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INTEGRATION OF HETEROGENEOUS PHOTOGRAMMETRY DATA FOR VISUALIZATION OF CULTURAL HERITAGE OBJECTS

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Abstract

Technologies of digital photogrammetry provide the metric and thematic information for various data bases, including those which are created to visualize and archive the cultural heritage objects. Due to different sizes, shapes, locations and environmental conditions of objects, data is acquired by means of various photogrammetric methods based on aerial and terrestrial digital imagery and laser scanning data. They are also very often integrated with data from other sources.

Photogrammetric products dedicated for the cultural heritage are usually collected and integrated in 3D GIS data bases, which are used by various specialists involved in restoration of the historical monuments. The variety of photogrammetric data and possibility of multi criterion spatial data processing and analysis in 3D GIS, allow to reconstruct the accurate terrain topography and 3D models of valuable heritage monuments. In this paper, an integration of various photogrammetric products (created in the past and within the discussed project), used for the needs of visualization of the terrain topography and 3D models of historical buildings and vegetation for the Museum of King Jan III's Palace at Wilanów area, is presented. The following photogrammetric products were utilized: the orthophotomap of 0.1 m resolution from the Geodetic and Cartographic Documentation Centre (CODGiK), ALS – ISOK data, 3D vector data from stereo digitalization of 0.1 m resolution images, the vegetation layer for the area of the Museum of King Jan III's Palace at Wilanów, acquired from the 3D data base. In addition, some symbols of missing objects were used from the Google 3D WareHouse.

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Introduction

The cultural heritage area of high importance requires a permanent control and monitoring of historical architectural and vegetation objects. Results of revalorization and changes of historical objects should be regularly monitored and measured. In the case of a large area, which includes many historical, architectural and vegetation elements, the number of changes should be estimated a priori basing on interpretation of the high resolution images, before the real photogrammetric and/or surveying measurements are performed (BUJAKIEWICZ, ZAWIESKA 2013).

Due to the variety of heritage objects, in particular their sizes, shapes, locations and environmental conditions, data is acquired by means of various photogrammetric methods, which are based on aerial and terrestrial digital images and laser scanning data. This data is often integrated with data from other sources. The universal solution for analysis and storage of all available data (acquired in the past and at present) is a data base created in the 3D GIS environment. The advantage concerns not only the possibility to store the data in various forms (raster, vector, descriptive), but also the data integration with recently acquired data, as well as the easy way of data processing and administration. The Architectural Data Bases, which are created for the selected cultural heritage areas, can serve as the knowledge bases for various specialists involved in restoring of the historical monuments.

The variety of photogrammetric data and the possibility of multi criterion spatial data processing and analysis in 3D GIS, allow to reconstruct the accurate terrain topography and 3D models of objects and also to determine their geometric characteristics, that is very important for the cultural heritage.

In this paper, an integration of various photogrammetric products (created in the past and generated within the presented project), used for the needs of visualization of terrain topography with 3D models and historical buildings and vegetation for the Museum of King Jan III's Palace at Wilanów area, is presented.

Main assumptions of data integration for 3D modelling

Intensive development of photogrammetric technologies in the field of source data acquisition and its automatic processing allows to generate many different, complementary products, which are useful for documentation and analysis of cultural heritage objects. Documentation of architectural objects in the form of 3D models with texture has been widely applied (MARKIEWICZ 2013). Both approaches, based on digital images and high resolution laser scanning, are useful. In the case of historical monuments, which are frequently characterised by complicated shapes and are located in compact sites covered by dense vegetation, it is not sufficient to apply only one source data acquisition system (ANGELLO, LO BRUTTO 2007). In such cases, integration of photogrammetric data from aerial and terrestrial systems, supplemented by data from other sources, is necessary and recommended. Such approach allows for 3D modelling and visualization of the terrain surface and all spatial objects. The use of ALS data only is not sufficient for texturing of the terrain surface (KRAUS 2007).

