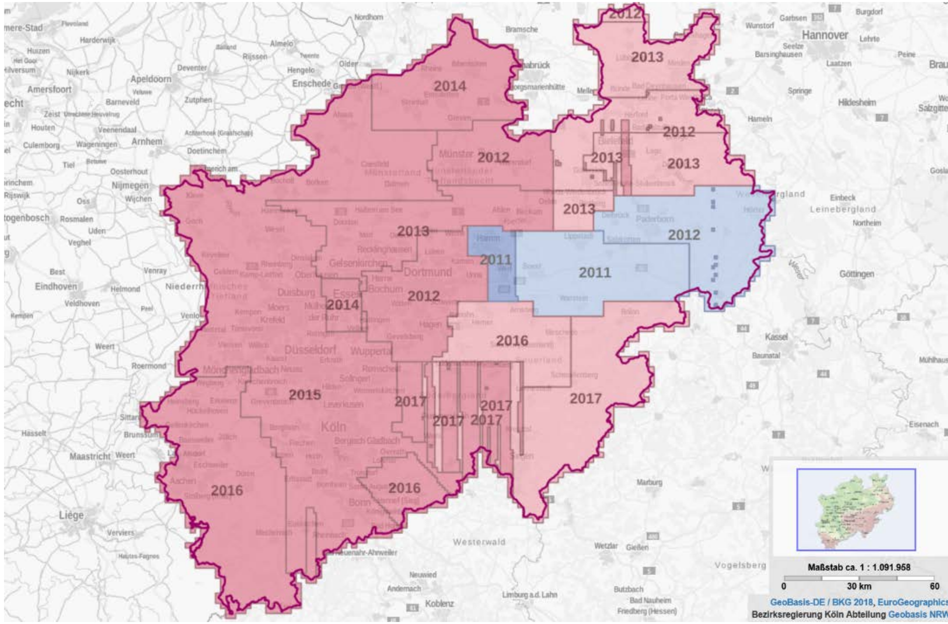
NATION WIDE POINT CLOUD ACQUISITION

State Survey of North Rhein Westphalia – complete state by 2018

Density > 4 points / m^2

Height RMSE < 20 cm

6 year update cycle



NATION WIDE POINT CLOUD ACQUISITION

Netherlands – complete third acquisition by 2019

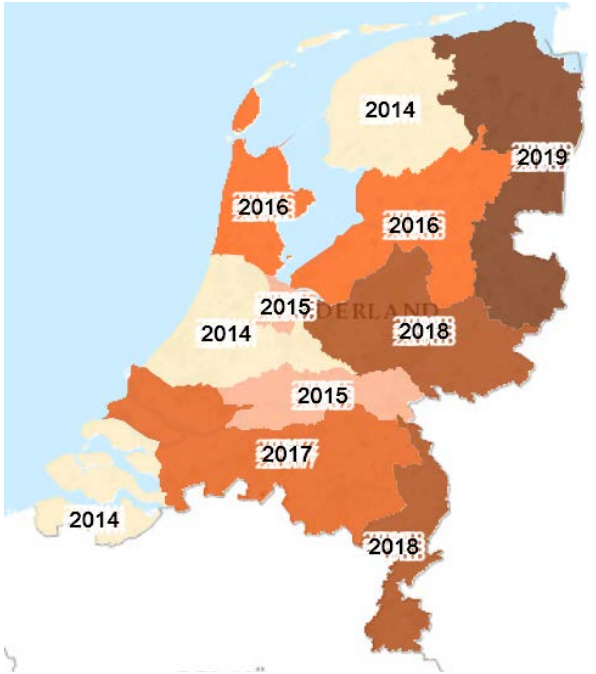
AHN1 (1997 – 2003)

- Density 1 point / 16 m^2
- Height noise < 15 cm, offset < 10 cm

AHN2 – 2007 - 2012

AHN3 – 2014 - 2019

- Density > 8 points / m^2
- Height noise < 5 cm, offset < 5 cm
- Planimetric error in object outlining < 50 cm



