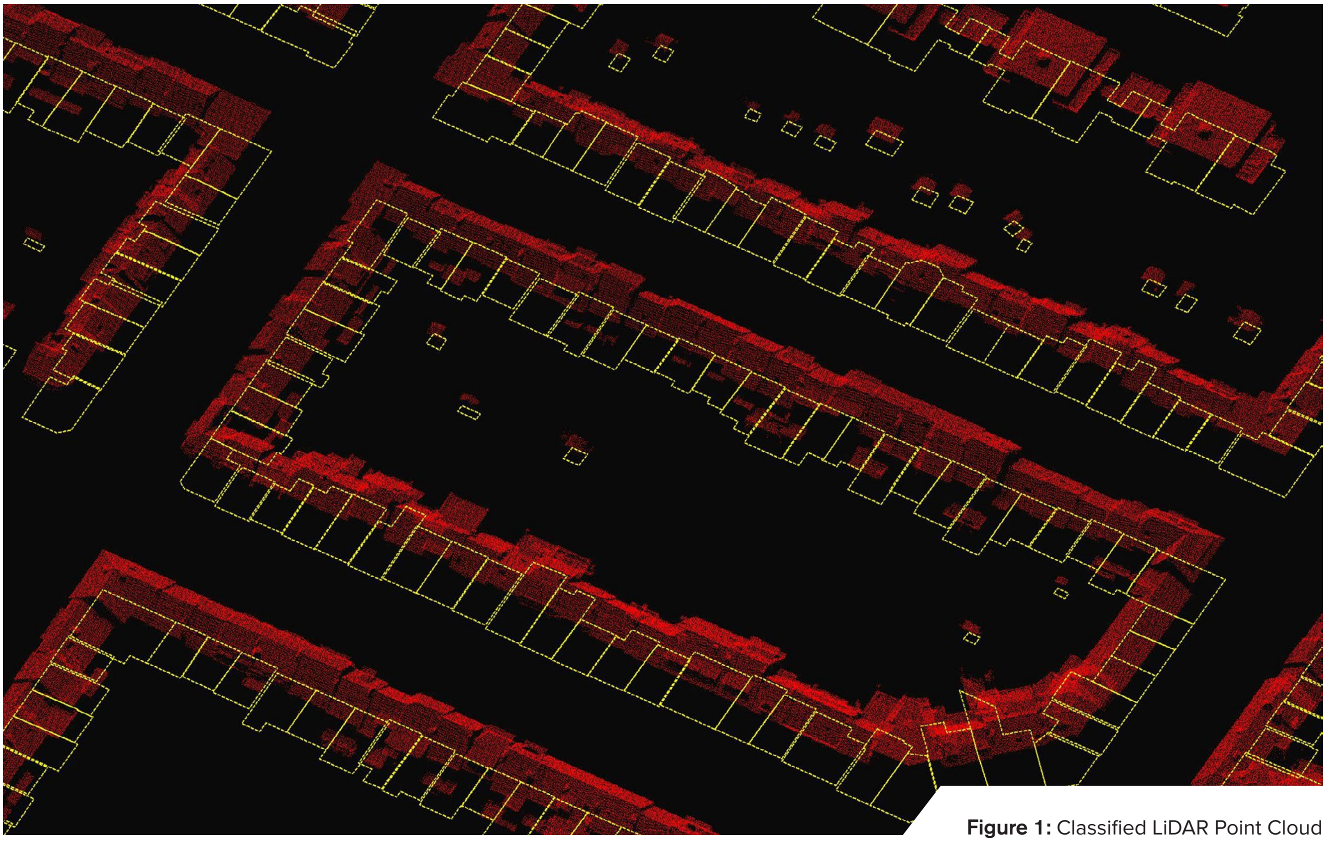

**Figure 1:** Classified LiDAR Point Cloud

# Taking Maps to the NEXT DIMENSION

The Centre for Informatics of the Brussels Capital Region (CIBG) has long maintained large scale base maps of the Brussels Capital Region in a system known as UrbIS (Urban Information System). In 2011, in addition to the regular bi-annual update, the CIBG decided to add 3D representations of more than 250 thousand buildings and approximately 200 bridges to UrbIS.

Following a competitive tender process, the CIBG selected the team of Aerodata International Surveys NV (Aerodata), headquartered in Antwerp, Belgium, and Avineon, Inc. (Avineon), with offices in Herentals, Belgium, to perform the project. Aerodata was responsible for acquiring the source data while Avineon's India office was tasked with updating the 2D base maps and creating the 3D models in accordance with CityGML LOD2 standards. Working closely together, the CIBG, Aerodata, and Avineon completed the project on schedule in one year.

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Given the volume of structures involved, innovative techniques were required to generate accurate models in a cost-effective manner. Avineon applied traditional photogrammetric and LiDAR mapping techniques to automate a substantial portion of the progress. This article provides an overview of the methods used and benefits realized during the course of the project.

