AUTOMATIC GENERATION OF RASTER-BASED HEIGHT DATA FOR THE NETHERLANDS BASED ON THE AHN2 DATA SET

Graduation presentation

MSc Geomatics

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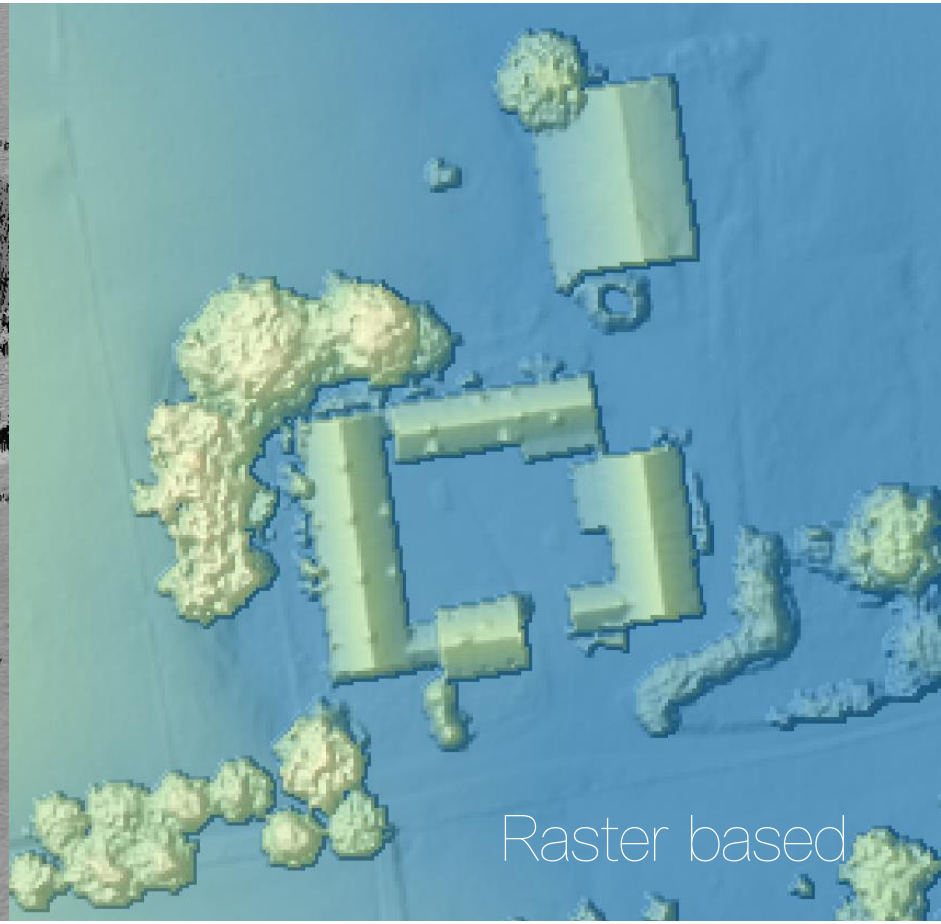
TU Delft

Outline

- Introduction
- State of the art
- Research question
- Methodology
- Implementation
- Conclusion
- Future work

Introduction

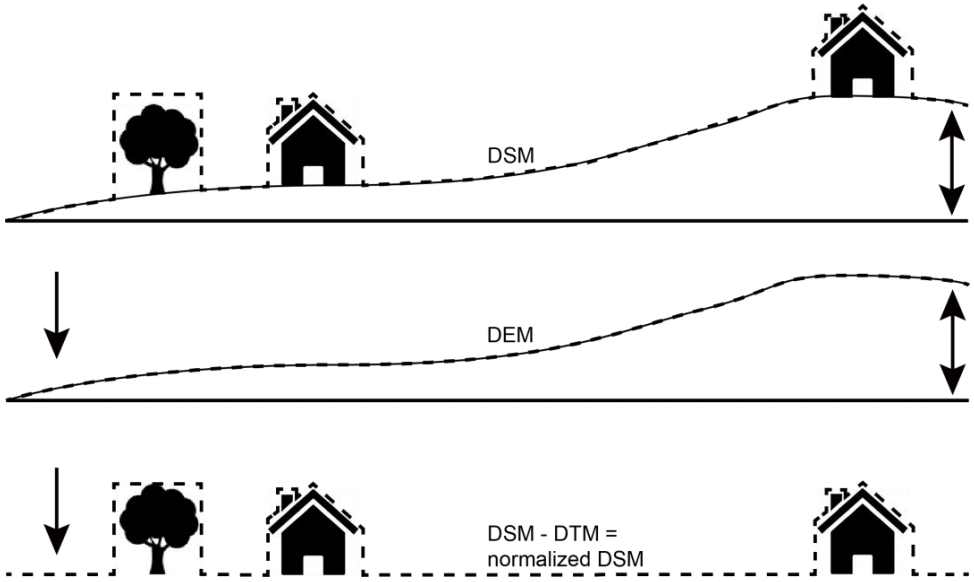
Digital terrain modeling



Introduction

Digital terrain modeling

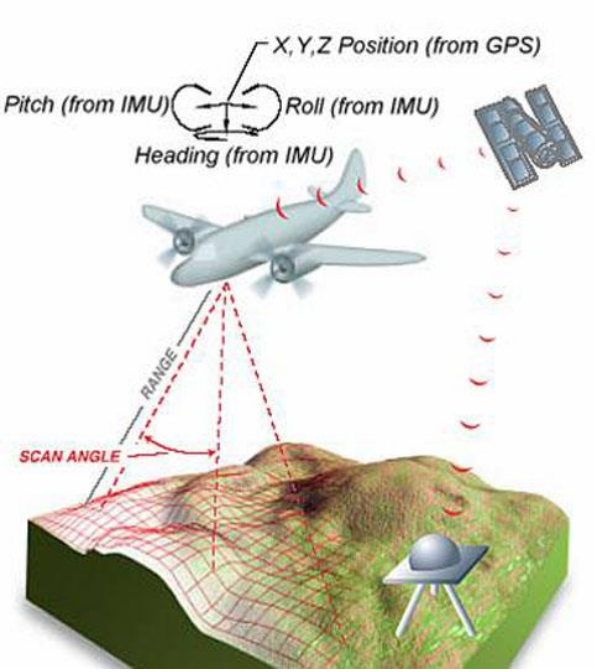
- Digital surface model
- Digital elevation model
- Normalized digital surface model
  - Digital building model
  - Canopy height model

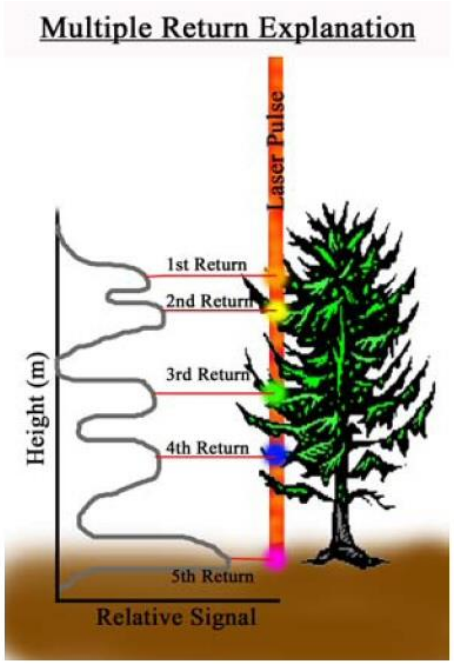


Introduction

LiDAR

- Active remote sensing technology
- Precise 3-dimensional point-based information
- Topographic/bathymetric LiDAR
- One or more returns

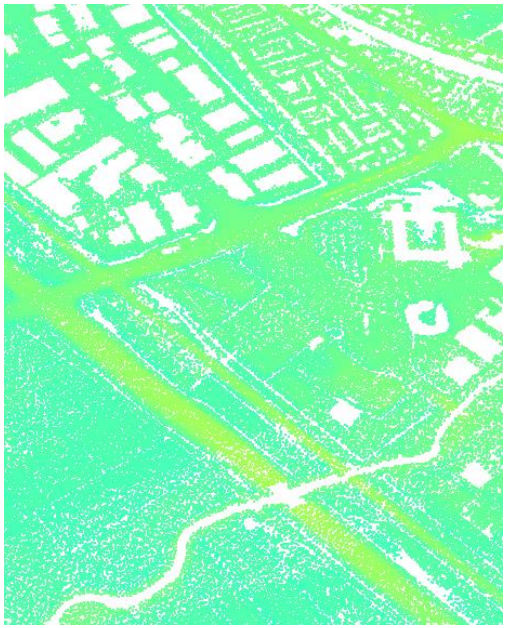


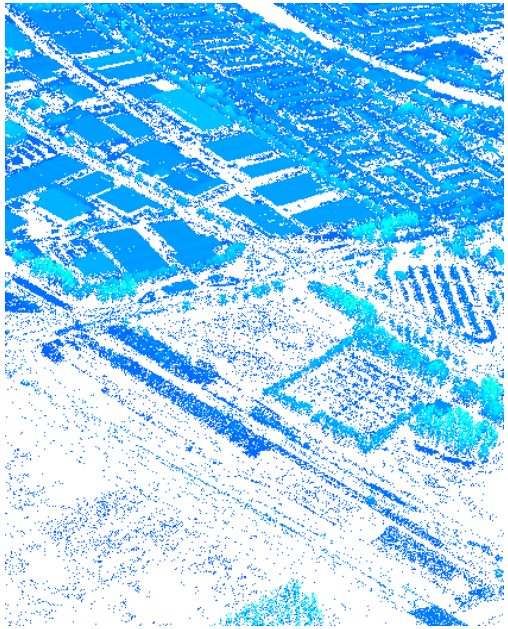


Introduction

The AHN2 data set

- Actueel hoogtebestand Nederland 2
- Topographic LiDAR
- ~640 billion points
  - 6-10 points/m²
- Collection of ground information





Introduction

The AHN2 data set

- Available as open data
- LAZ-file
- Meta data
  - XYZ coordinates for each point
- Downloadable in tiles
  - 1372 tiles
  - 5 x 6.25 km

State of the art

Existing raster-based height maps

- PDOK – Inverse distance weighting
- OHN – Filling ‘holes’ within the PDOK height maps

State of the art

PDOK

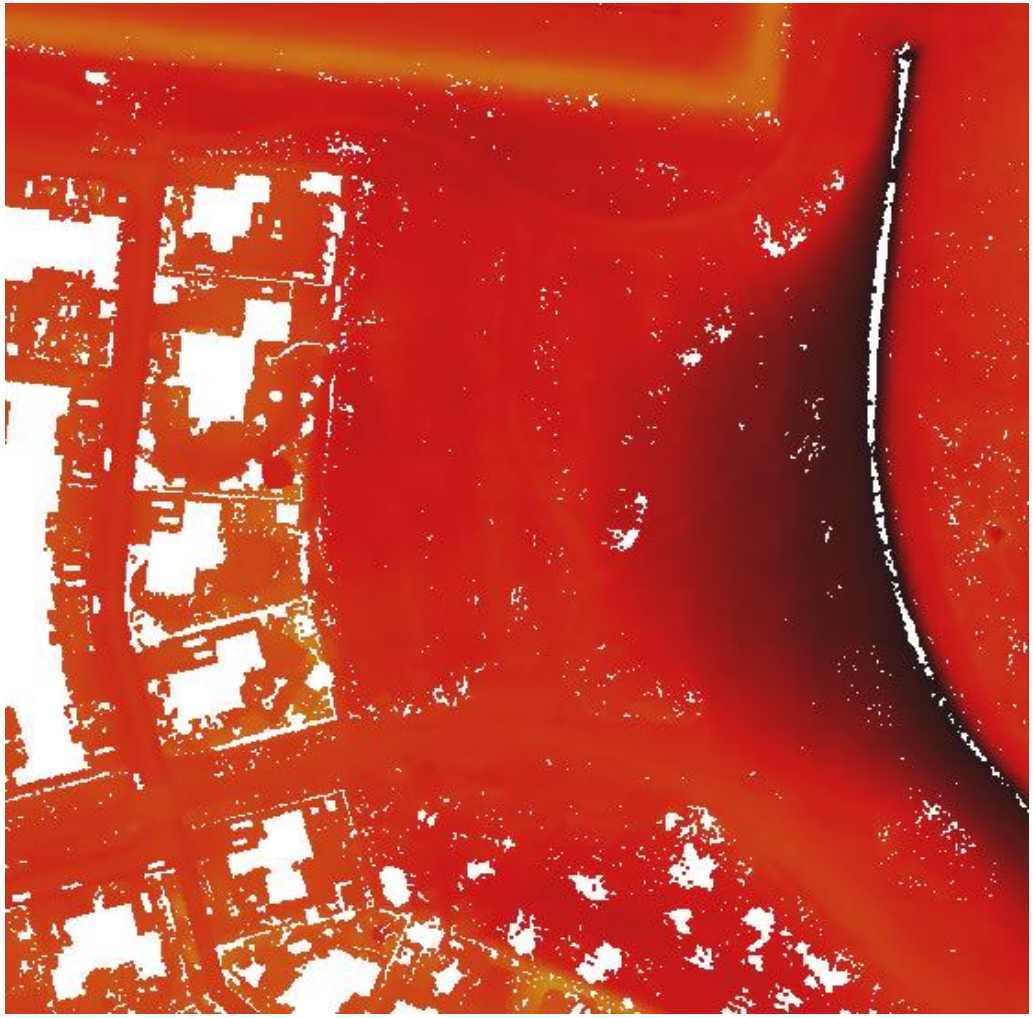
- DEM
- DSM
- Spatial resolution = 0.5 meter

