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GIS three-dimensional Modelling with geo-informatics techniques

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Abstract. The integration issue of virtual models and geo-referenced database have a very broad spectrum of potential applications. Before the integration issue was on the cusp, it was quite problematic to combine three-dimensional models with the geo-referenced database. An integrated database contains a variety of data including such as object orientated data model and raster data. Within this paper, authors present an integration process aiming to make real virtual GIS database which includes the creation of structures, such as bridges, buildings, roads and terrain formations. To create a three-dimensional GIS model high-resolution satellite images/point cloud has been used. For 3D modelling and reconstruction purposes, The Blender program has been used since the software provides with quick workflow and user-friendly interface. As a result of this study authors concede that integrated techniques for three-dimensional GIS databases allow conducting easy as well as sophisticated operation in an efficient and non-time consuming way. The subject holds great promise for a future, current challenges focusing on new approaches for conjectures of spatial objects that will be used to boost the capabilities for automatic visualization.

Keywords: discrete-event simulation, GIS, laser scanning, LoD.

Conference topic: Technologies of Geodesy and Cadastre.

Introduction

Models, which were created by using City GML standards are representing buildings, roads, monuments, trees, etc. The value described the information of the spatial object based on the resolution of the data is called LoD (Level of Detail) (Kolbe, Bacharach 2006; Gröger, Plümer 2012). In today's, the biggest the problem is that people who are not familiar with city modeling visualization are often working on computers which do not fulfill the requirements needed to service the GIS databases where the 3D model of the city (Tse *et al.* 2008: 161–175; Kolbe, Gröger 2004) is implemented. Very often programs which could operate the 3D databases demand the high quality of hardware and funds of the companies be much lower than expenditure on the new equipment. The solution for that issue is to create databases, which could work in the cloud. It means that people who want to work on that type of the data, constraint only to acquire web browser and real internet connection. The city model, which were created during the post processing of the data is loaded on the server where the GIS database is implemented. The example of the structure of that type of the system is presented in Figure 1.

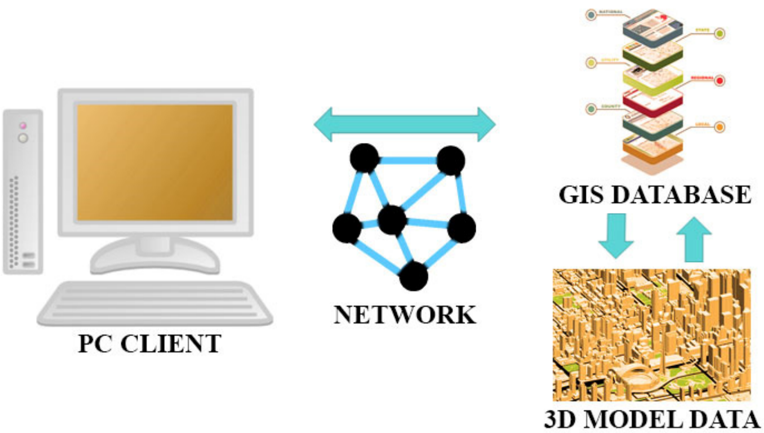

Fig. 1. System structure

Laser scanning as the source for 3D model creating

Laser scanning technology is an effective tool for gathering spatial information about the terrain and other areas such as diagnostics of structures (Janowski *et al.* 2015a; Janowski et al. 2016; Nagrodzka-Godycka *et al.* 2014, 2015). Moreover, it supports a geodetic data in GIS applications (Szulwic *et al.* 2015). Usefulness of this technique has a reflection in the administration of the city documentations. The example of actions based on this photogrammetry method is helping to save and improve human life standards like taking care of cultural heritage or creating an open database where the citizens, potentially investors or tourists could find basic information about the terrain with coverage (for example buildings) (Thomson, Boehm 2015: 11753–11775; Bernat *et al.* 2014: 307–318;).