Integration of ALS data with aerial images allows to generate 3D realistic models of the terrain topography and all objects existing on the terrain surface. High resolution digital aerial photographs and ALS data are used for creation of orthomosaics and provide information on the terrain elevation, vegetation cover and roofs of buildings. The basements of buildings can be acquired from the vector basic map or by monoploting the orthomosaic. The terrestrial scanning laser and close range photogrammetric image data provide supplementary spatial information on 3D objects and also for texturing of their walls. Using TLS data, some imperfections, such as dead areas or lack of information in case of very smooth or glass surfaces, must be considered. To avoid such problems, the additional scans from other TLS stations, supplemented by terrestrial photographs, should be applied (DORNINGER, BRIESE 2005, AGNELLO, BRUTTO 2007).

Taking into account the integration of data acquired from various sources, the *a priori* analysis of many factors which may influence the data usefulness for modelling the terrain and objects, should be performed. In respect to (EL-HAKIM et al. 2005), the discussed factors include: the ability to acquire all details with the high geometric accuracy and reality, low cost and availability of equipment and universal software, and the fidelity of reconstruction and visualization of the terrain topography and 3D models of objects.

One of the data integration methods consists of hierarchical allocation of data into classes of different accuracy and resolution, aiming at creation of general shapes of objects and their details (AUGILERA et al. 2006).

The essential problem of the data integration process, which is connected with the variety of data sources, is to guarantee the common georeference of data. This can be achieved either by independent transformation of each data type (source) to the common reference system (ANDERSON et al. 2011), or by *a priori* matching the particular co-ordinate systems in which the data are determined. The simultaneous relative orientation of aerial and terrestrial data performed at the stage of the data integration results in some restrictions. They are connected with different ways of data recording by different systems and with various specifications of measurement. The examples of relative orientation of ALS data and aerial images and integration of close range images with point clouds are presented in (ANDERSON et al. 2011, BOEHM et al. 2007, BOULAASSAL et al. 2011, MARKIEWICZ 2013). In some cases, data integration is carried out by visualization and connection of final products with the use of external software tools (ANDERSON et al. 2011).

Integration of multi-source data of the Museum of King Jan III's Palace at Wilanów

Description of the object

The area of the Museum of King Jana III's Palace at Wilanów area comprises the palace, the garden, the park and the Wilanów lake. The Palace-Park set of 89 ha size, is located in the south part of Warsaw. In the past, the palace and park were the suburban, summer residence of King Jan III Sobieski. Under his order, the nobleman's mansion located in the central part of the area, was considerably extended. As the result of developments between 1681 and1696 the wonderful baroque Palace was built. The Palace history is indissoluble tided with the famous aristocratic families, such as Czartoryski, Lubomirski and Potocki.

At present, the Palace-Park set is administrated by the Museum of King Jan III's Palace at Wilanów, which was created in 1995. Recently, many essential works have been executed. In the period 2004–2008 the Palace was completely renovated and in 2011 the gardens were set in order. Since 2010, the Documentation Section has been involved in the development of the Spatial Information System (GIS), and at present the data base contains large files of data, 3D models of buildings, sculptures and other items, and also some results of archaeological research carried out in gardens.

For the needs of the discussed project, for presentation of the results of the multi source data integration, the most representative fragment of the Museum area has been selected. It comprises the most important buildings, such as the baroque Palace with the wonderful gardens located around on the upper bottom terraces.

The source data

Data integration and edition of information layers in the GIS have to be preceded by acquisition of photogrammetric products. The data base layers, acquired using various software tools, should have suitable accuracy and formats, which allow to input and display the data in the GIS system.