State of the art

PDOK - DEM

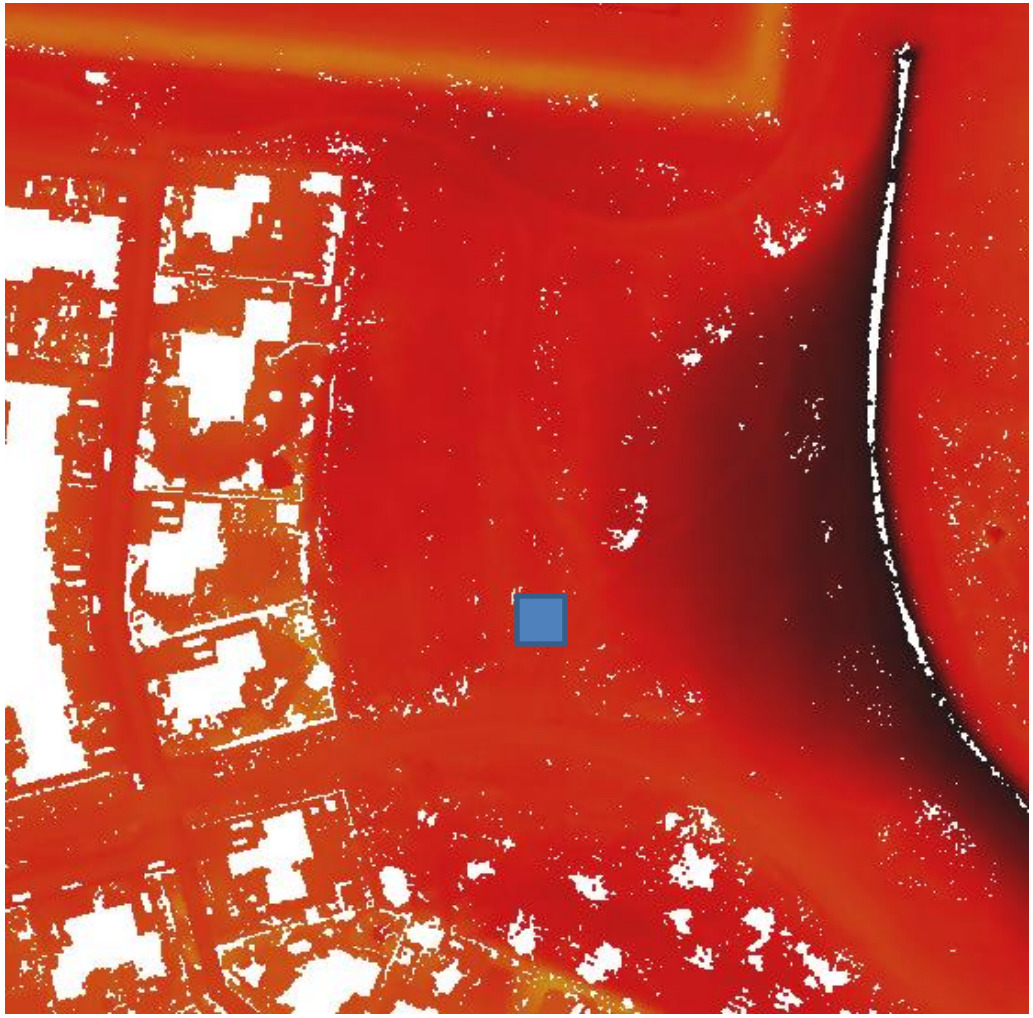
State of the art

PDOK - DEM



State of the art

PDOK - DEM



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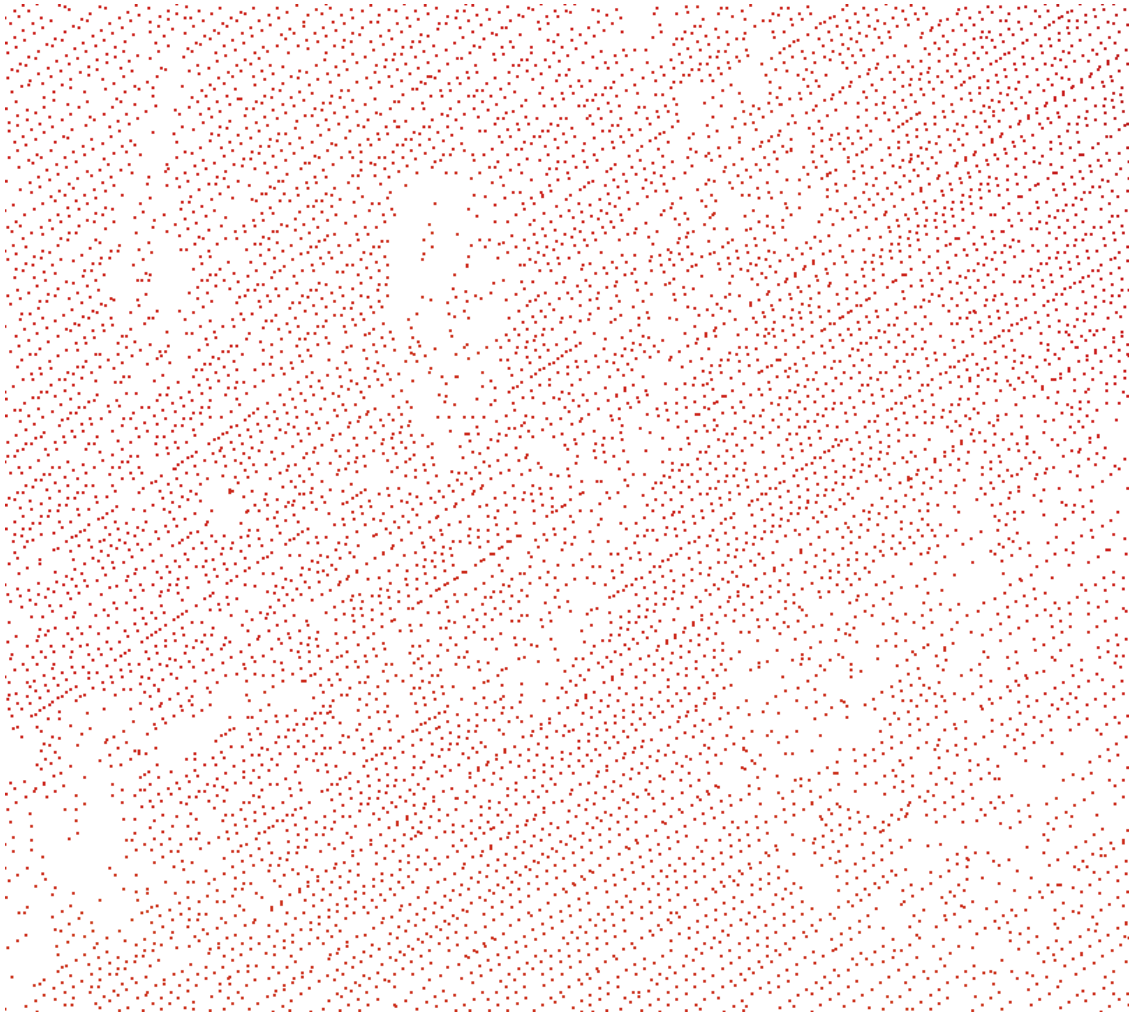
PDOK - DEM



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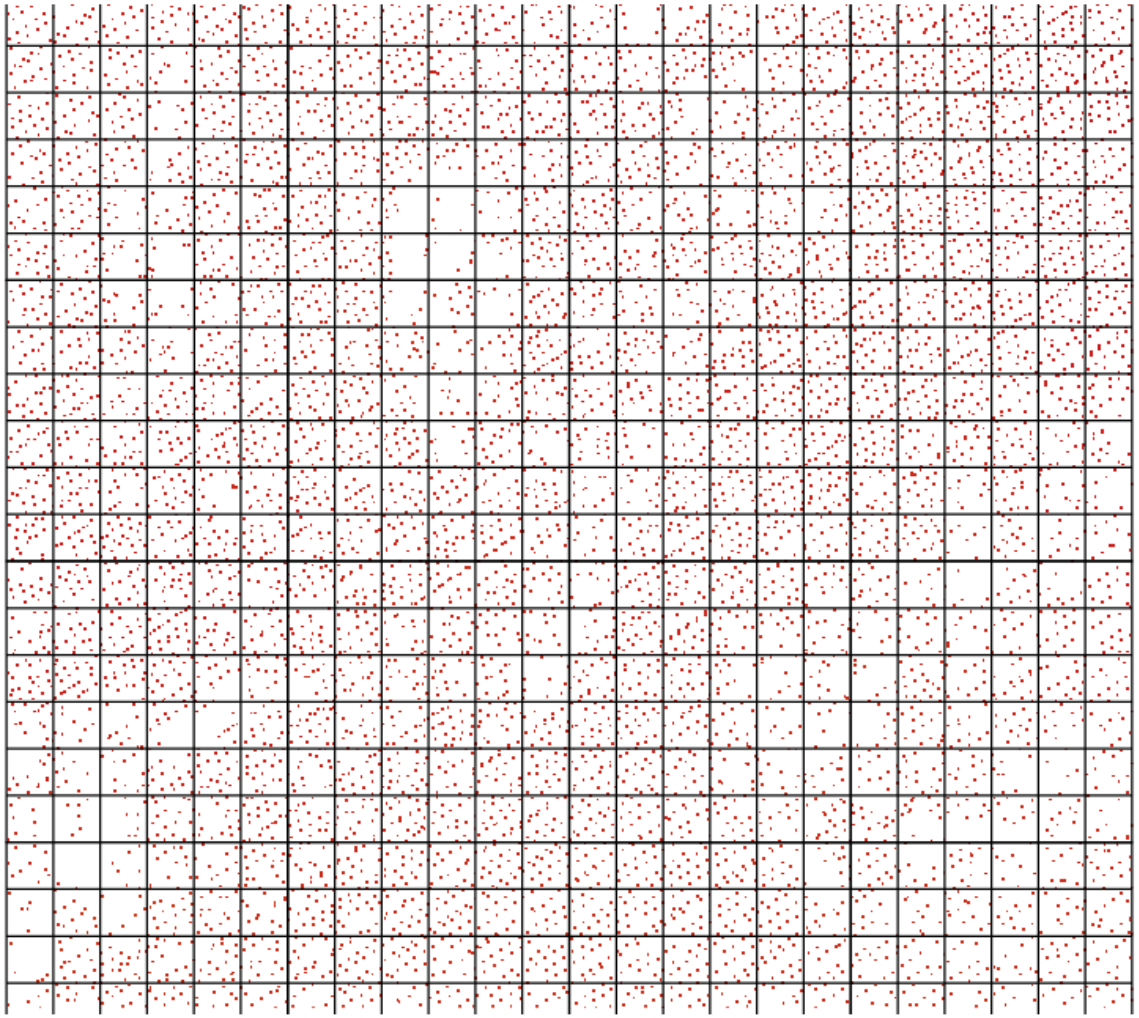
PDOK - DEM



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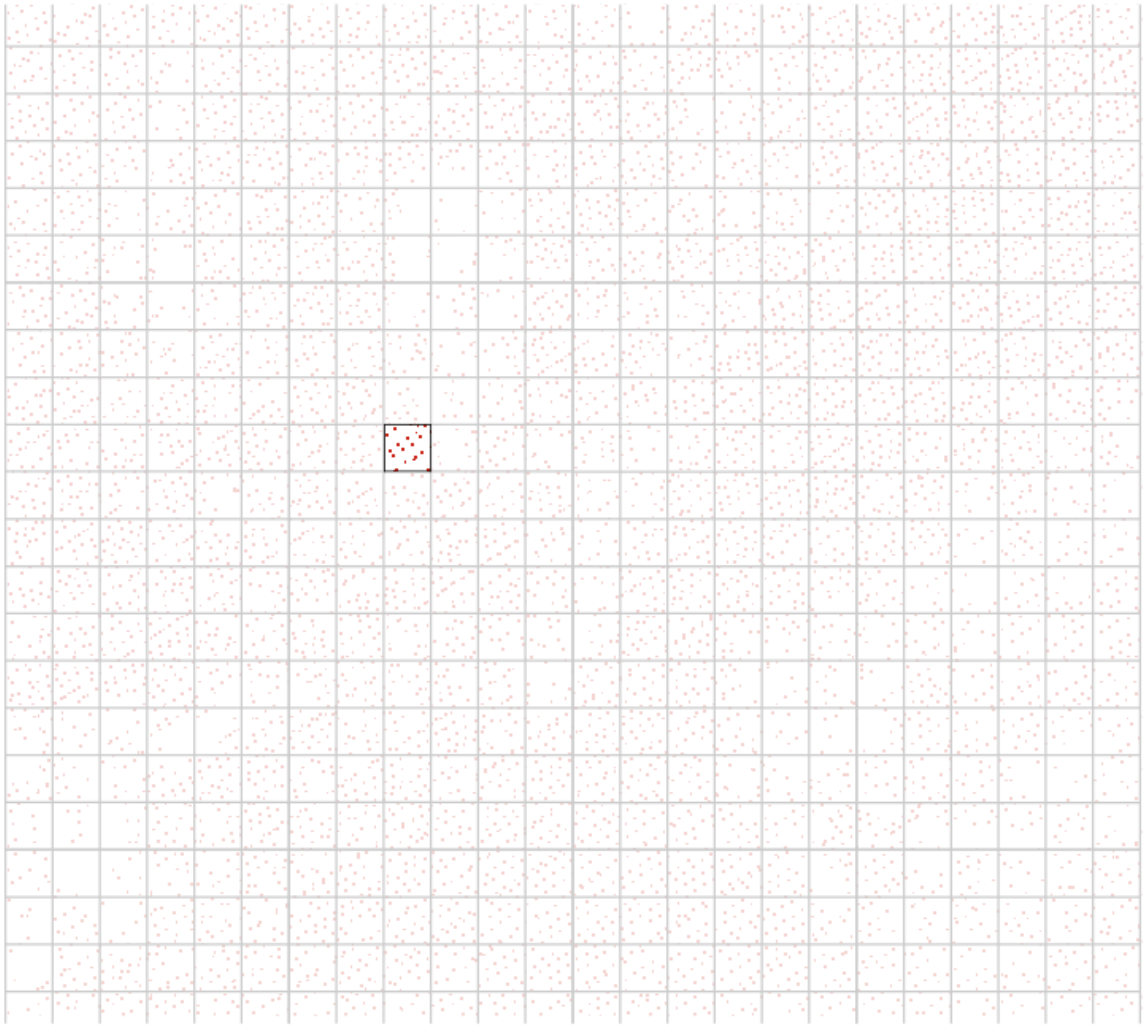
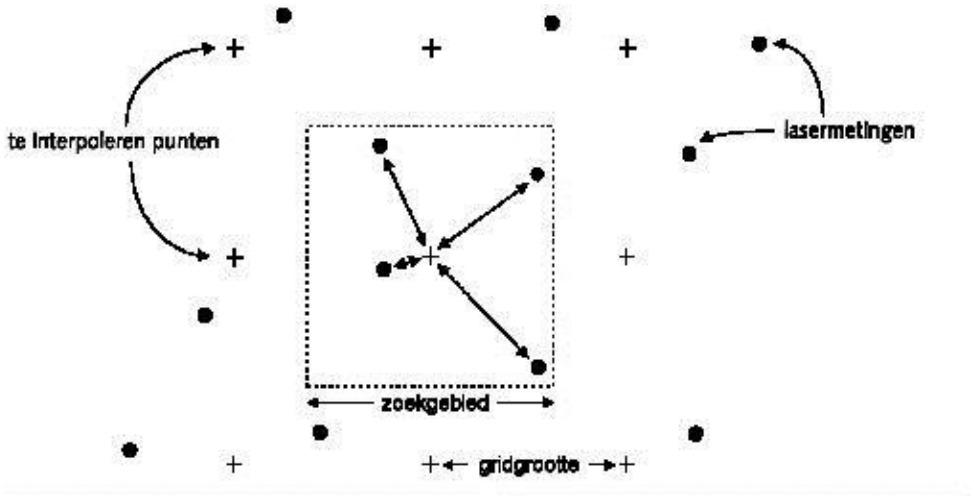


