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Hybrid processing of laser scanning data

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Abstract. In this article the analysis of gaps in processing of raw laser scanning data and results of bridging the gaps discovered on the base of usage of laser scanning data for historic building information modeling is presented. The results of the development of a unified hybrid technology for the processing, storage, access and visualization of combined laser scanning and photography data about historical buildings are analyzed. The first result of the technology application for the historical building of St. Petersburg Polytechnic University shows reliability of the proposed approaches.

1 Introduction

Laser scanning is the most modern and actively developing type of remote sensing technologies. Nowadays the three-dimensional (3D) technologies are applied worldwide in a wide range of applications: road management, urban modeling, industry survey, heritage preservation [1]. Corresponding types of acquisition systems are the following terrestrial, mobile and airborne laser scanning [2]. Laser scanning is one of the common remote sensing methods. The principle of operation of laser scanners, regardless of their type and purpose, based on measuring of distance from the source of the laser pulse to the object. During the survey of an object, the required distance is determined according the time delay (pulse method) or the phase shift (phase method) in signal reflected by object surface [3]. The result of laser scanning is a cloud of points that is usually combined with photos [4]. Therefore for each point in the cloud user can get the following information: three coordinates, intensity of reflected signal and color (R, G, B), that accurately describe the surveyed object. Geometrical accuracy and point density of such clouds has recently significantly increased [5].

The objectives of this article are to analyze of some gaps in processing of raw laser scanning data and to present of some results of bridging the gaps discovered on the base of usage of laser scanning data for historic building information modeling. In the article results of the development of a unified hybrid technology for the processing, storage, access and visualization of combined laser scanning and photography data about historical buildings are presented.

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2 Methods

An experience in architectural measurements of historical buildings using laser scanning technologies has shown that the measuring drawings of the facades and interiors of buildings most effectively created on the base of raster orthoimages, which are obtained by projecting laser point cloud on the picture plane. A similar approach has been traditionally used in photogrammetry [6]. Mobile Laser Scanning (MLS) is the most advanced and least common practice in Russian. But the number of MLS equipment in Russia has already surpassed the number of airborne laser scanners as well the amount of information per unit of time received by the MLS (up to 3-5 million points per second) several times higher than the volume produced during airborne scanning. There are numbers of promising applications that require the collection of geospatial data using MLS. However, MLS data processing are underdeveloped.

The analysis of the current state of research in this area has shown that there are a large number of publications dedicated to tasks of construction of digital models of buildings, the detection of the surface of the earth and the reconstruction of the road surface, detection and recognition of road facilities on the basis of MLS data [5, 7, 8].

Despite the existing successes, it is possible to single out the following algorithms, which require deeper study:

- for the hierarchical processing of big amount of data that provide a hybrid processing and data compression without loss of accuracy,
- for the integration of the scan data obtained from various sources,
- for the seamless linking of data processing in real time during forming orthoimage based both on a single scan, and a series of scans received from different sources for providing a reduction in the area of "dead zones".

The proposed method is a comprehensive solution to the problem by creating an algorithmic support for the hybrid system for processing of data received from all types of laser scanning (mobile, terrestrial and airborne), as well as photo. The solution proposed by authors is not the total three-dimensional modelling of urban areas or, for example, historical buildings and structures. Proposed method provides a method for semi-automatic and automatic data processing and visualization based on forming cylindrical reamers for point clouds. To solve the problems of historical building informational modelling (HBIM) [9] creation of based on laser scanning data a method for processing big volumes of data is developed. The method provides more accurate detailing of HBIM including a combination of scan data for each scale and a level of representation of survey information obtained by different scanning methods.

Factors determination and evaluation of metrics for the factors that affect the accuracy is not analyzed in the method. Special approaches for data compression without loss of accuracy and reducing the area of "dead zones" in the orthoimages are used. The problem of determining the geometry of the buildings is solved with existing methods with the usage of the integrated information obtained by various methods using interpolation and extrapolation of the collected data. However, to support the proposed method the experimental study of the effectiveness of various methods of surface modelling had been performed to ensure the acceptable level of accuracy.

