ifp

Universität Stuttgart

Terrestrial LiDAR in Urban Data Acquisition

Dr. Jan Böhm
Institute for Photogrammetry
Universität Stuttgart
jan.boehm@ifp.uni-stuttgart.de

ifp

Universität Stuttgart

Contents

- Motivation – Why do we need terrestrial LiDAR in urban modeling?
- How does this integrate with the final products (CityGML)?
- Direct visualization of terrestrial point clouds
  -> Point Splatting
- Modeling Facade Details from terrestrial LiDAR
  -> LASERMAP
- Modeling building interiors from terrestrial LiDAR
  -> Plane Sweeping & Cell Decomposition
- New Sensor Developments
  -> Potential for better models

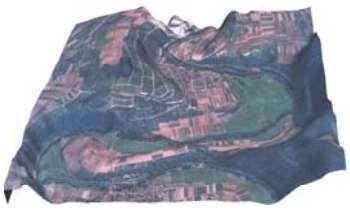
Motivation

Intergraph DMC Image

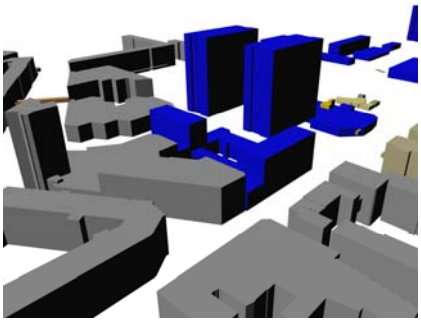
Burkert (2000)

- Aerial data capture is the „workhorse“ of urban data acquisition.
- Bird‘s-eye-view limits the geometry we can capture / reconstruct.
- Many applications visualize the data from a pedestrian's point-of-view (fly-through, mock-up, navigation, etc.).
- Terrestrial LiDAR perfectly matches the pedestrian's point-of-view in data capture.

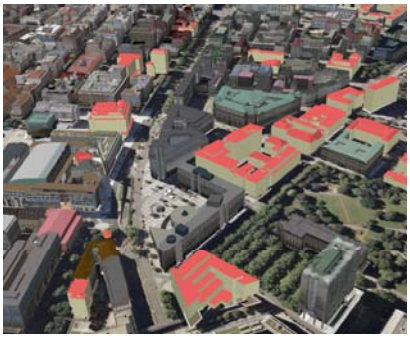
Urban Modeling - CityGML



LOD0

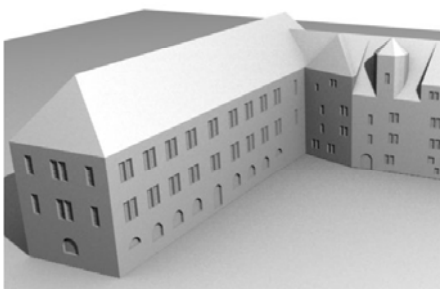


LOD1

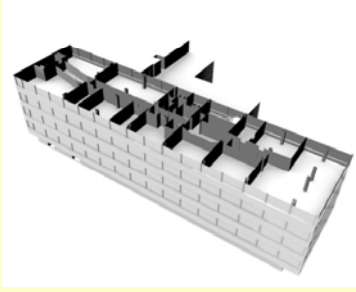


LOD2

LOD3



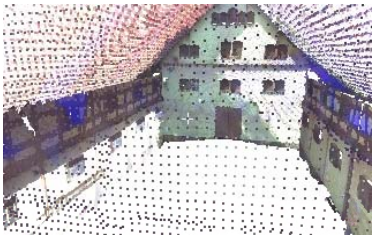
LOD3



LOD4

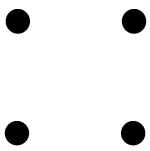
Terrestrial Point Clouds

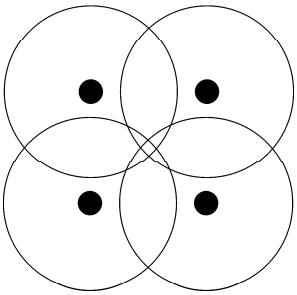
- A colored point cloud acquired with the terrestrial LiDAR system HDS 3000.
- The point cloud gives a good impression of the object from a far away view point.
- When we zoom in the impression of a solid surface collapses.
- “Gaps” in-between the points become visible and the background dominates the foreground.
- To close the “gaps” we can use triangulation, which is often difficult and time-consuming.



