Capturing Reality with Point Clouds: Applications, Challenges and Solutions

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Hasso Plattner Institute
Point Cloud Analytics and Visualization

OVERVIEW
• IT solutions for the management, computational use, and visualization of large-scale, highly detailed 3D point clouds
• Partner: Ordnance Survey Ireland, national mapping agency
• Data: 3D point clouds, image data, vector data

CHALLENGES / OPPORTUNITIES
• Massive amount of spatial data
• Need for high performance processing
• Variety of applications
• Compression techniques

SOLUTIONS
• Oracle Database 12c
• Oracle Spatial and Graph, with SDO_PC_PKG Package (Point Clouds)
• Exadata
• Flat Table

RESULTS
• Fast loading of LAS files
• Tile queries are 4 times faster
• Determination of overview and statistic information
• Consolidation of raster, vector, point cloud data in a central repository
• Integration in 3D date processing workflow possible
Background

**Hasso Plattner Institute (HPI):**

- Computer Graphics Systems group of Prof. Döllner
- Research in the field of analysis, planning, and construction of software systems for massive geodata
- www.hpi3d.de

**Point Cloud Technology GmbH:**

- IT solutions for the management, computational use, and visualization of large-scale, highly detailed 3D point clouds
- HPI Spin-Off
- www.pointcloudtechnology.com
Agenda

• Context & Problem
• Objectives and Challenges
• Analysis Tasks
  • Point Cloud Classification
  • Change Detection
• Case Study with Exadata
• Conclusions
Context

3D Point Clouds
- Set of points in the 3D space with an unorganized structure having no order or hierarchy
- Accurate and discrete representation of surfaces, i.e., real-world objects or urban areas
- Base data for 3D reconstruction algorithms

Airborne Laserscanning and Image-matching:
- 4-100 points per m²

Mobile and terrestrial Laserscanning:
- Up to 10,000 points per m²

Consumer hardware:
- Kinect, stereo cameras
3D Point Clouds
Aerial Laserscanning
Dense Image Matching
Mobile Laser Scanning
Mobile Laser Scanning
Objectives and Challenges
“Data is the new oil. Data is just like crude. It’s valuable, but if unrefined it cannot really be used.” Clive Humby
Data Collection

- Data collection is performed in **regular intervals** (e.g., once a year), with **high resolution** and **coverage** for cities, metropolitan areas, and countries.

- Applications and workflows are faced with large amounts of dense, and redundant 3D point clouds:
  - Availability, accuracy, density, and massivity of 3D point clouds will vastly increase within the next years.
  - It is not feasible to derive 3D models due to time, economic, and financial reasons.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Area</th>
<th>Density</th>
<th>#Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berlin (ALS)</td>
<td>890 km²</td>
<td>100 pts/m²</td>
<td>80 billion</td>
</tr>
<tr>
<td>Baden-Württemberg (ALS)</td>
<td>36.000 km²</td>
<td>25 pts/m²</td>
<td>900 billion</td>
</tr>
<tr>
<td>Historical site (TLS)</td>
<td>10.000 m²</td>
<td>Up to 10.000 pts/m²</td>
<td>5 billion</td>
</tr>
<tr>
<td>Railroad line (mobile mapping)</td>
<td>80 km</td>
<td>11 million pts/km</td>
<td>880 million</td>
</tr>
</tbody>
</table>
Challenges

1) Real-time 3D rendering of arbitrarily large 3D point clouds
   • Interactive exploration of a captured area without having to derive mesh-based 3D models
   • Support for different hardware platforms (e.g., mobile devices)

2) Efficient processing and analysis based on 3D point clouds
   • Change detection, continuation, and updates
   • Monitoring based on 3D point clouds
   • Identification of objects and surface categories

3) Storage and Management of 3D point clouds to enable an efficient access to the data
   • Heterogeneous input data
   • Homogeneous data model
   • Database for 3D point clouds (e.g., Oracle Spatial and Graph)
Visualization
Web-based Visualization
Classification of 3D Point Cloud
Categorization of Changes

Ground:

Vegetation:

Building:
Case Study Berlin

Facts:
• 890 km² urban area
• 120 TB data
• 527,000 buildings

Data:
• 3D point cloud 2009
  • 5-10 points/m²
  • 5 Bil. points
• 3D point cloud 2013
  • 100 points/m²
  • 80 Bil. points
  • Building footprints

Classified 3D point cloud.