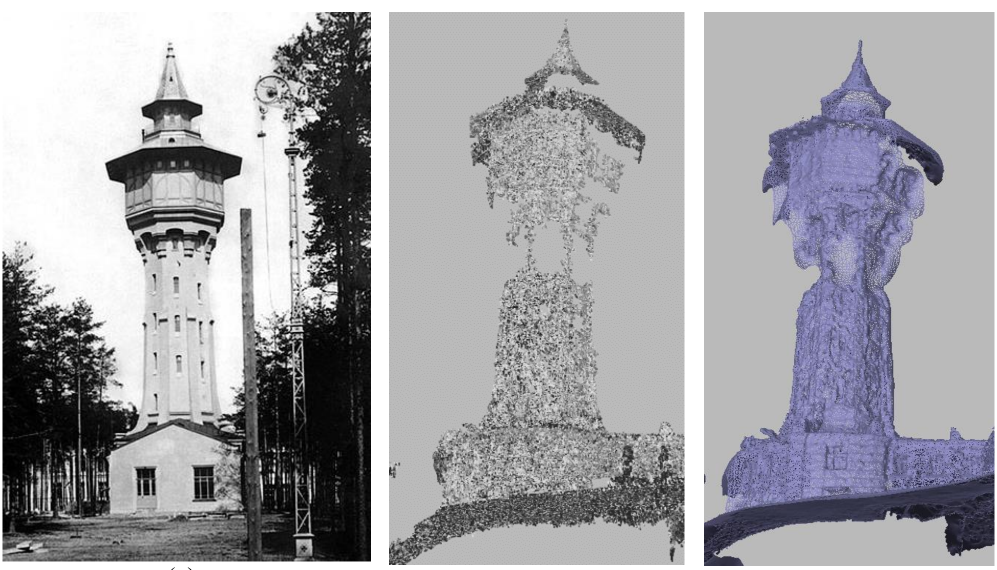
3 Results

The task of the research is to develop new algorithms of cloud of points processing (big data processing) received from laser scanner. Creation of the software for the processing, visualization and vectorization of laser scanning data, as well as the presentation of data through the Internet, providing: (1) improved efficiency and accuracy of processing of laser scanning data (decoding and vectorization not less than 99.5%); (2) to provide to the customer of laser scanning process (within the engineering survey) the functionality of the post-processing of results of the scan on the basis of the primary (raw) information about the object(which is most valuable information).

Testing research for the technology was conducted to establish of 3D data for buildings of Peter the Great St. Petersburg Polytechnic University (former St. Petersburg Polytechnic Institute). St. Petersburg Polytechnic Institute was built on the model of Oxford and Cambridge as a complex with thoroughly designed and implemented infrastructure. The construction of the based buildings of the Institute was carried out after the designs of architect E. Virrich, artist architecture 1-St degree, academician of architecture since 1908, the outstanding representative of rationalist architecture, one of the pioneers in the use of reinforced concrete structures, in 1900 – 1905.

The complex of the Polytechnic Institute interesting as a coherent architectural ensemble, one of the few that have survived in a relatively unchanged form. Buildings represent the unique architectural buildings of the turn of XIX - XX centuries. The complex of buildings and Park are included in the "List of objects of historical and cultural heritage of Federal importance", approved by the decree of the President of the Russian Federation No. 176 of February 20, 1995, and are particularly valuable objects of cultural heritage of the peoples of the Russian Federation as a complex historical, cultural, architectural ensembles and structures and natural landscape monument representing material, intellectual, and decorative value.