QUALITY CONTROL

Large data sets require automation

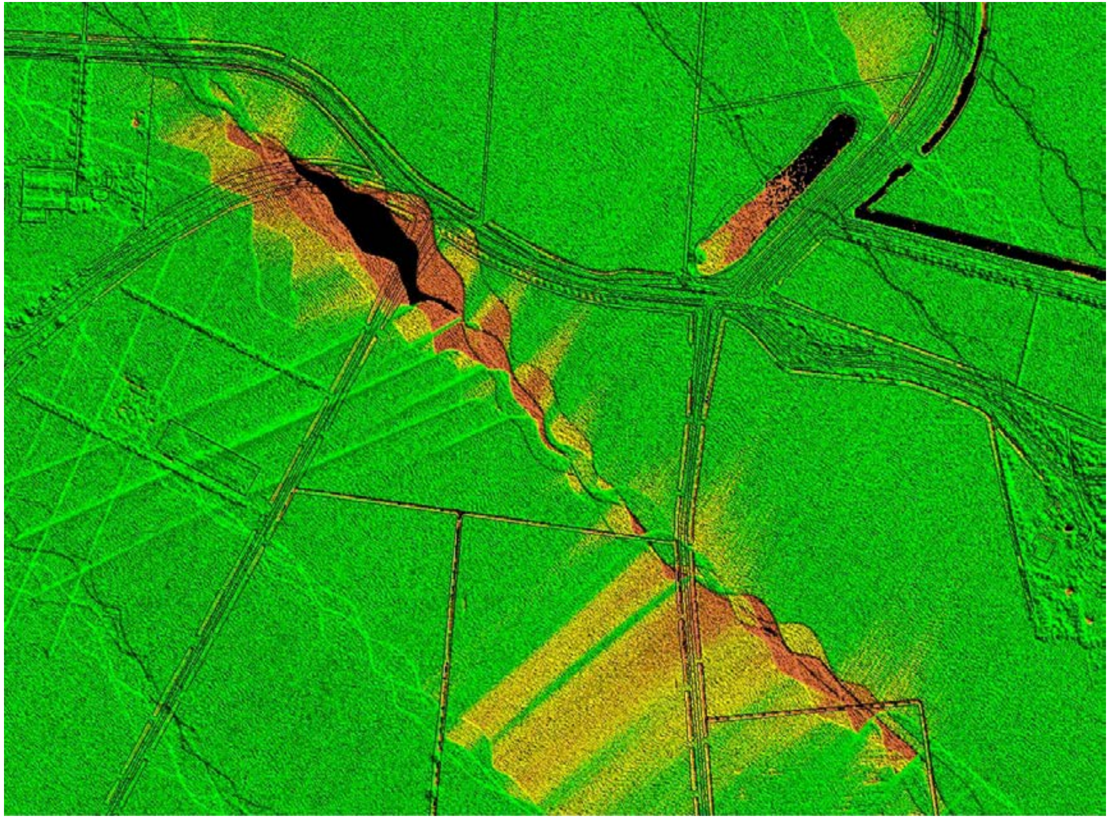
- Point density
- Relative accuracy: consistency of measurements in overlapping strips
  - Both for height and planimetry
  - Reliable statistics based on large numbers of measurements

Limited amount of reference data

Visual inspection (artefacts, filtering)

