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A METHOD FOR MODELING SELECTED ELEMENTS OF A BUILDING BASED ON THE DATA FROM TERRESTRIAL LASER SCANNING[1, 2]

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Summary

Latest reports in subject literature, both Polish and international, testify to significant needs for the application of 3D models of architectural objects. There are many methods of 3D modeling, including methods of automatic extraction from point cloud, mesh nets, and manual methods. Despite being highly time-consuming, the manual methods still provide the best accuracy of fitting the model into a point cloud, which suggests the possibility of their use for various purposes, including 3D visualization, and architectural inventory taking. This article presents the methods of manual 3D modeling of the teaching facilities at the University of Agriculture, using the features of MicroStation V8i. The paper discusses examples of modeling the various elements of a research facility, including architectural details, while giving the exact procedure, as well as pointing to major causes of possible errors. In addition, the paper presents various levels of detail within the 3D models, taking into account the requirements of the CityGML standard, published by the Open Geospatial Consortium.

Keywords

terrestrial laser scanning • point cloud • 3D modeling • CityGML

1. Introduction

Both direct surveying and photogrammetric measurements have been used for the purpose of making inventories of sites and objects for a long time. Rapid development of measurement instruments and software tools continue to make the acquisition of three-dimensional spatial data easier every day. Modern measurement technologies such as terrestrial digital photogrammetry and terrestrial laser scanning provide information about the reality around us in the form of images and clouds of points.

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However, the data on the geometry of objects, stored in these formats, is often impractical from the point of view of the recipient or user of the site documentation. Therefore, it is necessary to translate the measurement results and point clouds into vector models supported by the CAD software [Mitka et al. 2013]. The main advantages of CAD software, according to Mitka and Szelest [2013], include high accuracy of modeling and the capacity to create additional documentation for 2D objects. In the modeling process, a variety of tools are used, made available in the software, for processing the product obtained from the TLS measurements, in other words, the point clouds [Fidera et al. 2004]. Also, the functions developed for modeling are applied, in software such as MicroStation or AutoCAD [Rabbani et al. 2011] and more specialized algorithms for 3D modeling [Kawashima et al. 2011]. The modeling of buildings in three-dimensional space is a labour-intensive process, but to a large extent it depends on the complexity of the architectural object in question. Beyond the building's walls, we often deal with openings, irregular roofs, balconies, cornices, pediments, columns, and sometimes also hand-carved elements. According to the guidelines published by the Open Geospatial Consortium, 3D modeling of buildings is carried out according to a specific CityGML procedure, which distinguishes 5 levels of detail [Open Geospatial Consortium 2012], where the amount of detail in the model is determined by its application – its use for the given purpose. According to Jędryczka [2009], while following the CityGML standard, it is possible to present the object at different levels of detail.

The work is divided into two parts. The first part is focused on the description of the rules of the 3D modeling, using the functions of Microstation V8i software, and the second part contains examples of 3D models developed at different levels of detail. In the conclusions, particular attention is paid to the possible applications of 3D models depending on their level of detail.

2. Materials and methods

The study was based on point clouds from terrestrial laser scanning (TLS), obtained during the measurements conducted at the Faculty of Environmental Engineering and Geodesy of the University of Agriculture in Kraków throughout March 2012. The selected object of the study was the University's teaching facility (a lecture hall), located at Balicka 253a, for which the TLS measurement was made (Figure 1) as well as the photographic documentation was developed, necessary for texturing a 3D model.

The object has been measured with a phased Z + F Imager 5006 laser scanner. The measurement was performed at 17 sites, and point clouds were saved in a local scanner in the *.zfs format. Prior to the work related to the creation of a 3D model at three levels of detail, clouds of individual sites have been processed using the Leica Cyclone 8.1 software. 3D models were made using the tools available in the Bentley – Microstation V8i Series 3 software.

The Microstation V8i software allows you to work with a point cloud stored in different formats provided by leading suppliers of laser scanners, such as Leica, Riegl, Faro, and Topcon. After the point cloud is imported to the program, it gets automatically converted within the Microstation environment into a *.pod format. The user has the option to control the visibility of clouds in several views, or to disable selected ones, as well the option to adapt and attach the cloud on a specific layer. Furthermore, the *Point Cloud* tab includes the available transformations, which are possible for a cloud of points, such as setting the visibility of individual views, snapping the point cloud, or changing the position of the point cloud.