The following data were utilized in this project: (1) data from the Geodetic and Cartographic Documentation Centre (CODGiK), from the ISOK Project (the System of the Country Protection Against Extreme Hazards), ALS data in LAS format, the orthophoto with GSD of 0.25 m resolution, (2) vector data from the stereo digitizing of 0.1 m resolution aerial images using the Summit Evolution System, Inpho (KASPRZAK 2012), (3) the vector data base from the Museum of King Jan III's Palace at Wilanów, (4) symbols of trees from 3D Warehouse library.

The ALS data, with the average density of 12 points/m^2, in the „1992" co-ordinate system. 8 basic classes were distinguished in the point cloud (CODGiK 2014).

Modelling of selected 3d object types

The integration process was preceded by modelling of various 3D objects which were to be introduced in the projected data base. For this process the Google SketchUp 6 software was used. Such approach allows to input both, the digital images in .jpg format and the vector .dxf data.

Modelling of 3D trees. For visualization of 3D trees (Fig. 1), the symbol library of 3D Warehouse was utilized. This is a free set of 3D models available for Google SketchUp users.

a *b*

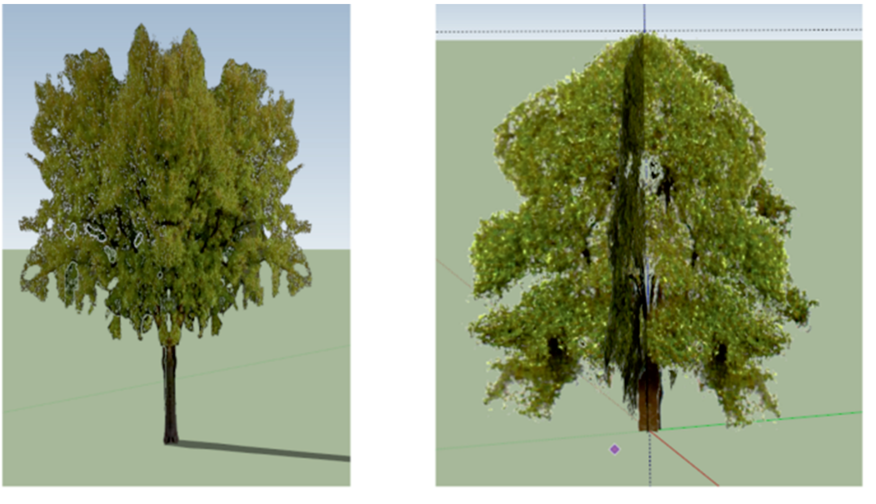

Fig. 1. Examples of 3D models of trees: *a* – oak, *b* – lime