The 2D source data for the project consisted of UrbIS-Topo and UrbIS-Admin. UrbIS-Topo is a 2D vector product with over 200 different layers of data including buildings facades, road elements, tramlines, aerial vents, tunnels, fences, hedges, walls, and trees. UrbIS-Admin includes a 2D polygonal representation of a number of UrbIS layers, including the building facade layers.

To support both the 2D data update and 3D modelling, Aerodata acquired three main types of new data for the entire Brussels Capital Region. First, aerial images with a ground spatial distance (GSD) of 7.5cm were captured and formed the basis for creation of orthophotos. Second, oblique images with a GSD of 10 cm were shot at a 45 degree angle. Oblique images provide additional information about the lateral façade of buildings, which was important both for updating the 2D UrbIS-Topo data and creating 3D representations. Third, LiDAR was used to capture a digital surface model (DSM) containing more than 10 billion points with a density of 34 points per square meter. This data was also used to create a digital terrain model (DTM).

Before 3D modelling began, Avineon performed a traditional update of the 2D data. The project area was divided into tiles and the UrbIS-Topo layers were visually compared to the data in the new orthophotos. Each difference was assigned a change code and the relevant UrbIS-Topo layers were updated using the stereo images for accuracy.

The next step in the 2D update process laid the foundation for 3D building models. Initially, building facades were depicted in UrbIS-Topo as vector lines. Avineon converted the linear objects to closed polygons representing building footprints. Since they were created from the updated 2D UrbIS-Topo data, they provided current representation of buildings in the project area and were generally aligned with the orthophotos and LiDAR data.

However, the resulting building footprints were 2D polygons and thus had a uniform height of zero meters. Since the specifications required that the 3D representation of each building fit 100% topologically with its footprint,