The idea of creating the city model itself based on using photogrammetry techniques data collected from a plane (aerial photographs and LiDAR) (Wehr, Lohr 1999) which could be filled with mobile technologies (Mobile Laser Scanning) in the places where is not possible to gather spatial information about the terrain's coverage (for example walls of buildings) (Janowski *et al.* 2015b: 17–24; El-Omari, Moselhi 2008: 1–9). Grounded in that three- dimensional data, the hybrid digital model could be created (Błaszczak-Bąk *et al.* 2014: 583–589). Previously measured points were calculated on the interpolation grid, and the base of the spatial data is described with vector data which contain characteristic points and lines. The integration between the MLS and ALS is on the level of .las files. The main methods which could be used for connection between those systems are manually and semi- automatic (Warchoł, Hejmanowska 2011: 411–421). The first is to create points which define the same characteristic objects, presented in the point clouds from ALS and MLS. The second one is to estimate the position of the scanner and create planes which are described as the center of gravity position, and direction of the normal vector. If the planes are matched on some circumstances (Bobkowska *et al.* 2017), the data could be integrated. It has to be taken into consideration that during the data acquisition, the photos are triggered automatic and the time of making photographs are set by the operator. Based on LiDAR data, the 3D models are created (Zhang *et al.* 2006: 2523–2533; Forlani *et al.* 2006: 357–374) and on that models, aerial photographs are implemented through the proper calibration of the system where the offsets between the components (IMU, scanner, GNSS receiver, camera). Quality of the acquired data depends on the accuracy of the positioning, terrain coverage and GNSS satellites availability (Janowski *et al.* 2014; Nowak 2015; Nykiel, Figurski 2016; Nykiel, Szolucha 2014). Deliberate only Airborne Laser Scanning as the technique of the data acquisition we could generate related less detailed model objects, than additional using the Mobile Scanning System. Moreover, besides of Laser scanning technology, there are many different methods to create 3D model databases. One of the examples could be a graphic reconstruction of the objects based on the CAD documentations of the buildings, roads.

To prepare the data for further processing, the filtration has been made. In the case of the example, described in this paper the noise filter was used, but the classification could be done in different ways (Puttonen *et al.* 2011). The noise filter computes the average distance between each point and the underlying surface. About CloudCompare wiki, algorithm locally fits a plane and then removes points which are too far from created surface. The next step of processing the data is to classify the point cloud. As the part of this study, Trabki Male village was subjected to classification. On the need for this study (usefulness of this process is described in the next chapter), the roads were organized into a separate layer. To achieve that result, the KNN (K-nearest neighbors) method of point classification was used. The entire file that was used was composed of 2 807 699 points. Each point has the data:

- spatial coordinates (x, y, z),
- the value in the range [0, 255] representing red color,
- the value in the range [0, 255] representing green color,
- the value in the range [0, 255] representing color blue,
- the value of reflectance the range: [–18.300, 7.240].

The assumption was the division of clouds on a set which represents the road. On a set representing different elements and objects of the area and its coverage. As a training set was chosen set 36 points. Features that were taken into consideration are the values representing the color in RGB (each color was a separate feature) and the value of reflection. The value of the reflection due to the applied classification method, which consists in calculating the distances (Euclidean in this case) between the points in four-dimensional space, applied rescaling the reflectance. This value was multiplied by 10. Number 10 was set up arbitrarily.

$$dist_{ij} = \sqrt{\left(R_i - R_j\right)^2 + \left(G_i - G_j\right)^2 + \left(B_i - B_j\right)^2 + \left(10r_i - 10r_j\right)^2},$$

where: R_i – value representing red color of the point i; R_j – value representing red color of the point j; G_i – value representing green color of the point i; G_j – value representing green color of the point j; B_i – value representing blue color of the point i; B_j – value representing blue color of the point j; r_i the value of reflection of the point i; r_j the value of reflection of the point j.

Due to the preliminary tests, the number of neighbors is assumed to equal to 1. Point *i* was assigned to the class to which point *j* belonged, which was in the nearest neighborhood, that is the shortest distance $(dist_{ij})$ .The classification process was automated. Figure 1 shows the entire unclassified cloud in RGB color space, while Figure 2 shows the same cloud that represents the reflection values of individual points with histogram.

