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Enhancing the Resolution of Urban Digital Terrain Models (DTMs) using Mobile Mapping Systems

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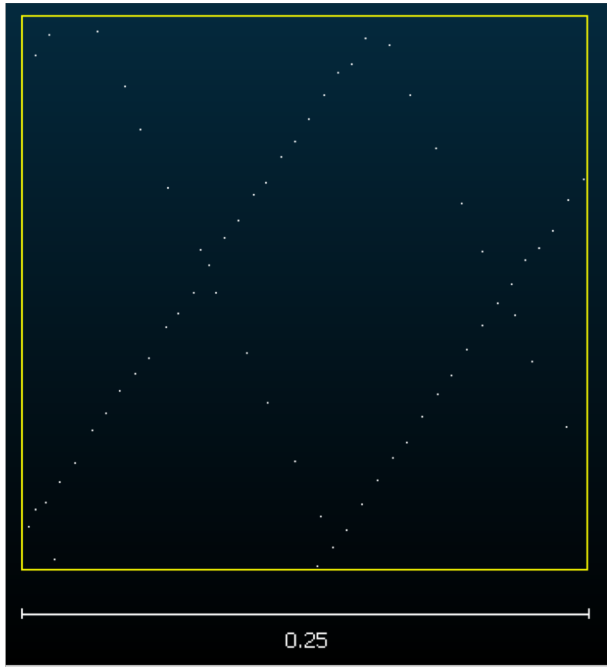
Motivation

- Higher resolution DTMs
  - Beneficial for terrain based analyses, e.g. flood modelling in urban area
- Surveying Methods
  - Airborne Laser Scanning (ALS)
    - Large coverage area
    - Point density limited by flying height
    - Insufficient measurements for complicated urban areas
  - Mobile Mapping Systems
    - High density measurements on the ground
    - Only cover area around roads

Source: http://news.ifeng.com/a/20160720/49459048_0.shtml
http://news.cnnb.com.cn/system/2015/07/22/008362370.shtml