QUALITY CONTROL – POINT DENSITY

- > 6 points/m^2
- 5-6 points/m^2
- < 5 points/m^2

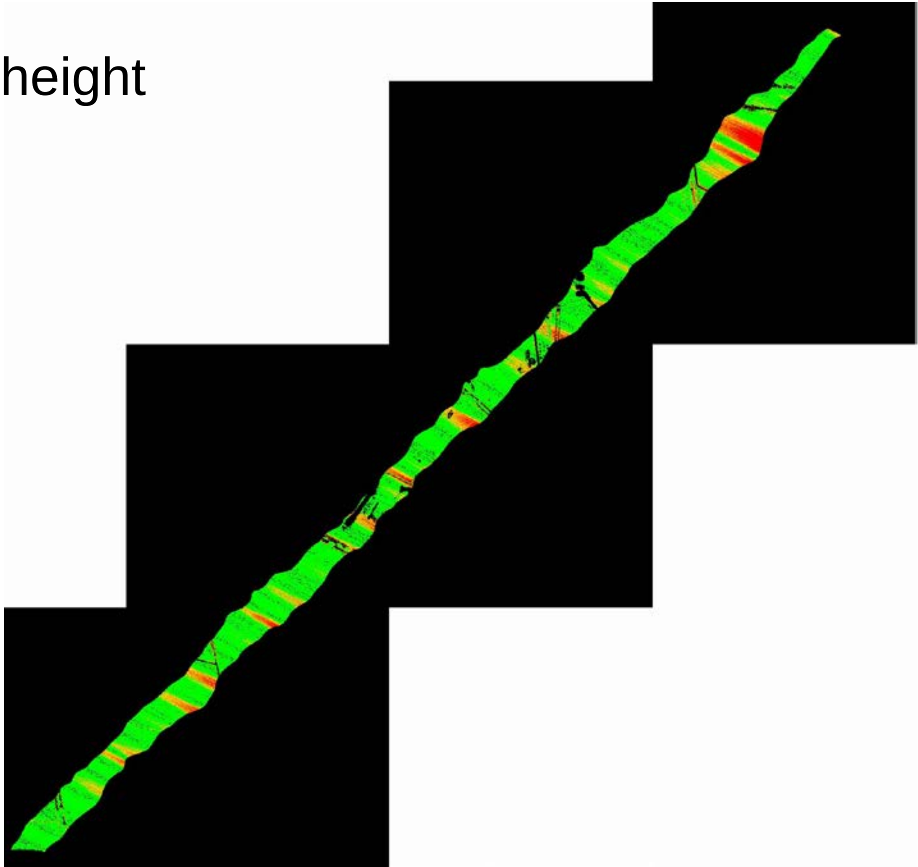


Exclude water surfaces

QUALITY CONTROL – RELATIVE HEIGHT

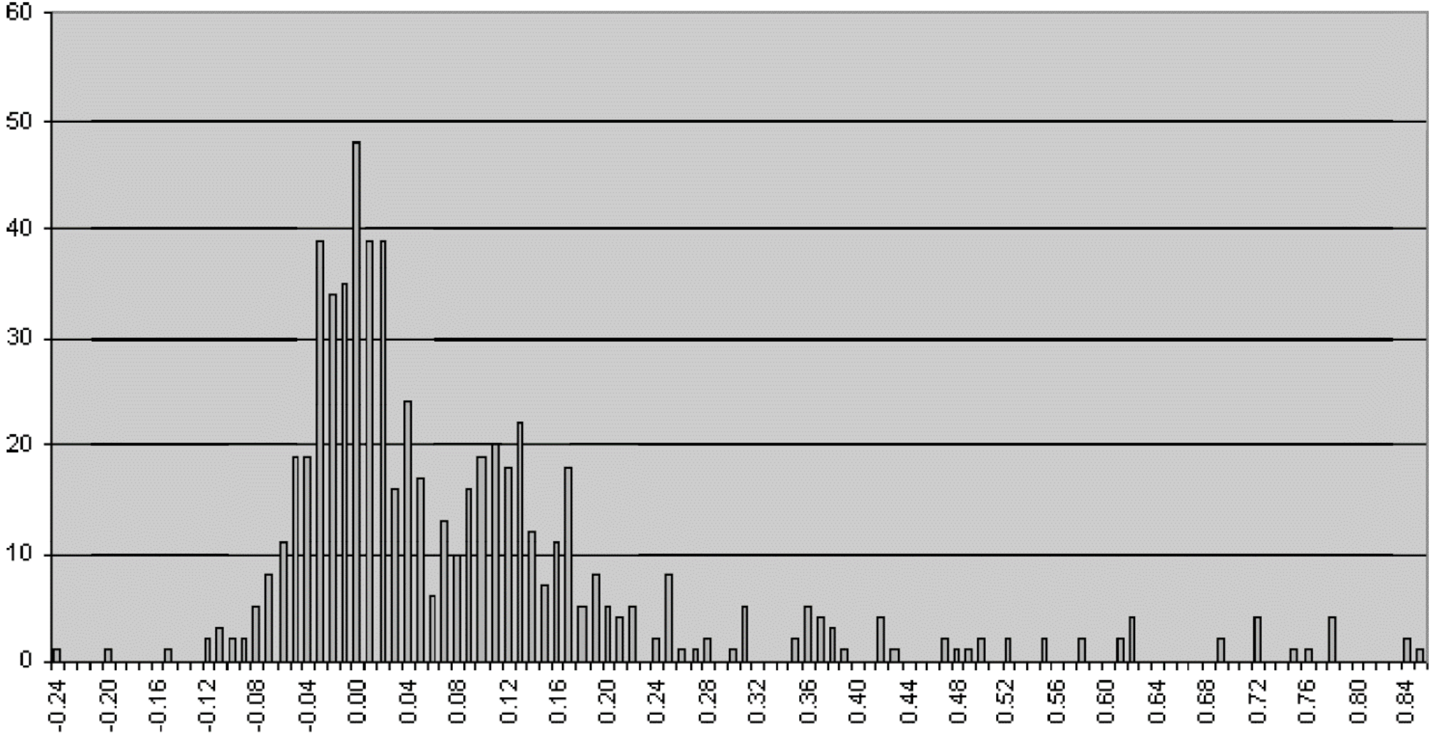
Selection of smooth surfaces for height comparisons in strip overlaps

Exclude large differences, e.g. caused by vegetation or vehicles



QUALITY CONTROL – ABSOLUTE HEIGHT

Comparison of point cloud heights against levelled manholes



QUALITY CONTROL – PLANIMETRIC ACCURACY

Requirement: An object of 2x2 m can be outlined in the point cloud with a maximum error of 50 cm.

Mapping accuracy determined by

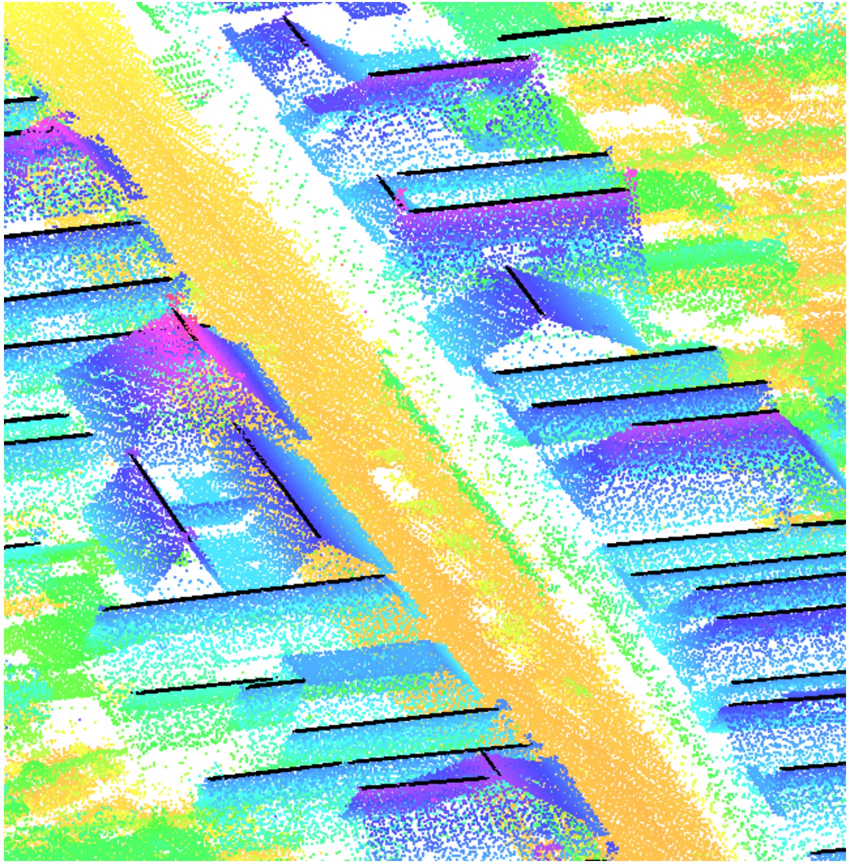
- Maximum outlining error caused by point spacing $\frac{1}{2\sqrt{n}}$
- Platform positioning noise (3σ confidence interval)
- Systematic errors