Point Splatting

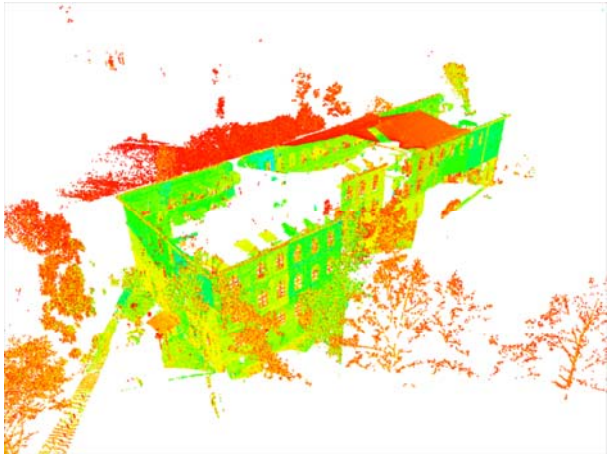
- When the number of triangles exceeds the number of pixels on the screen, most triangles cover less than a pixel and the rasterization of the triangles becomes extremely expensive.
- Point-based methods have been proposed (Pfister, 2000), which represent the surface by a point-wise sampling, where each point also stores the normal vector of the surface at this point.
- Point-based geometry provides all processing needs, such as editing, filtering and texturing.





Façade Modeling

- Terrestrial Laserscans are not the only available data source.
- Often we can reuse existing reference data.
- Georeferencing is essential for data fusion.
- Coarse 3D building models can be used to prepare / segment the point cloud.
- The part of the point cloud on a facade is resampled to a regular grid, aka **LASERMAP**



J. Böhm, 2007

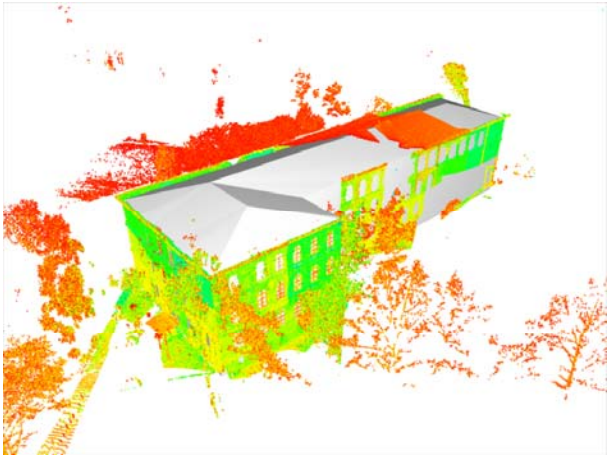
Façade Modeling

- Terrestrial Laserscans are not the only available data source.
- Often we can reuse existing reference data.
- Georeferencing is essential for data fusion.
- Coarse 3D building models can be used to prepare / segment the point cloud.
- The part of the point cloud on a facade is resampled to a regular grid, aka **LASERMAP**

J. Böhm, 2007

Façade Modeling

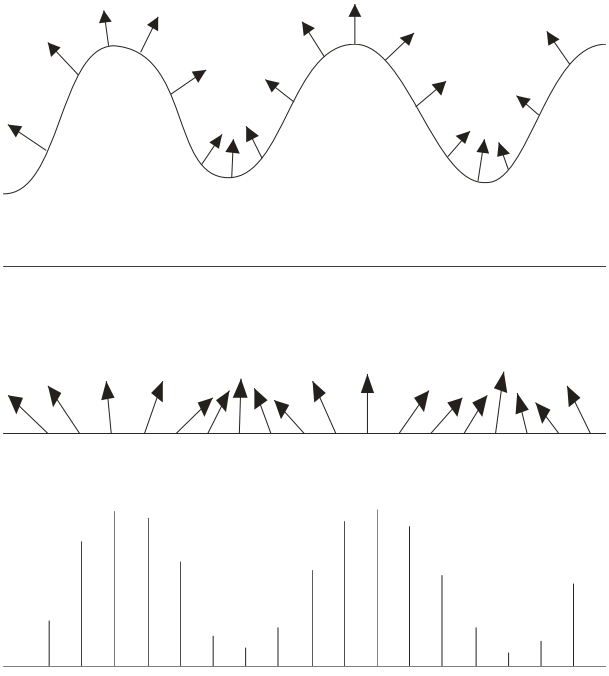
- Terrestrial Laserscans are not the only available data source.
- Often we can reuse existing reference data.
- Georeferencing is essential for data fusion.
- Coarse 3D building models can be used to prepare / segment the point cloud.
- The part of the point cloud on a facade is resampled to a regular grid, aka **LASERMAP**