Measurement Campaign with Mobile Mapping Systems in Ricklingen, Hannover

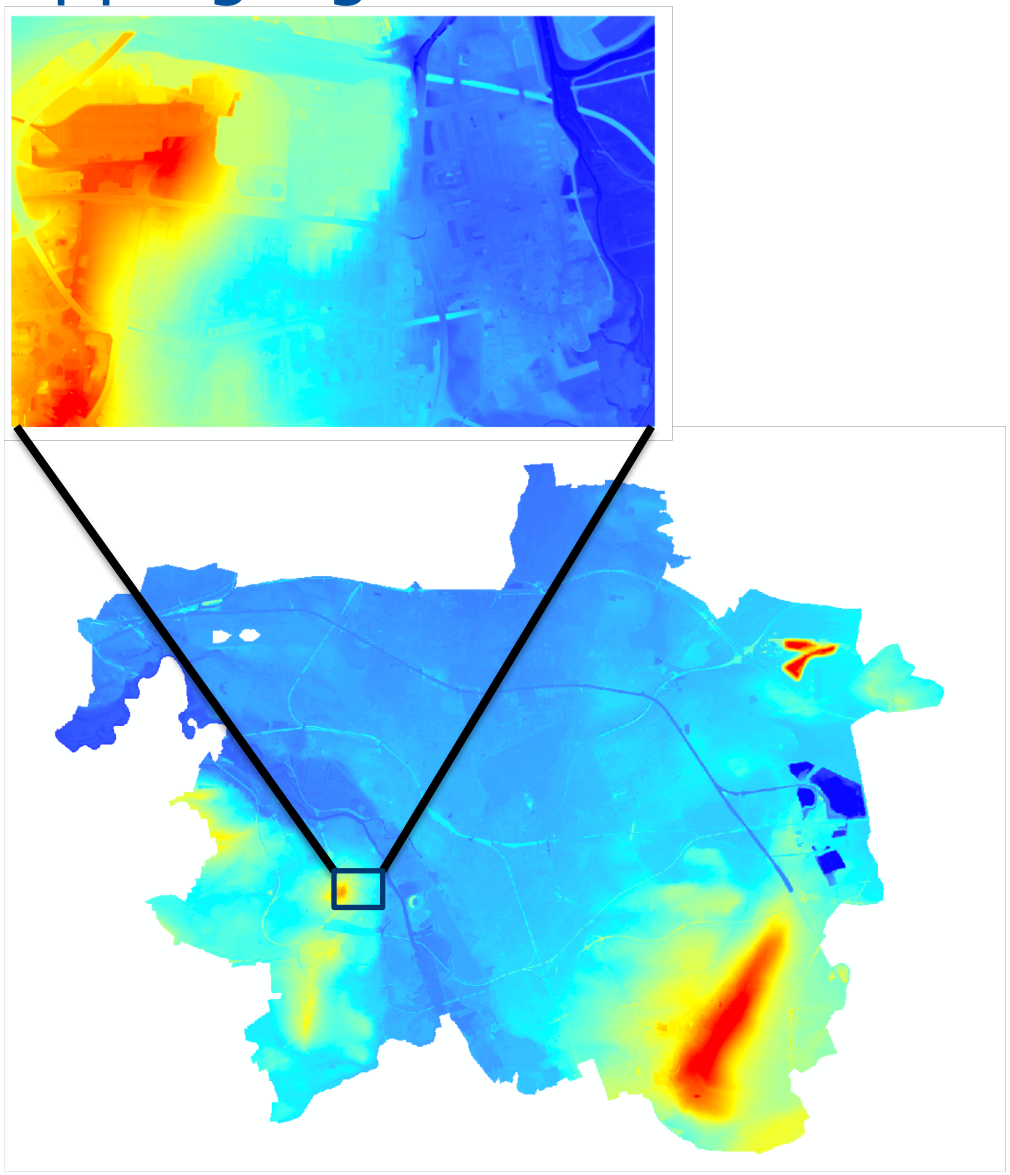


0.25m x 0.25m ≈ 69 Points

Date	02. Dec. 2015
Points	5.1 billion
Point data	199 GB
Scan strips	485

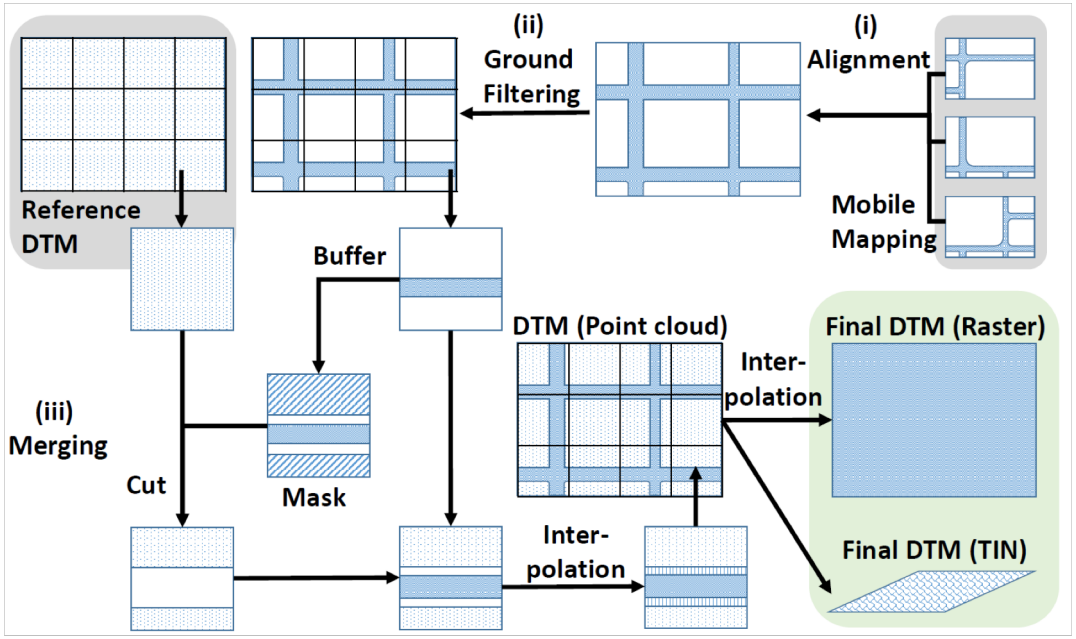
Reference DTM from Mapping Agencies

- 0.5m resolution
- Airborne Laser Scanning
- Study area in Ricklingen, Hannover
  - 6.55 km^2
  - 26 million cells
  - Position accuracy: ±20cm
  - Height accuracy: ±30cm