QUALITY CONTROL – RELATIVE PLANIMETRY

Check distances between ridge lines in strip overlaps

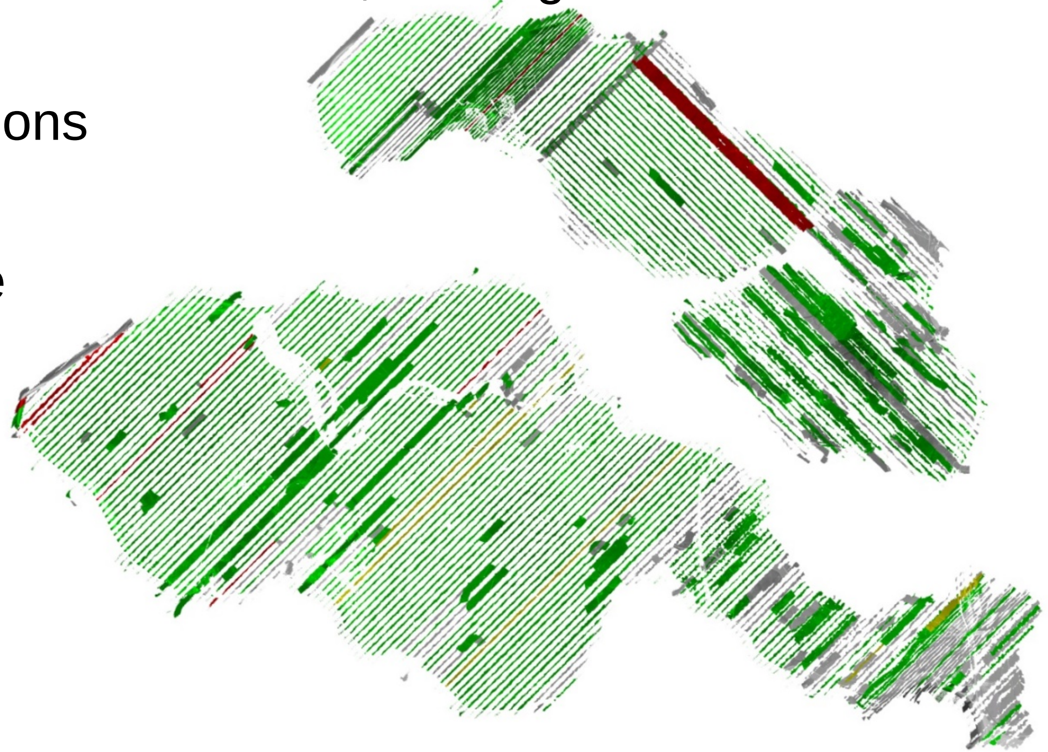
Estimate systematic strip shift

Use residuals to estimate σ



QUALITY CONTROL – RELATIVE PLANIMETRY

- Analysis per strip overlap based on > 20,000 ridge lines
  - Within specifications
  - Just outside specifications
  - Outside specifications
  - No evaluation possible



UPDATING NATIONWIDE POINT CLOUDS

Current revision cycles of 5-7 years

Updating = Produce new point cloud

Can this be done

- faster?
- cheaper?
- smarter?

GEIGER MODE LIDAR

Harris Corporation

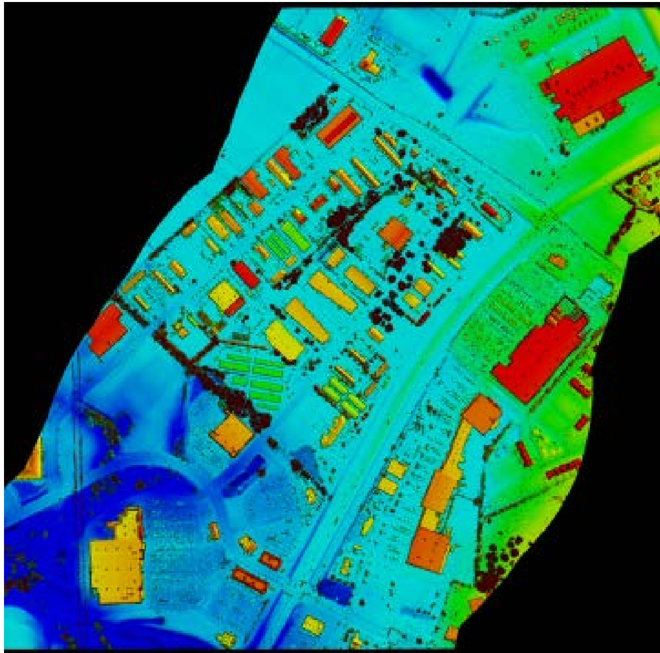
- Photo diode array with 4096 detectors
- 200 million points per second
- 8 points/m^2 at 9 km flight altitude
- > 1000 km^2 per hour
  The Netherlands in 33 hours
  Italy in 300 hours

(Harris Corporation)

SINGLE PHOTON LIDAR

Sigma Space Corporation (acquired by Hexagon)

- High Resolution Quantum Lidar System (HRQLS, HRQLS-2)
- High Altitude Laser (HAL)
- 100 beamlets
- Altitude 2.3 – 7.6 km
- 20 points/m^2 at 4 km flight altitude



(Sigma Space)