J. Böhm, 2007

Separation of Geometry

- The planar facades of a coarse building model serve as a reference for segmentation.
- The true geometry of a surface is separated into
  - it's coarse geometry,
  - the normal map and
  - the displacement map which contains the difference of the true geometry and the coarse geometry.
- The displacement map and the normal map can be directly used for visualization.

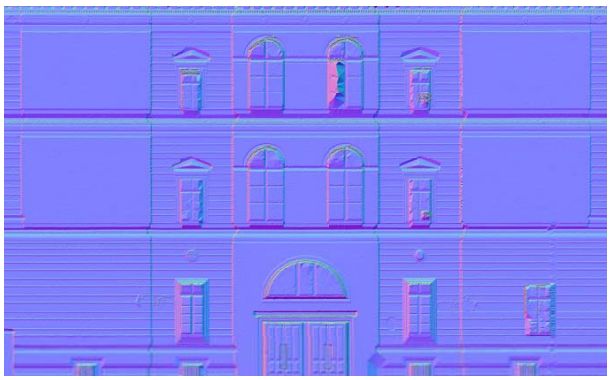


LASERMAP

- The planar facades of a coarse building model serve as a reference for segmentation.
- The true geometry of a surface is separated into
  - it's coarse geometry,
  - the normal map and
  - the displacement map which contains the difference of the true geometry and the coarse geometry.
- The displacement map and the normal map can be directly used for visualization.

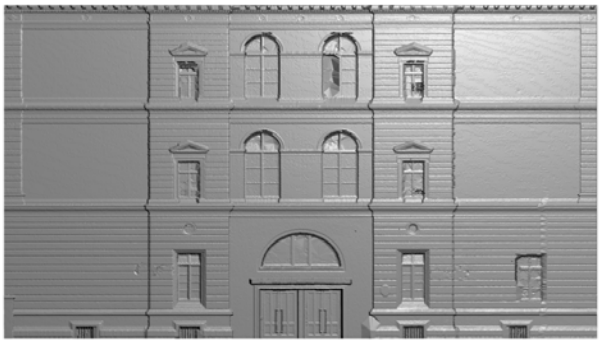
Normal Map

- Blinn (1978) observed that the effect of fine surface details is "primarily due to their effect on the direction of the surface normal … rather than their effect on the position of the surface".
- Normal maps store only the normal of the surface at each position.
- This can efficiently be encoded in a raster color image.
- The Normal map image is applied to the geometry like a texture image using an appropriate render engine.



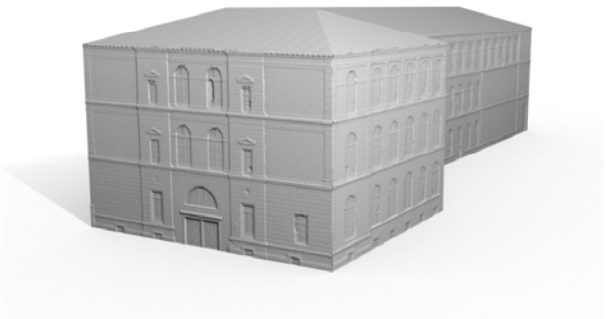
Normal Map

- Blinn (1978) observed that the effect of fine surface details is “primarily due to their effect on the direction of the surface normal … rather than their effect on the position of the surface”.
- Normal maps store only the normal of the surface at each position.
- This can efficiently be encoded in a raster color image.
- The Normal map image is applied to the geometry like a texture image using an appropriate render engine.



Displacement Map

- Displacement Mapping creates true 3D geometry.
- Each vertex is displaced according to the difference stored in the displacement map.
- The vertices need not be stored explicitly in the model.
- They are created on-the-fly by the visualization soft- or hardware.
- Using a recursive algorithm the simple geometry of the facade is subdivided in smaller triangles.