Source: authors' study

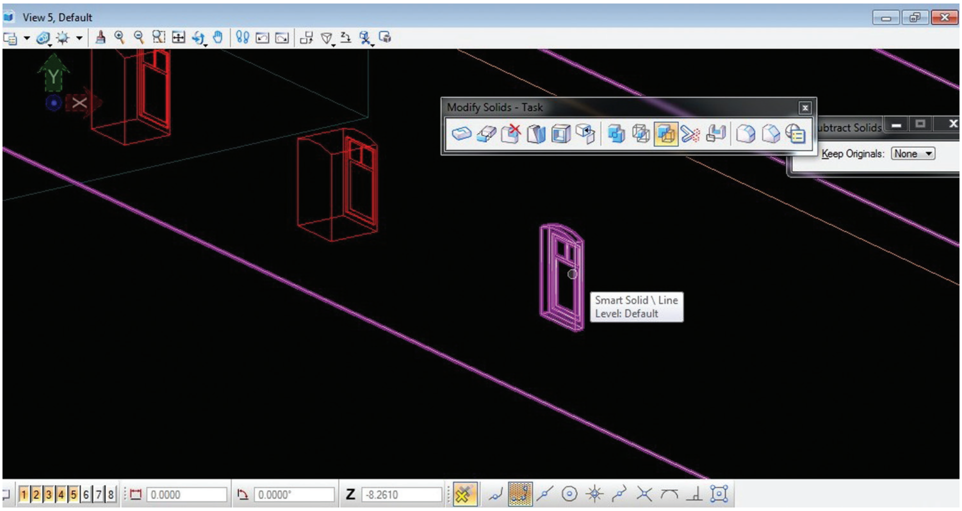
Fig. 1. Processed point cloud of a teaching facility at the University of Agriculture in Krakow

2.1. Developing 3D models for particular elements of the building

The basis for the modeling is to determine the main solid of the object. For the building in question, the main body is a rectangle consistent with the actual layout of the walls. Subsequently, in reference to the main solid, through Boolean operations, other elements of the building are created such as the roof, bays, chimneys, balconies and architectural details corresponding to the Level of Detail 3. Modeling of the roof should be performed independently of the main solid, due to the differences in geometry, resulting from the presence of the chimneys, bays, other items and technical infrastructure. The first step is to define the base of the roof and its height. Subsequently, we fit the cuboid into the cloud of points – the lower base of the cuboid being compatible with the base of the roof. Then we edit the edges of the upper base, using the function of *Modify Solid Entity by Edges*, so that they are consistent with the roof ridge. In this case, entering the appropriate view setting is an important part of the development of the roof model. Also of importance is the quality of the cloud, out of which we develop our model. For low buildings, the scanner is able to capture, without any major difficulty, not only the course of the edge of the roof, but also its texture (i.e. shingles).

The geometry of chimneys is similar to the geometry of the main solid; therefore the modeling thereof should be guided by the same principles. The modeling of chimneys is based on creating basic shapes, such as rectangles, and subsequently modifying them. We need to keep in mind that it is necessary to cut the lower part of the chimney to the roof surface, using the function of *Replace Face*. If the building is equipped with several identical chimneys, it is possible to develop one, and then copy the model repeatedly. This operation can be performed on the FRONT view, with the switched-off option of dragging to point cloud. After the main solid of the chimney has been modeled, we should proceed to develop other elements, such as the eaves, or any other openings, guided by the same principle as when modeling the roof and the window openings.

The modeled object has several types of windows, differing in shape. These elements should be treated as recesses in the main solid of the building, and modeled using the so-called punches. Punchs are modeled independently, by using the functions of *Solid by Extrusion, Modify Solid Entity, Unite Solid, Subtract Solid*, according to the course of the building within the cloud of points, and then extruded into the correct object on the main solid (Figure 2). Before modeling the recesses, groups of identical or very similar elements are defined, e.g. the windows, and props are created to represent such elements. Further on, we copy the template, set it in the right location, and modify the cloud. This speeds up the modeling process and eliminates the necessity to develop each punch separately.