QUALITY OF NEW LIDARS

- Study conducted by USGS
- Flights with Geiger mode lidar at 8000 m, HRQLS at 2300 m
- Analysis of vertical accuracy

	Non-vegetated	Vegetated
Geiger mode	15-17 cm	26-92 cm
HRQLS	14-17 cm	17-41 cm
USGS requirement	20 cm	30 cm

QUALITY OF NEW LIDARS

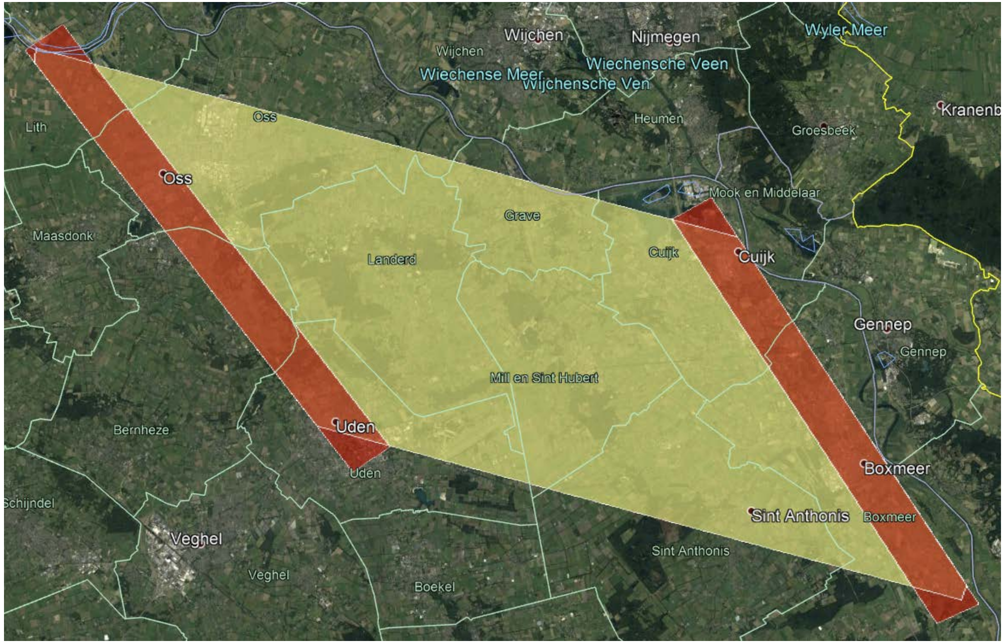
Further analyses are needed

- Behaviour on wet surfaces
- Ground measurements in shallow waters
- Ground measurements in densely built-up areas
- Planimetric accuracy

Comparisons between Single Photon Lidar and Riegl 1560i DW underway by Het Waterschapshuis

QUALITY OF NEW LIDARS

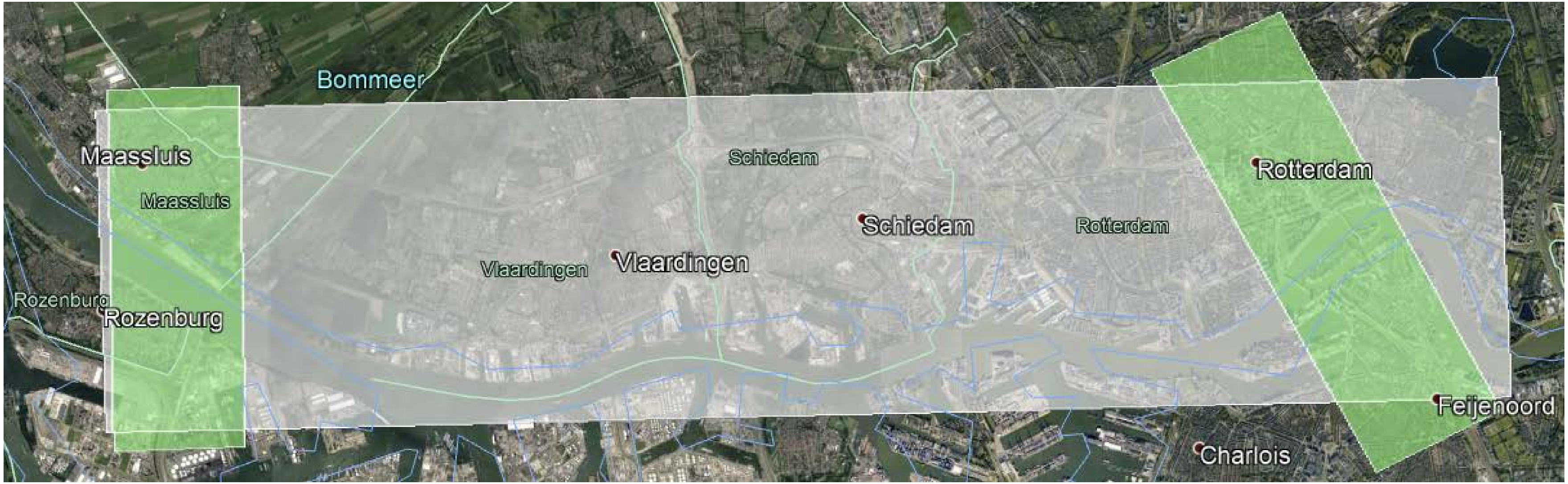
Agricultural area, smaller cities, 8 points/m^2



(Het Waterschapshuis)