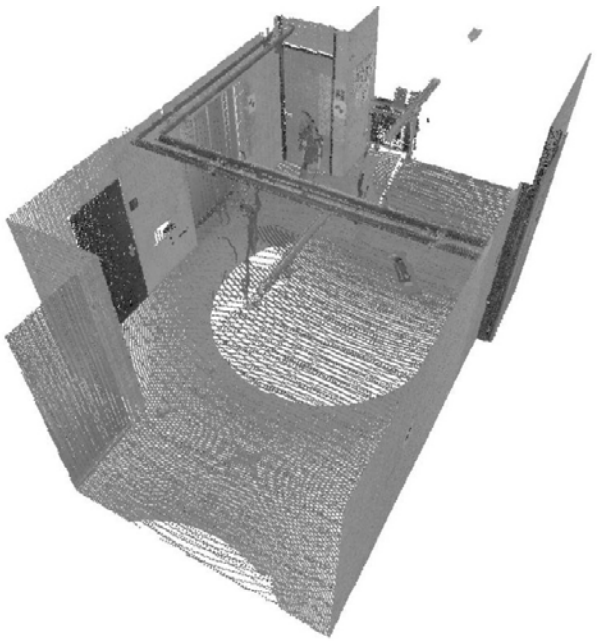
Indoor Modeling

- State-of-the-art in urban modeling is the reconstruction of the outer geometry of a building.
- CityGML‘s LOD4 requires modeling of the interior structures of a building.
- We try to built upon our experience of LOD3 modeling and fully automate the reconstruction of indoor models.
- Under the assumption of horizontal floors, ceilings and vertical walls, “Plane Sweeping” is a promising approach.

A. Budroni & J. Böhm, 2009

Indoor Modeling

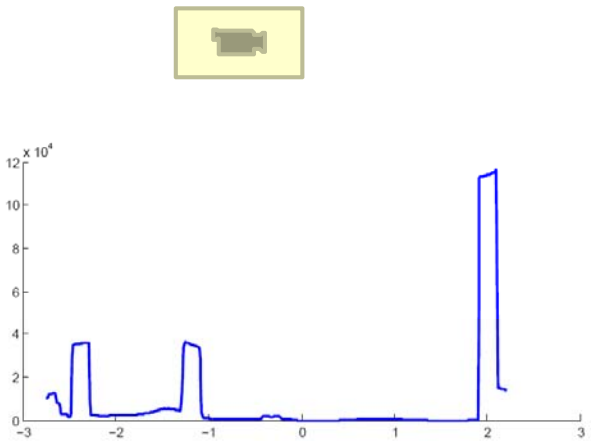
- State-of-the-art in urban modeling is the reconstruction of the outer geometry of a building.
- CityGML‘s LOD4 requires modeling of the interior structures of a building.
- We try to built upon our experience of LOD3 modeling and fully automate the reconstruction of indoor models.
- Under the assumption of horizontal floors, ceilings and vertical walls, “Plane Sweeping” is a promising approach.



A. Budroni & J. Böhm, 2009

Plane Sweeping

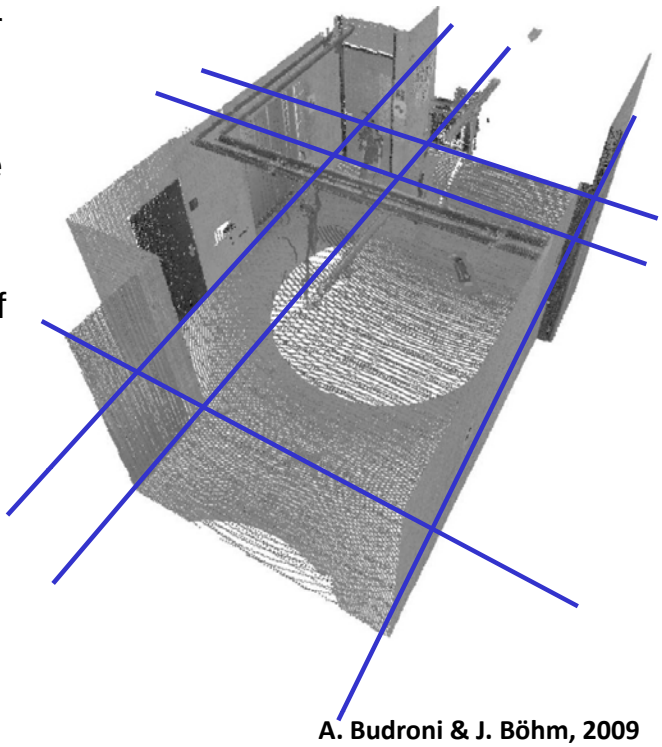
- Plane Sweeping is a simple segmentation method to detect horizontal and vertical structures in a point cloud.
- In a „hypothesis-and-test“ approach planes are tested at discrete positions for compatibility with the point cloud.
- Peaks in the histogram indicate candidates for planes.