State of the art

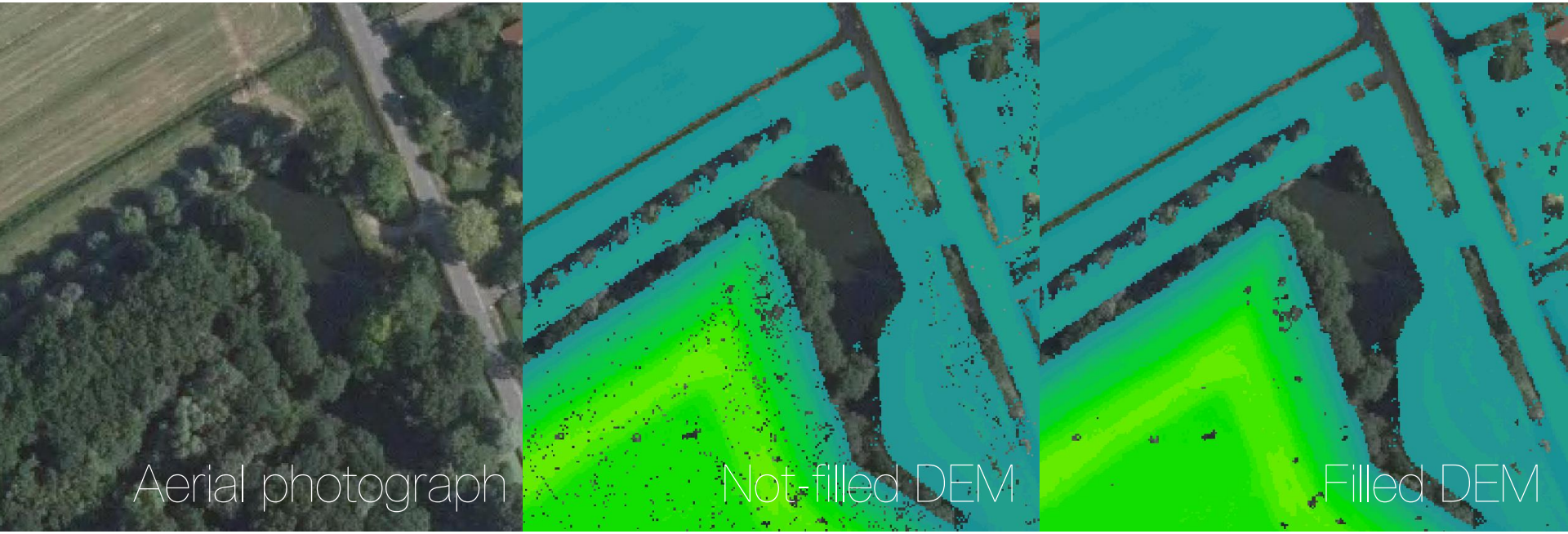
PDOK – DEM

- Inverse distance weighting



State of the art

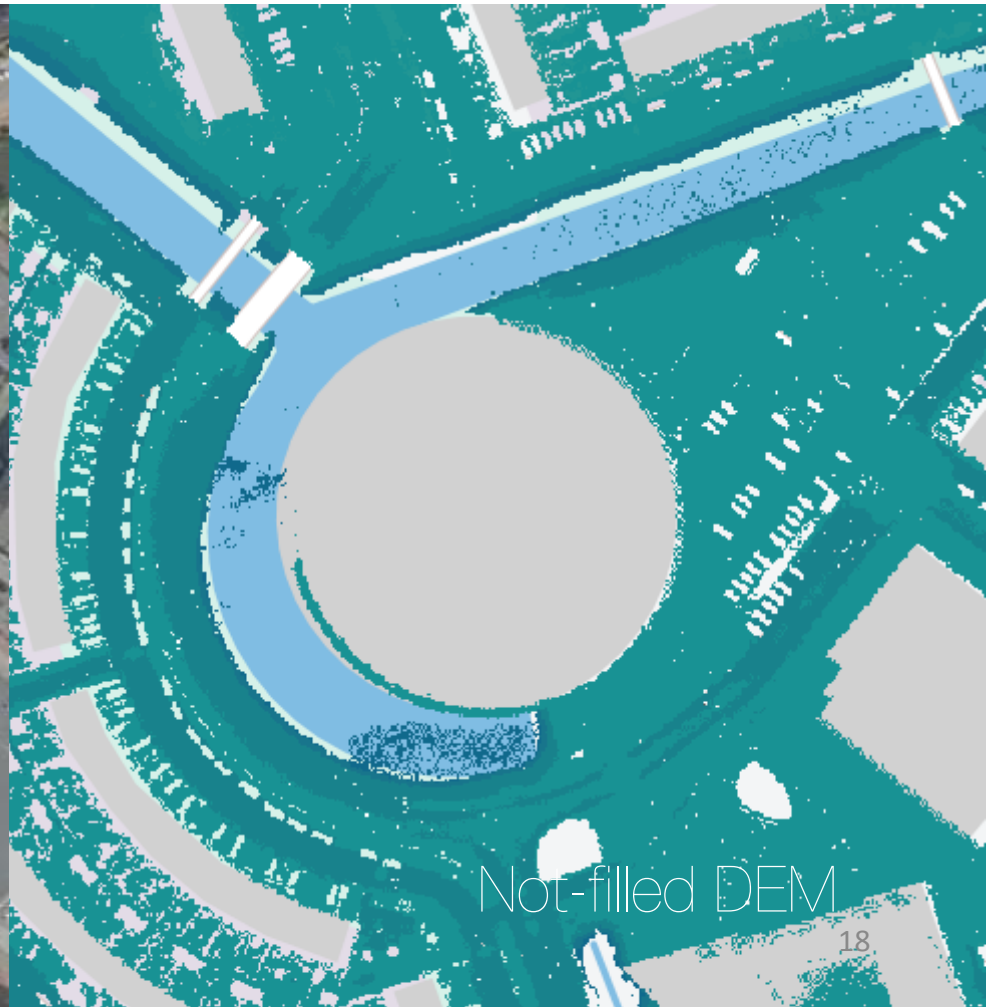
PDOK - DEM



State of the art

PDOK - DEM

Aerial photograph



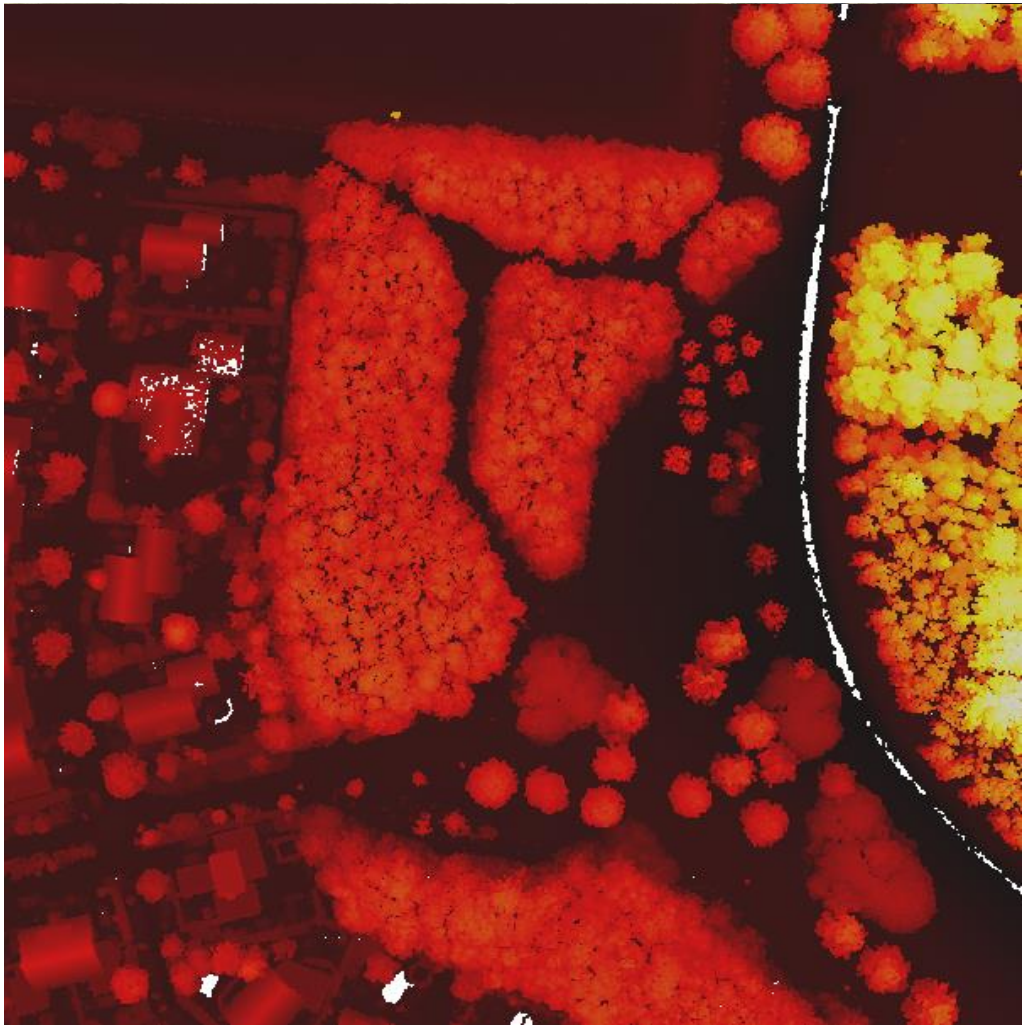
Not-filled DEM

State of the art

PDOK - DSM

State of the art

PDOK - DSM



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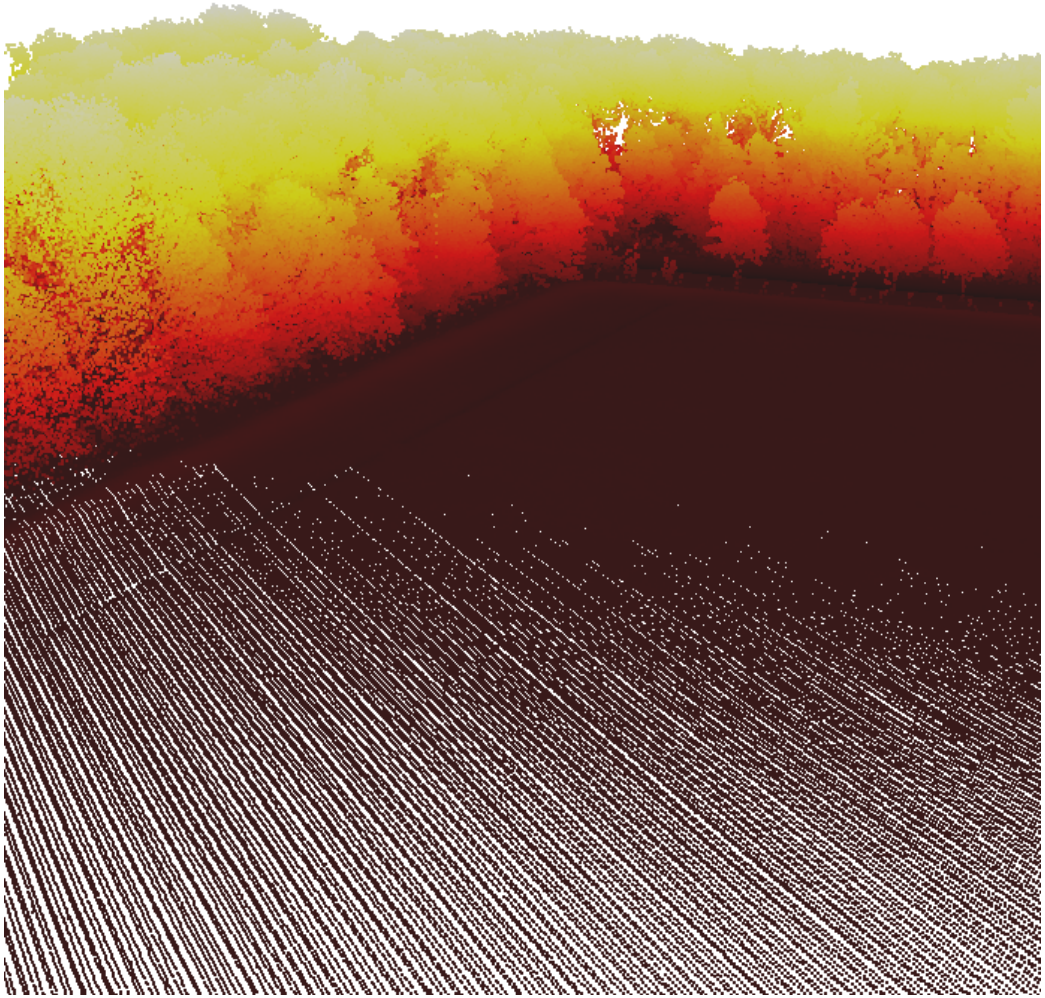
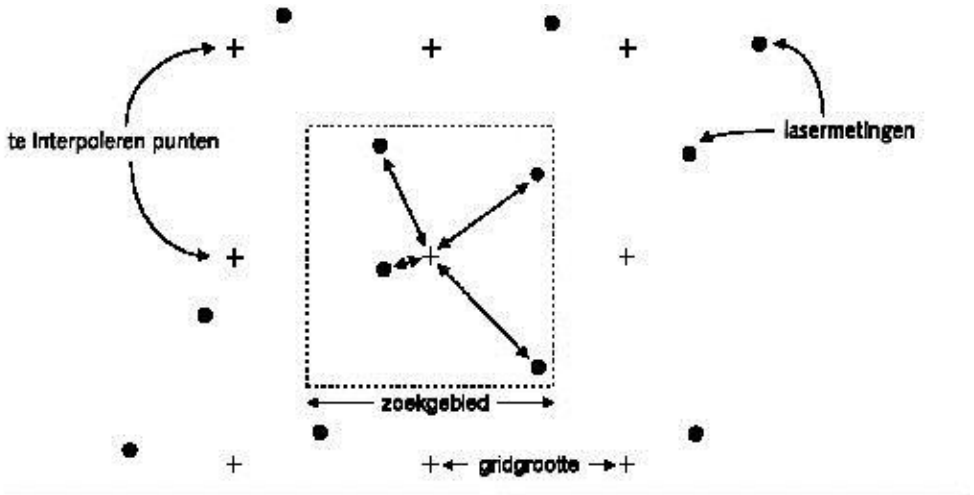