QUALITY OF NEW LIDARS

Rotterdam, 60 points/m^2

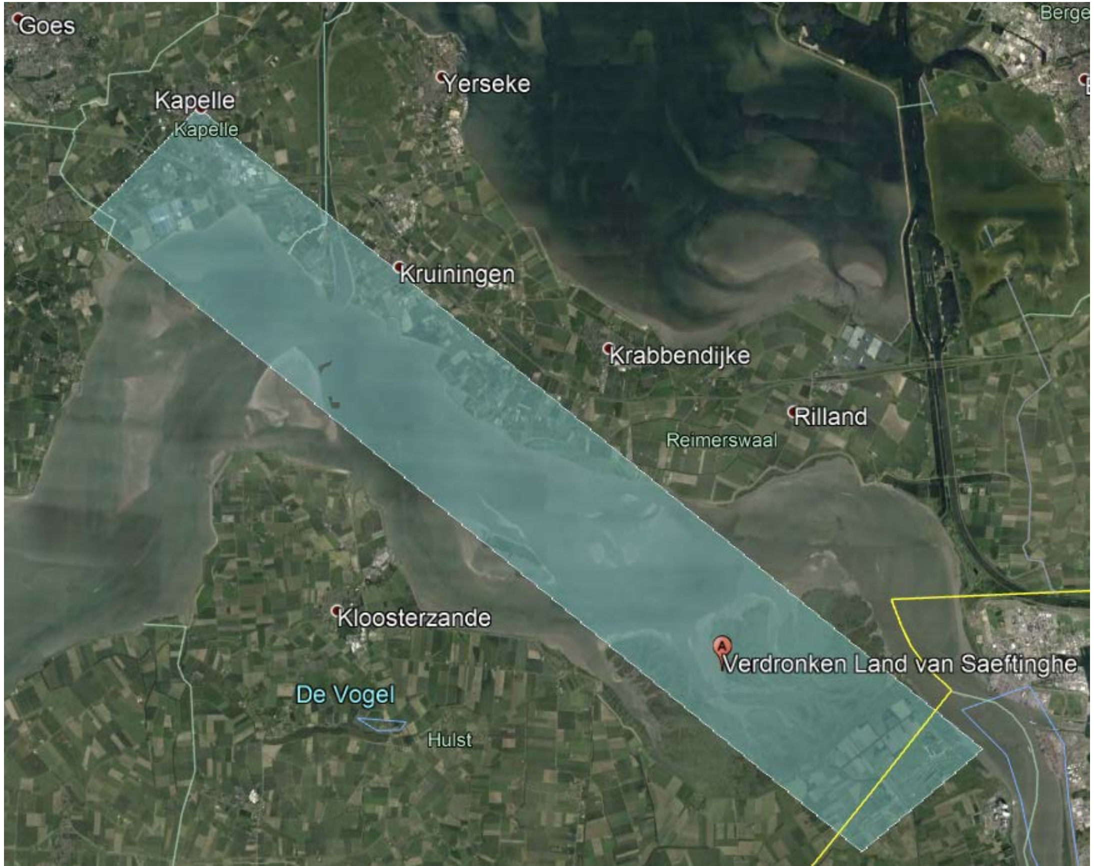


(Het Waterschapshuis)

QUALITY OF NEW LIDARS

Tidal areas

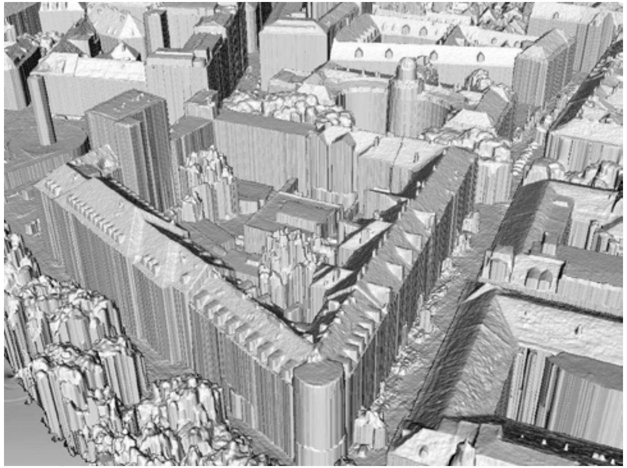
8 points/m^2



(Het Waterschapshuis)

DENSE MATCHING OF AERIAL IMAGERY

- Large advances in image matching

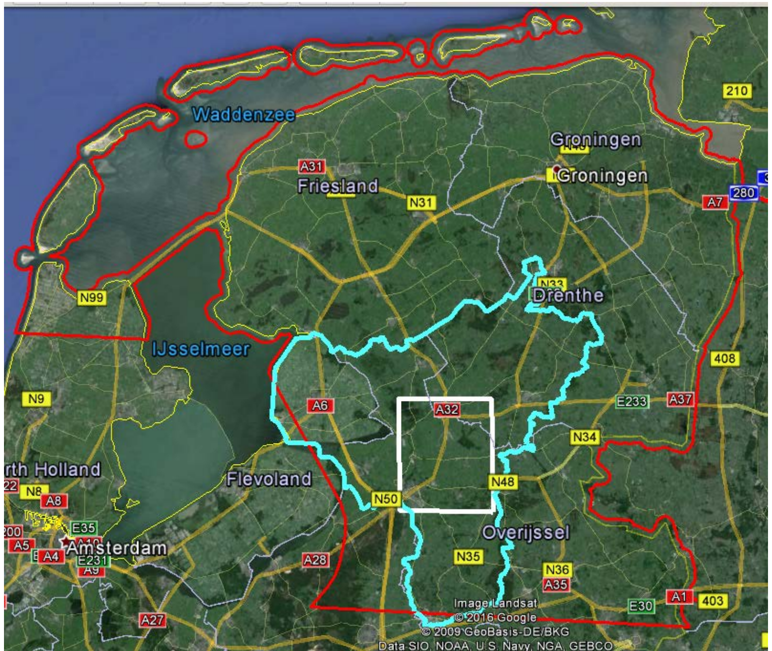


(Hirschmüller, 2007)