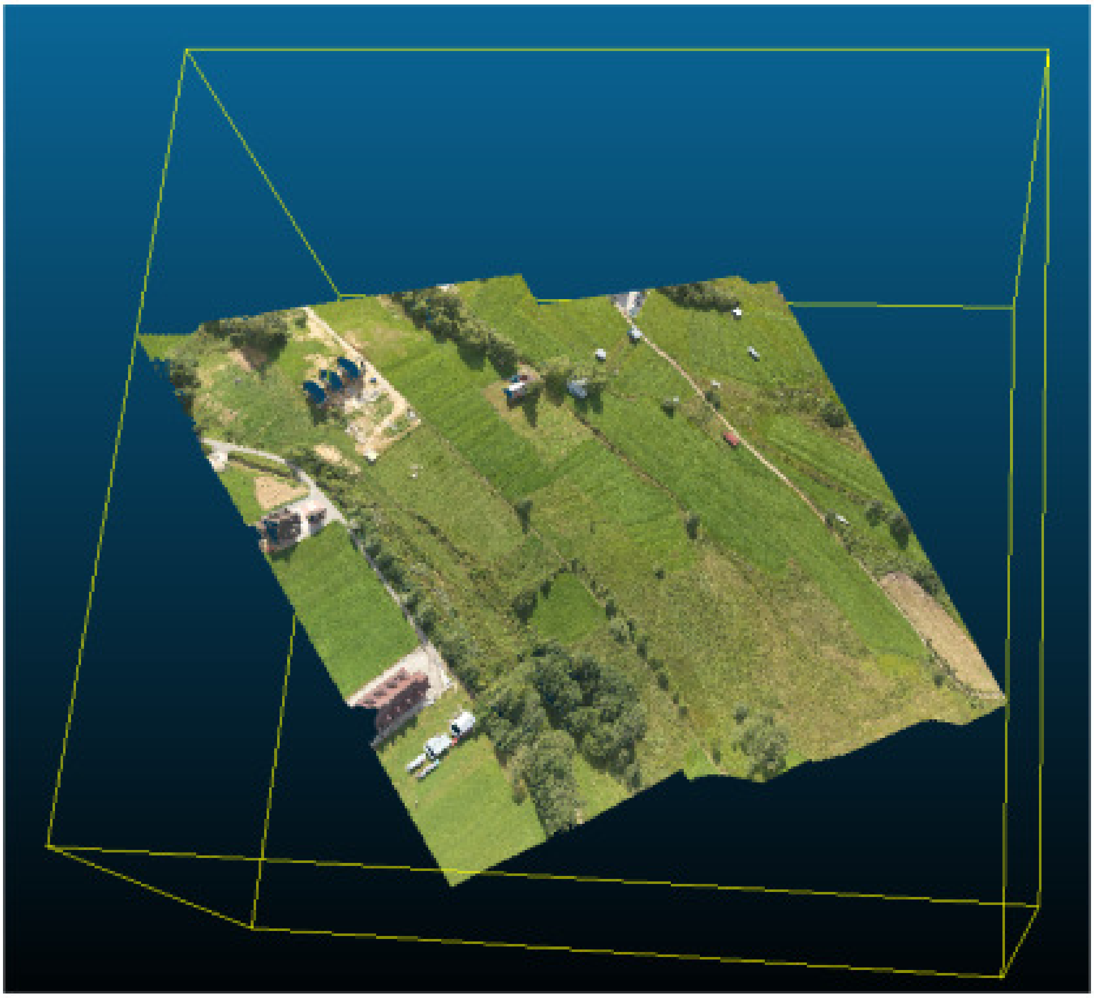

Fig. 2. Input data – the representation of clouds in the RGB color

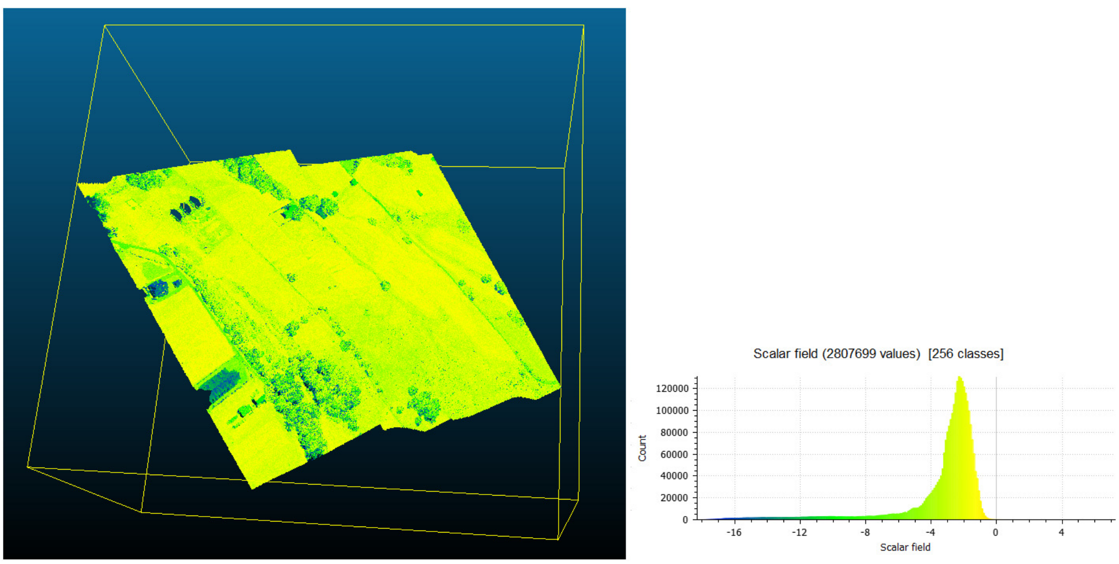

Fig. 3. Input data – the representation of clouds in the range of reflectance

To collect training data for classification, an indication of individual points representing the class of the road and the other was made. Moreover, then record the characteristics of these points, which were used for further classification, have been saved. Example point representing the road with its information was presented in Figure 3. After collecting training data, the classification process was performed automatically by the developed algorithm. The effect of the algorithm works is shown in Figure 4 as can be seen, after the visual assessment, the result is not satisfactory, but thanks to the additional filtration (described above), it is possible to extract the better-classified cloud (Figure 5). Also, the point cloud, representing the classified road is presenting in Figure 6.

Fig. 4. Data acquisition for the training set of classifier

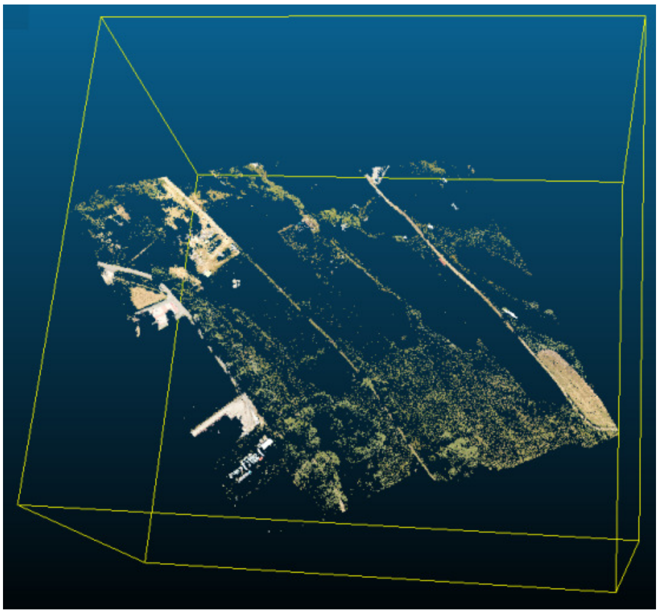

Fig. 5. The cloud of points after the reclassification

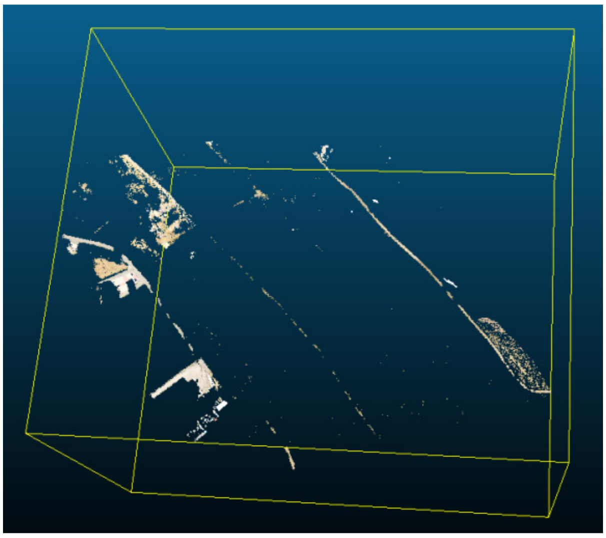

Fig. 6. The cloud of points representing the classified road.

That integrated, classify and filtrated data could be combined into a single point cloud. The example of the point cloud from two different systems is presented in the figure below.

Fig. 7 ALS+MLS integrated data

On that spatial information, the hybrid model of the terrain could be created. The detail of that information could be named as LoD 2 or LoD 3 in the standard format City GML. The City GML has five levels of object details. The first one is Digital Elevation Model, covered by orthophoto map (LoD 0). The second one has blocked models of the data with flat roofs (LoD 1). We could think the third (LoD 2) as the representation of textured model with the detailed roof. The LoD 3 is extended with wall structures, which were mapped with very high precision and accuracy. The last one of the standards (LoD 4) is full architectural projection with interior rooms, or furniture. To use the city model on the level of detail 2 or 3 for further analysis, the proper database which contains cadastre information about the estates, covered by generated model should be created (Buśko 2016). Also, according to (Russell-Smith, Lepech 2011) the dynamic life cycle models that capture environmental impacts associated with every life cycle phase.