State of the art

PDOK – DSM

- Inverse distance weighting



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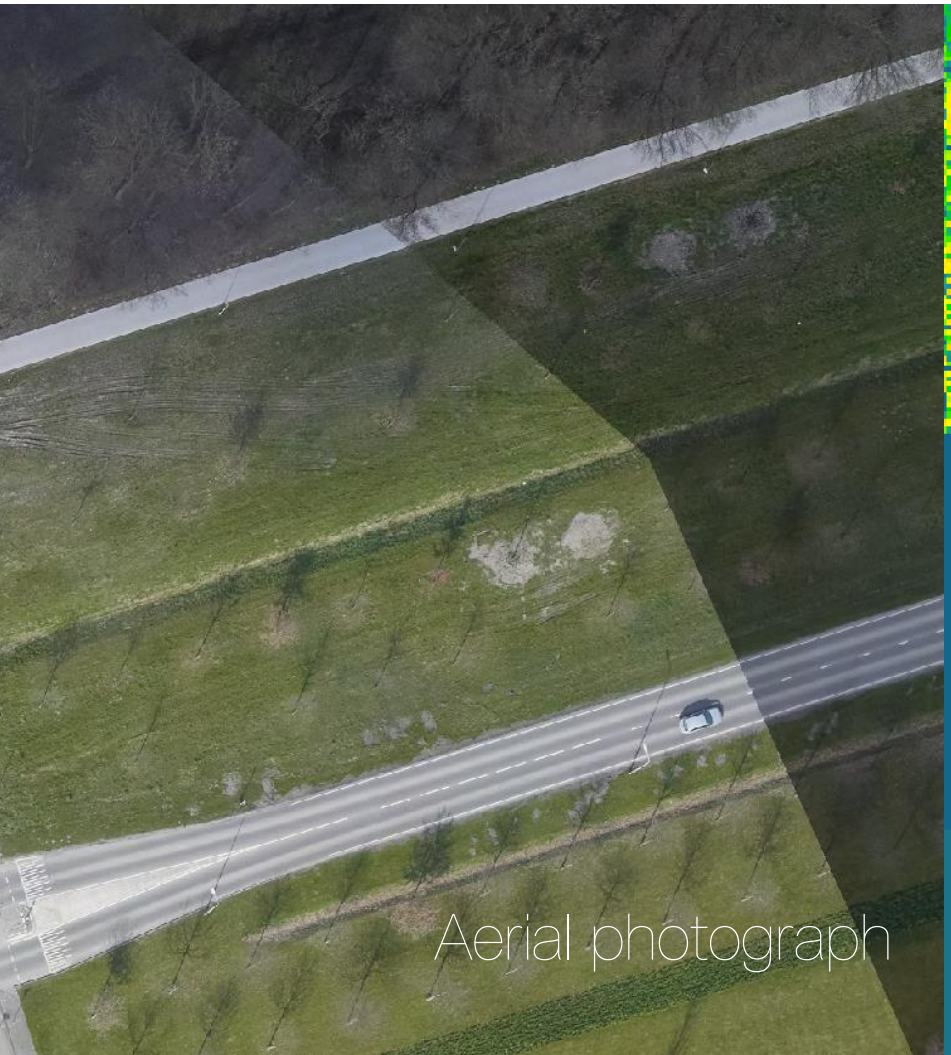
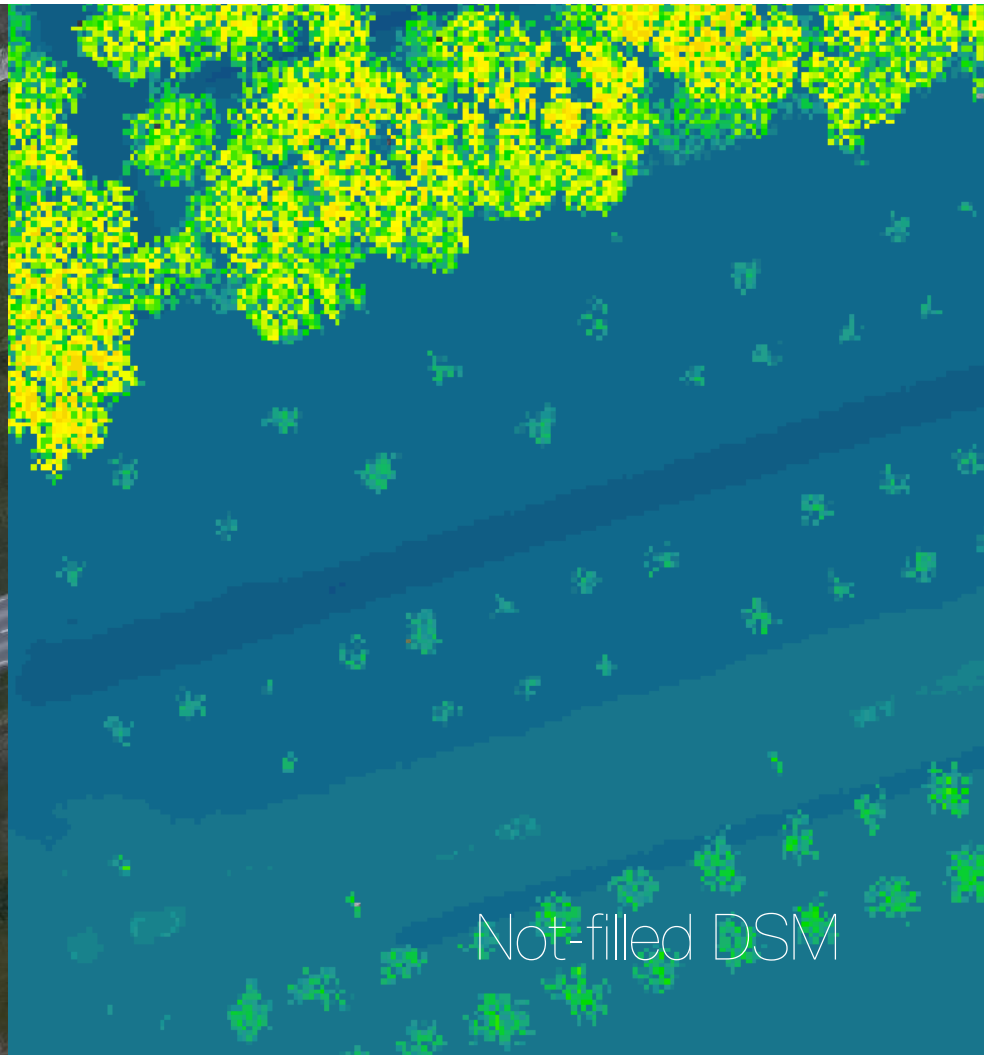
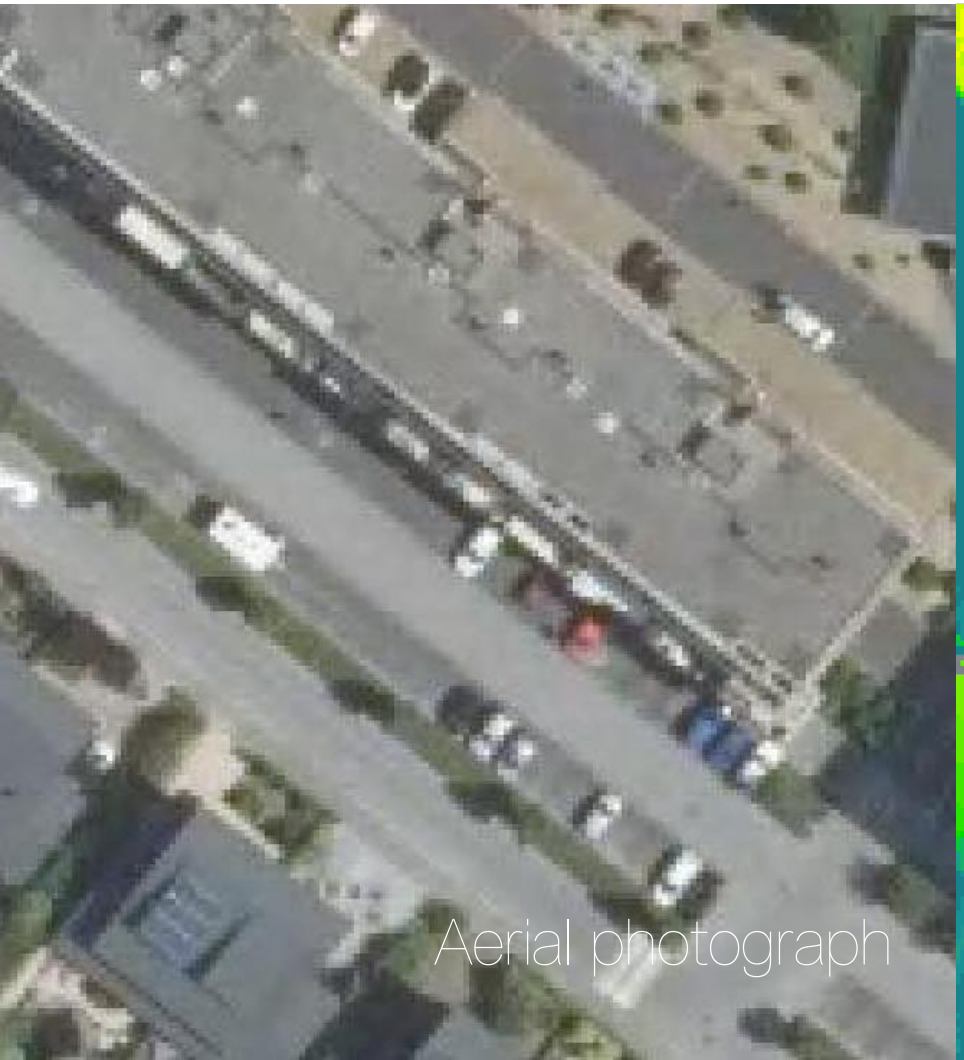


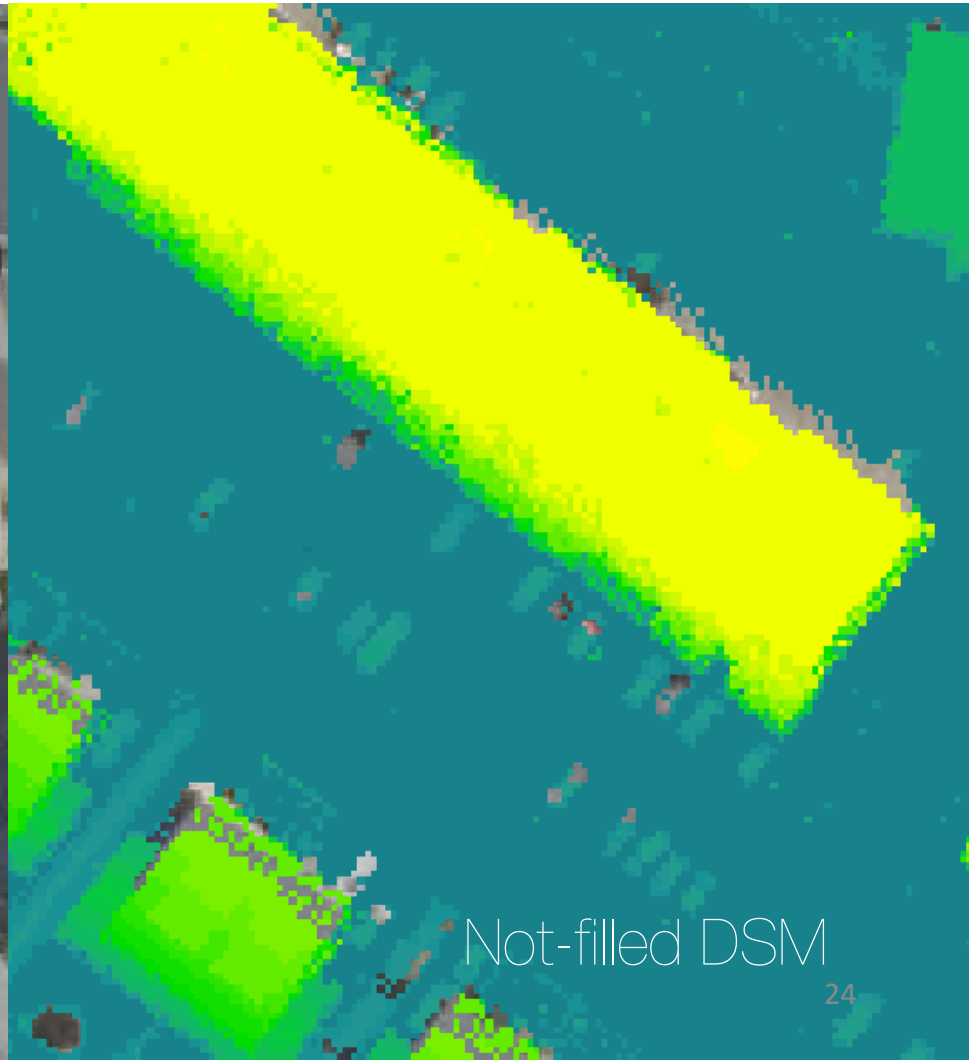


State of the art

PDOK - DSM



Aerial photograph



Not-filled DSM

State of the art

OHN (Kramer et al., 2014)

- Object Hoogte Nederland
- Filling holes within raster-based height maps of PDOK
- External 2D geodata sets
  - TOP10NL - water bodies
  - BAG - buildings
  - Aerial photography - vegetation
- Filling of remaining holes using inverse distance weighting

State of the art

OHN (Kramer et al., 2014)

State of the art
Evaluation

PDOK

- 'Holes' within height data (no-data values)
- Height is often wrongly determined
- Presence of dynamic objects

OHN (Kramer et al., 2014)

- Filling of incomplete height data ('holes')
  - Modification of 'correct' height data

Research question

What quantitative degree of quality can be achieved
for raster-based height maps
generated from AHN*2* point cloud data
by the application of an automated process?