Keep Originals: None

Smart Solid \ Line
Level: Default

0.0000 0.0000° Z -8.2610

Source: authors' study

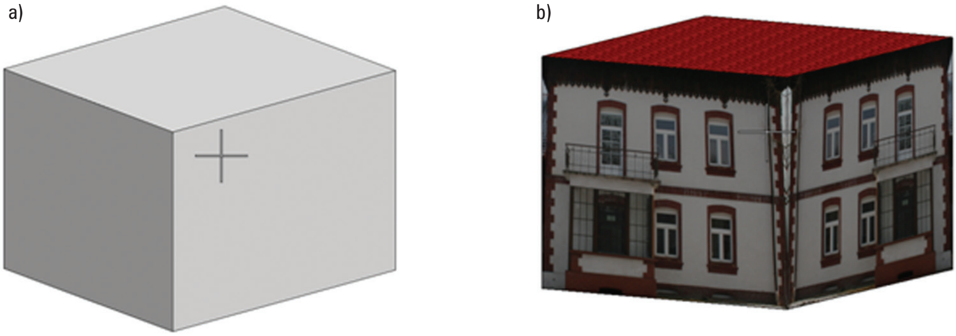
Fig. 2. Punch for the window opening

The Microstation V8i environment offers the user a variety of tools to model the complex geometry of various railing types. When rendering a solid of the balcony, the aforementioned function of *Solid by Extrusion, Modify Solid Entity* was used, while modeling of the railing was made possible by the functions of *Place SmartLine* and

Solid by Extrusion Along. In order to do this, first we need to follow the contour of the barrier, or the so-called path (the path must form one chain – in order to integrate a number of lines into one chain, we use the tool called *Create Complex Chain*), and anywhere along the path, we draw a horizontal section through the balustrade. Based on the horizontal cross section, as well as the path, the program automatically generates a 3D object (a cylinder) over the entire length of the path, in the specified direction of modeling. The method should be applied to any linear objects, for which it is possible to fit the constant geometric figure.

2.2. Determining the level of detail

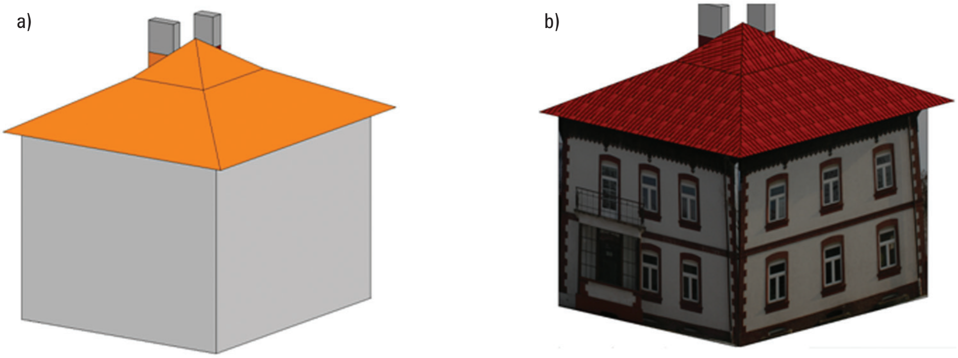
The test facility has been modeled on 3 levels of modeling detail: *Level of Detail 1, Level of Detail 2*, and *Level of Detail 3*, distinguished within the standard CityGML version 2.0.0, as published by the Open Geospatial Consortium. *Level of Detail 1* determines the buildings represented by rectangles, in which the geometry of the roof is not distinguished. This level of detail is dedicated for large areas of the whole city or region in which the accuracy of the position of the 3D point (both in terms of situation and altitude) is 5 m. Texturing of a model developed in the *Level of Detail 1* is allowed. Figure 3 shows a 3D model of the teaching facility, made in the *Level of Detail 1*.