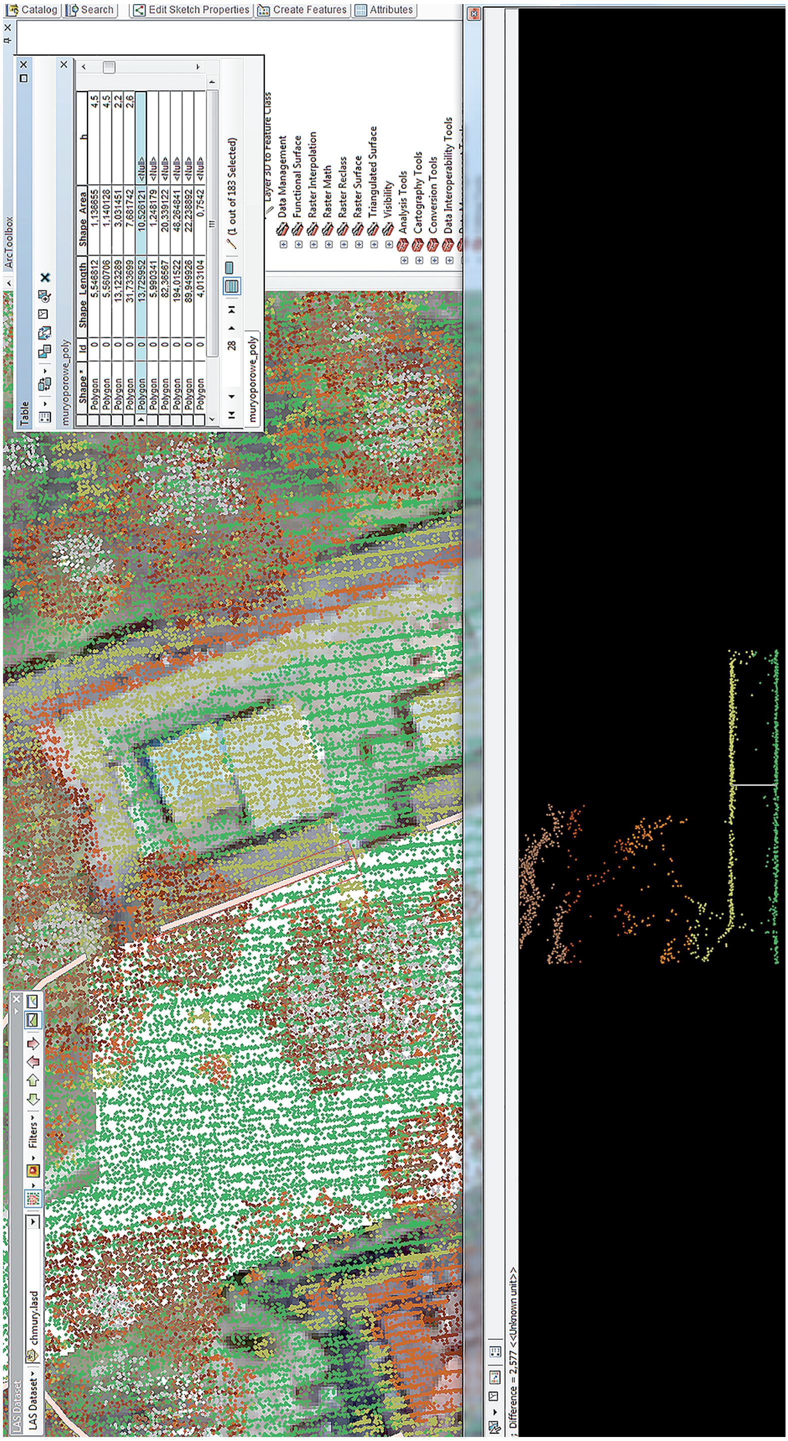

Fig. 2. Measurements of heights using the ALS point cloud in ArcGIS

3D modelling of fences and walls. 3D modelling of fences and walls was carried out in two steps with the use of ArcScene 10.2.1 (ArcGIS).

Step. 1 Utilisation of 2D vector data of walls and fences, from the vector data base of the Museum of King Jana III's Palace at Wilanów.

Step. 2 Interpolation of heights of walls and fences basing on the ALS data (Fig. 2).

3D modelling of the structure of the Palace and other historical buildings. For modelling of the Palace and other historical buildings located within the area of the Museum, the vector data base of buildings basements and edges of roofs was utilized (KASPRZAK 2012).

In the first step, all data was imported to Google SketchUp free software (version SketchUp Pro has not been available). Unfortunately, during this process all georeference information was lost. Therefore, the models were georeferenced again during the next step (Fig. 4).

During the final modelling stages, for the Palace, the basement data and data concerning the complicated shape of the roof, was used. For other historical buildings, only information on heights and shapes of roofs was available. The final models of all historical structures were generated at the level between LoD1 and LoD2 (Fig. 3).