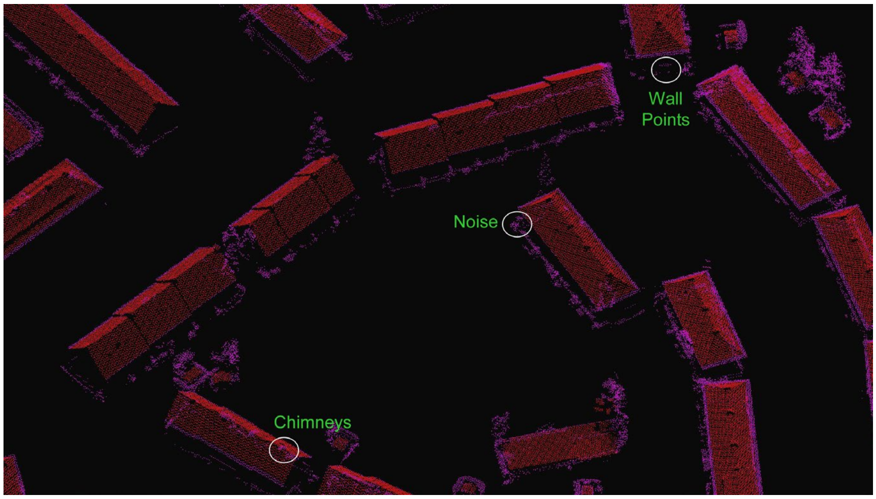


**Figure 2:** Clean Up of Point Cloud

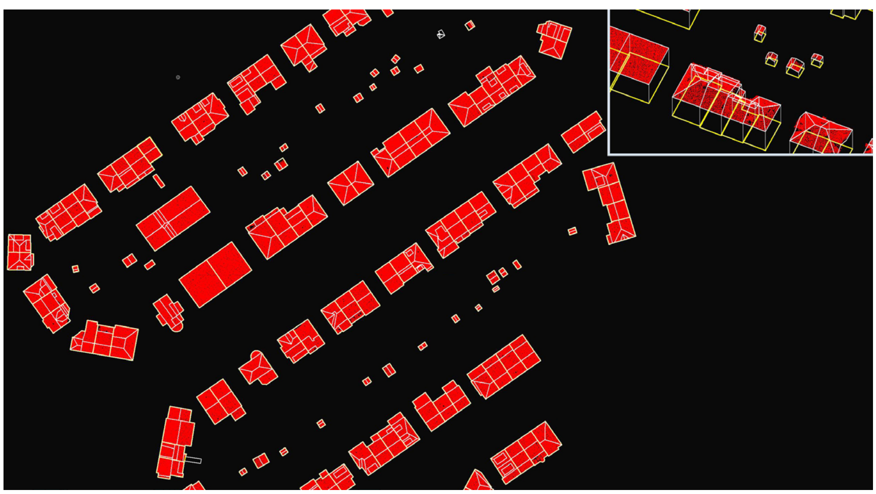

**Figure 3:** Creation of Roof Surfaces

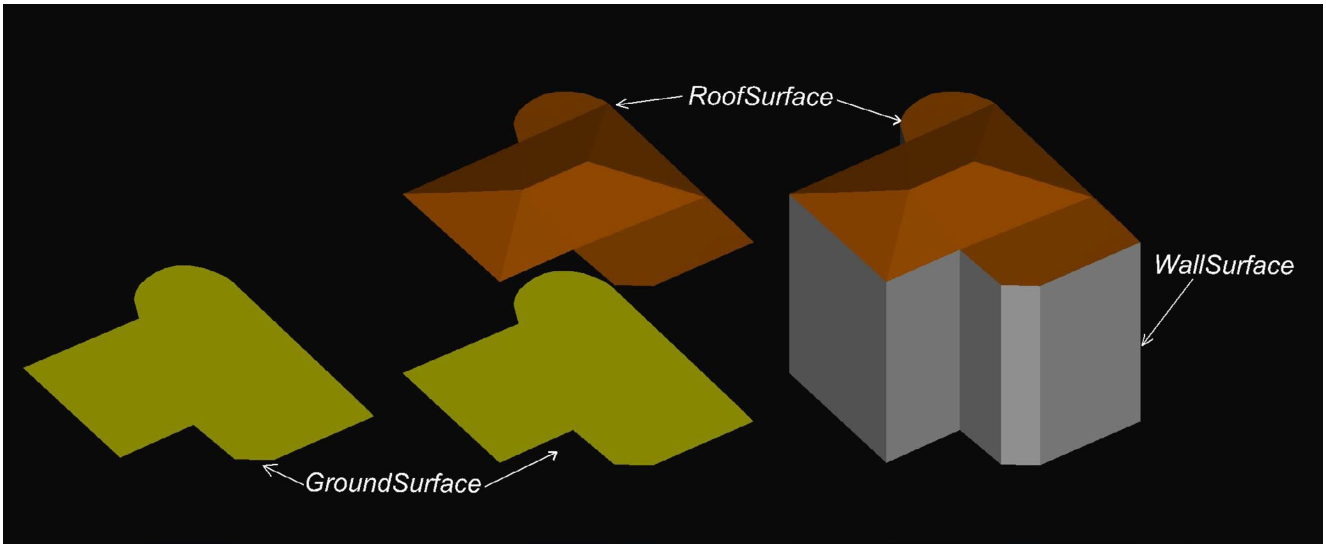

**Figure 4:** Ground, Roof, and Wall Surfaces

the footprints had to be adjusted to match the ground surface. To achieve this, Avineon draped the building footprints over the DTM. Each footprint was assigned a height corresponding to the lowest height of the DTM within the footprint polygon. Subsequently, each footprint was "sunk" into the DTM by 1 meter before 3D modelling. This eliminated the possibility of a gap between the ground surface and the DTM, enabling a "water tight" model of each building. The XY-locations of the footprints remained unaltered during this transformation.

With the foundation in place, Avineon began the first automated step of 3D modelling, roof surface creation. The process uses software designed by Avineon to generate roof surfaces from 2D building footprints and LiDAR data.

The LiDAR data were provided in a raw classified form with three main categories: water, ground, and other. "Other" was divided into sub-categories such as low vegetation, high vegetation, and buildings. All points not required for creation of the building models were discarded (**Figure 1**).

The building point cloud was further refined to remove any unwanted points that fell within the boundaries of the building footprints (known as "noise"). Examples include signals that represent walls, unnecessary rooftop structures such as dormers or chimneys, overhanging trees, distorted point patterns (e.g., from glass roofs), and other irregularities. While this process is not fool-proof, it does greatly reduce the amount of noise that must be removed manually from the roof surfaces (**Figure 2**).

LiDAR points were also added to make the point cloud dense at locations that have sharp vertical structures at the edges of the roof. The goal was to create a point cloud optimized for automatic creation of roofs.

Once the LiDAR data has been processed, creation of building roof surfaces and associated structures is a parameter-driven automated process based on regression analysis. The software selects only those LiDAR building points with XY coordinates that fall within the boundary of a building footprint polygon and uses those points to create the roof surface. Buildings were also categorized based on their roof structures (**Figure 3**).

The roof created for each building must align exactly with its associated footprint in the XY direction, as misalignment results in topologically incorrect gaps between the walls and roofs. Other automated tools detect any misalignments, align the roof edges to the footprint if it is within tolerance, and remove any unnecessary vertices along roof edges.

While it substantially reduces manual effort, the automated clean-up of the LiDAR data and generation of roof surfaces are not perfect. For instance, where the misalignment is outside the defined tolerance or the roof structure is complex, manual editing is required. The automated process also sometimes generates unnecessary rooftop structures that must be edited and removed.