Methodology

Methodology

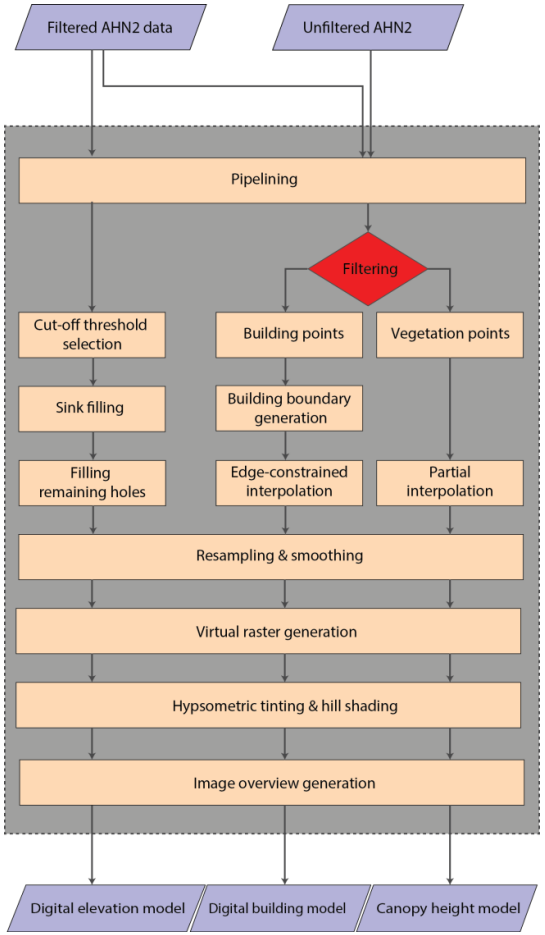
Methodology

Methodology

Methodology

Proposed workflow

- Pipelining
- Filtering
- Spatial interpolation
- Post processing
- Visualization



Methodology

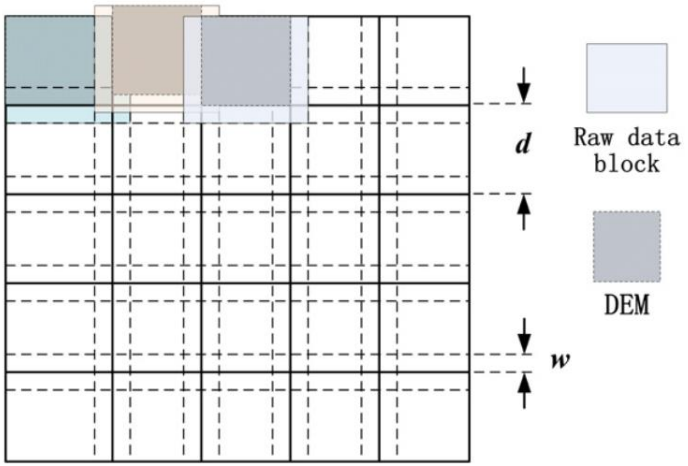
Pipelining

Methodology

Pipelining

Divide-and-conquer strategy

- Tile size
  - Controls granularity of pipeline

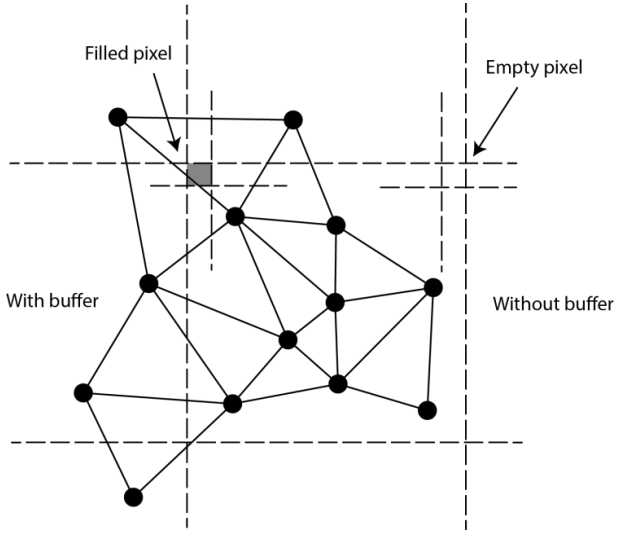


Methodology

Pipelining

Divide-and-conquer strategy

- Tile size
  - Controls granularity of pipeline
- Buffer size
  - Results of decomposition similar to non-tiled data



Methodology

Filtering

Methodology

Filtering

- Filtering ground points from non-ground points
- Filtering of features from non ground points
  - Buildings
  - Vegetation

No filtering procedure exists that can guarantee a 100% correct classification of LiDAR points

Methodology

Filtering

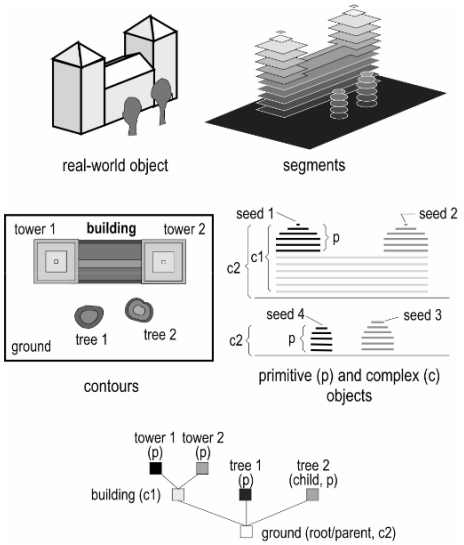
- Filtering ground points from non-ground points
  - Insignificant number of points are filtered as being non-ground
  - Above-ground points are classified as ground

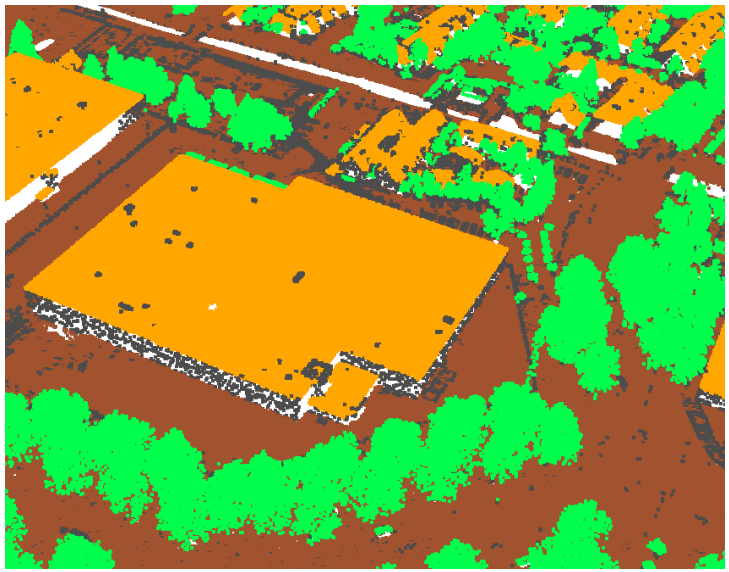
Additional filtering of ground points does not provide a better classification

Methodology

Filtering

- Filtering of features from non ground points
  - Contour/segmentation based object-oriented classification algorithm [Hug et al. ,2004]
  - Standard deviation points can have for the planar region they share





Methodology

Spatial interpolation

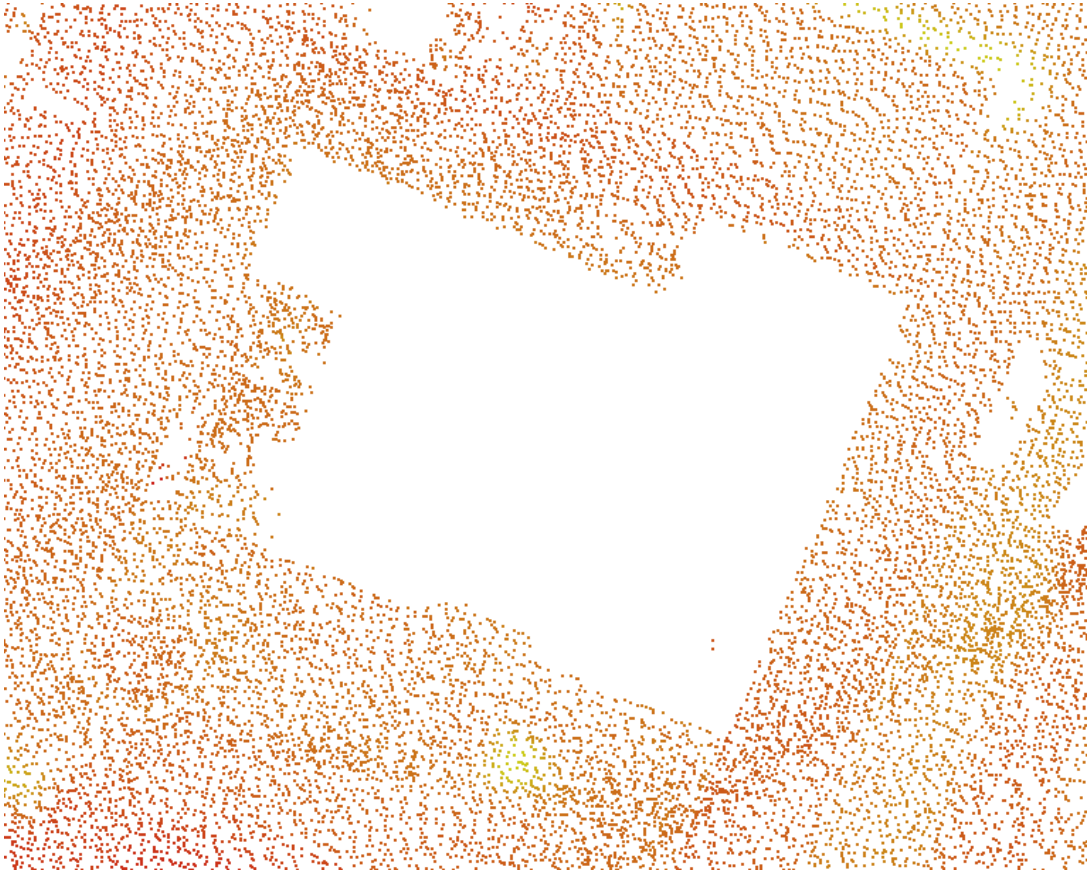
Methodology
Spatial interpolation

- DEM
  - Interpolation based on a TIN
  - Sink filling
  - Filling of remaining holes
- DBM
  - Edge-constrain interpolation
- CHM
  - Partial canopy height model generation

Raster resolution = 0.25 meter

Methodology

Spatial interpolation - DEM



Methodology

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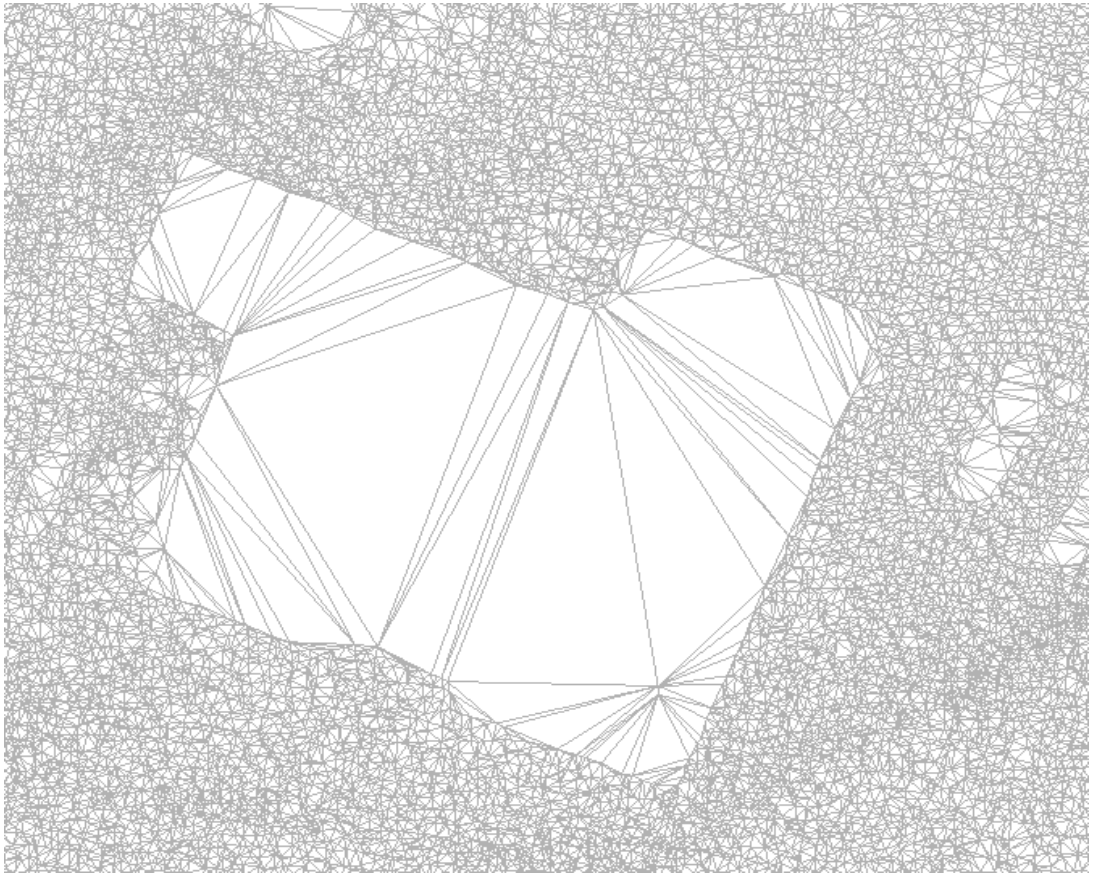