a

b

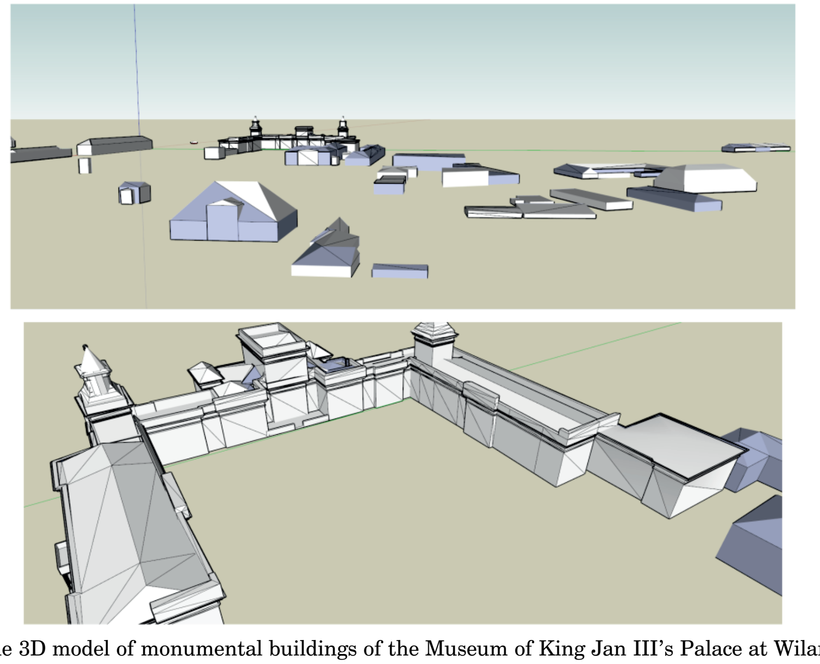

Fig. 3. The 3D model of monumental buildings of the Museum of King Jan III's Palace at Wilanów: *a* – other historical buildings, *b* – Palace