With roof surfaces in place and aligned with the building footprints, walls were automatically raised from the ground surface to the roof edge using tools developed by Avineon. While this process is almost completely automated for most buildings, one important CIBG specification required some manual verification. Specifically, Avineon had to ensure that the creation of the walls did not unintentionally create new vertices in the building footprint (**Figure 4 and 5**).

There were only two types of structures that were not addressed by Avineon's automated modelling methods. First, buildings with substantial wall/roof curvature or similar irregularities were too complex to be modelled automatically. In such cases, the automated geometries did not accurately depict the structure and were of little usefulness in the manual editing process. Thus, a small number of complex buildings were created manually using stereo-restitution (**Figure 6**).

Second, bridges did not have the data structure necessary to support the automated process nor were they classified as separate structures in the LiDAR data. As such, they were captured using stereo restitution in the same manner as irregular buildings (**Figure 7**).

Avineon created the 3D building and bridge models in MicroStation. Before delivery, they were migrated to CityGML, subjected to quality assurance checks, and delivered to the CIBG using FME and an ORACLE Spatial 11g dump file. Key quality assurance measures included semantic checks; geometry inspection to remove errors

**Figure 5:** 3D Models of Buildings

such as sliver polygons, extra vertices, etc.; topological inspection to remove or add any duplicate or missing IDs; and inspection to correct any "flipped" faces by overturning those faces.

The key advantage of Avineon's approach is that it delivers realistic 3D models with reduced manual effort. It leverages building footprint data to generate roofs with 5 cm horizontal and 20 cm vertical accuracy with much greater efficiency than traditional manual processing.

Increased efficiency offers a number of resulting benefits. Obviously, less interactive work by a technician reduced costs for the CIBG. In addition, it enables the final data to be delivered sooner after imagery capture, increasing the currency of the data and its value to the CIBG.

The CIBG was pleased with the results of the project. Claude Hannecart, Head of UrbIS Data Services at Brussels Capital Region, stated, "We are very happy to announce that Avineon has helped CIBG complete its 3D City modeling project in LOD2 standard for the city of Brussels ahead of time, within the budget and meeting high levels of quality standards in terms of precision and accuracy. This project had several challenging aspects from the standpoint of Avineon's ability to delve into the unexplored and develop innovative processes to create an accurate 3D city model, scale up by imparting knowledge of the same to their project team members, maintaining high level of quality standards set by CIBG and doing all of the above within the limited timelines defined by the project schedule. In doing so, Avineon has not only helped CIBG in realizing its strategic tasks, but also in extending CIBG's understanding of 3D city technology."

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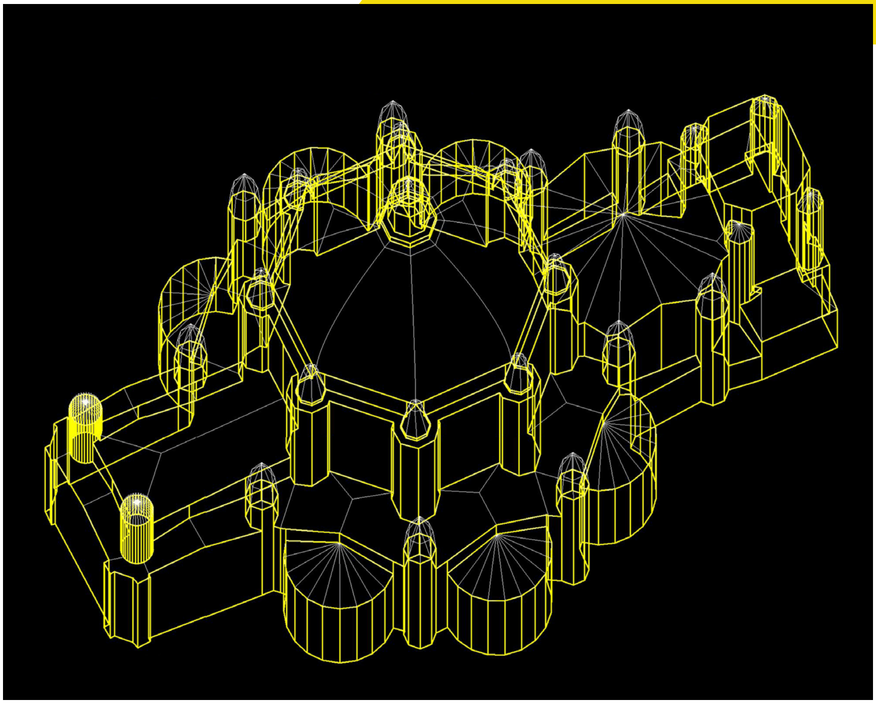

**Figure 6:** Modelling of a Complex Building Using Stereo-Restitution

**Figure 7:** 3D Bridge in CityGML