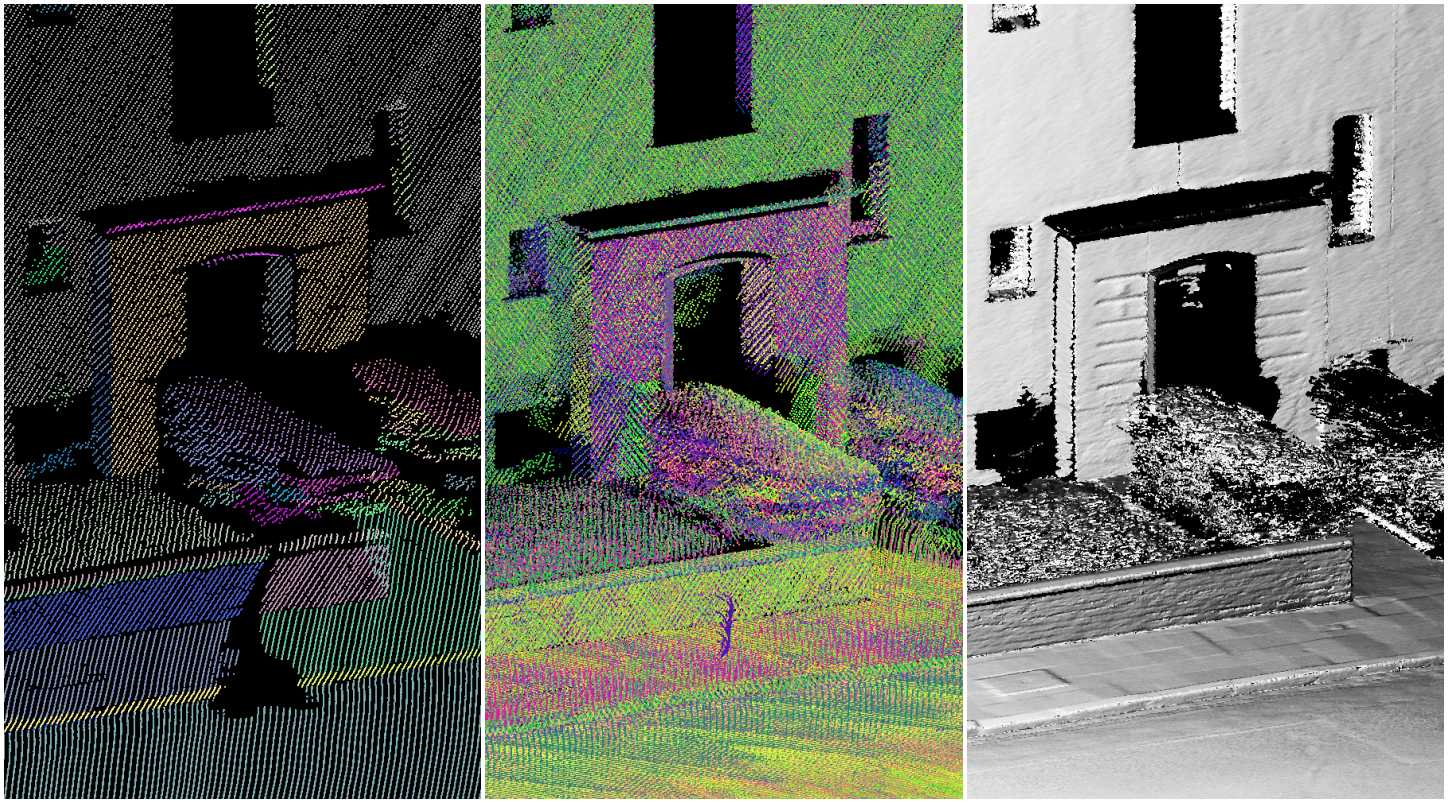


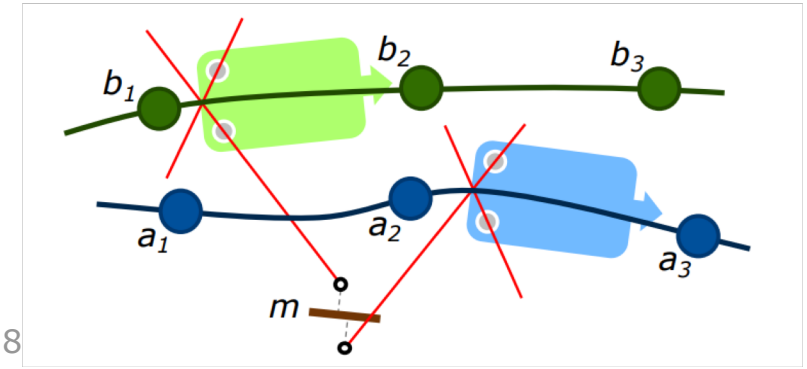
Methods

- (i) Alignment of point clouds from different epochs
- (ii) Ground filtering
- (iii) Merging of DTMs with different resolution
- (iv) Height Adaption



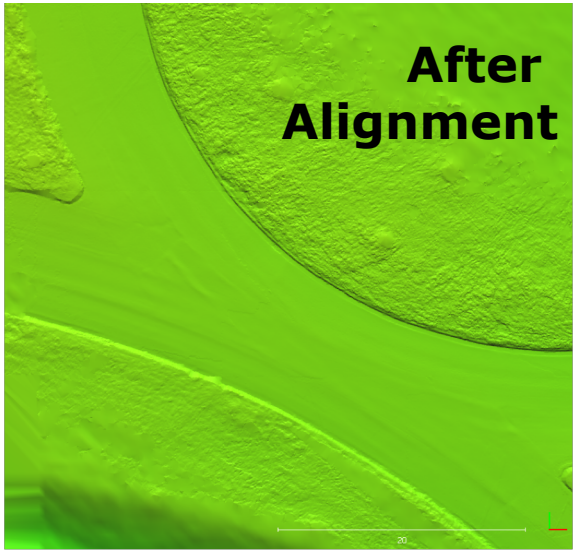
Alignment of point clouds from different epochs





Brenner, C. (2016). Scalable estimation of precision maps in a MapReduce framework. In *Proceedings of the 24th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems* (p. 27). ACM.

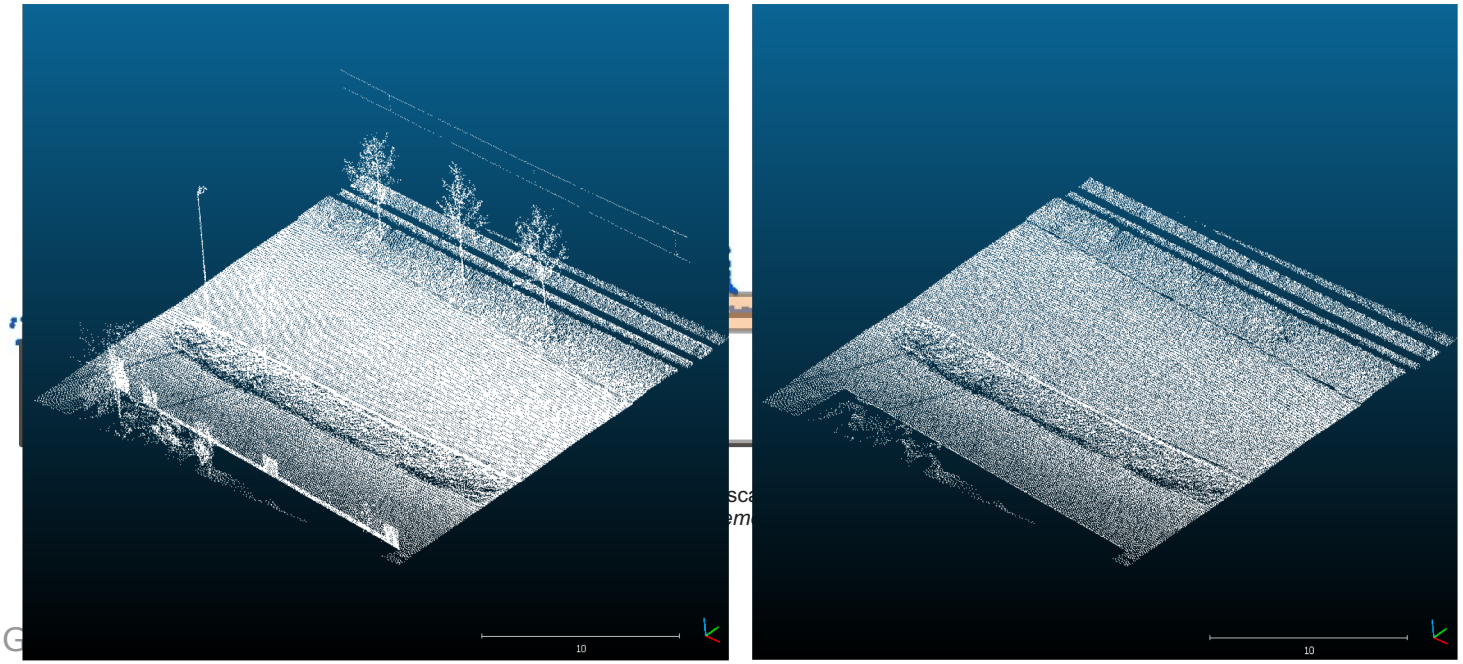
Alignment of point clouds from different epochs