- Available in various commercial and open source implementations
- Better results with large image overlaps

DENSE MATCHING OF AERIAL IMAGERY

- Use annual aerial photographs for point cloud generation?
- Default 60% / 30% overlap insufficient
- Experiment with 80% / 30%
- Pixel size 10 cm
- Hard to get 5 cm height accuracy
- No penetration in vegetated areas
- TMA-zones



DENSE MATCHING OF AERIAL IMAGERY

60% vs. 80% overlap

84% vs 94% no data pixels

3-fold improvement of height accuracy

(van Hinsbergh, Kadaster)

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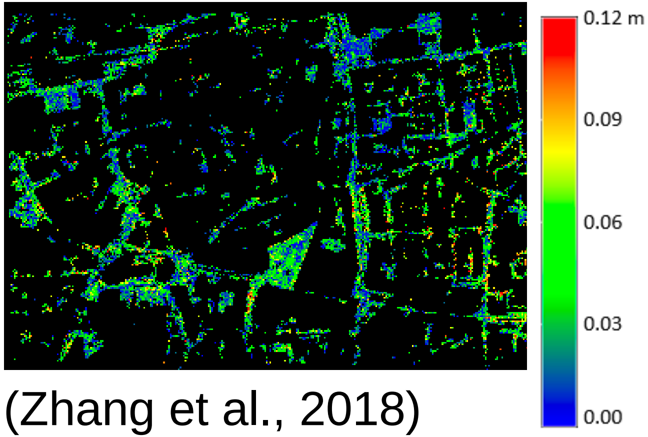
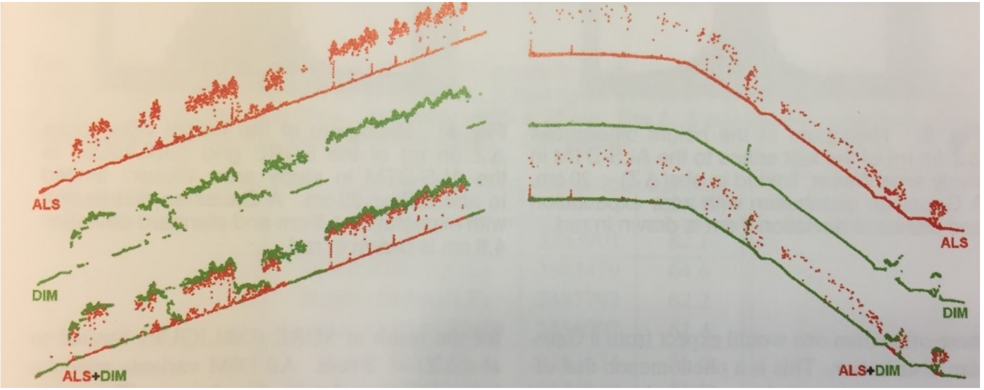
DENSE MATCHING OF AERIAL IMAGERY

Comparisons against lidar

- Effects of low vegetation
- Effects of tree density
- Patch-based evaluation



(Zhang et al., 2018)



Dense vegetation Sparse vegetation

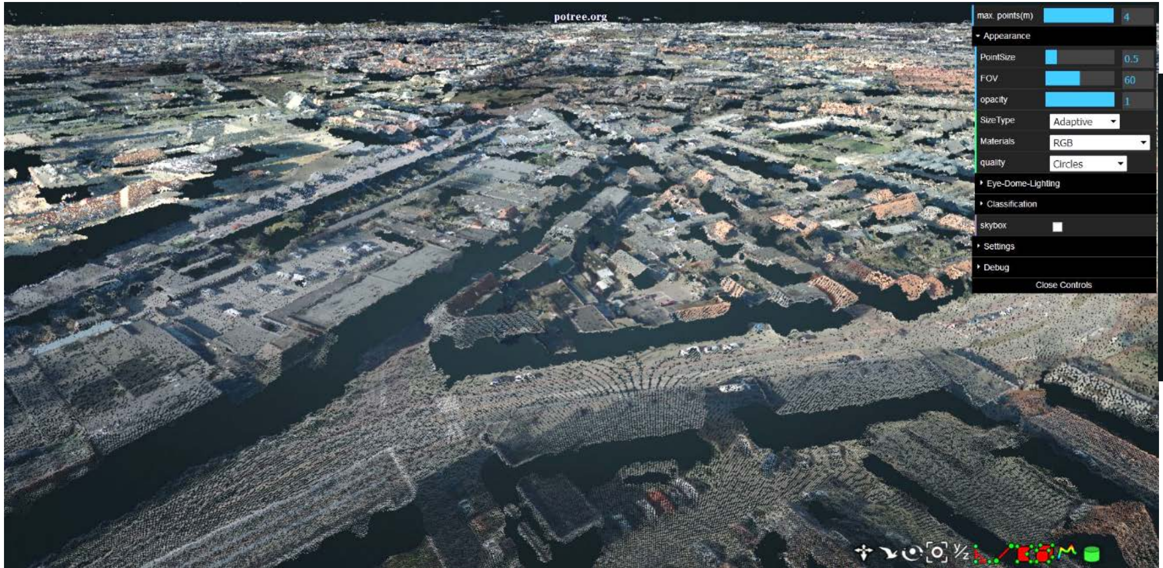
(Ressl et al., 2016)