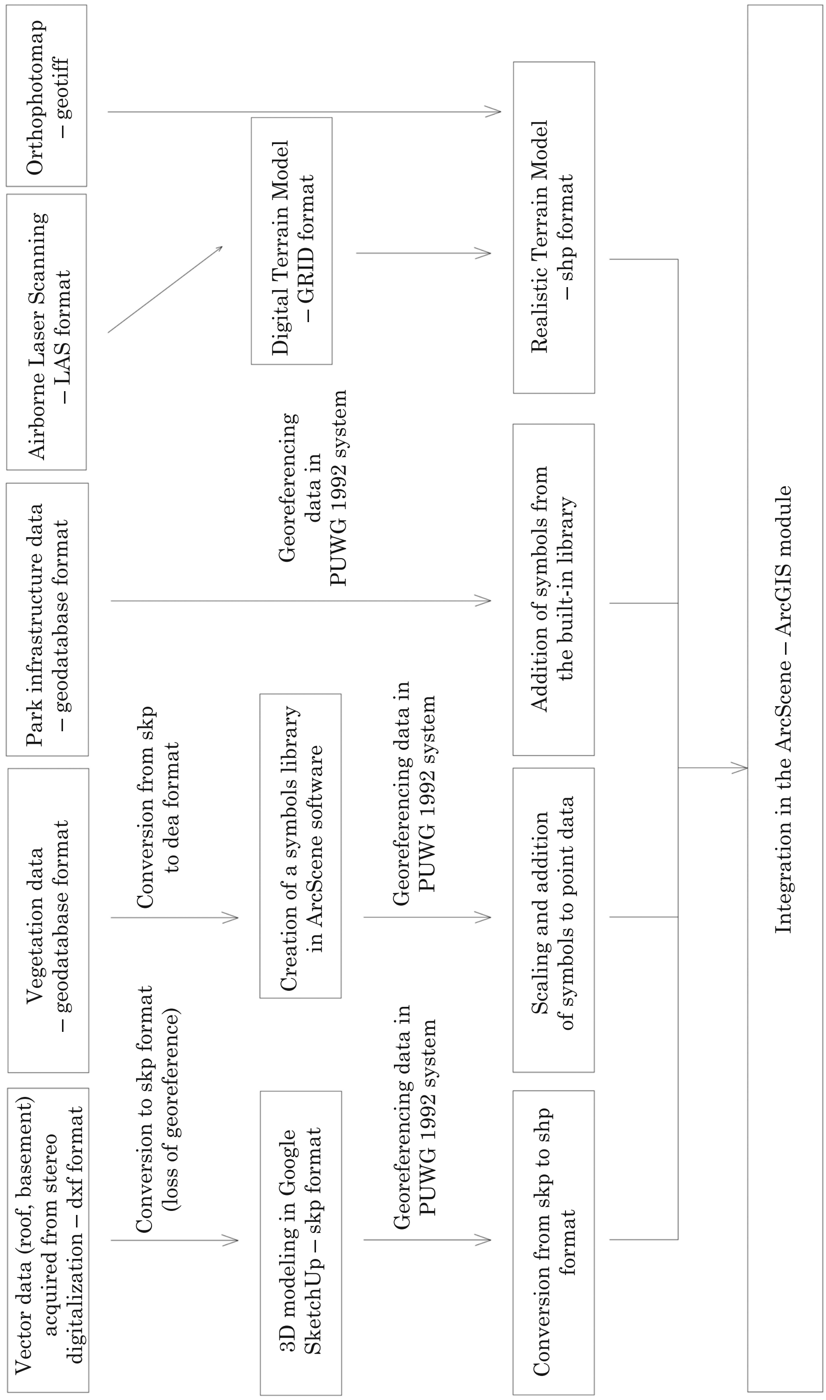

Fig. 4. The scheme of photogrammetric data processing and integration for modelling and visualization of 3D objects

Data integration and vizualization of the object

Integration of all data from various sources has been carried out basing on the block diagram proposed in (ANDERSON et al. 2011).

Figure 4 presents the scheme of programs and file formats used in the final data integration process, carried out by the authors.

During integration of data from various sources some problems were noticed, which were mainly caused by incompatible data formats. The main problem resulted from the missing georeference of data during the data input to SketchUp. Therefore data reference had to be introduced manually basing on the source data. According to the ArcScene manual, it should be possible to import data directly from *skp,* but unfortunately, it was not confirmed by the executed experiments. To solve such problems in this project, *skp* format was substituted by COLLADA format.

Format *skp* is used to store files in SketchUp (Trimble Navigation) software. This format is adequate not only for recording information on the objects' geometry but also on texture and type of materials (SketchUp 2014). Format COLLADA is used to record 3D data. Models described in such a way are compatible with the open XML standard, recorded with *dae* format (COLLADA 2014). This allows not only for correcting the read-out of symbols but also for assigning their heights. All elements of the data base were recorded in the PUWG 2000 reference system.

The limitation which was noticed during the processing concerned the lack of possibility to transform the point clouds recorded in the LAS format from the „1992" to the „2000" co-ordinate system. This caused the necessity to supplement data concerning trees, when the terrain surveys were not available.

The binary LAS files, containing ALS data, are recorded according to the standard 1.2. They contain information on the point co-ordinates and the intensity of the laser beam reflection, and classes of points and colours (RGB), from aerial photographs (CODGIK 2014).

The results of visualization after the final data integration are presented in Figure 5.

Analysis of data integration

The 3D model, reconstructed in the realistic scale, was transformed to the „1992", 2D co-ordinate system and to the 3D co-ordinate system „Kronsztad 86" using the 6-parameter transformation (translation and rotation).

The accuracy was estimated with the use of data from the basic map recorded in data base, which was utilized for 3D modelling and visualization.