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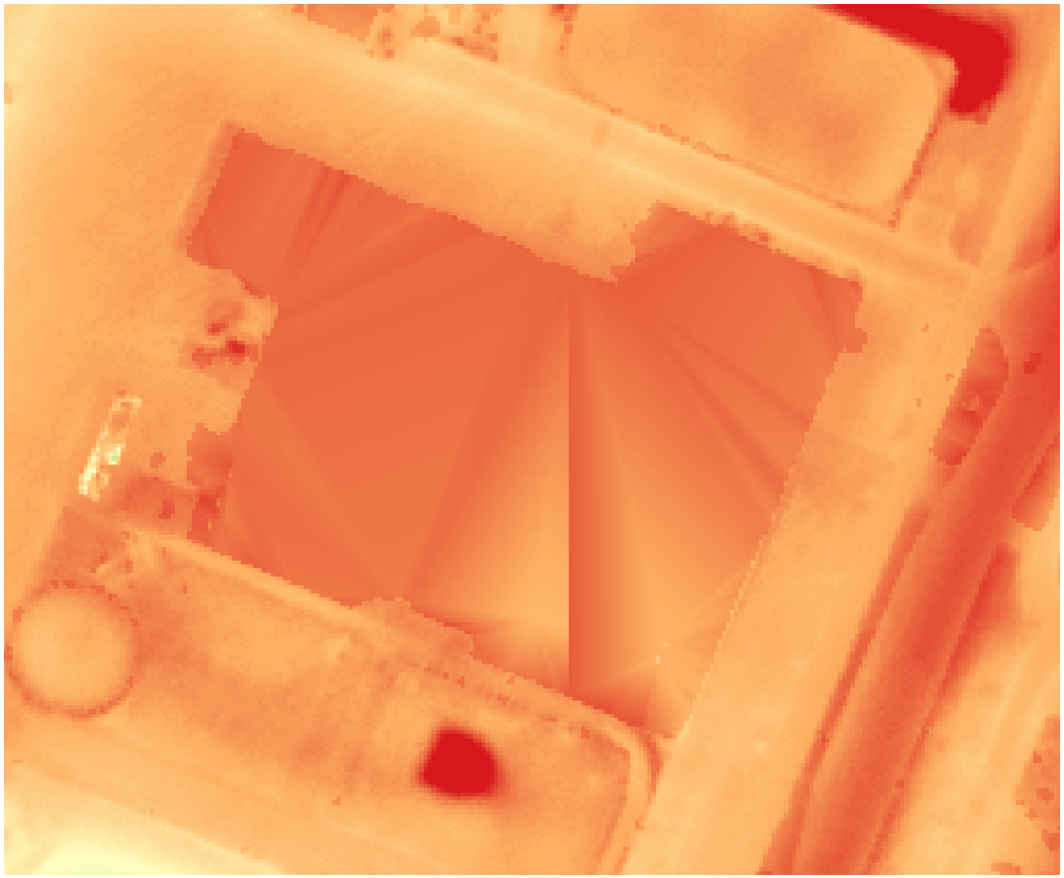
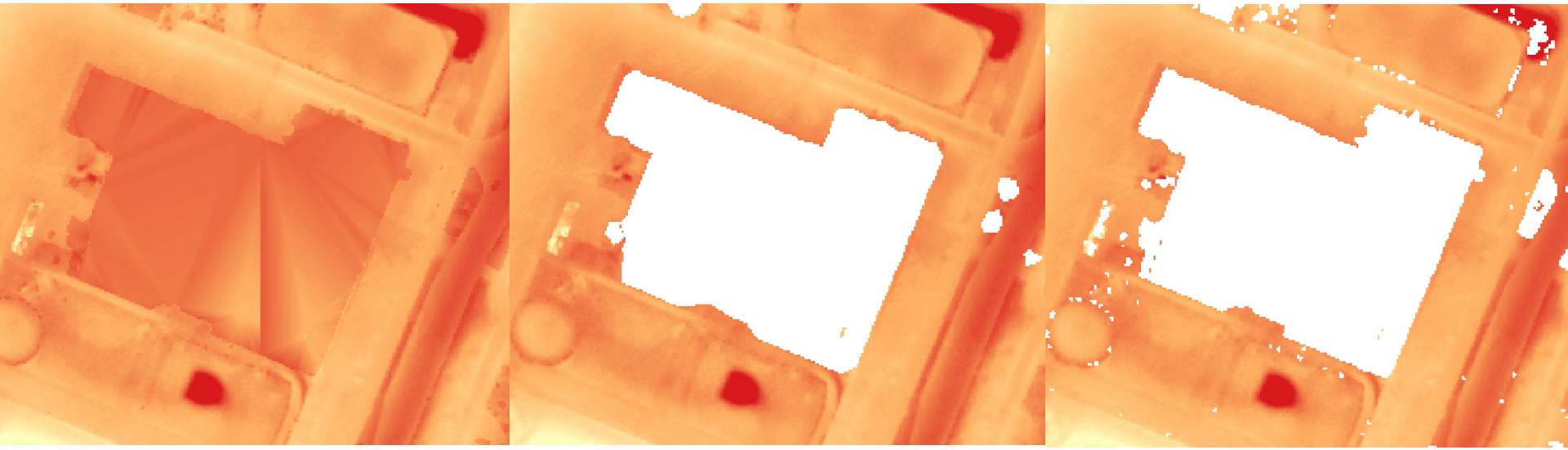


Methodology

Spatial interpolation - DEM

- Cutoff threshold
  - Longest edge of a triangle



Methodology

Spatial interpolation - DEM

- Remaining holes
  - Water bodies
  - Building footprints
  - Local deviations

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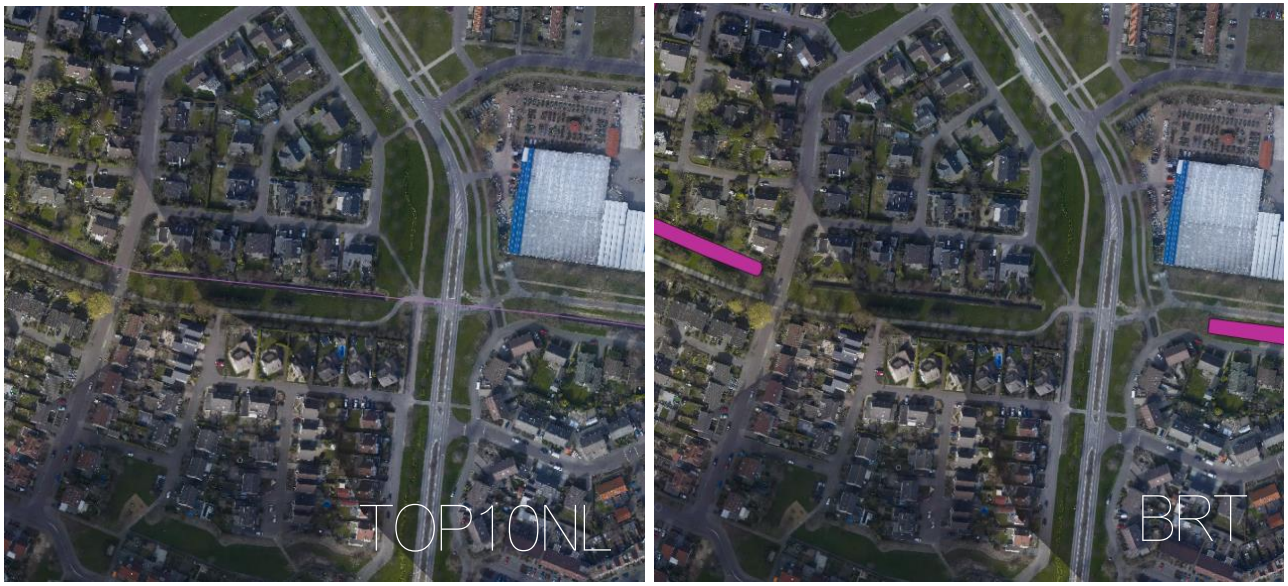
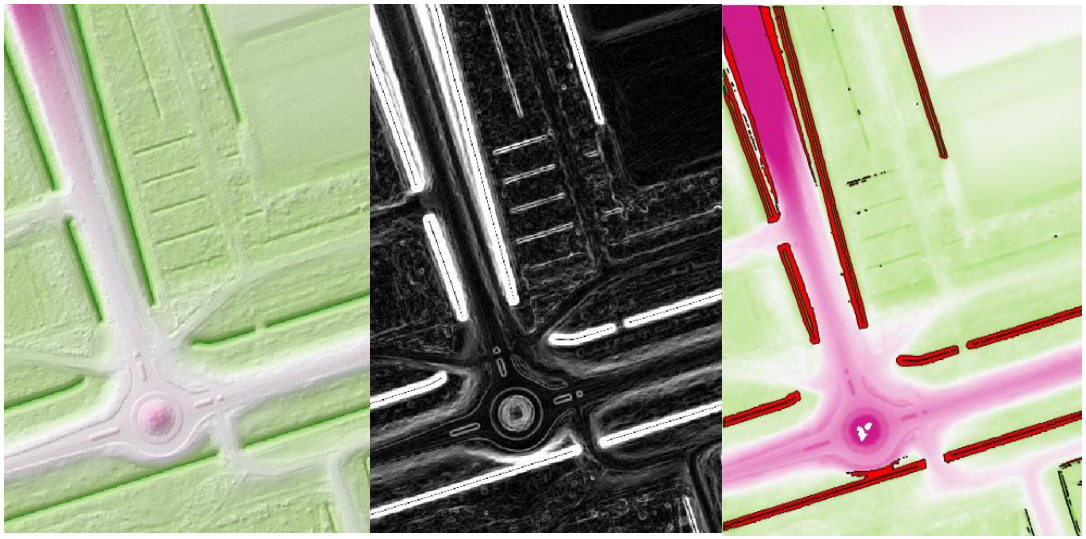


Methodology

Spatial interpolation - DEM

- Remaining holes
  - Water bodies
    - Slope
    - B-REP
    - Breadth-first search



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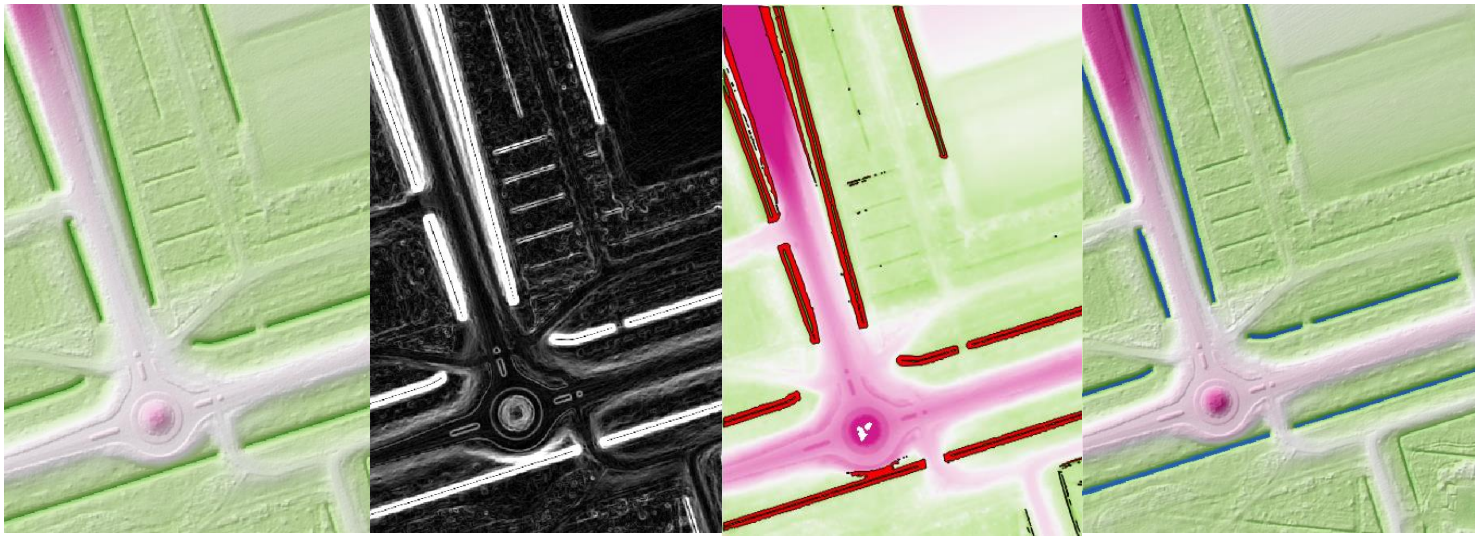

Methodology

Spatial interpolation - DEM

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Methodology

Spatial interpolation - DEM

Remaining holes

- Water bodies
- Building footprints
- Local deviations

Methodology

Spatial interpolation - DBM

- Edge-constrained interpolation
- Extracting building boundaries
  - From classified LiDAR data
    - Concavity

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    - Holes
  - From the BAG data set
    - Temporal accuracy: 1 year