Use of integrated 3D models in discrete-event simulations

Integration of 3D models has a broad spectrum of potential application. One of this application is the use of integrated 3D models in discrete-event simulations, which creates continuous sequences of particular events in time. For every event, time of occurrence might be established. Modeling space contains entities, which have certain properties design by the user. Each entity actives at a certain instant in time and modify part of the system. Simulation can be controlled in time, both accelerated and slowed down, as well as move to a specified place at a time. In contrary to the continuous simulations, where the system dynamics continuously tracked over time. In the continuous simulation, events are replaced with activities. Time can be breaking up into tiny pieces, and the system calculates the relationship between entities and the system. However, in a simulation which contains a large amount of data, such as simulations with integrated 3D models, event-based simulations are much faster, because it does not simulate every time slice. One of the applications of integrated 3d models appeared in transportation engineering simulation (Fig. 7)

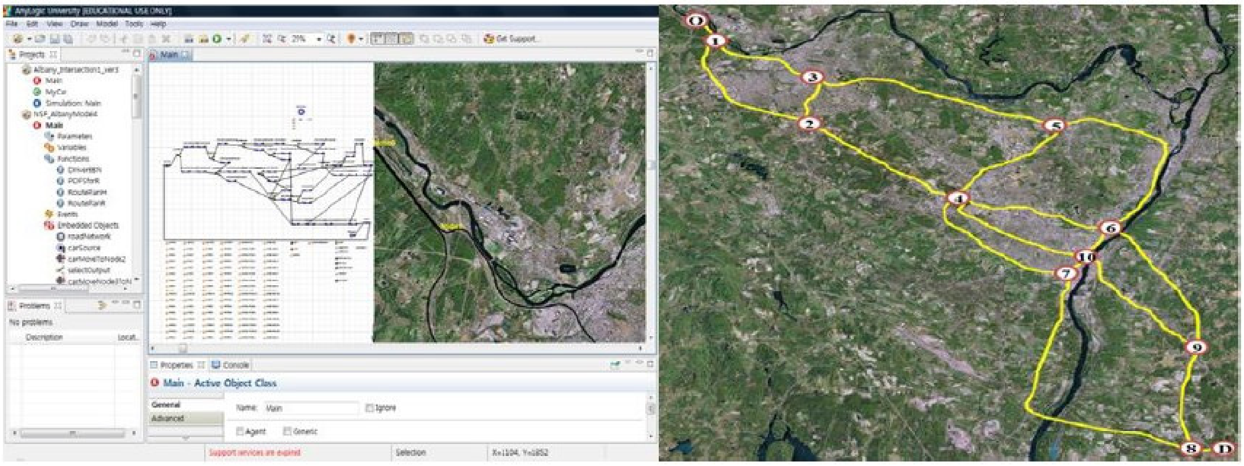

Fig. 8. AnyLogic simulation of hazardous material transportation with ALS+MLS integrated data (Anylogic 2017)

There are special libraries which are prepared for road traffic simulations. The libraries allow the user to simulate vehicle road traffic and support patterning of vehicle movement on transportation routes. There are a number of elements that can be imposed on the simulation modeling space, such as driving regulations, public transportation flows, parking lots, pedestrian crossing, traffic lights, junctions with movement priorities (Fig. 8). The library is suitable for modeling of heavy as well as light highway traffic and also contains dedicated tools to conduct traffic load analysis (Sojung *et al.* 2013). Figure 9 is presenting the example of a Road Traffic Library in AnyLogic simulation.

Fig. 9. Road Traffic Library in AnyLogic simulation (Anylogic 2017)

Summary

Dawn of optical technologies brings new inventions, such as precise laser scanners. Gathering huge amount of data in relatively short time allows modeling large areas and brings more comprehensive solutions in various types of simulations. Integration of 3D models have a wide-ranging field of the possible appliance and might be a useful source of data in discrete-event simulations. In this paper, authors considered processed data acquired in Trabki Male, Poland. Obtained results have been transformed by the developed algorithm and were evaluated by the visual assessment. To increase the quality of analysis performance, additional filtration has been used, which resulted in better-classified cloud extraction. Spatial information was imposed on the virtual terrain model, forming hybrid model, which can be categorized in four accuracies LoD 1, LoD 2, LoD 3 and the highest LoD 4.

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