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.ifeng.com/a/20160720/49459048_0.shtml)
Measurement Campaign with Mobile Mapping Systems in Ricklingen, Hannover

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

Source: http://www.riegl.com/

0.25m x 0.25m ≈ 69 Points
Reference DTM from Mapping Agencies

- 0.5m resolution
- Airborne Laser Scanning
- Study area in Ricklingen, Hannover
  - 6.55 km²
  - 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

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) Measurements after ground filtering

(c) Adapted DTM filling

(d) Merged DTM
Adapt Height Difference

Height Difference [m]
-0.2
-0.1
0.0
0.1
0.2

Mobile Mapping DTM
Mobile Mapping DTM+

Mobile Mapping Measurements (10cm)

Height Differences (Outlier Rejection)

Reference DTM (50cm)

Updates in 10cm Resolution Grid
Adapt Height Difference

<table>
<thead>
<tr>
<th></th>
<th>Mean [m]</th>
<th>STD [m]</th>
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<tbody>
<tr>
<td>Mobile Mapping DTM</td>
<td>0.0020</td>
<td>0.0989</td>
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<tr>
<td>Mobile Mapping DTM+</td>
<td>-0.0022</td>
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Mobile Mapping generated DTM (0.1m)
Evaluation – Manholes Leveling Measurements

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</tbody>
</table>

Reference DTM

Mobile Mapping DTM

Mobile Mapping DTM+

Mean [m]

STD [m]
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