Methodology

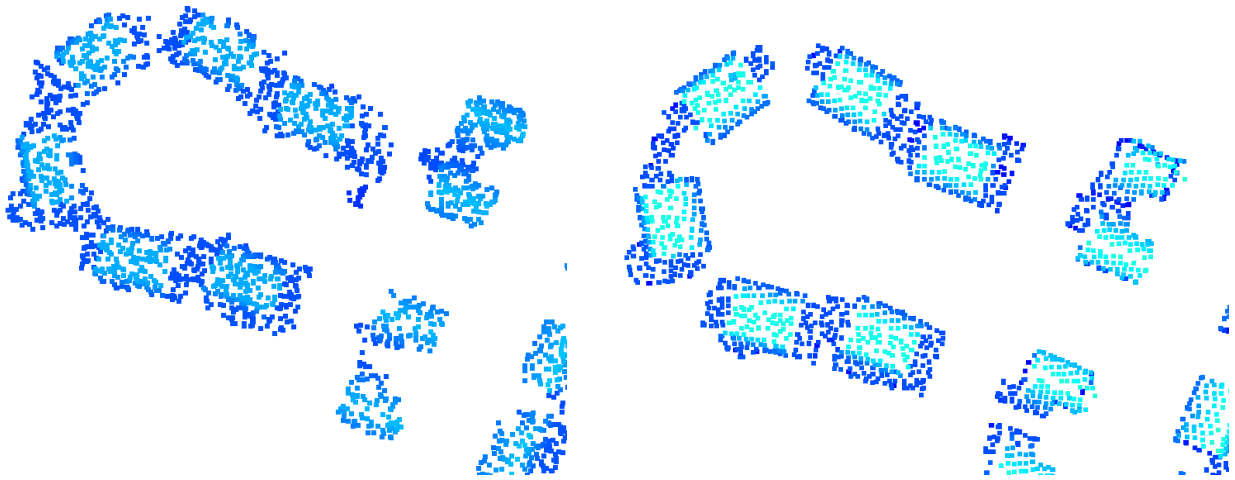
Spatial interpolation - DBM

- Edge-constrained interpolation
- Extracting building boundaries
  - From classified LiDAR data
    - Concavity
    - Holes
  - From the BAG data set
    - Temporal accuracy: 1 year

Methodology

Spatial interpolation - DBM

- Edge-constrained interpolation
- Extracting building boundaries
- Point cloud manipulation
  - Thickening
  - Thinning



Methodology

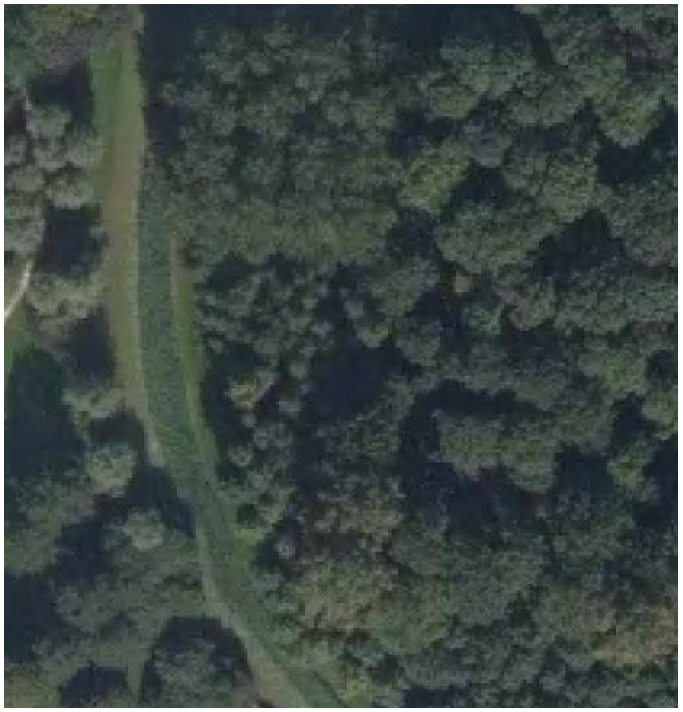
Spatial interpolation - DBM

- Edge-constrained interpolation
  - Based on a TIN
- Extracting building boundaries
- Point cloud manipulation

Methodology

Spatial interpolation - CHM

- Vegetation
- Interpolation based on a TIN



Methodology

Spatial interpolation - CHM

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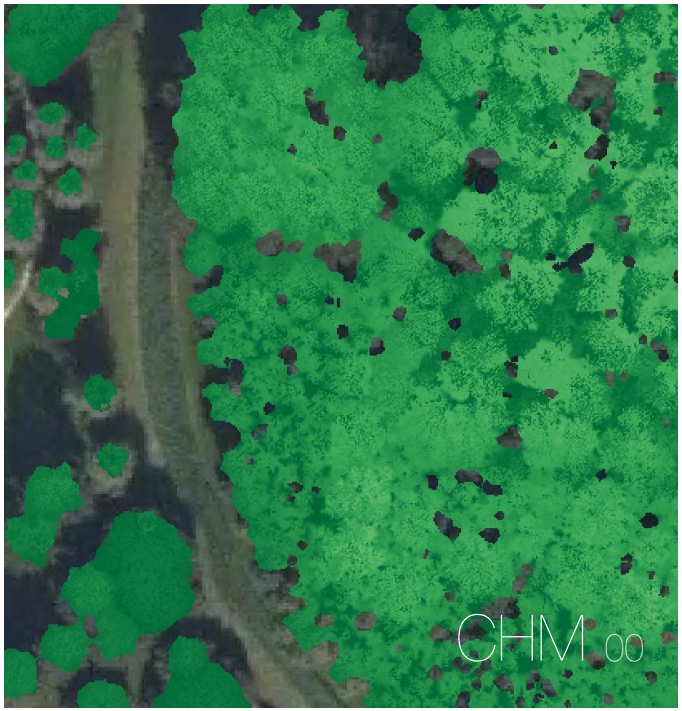

Methodology

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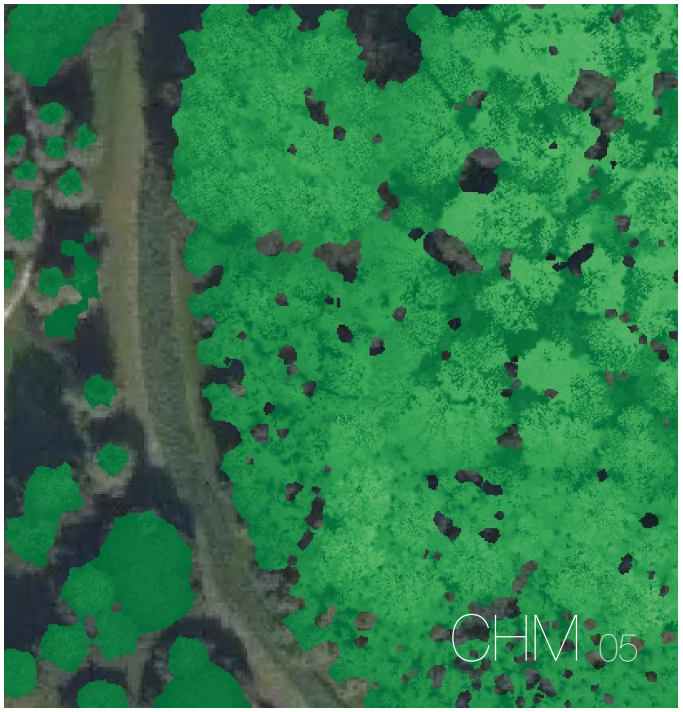


Methodology

Spatial interpolation - CHM

- Vegetation
- Interpolation based on a TIN

Methodology

Spatial interpolation - CHM

- Vegetation
- Interpolation based on a TIN

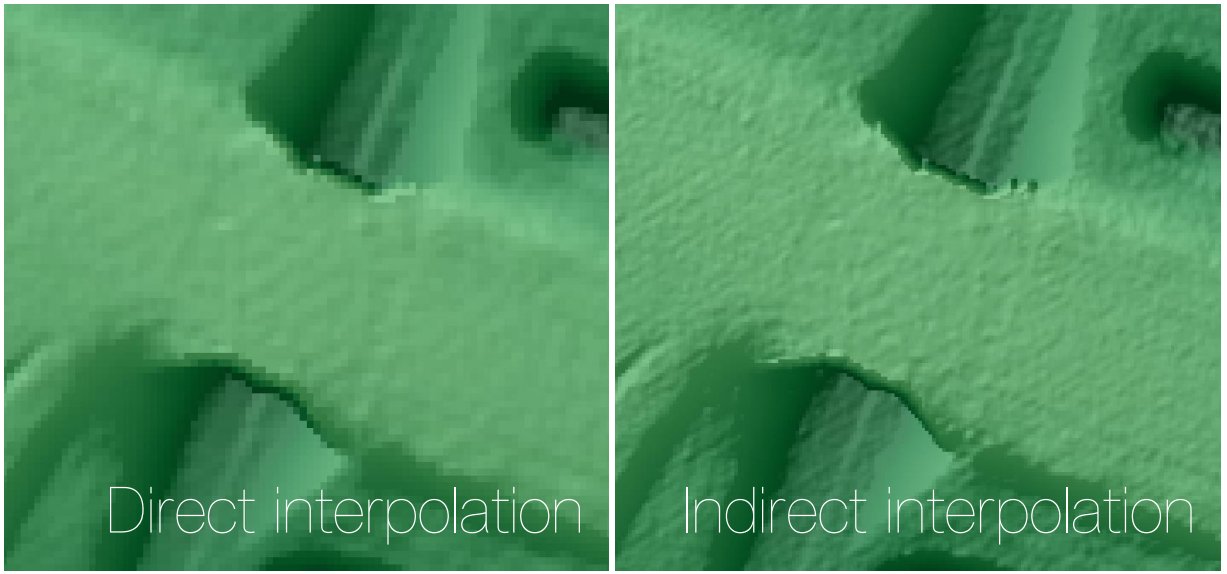
Methodology

Post processing

Methodology

Post processing

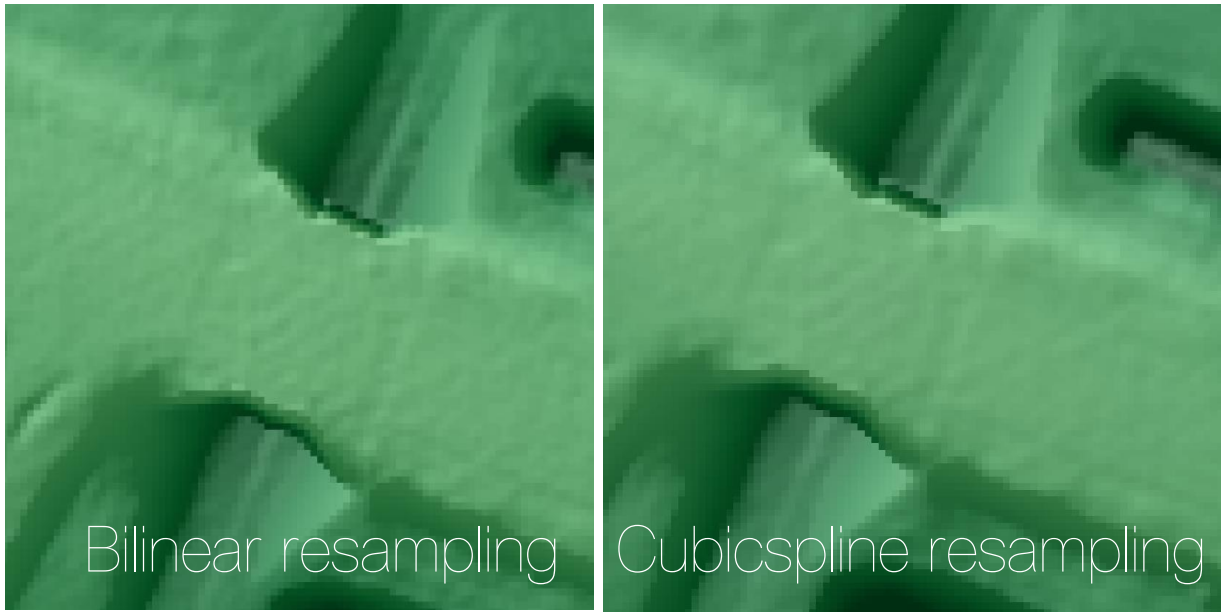
- Raster resampling
  - Direct interpolation
  - Indirect interpolation



Methodology

Post processing

- Raster resampling
  - Direct interpolation
  - Indirect interpolation
- Raster smoothing



Methodology

Post processing

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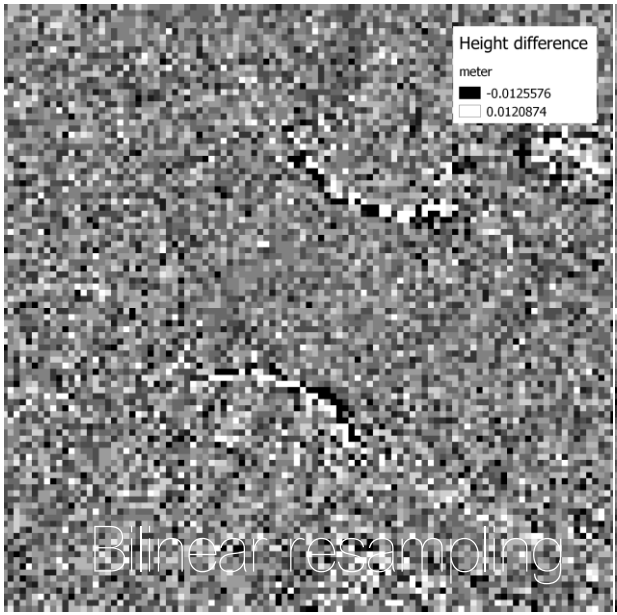
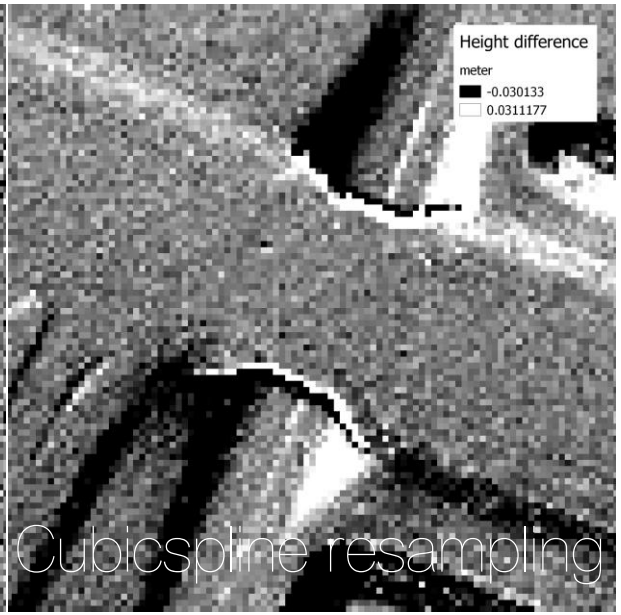
  - Indirect interpolation
- Raster smoothing