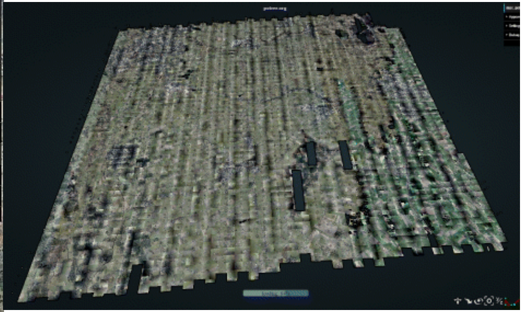
DENSE MATCHING OF AERIAL IMAGERY

Dealing with large image blocks – strategies for tie point reduction

Test with 1200 images of 17.000 x 11.000 pixels in MicMac

6 hour for tie point generation of 676 km^2 with 10 cm pixels, 60%





UPDATING NATIONWIDE POINT CLOUDS

Faster?

Cheaper?

- Geiger mode lidar / Single photon lidar seem to result in higher productivity, but likely have lower accuracies.
- Dense image matching can be based on annual photo flights, but will not obtain ground points below dense vegetation and image resolution and image overlap may need to be increased.
- Review user demands.

UPDATING NATIONWIDE POINT CLOUDS

Smarter?

- Large areas may require no update
- Use low quality point clouds to determine need for updating high quality point clouds
- Requires understanding of observed changes
- Cost/benefit analysis for partial updates
- Point clouds may be less homogeneous

UPDATING NATIONWIDE POINT CLOUDS

Relevance of changes depends on application

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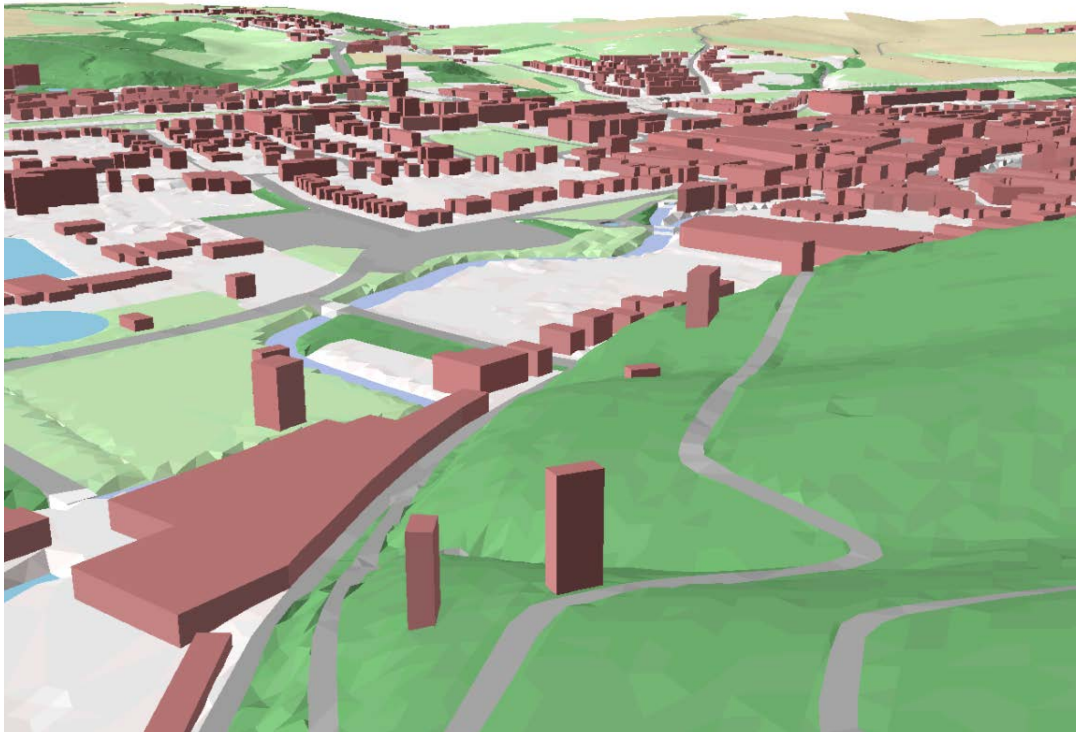
Relevance of changes depends on application

3D LANDSCAPE AND BUILDING RECONSTRUCTION

3D TOP10NL - Integration of 1:10.000 map with point cloud



3D LANDSCAPE AND BUILDING RECONSTRUCTION

LOD2 modelling

Needs manual editing

UPDATING 3D LANDSCAPE AND BUILDING MODELS

- LOD1 models could well be obtained with new lidars and dense matching (assuming available 2D maps)

- Quality of LOD2 building models strongly depend on point cloud quality
  - Missed smaller surfaces
  - Smoothed ridge lines
  - Non-planar surfaces around chimneys, dormer windows

CONCLUSIONS

- Geiger lidar and Single photon lidar will have a market
- Potential of the new lidars needs to be explored further
- New lidars and dense matching can be used to guide smarter point cloud updating
- Review application demands and costs/benefit analyses of updating strategies