- 485 scan strips
- 1.9 billion surface elements
- 781,000 exterior orientation correction parameters

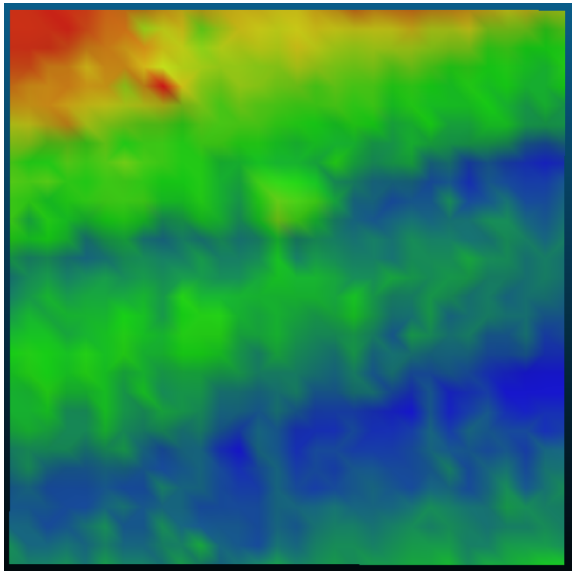
Ground Filtering

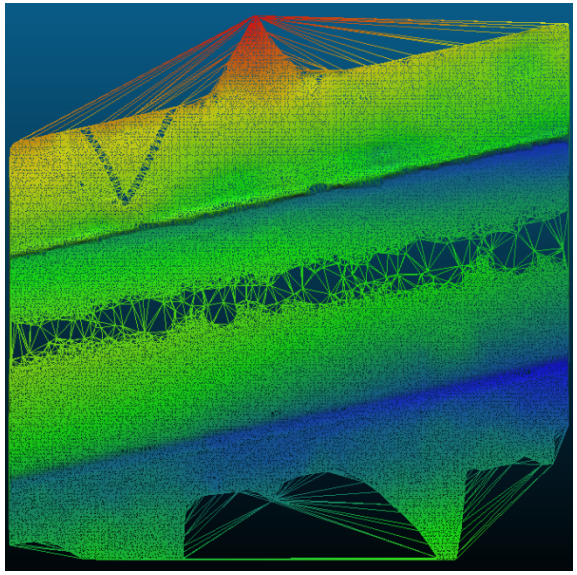
- Use reference DTM as prior to remove big objects
- Refine with a grid-based approach (Wack and Wimmer, 2002)
  - Point cloud tile to 1m raster – lowest height within the cell
  - Use gradient of raster to reject non-terrain cells
  - Use max allowed height derivation to remove non-terrain points
  - Decrease the grid size to 0.33m and 0.11m, iterate the procedure