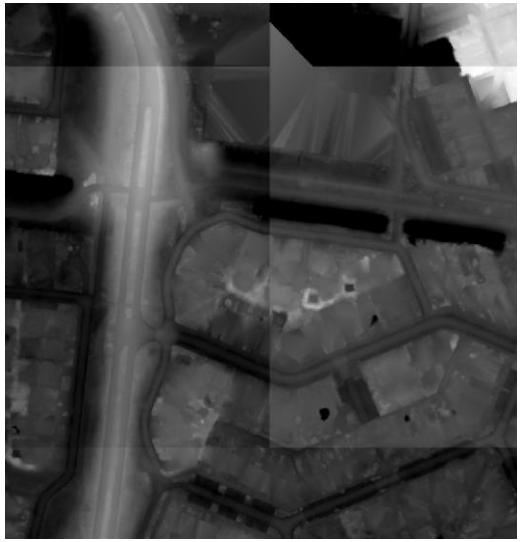
Bilinear resampling



Cubicspline resampling

Methodology
Post processing

- Raster resampling
- Virtual raster generation
  - Composition of tiled data
  - Removal of buffers
  - Georeferencing



Methodology

Raster visualization

Methodology

Raster visualization

- Hypsometric tinting
- Hill shading

- Image overview generation
  - Multi-scale visualization

Methodology

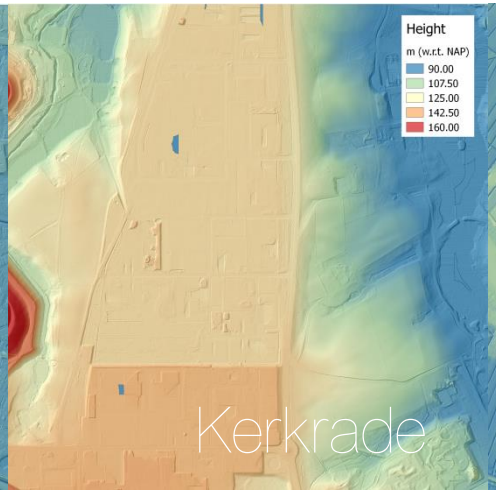
Implementation

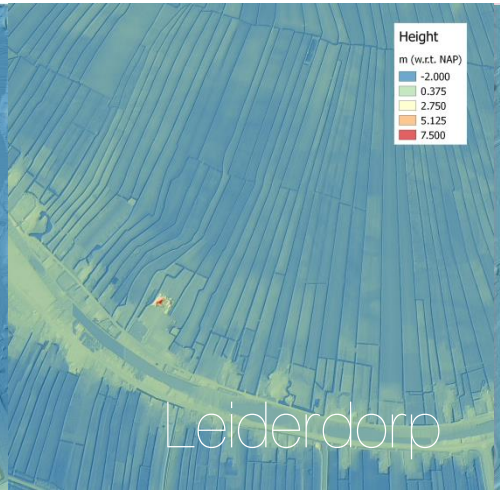
Methodology

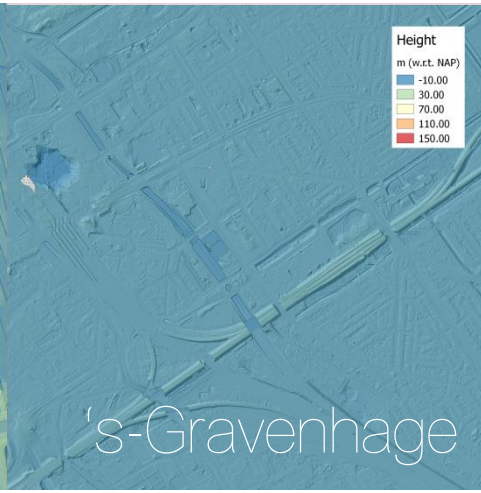
Implementation – test data sets

Methodology

Implementation – DEM

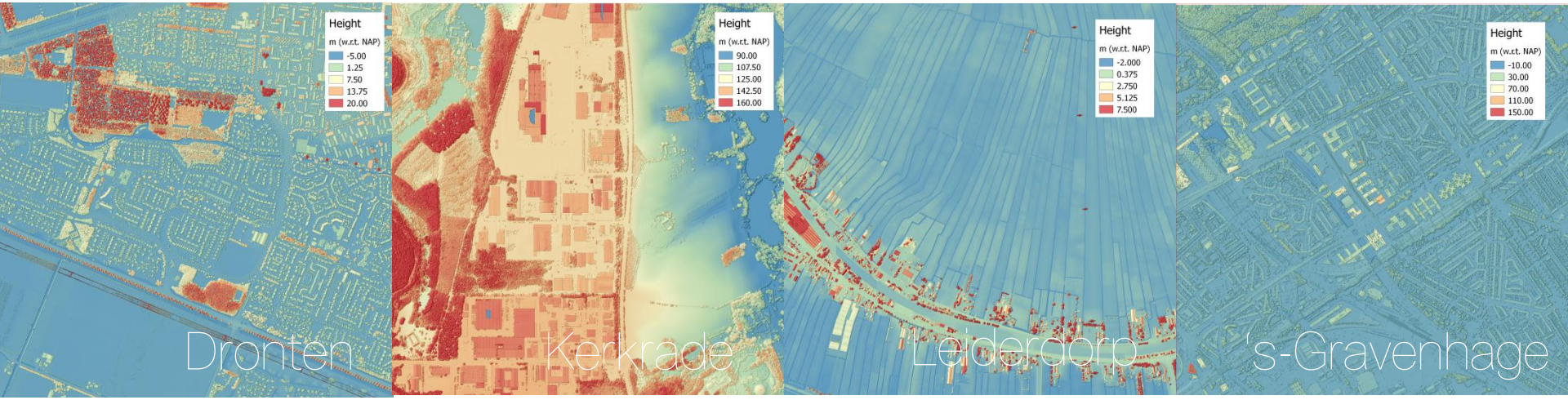






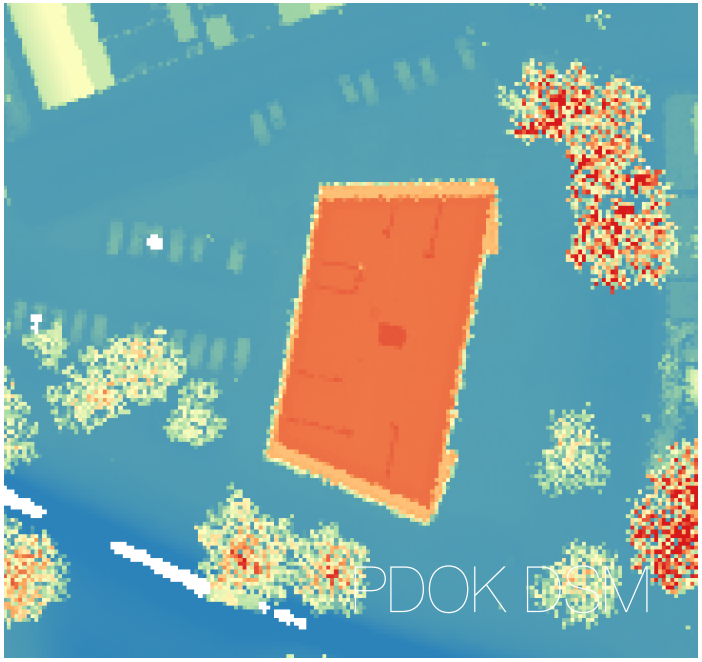
Methodology

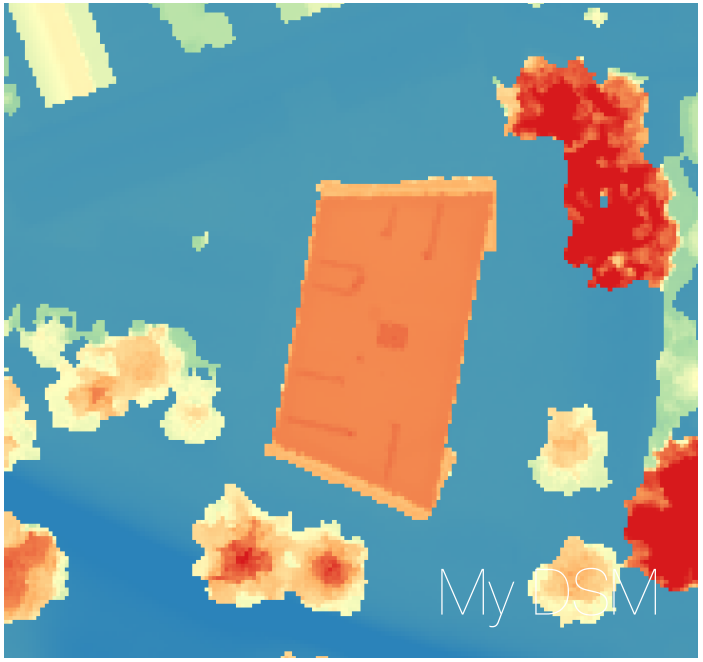
Implementation – DSM



Methodology

Implementation – DSM





Conclusion

What quantitative degree of quality can be achieved
for raster-based height maps
generated from AHN*2* point cloud data
by the application of an automated process?

Conclusion

Quality

- No ground truth height data available
- With respect to raster-based height maps
  - Not-filled DEM and DSM (PDOK)
  - Filled DEM (PDOK)
  - DEM and DSM (OHN)

Conclusion

Quality

- ISO19157: Geographic Information Quality principles
  - Completeness
  - Logical consistency
  - Positional accuracy
  - Temporal accuracy
  - Thematic accuracy

Conclusion

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Conclusion

Quality – completeness

DEM

	Dronten		Kerkrade		Leiderdorp		's-Gravenhage	
	C (%)	O (%)	C (%)	O (%)	C (%)	O (%)	C (%)	O (%)
Not-filled DEM	81.00	19.00	79.00	21.00	63.05	36.94	88.24	11.76
Filled DEM	82.87	17.13	80.32	19.62	64.64	35.35	88.63	11.37
OHN DEM	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
My DEM	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00

DSM

	Dronten		Kerkrade		Leiderdorp		's-Gravenhage	
	C (%)	O (%)	C (%)	O (%)	C (%)	O (%)	C (%)	O (%)
Not-filled DSM	98.31	1.69	94.49	5.51	96.81	3.19	92.72	7.28
OHN DSM	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00
My DSM	100.00	0.00	100.00	0.00	100.00	0.00	100.00	0.00

Conclusion

Quality – positional accuracy

DEM

	Dronten			Kerkrade			Leiderdorp			's-Gravenhage		
	ΔH_{max}	RMSE	SD	ΔH_{max}	RMSE	SD	ΔH_{max}	RMSE	SD	ΔH_{max}	RMSE	SD
Not-filled DEM	0.00	0.0000	0.0000	0.00	0.0000	0.0000	0.00	0.0000	0.0000	0.00	0.0000	0.0000
OHN DEM	2.36	0.0568	0.3121	5.59	0.0859	0.4812	2.25	0.0330	0.1981	5.63	0.0509	0.4543
My DEM	1.08	0.0054	0.0229	5.71	0.0185	0.1186	1.04	0.0154	0.0445	6.68	0.0301	0.2292
My DEM (w.r.t. **OHN** DEM)	2.87	0.0666	0.3139	5.72	0.2188	0.8078	2.48	0.1126	0.3098	10.19	0.4951	1.8893

DSM

	Dronten			Kerkrade			Leiderdorp			's-Gravenhage		
	ΔH_{max}	RMSE	SD	ΔH_{max}	RMSE	SD	ΔH_{max}	RMSE	SD	ΔH_{max}	RMSE	SD
OHN DSM	40.05	3.5546	7.5510	21.22	0.1469	1.1118	76.25	0.3935	4.7111	36.58	0.1622	1.6135
My DSM	39.81	3.9822	8.1147	40.246	4.7380	7.9163	81.88	1.3701	6.33422	133.40	4.4689	13.5727
My DSM (w.r.t. **OHN** DSM)	39.81	3.9853	8.1164	40.246	4.7520	7.9275	81.88	1.3367	5.8172	132.71	4.6733	13.9945

Conclusion

Quality – thematic accuracy

DEM

	Dronten	Kerkrade	Leiderdorp	's-Gravenhage
Ground	97.67%	99.33%	99.69%	99.48%
Water	85.71%	83.72%	56.00%	76.92%

DSM

	Dronten	Kerkrade	Leiderdorp	's-Gravenhage
Ground	97.67%	99.33%	99.69%	99.48%
Water	85.71%	83.72%	56.00%	76.92%
Buildings	100.00%	100.00%	94.74%	91.09%
Vegetation	98.00%	100.00%	100.00%	100.00%

Conclusion

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The presented methodology can generate raster-based height maps having a **high completeness**, **positional accuracy** and a **high thematic accuracy*,** detecting more object classes with respect to currently existing raster-based height maps.

*Except water

Future work

Future work

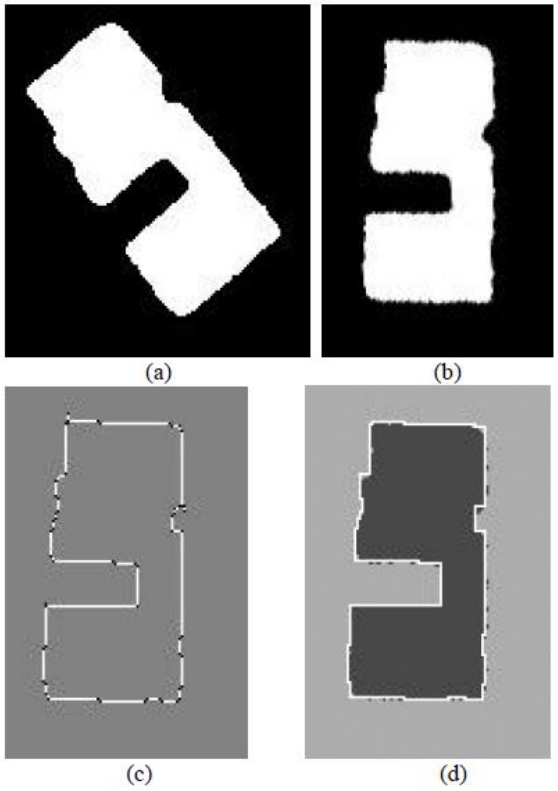
DEM

- Improve Sink filling
  - Adjacent tiles
  - Combine slope-based data with external geodata sets

Future work

DBM

- Optimize building footprints (Alharthy, et al., 2002)



Future work

CHM

- Improve point classification
- Statistical filtering of raster-based data

Thank you for your attention!