A. Budroni & J. Böhm, 2009

Cell Decomposition

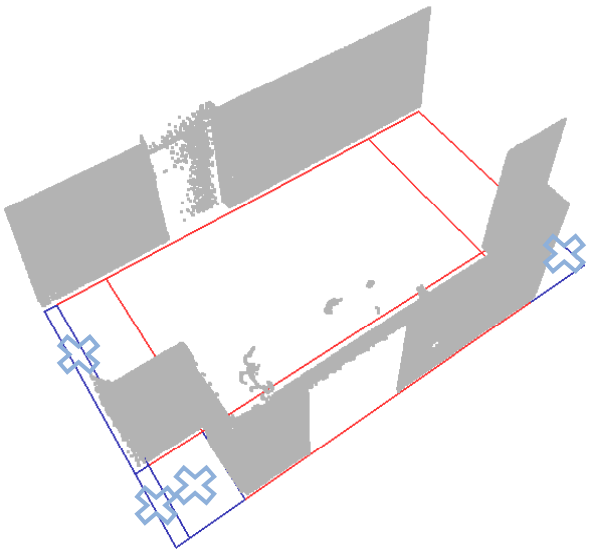
- Horizontal planes form the floor and the ceiling.
- Vertical planes (extended to infinity) are used to decompose the whole space in separate cells.
- Each cell is tested, if it is part of the room or not.
- All the cells of a room are merged and the bounding surface is computed.



A. Budroni & J. Böhm, 2009

Cell Decomposition

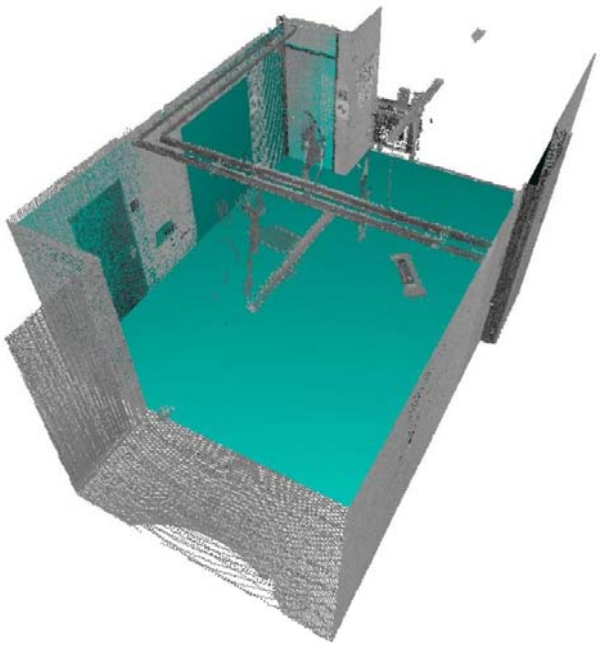
- Horizontal planes form the floor and the ceiling.
- Vertical planes (extended to infinity) are used to decompose the whole space in separate cells.
- Each cell is tested, if it is part of the room or not.
- All the cells of a room are merged and the bounding surface is computed.



A. Budroni & J. Böhm, 2009

Cell Decomposition

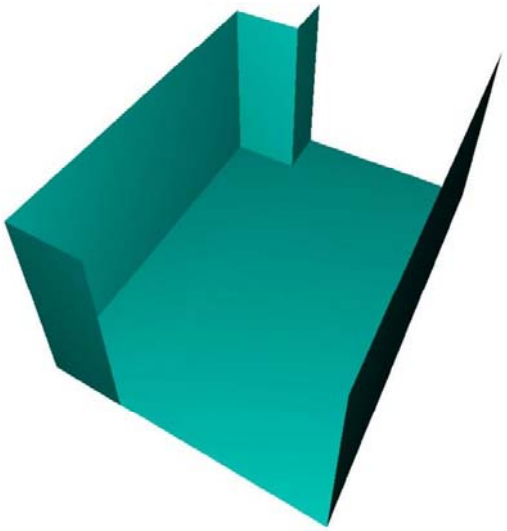
- Horizontal planes form the floor and the ceiling.
- Vertical planes (extended to infinity) are used to decompose the whole space in separate cells.
- Each cell is tested, if it is part of the room or not.
- All the cells of a room are merged and the bounding surface is computed.