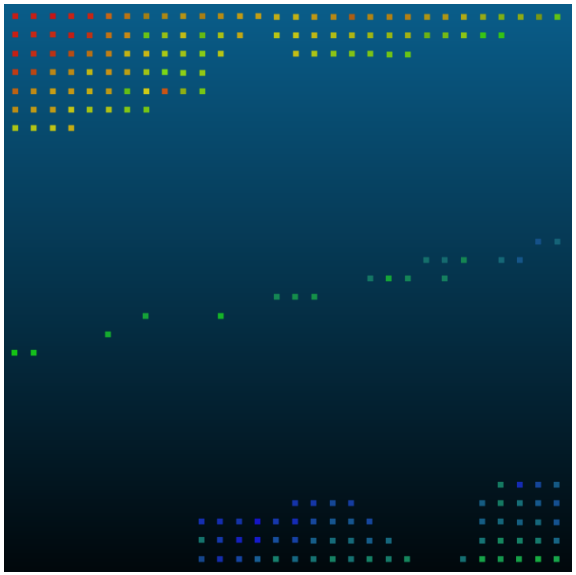
Merge

(a) DTM from mapping agency in lower resolution

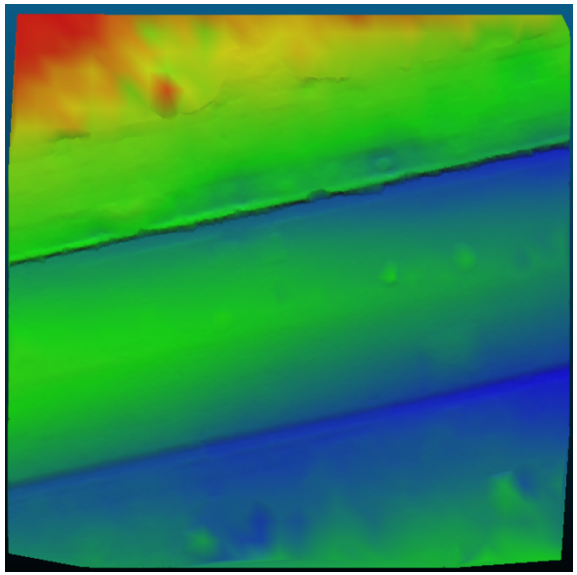




(b) Measure-ments after ground filtering

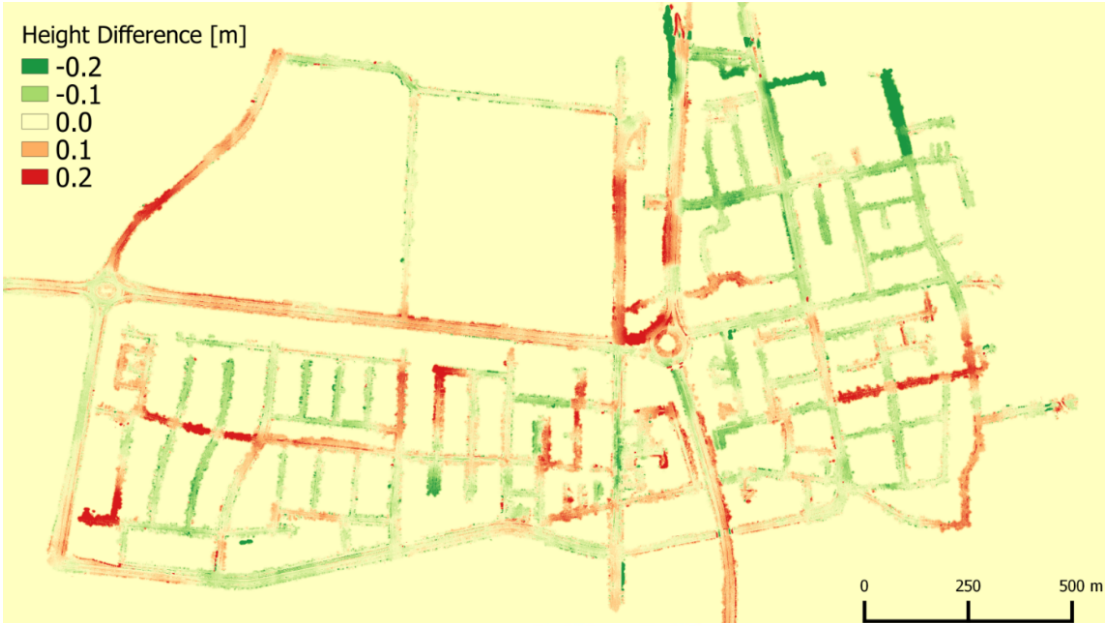


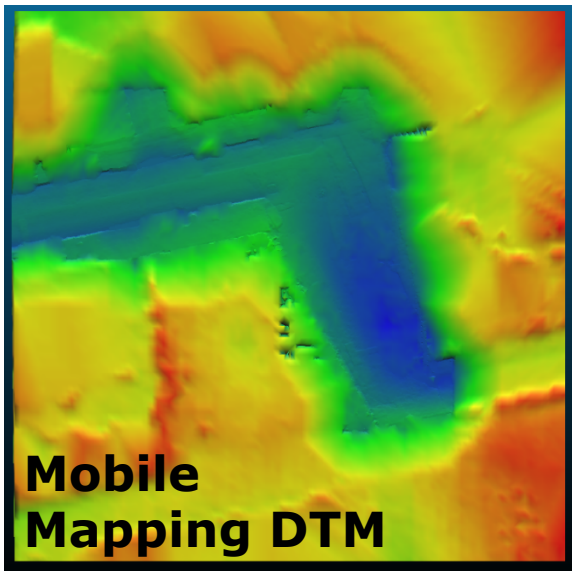
(c) Adapted DTM filling

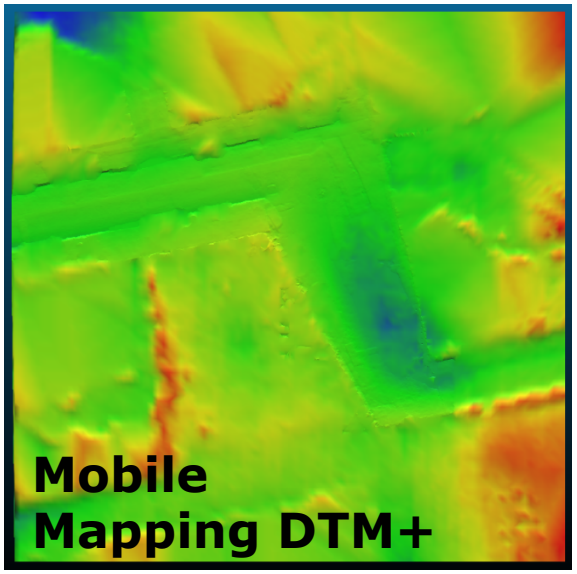