Source: authors' study

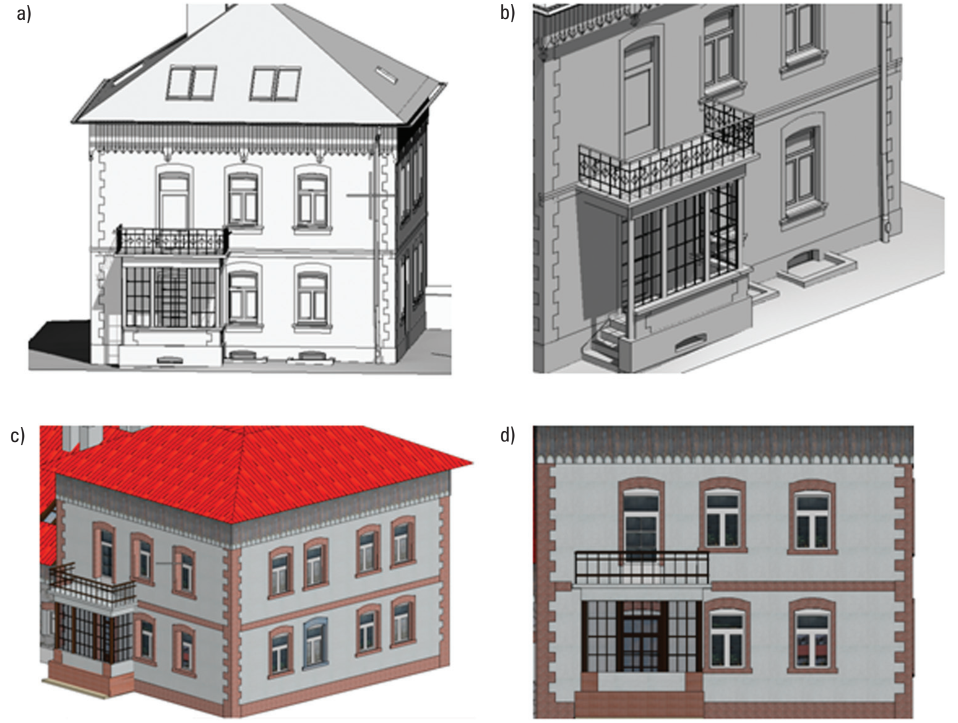
Fig. 3. 3-D model of a fragment of the studied object, modeled on the *Level of Detail 1* a) model without texture and b) textured model

According to the CityGML 2.0.0. standard, the Level of Detail 2 presents a 3D object in the form of a cuboid with the distinction of roof geometry. Moreover, the said level allows for modeling of the elements protruding from the roof, wherever such elements exist. The accuracy of the position of a 3D point, both in terms of situation and altitude, amounts to 2 meters. Level of Detail 2 is dedicated to the modeling of areas such as cities or city districts, while allowing the use of textures. Figure 4 shows a fragment of the object (teaching facility) modeled on the Level of Detail 2.



Source: authors' study

Fig. 4. 3D model of a fragment of the studied object modeled on the *Level of Detail 2*: a) model without texture and b) textured model



Source: authors' study

Fig. 5. 3D model of a fragment of the studied object modeled on the *Level of Detail 3*: a), b) model without texture and c), d) textured model

The paper presents a 3D model of a teaching facility (building) modeled at Level of Detail 3 (Figure 5), which means – according to the Open Geospatial Consortium standard – that the geometry of the main solid of the building and the geometry of the roof elements protruding from the roof are distinguished, as well as the openings in the horizontal and vertical planes. Moreover, at this level of detail, architectural details are also modeled. The accuracy of the 3D point location, in terms of height and situation, is no less than 0.5 meters, while models are dedicated to building compounds and individual buildings.

3. Conclusions

Manual modeling based on a point cloud from terrestrial laser scanning requires the ability to use extended features of MicroStation V8i. Due to the fact that each element of the object – such as a window, a door, a chimney, or an architectural detail – needs to be modeled separately, this method is time-consuming, but at the same time, it ensures high accuracy of fitting the model into the cloud. Furthermore, an important (and strictly necessary) condition to be met is maintaining the topology of the 3D model. The program Microstation V8i software makes available a number of tools, which facilitate modifications of the solids, therefore it can be used both for modeling architectural and industrial objects, with no need to apply any additional toolboxes. Particularly noteworthy is the fact, that the program allows the user to integrate point clouds from both aerial and terrestrial laser scanning, which is particularly important when modeling the roofs of buildings. In addition, the program allows the user to develop the texture of the 3D model, based on digital images imported as an external palette. Due to the ability to export and import the most popular formats of data exchange, 3D Microstation V8i is the optimal and preferred program for 3D modeling at different levels of detail.

The level of detail of a 3D model determines its applicability for specific purposes. 3D models in Level of Detail 1, due to their great simplification of geometry and low accuracy in terms of situation and altitude, are recommended for the purpose of spatial planning conducted on a scale of entire cities. While using 3D models, it is possible to design housing densities, for which the roof geometry in the models of existing buildings is of little importance. 3D models developed in Level of Detail 2, due to their inclusion of roof geometry, may well be used for spatial analyses such as sunlight or shading analysis. Thanks to reliable information about the building heights, it is also possible to relate these to the existing development, and to determine minimum and maximum building height for newly designed buildings. Level of Detail 3 is dedicated to accurate 3D models, in which architectural details are distinguished. However, in addition to the time-consuming execution, rendering the complex geometry of the building also generates large size data files, therefore this level of detail is recommended for individual objects. 3D models at this level of detail, with a layer of realistic texture, can be used to visualize the existing 3D space.

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