Partners:
Detection of **new, removed, and modified** buildings
- Buildings in the 3D model but not in the 3D point cloud
- Buildings in the 3D point cloud but not in the 3D model
- Buildings with a wrong digital footprint in the 3D model or cadastre
- Buildings with structural changes (e.g., regarding the volume)
Comparison of buildings in the old and new 3D city model.
Case Study Berlin – Tree Detection

- Vegetation is important for the appearance of 3D city models
- Official tree cadastres do not cover the entire area of a city
- Trees for backyards, parks, and forests are missing
Case Study Berlin – Tree Detection

• Detection of individual trees in the 3D point cloud
• Derivation of tree properties (e.g., size, volume, and color)
• Real-time visualization of trees
Case Study with Exadata
Participants

[Logos of OSI Ordnance Survey, Oracle, and Hasso Plattner Institut]
Objectives

3D point cloud from image matching
- 760 LAS files
- 4 and 16 pts/m² (LAS files)
- 43.9 billion points

Building polygons
- Shapefile
- 194,140 buildings

Objectives
- Tile queries
- Matching with polygons
- Point proximity
- Classification DTM
Data Access

Data Update

Processing on Exadata
(e.g., building polygon evaluation)

Configuration & Administration

Processing on Client
(e.g., classification)
Database Tool

[Image of DBTool interface with parameters and a progress bar indicating 86% completion of exporting point cloud into 45 tiles...]

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Statistics and Performance Numbers

Import of data:

- Input: 760 LAS files -> 1.8 TB raw data
- Flat table
- Import: 77 min with parallel 48 (load via external table, incl. pyramiding)
- „Query high“ compression on Exadata -> 318 GB

Queries:

- ~1 million points: 0.78 sec
- ~10 million points (x, y, z): 6.92 sec
- ~10 million points (all attributes): 10.45 sec
Building Polygon Analysis

**Approach:**

- Determine all points in building footprint
- Determine relevant DTM patch
- Calculate footprint metrics
- Export footprints to shape
Task: Getting the MAX, MIN, AVG height and count of points in a building

**Prime2 building polys**

Create table of buildings within point cloud area  42.446 sec (194140 buildings)
create table buildings_insert (  
  GUID VARCHAR2(114),  
  GEOM SDO_GEOMETRY);

insert into buildings_insert(  
  select guid,sdo_cs.make_2d(polyGeomValue) geom from prime2.building_poly a  
  where  
  sdo_filter(A.polyGeomValue, mdsys.sdo_geometry(2003,2157,NULL,  
        mdsys.sdo_elem_info_array(1,1003,3),  
        mdsys.sdo_ordinate_array(655555,590000, 720000,660000)),  
        'querytype=window') = 'TRUE');

Performance: 38.75 buildings per sec running for 43,985,178,918 points
Classification DTM

**Approach:**

- Classification int ground and non-ground
- Filling of terrain
Classification DTM

**Approach:**

- Classification into ground and non-ground
- Interpolation and filling of terrain
Our Infrastructure
Conclusions

“Data availability, accuracy, density, and massivity of 3D point clouds will vastly increase within the next years”

- **Point cloud analytics** is important for domain-specific applications.
- **Multi-temporal point cloud** enables selective updates and offer new insights.
- **Scalable infrastructures, GPU-based algorithms** and **out-of-core processing strategies** and are required to handle massive, dense, and large-scale point clouds.
- **Database** and **cloud infrastructures** to provide point clouds for different scales.
- **On-demand processing** and **analysis** with high-performance hardware.
Conclusions

“3D point cloud analytics constitutes a technology branch that will become relevant for manifold application areas beyond GIS-based fields.”
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