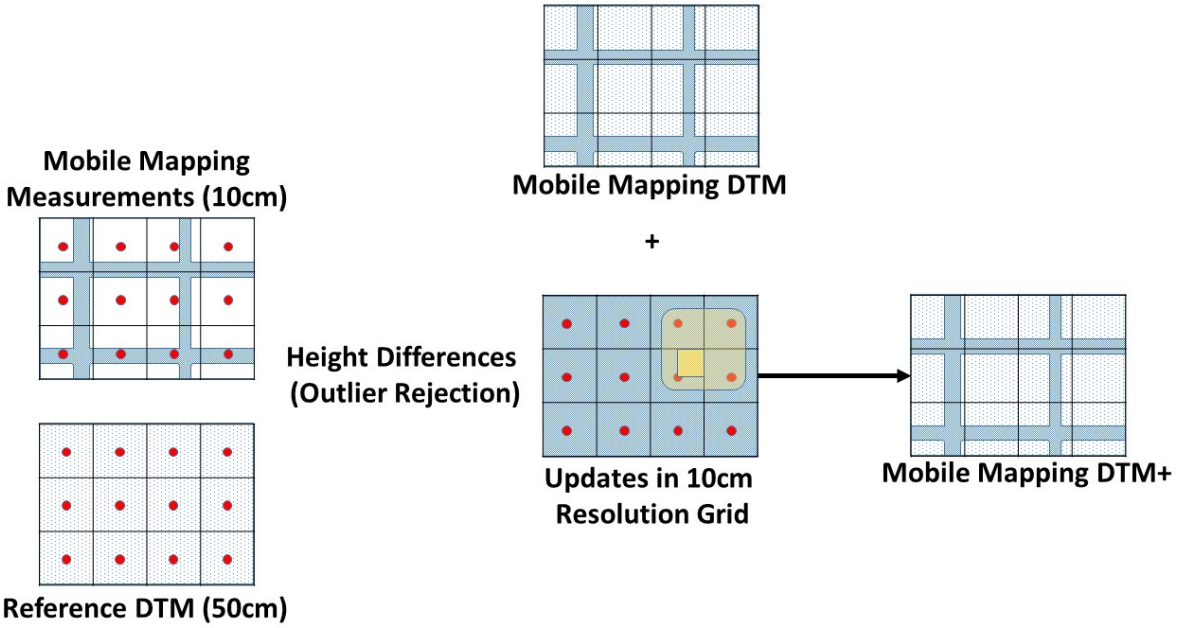
(d) Merged DTM

Adapt Height Difference

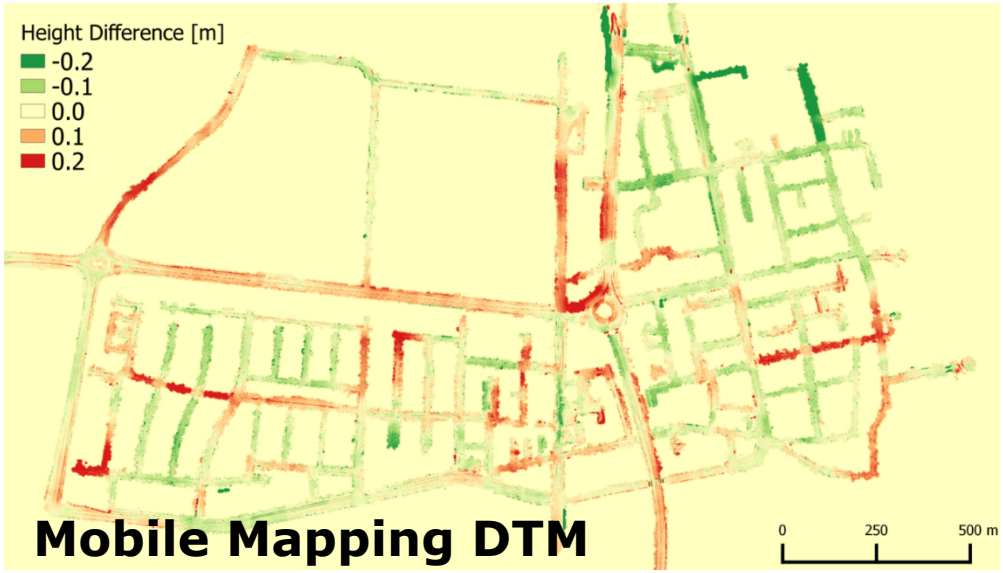


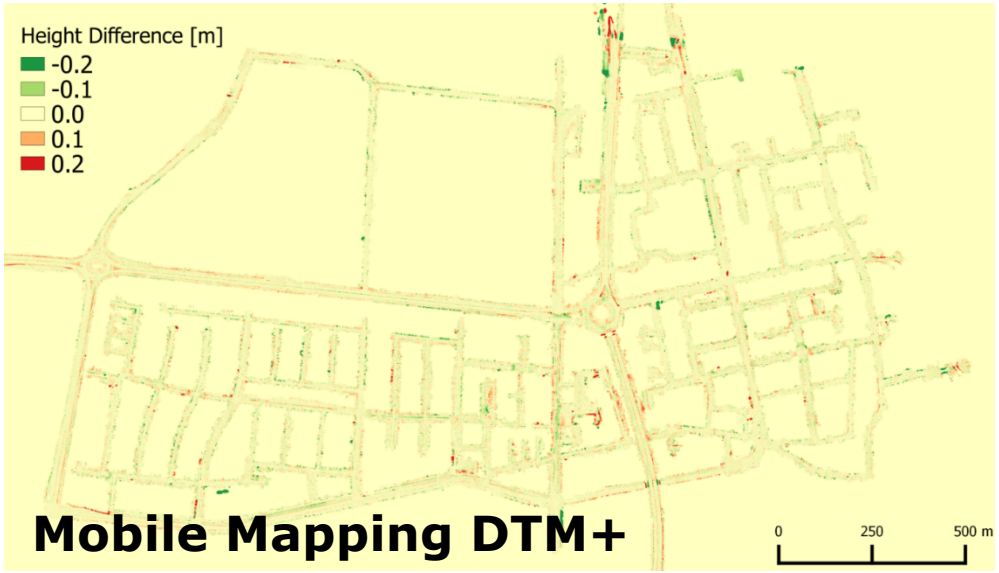






Adapt Height Difference

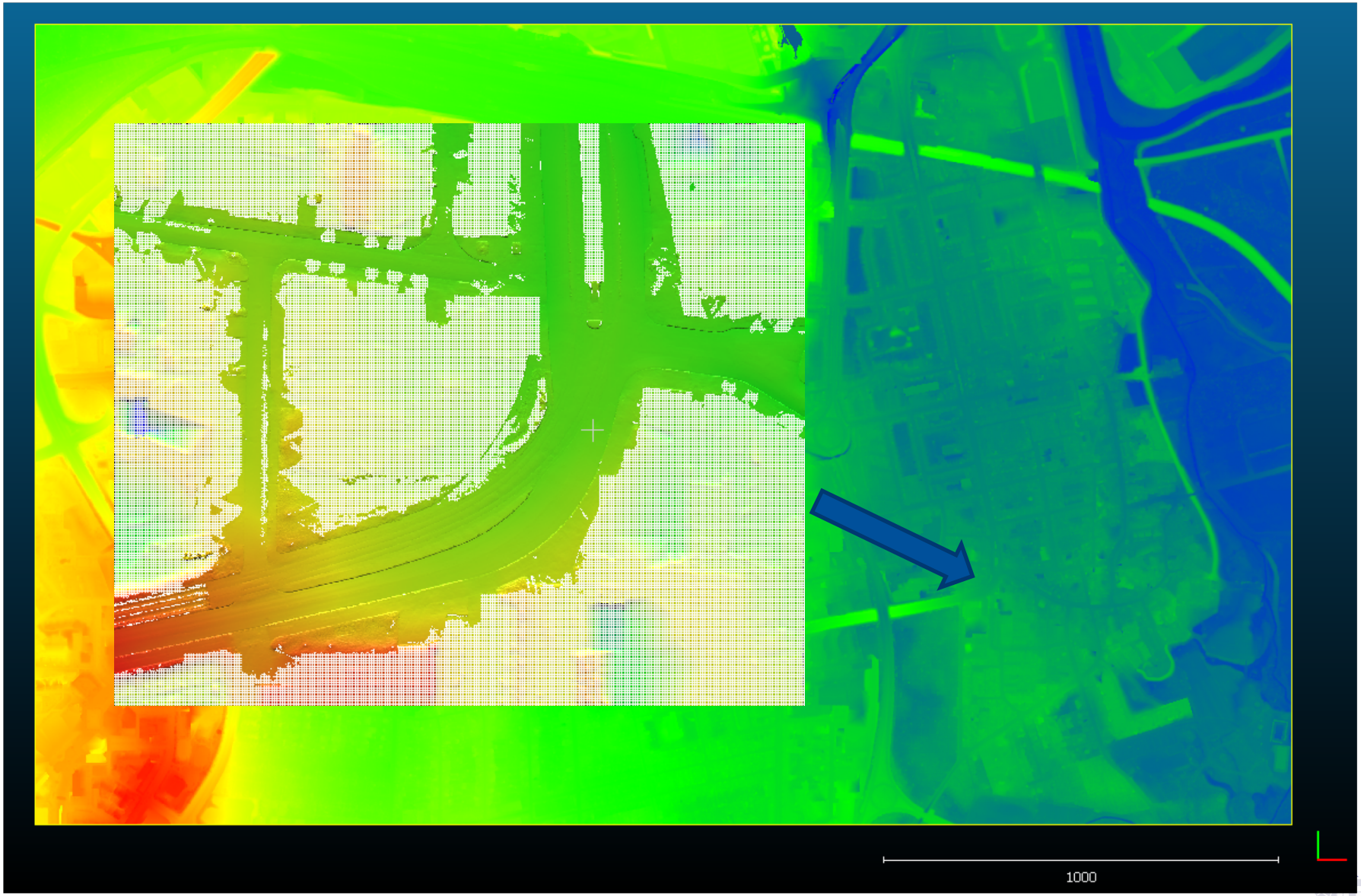


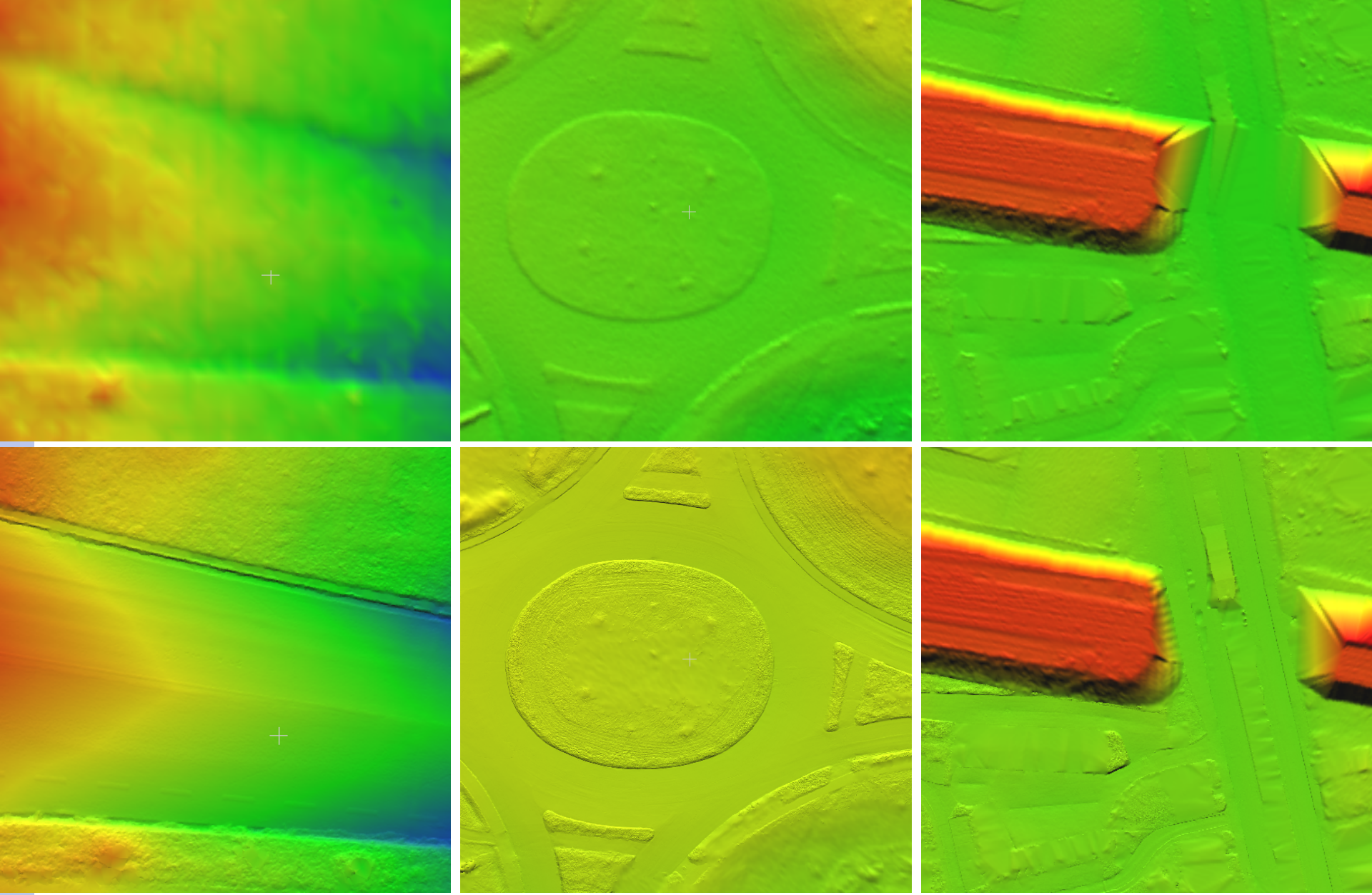


	Mean [m]	STD [m]
Mobile Mapping DTM	0.0020	0.0989
Mobile Mapping DTM+	-0.0022	0.0674