A. Budroni & J. Böhm, 2009

Cell Decomposition

- Horizontal planes form the floor and the ceiling.
- Vertical planes (extended to infinity) are used to decompose the whole space in separate cells.
- Each cell is tested, if it is part of the room or not.
- All the cells of a room are merged and the bounding surface is computed.



A. Budroni & J. Böhm, 2009

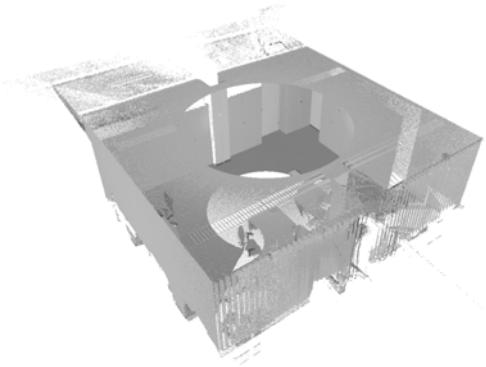
New Sensor Developments – Multi-Pulse

- A colored point cloud acquired with a V-Line terrestrial laser scanner from Riegl is shown on the right.
- The multi-pulse capability of the scanner facilitates 3D edge detection shown to the right, by selecting first return pulses only at multi-pulse points.
- LiDAR data is courtesy of RIEGL Laser Measurement Systems GmbH.

Riegl Laser Measurement Systems GmbH

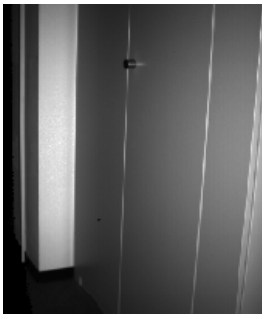
New Sensor Developments – TOF Camera

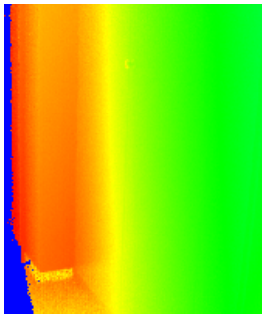
- Indoor point clouds acquired with a terrestrial laser scanner have very accurate global geometry.
- However, the point cloud is incomplete due to self-occlusion.
- Each station for a terrestrial LiDAR system is associated with high costs (scan time, registration, processing, etc.).

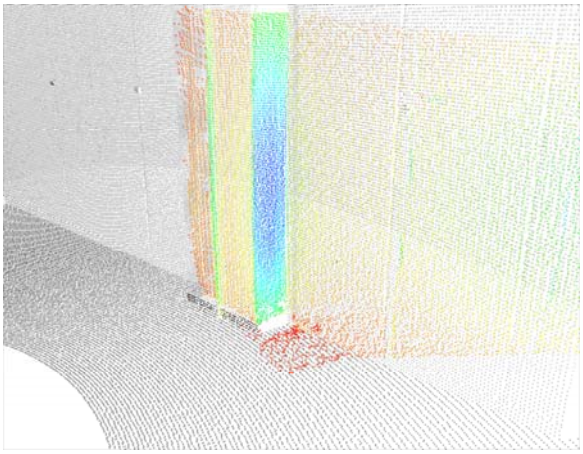


New Sensor Developments – TOF Camera

- TOF cameras capture point clouds at video rate.
- They are easy to set up and flexible to handle.
- Global accuracy is insufficient.
- Local accuracy is good enough to complement laser scanners.
- Simple ICP can be used to merge data sets.







Summary

- Terrestrial LiDAR supplements nicely classical data acquisition methods to perfectly match visualizations from pedestrians‘ viewpoints.
- It is ideally suited to capture facade details and thus provides the data for realistic LOD3 models.
- Terrestrial LiDAR is the most suitable data source for indoor data acquisition a prerequisite for LOD4 models.
- Modeling is still the bottle neck in the processing chain.
- Automated modeling solutions have been developed in the research community for LOD3 models.
- LOD4 is a hot topic in research right now.
- New sensors and capabilties need to be integrated with modeling algorithms to derive better models.