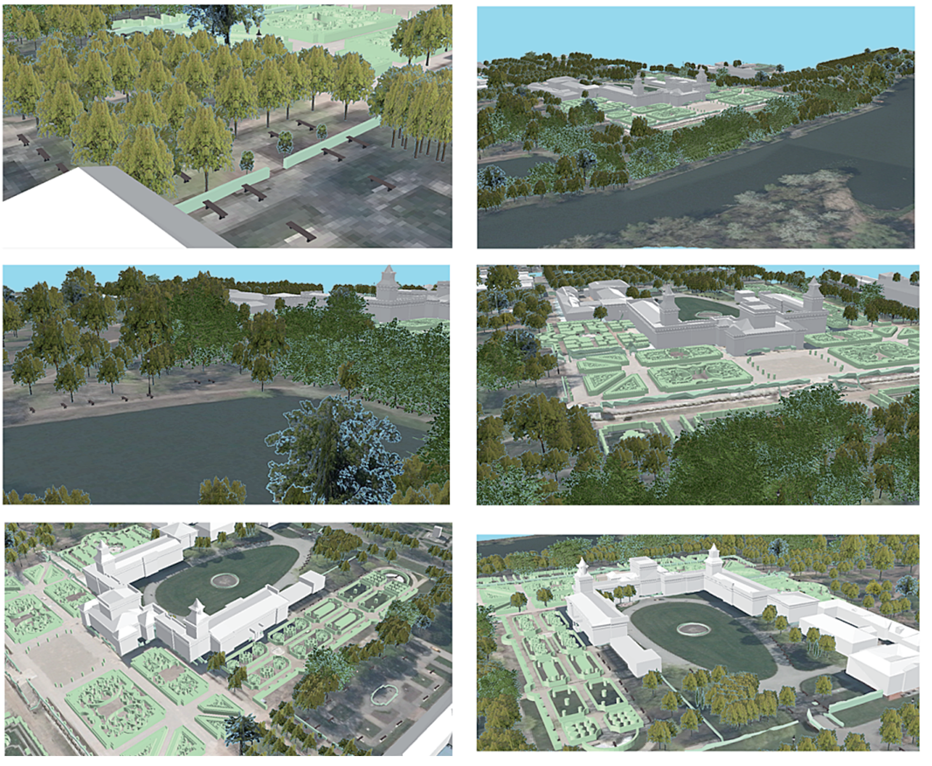

Fig. 5. Visualization of the final data integration for the Palace and park in Wilanów

Twenty control points were randomly chosen, their distribution is presented in Figure 6. These points were the corners of building basements, well visible in the data. The high values of errors of the model matching (above 1 m) result from modelling the buildings basing on vectorized roofs only.

Basing on the majority of points (16) the statistical indicators were estimated:

– Avarage deviation: 0.62 m

– RMSE: 0.28 m

– Deviation distribution: 25% of points between 0 and 0.4 m; 44% of points between 0.4 and 0.8 m; 31% bigger than 0.8 m.

The accuracy results show, that the average linear deviation does not exceed 0.95 m. This means that the accuracy condition for 3D modelling of buildings on the level LoD1 – LoD2 has been met.

Fig. 6. Distribution of 20 control points within the analyzed area. Points with deviations from the reference data which exceeded 1 meter are marked in blue

Conclusions

Summarizing the experiments concerning the photogrammetric data integration for visualization of cultural heritage objects, it should be emphasized that the process is labour-consuming with restricted degree of automation. Many intermediate processes require adequate data preparation and suitable software. The final general conclusions can be included in the following groups:

(1) In spite of intensive development of 3D modelling and GIS software, the problem of 3D visualization of architectural objects and their surroundings has not been properly solved yet.

(2) The typical problem related to the spatial modelling and processing of data from various sources concerns the difficulty of using various data formats and their exchange between different programmes.

(3) The 3D Google SketchUp (free of charge) software for modelling does not preserve data georeference information. Therefore, this requires reiteration of spatial orientation of the objects, resulting in additional difficulties and errors in data reference.

(4) The use of GIS software allows to manage and process data acquired from various sources. This is useful not only for the experts of conservation of monuments, analyzing particular scenes, but also for spatial analyses performed with the use of metric characteristics of the source data.

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