Mobile Mapping generated DTM (0.1m)

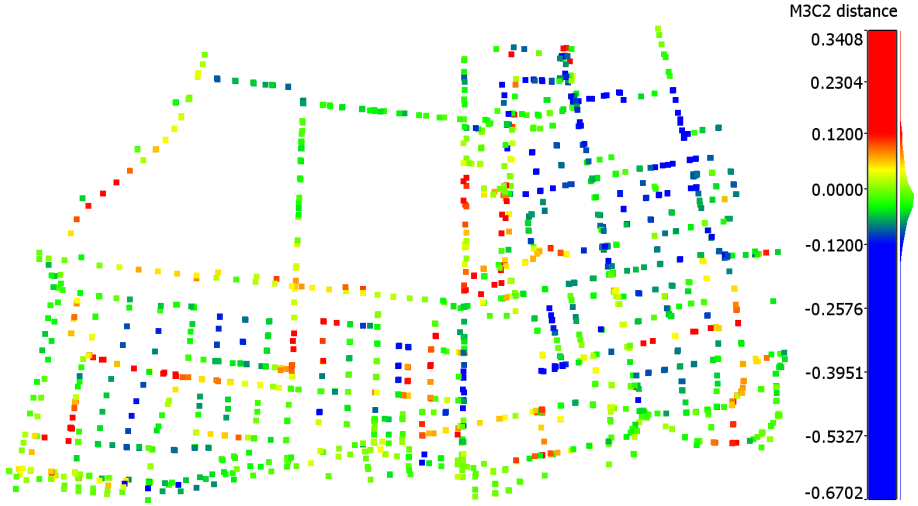
Final Product





Evaluation – Manholes Leveling Measurements

Reference DTM



Mobile Mapping DTM

	Mean [m]	STD [m]
Reference DTM	-0.0202	0.0307
Mobile Mapping DTM	-0.0197	0.0837
Mobile Mapping DTM+	-0.0193	0.0328

Mobile Mapping DTM+

Conclusion

- Pipeline methods to enhance an urban DTM to higher resolution using Mobile Mapping Systems
- Achieve the completeness by merging with DTM in lower resolution while maintain its height accuracy
- Outlooks:
  - Optimal ground filtering methods, e.g. deep learning
  - Analyze the benefit of this DTM product for flood modeling comparing with the lower resolution DTM