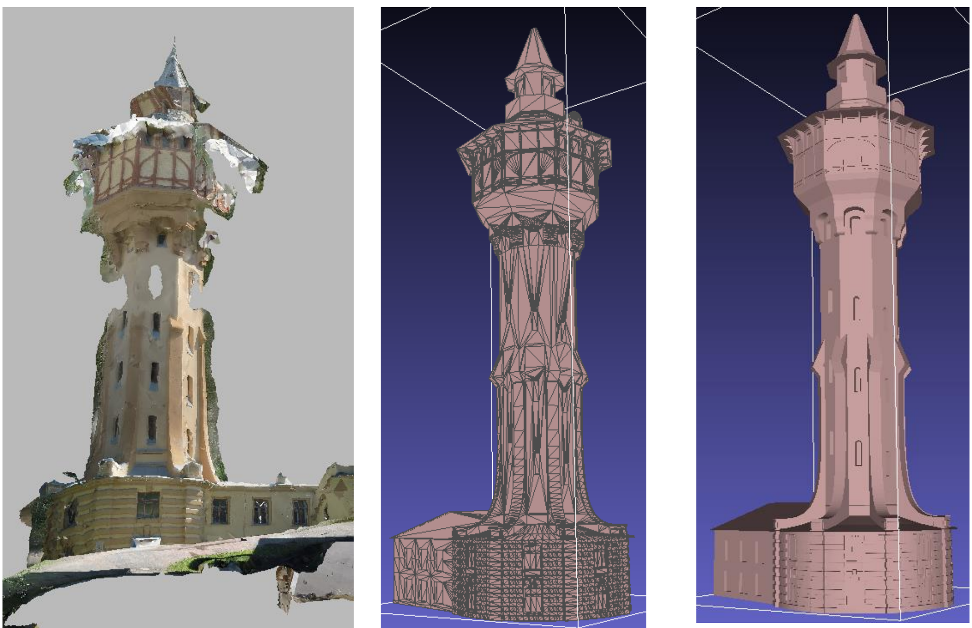
One of the oldest constructions on the University premises is the Water Supply Tower was built in 1905 (fig. 1a), three years after the opening of the Polytechnic Institute. It is the highest point among two- and four-story institute buildings, and goes in contrast with other constructions because of its intricate and fractured forms. The Water Supply Tower is 46 meters high. Until 1953, it had been used as an engineering construction to provide the work of the water pipe system. When it was built, the Water Supply Tower has became one of the education-supporting buildings on the Institute's territory. In 1905 the annex near the Water Supply Tower the Hydraulics Laboratory was housed.



(a) (b) (c)

Fig. 1. (a) Water Supply Tower in 1905; (b) point cloud for the historical building; (c) result of semi-automatic triangulation.

There are many options for creating digital models of large objects, among the highlights of the photogrammetry and 3D laser scanning. The complexity of the research is required the use both techniques. To establish a 3D model for HBIM of Heritage Resources were used methods of 3D laser scanning and photogrammetric data processing. Creating 3D model involves the following steps: the choice of object of study; collection of visual, technical and historical information; laser scanning and photogrammetric survey to obtain data – point cloud (fig. 1b); detection and extraction of segments of dense point cloud, and the procedure of semi-automatic triangulation (fig. 1c); obtaining external color models using (fig.2a); export data in applied architectural packages (fig.2b, fig.2c).



(a) (b) (c)

Fig. 2. (a) external colour model; (b) 3D mesh for BIM; (c) 3D BIM model.

It was built dense point cloud (fig. 1a) based on image comparison using OpenCV library [10]. A dense cloud of points is 1 point per 1 cm^2, in the case of shooting large objects. In the case of this object, the point cloud was 32KK points. Processing this amount of points makes no sense and is extremely costly in terms of hardware resources. For this purpose, it is necessary to reduce the number of points. For large objects, having a complex geometry optimally reduce the number of points is in 10-fold to 3.2 KK.

4 Discussion

The survey of existing building is an activity, which is increasingly used modern laser scanning high-tech devices and equipment [11]. Appropriate methods are used for surveying of various objects, ranging from historic buildings to uninhabited territories for road construction [4, 12, 13]. Laser scanning systems collect data more completely and efficiently than traditional surveying methods [14]. Future developments of these systems continues to design a compact, lightweight and relatively inexpensive multipurpose laser scanning system that should be quick and easy to deploy, and requires a minimum amount of existing equipment for operational support [1]. The well-known features of laser scanning data are high accuracy and density and as a result of which big spatial point cloud data are created [15]. The process of obtaining point cloud for each type of laser scanning is well explored and the appropriate software have been developed by providers [16].

A significant drawback of laser scanning technologies, which significantly limits its use, is the constantly existing gap between the rapid development of the technologies and the possibilities of processing results (cloud point processing) [17]. Existing methods of geo-processing and images analysis, as well as high demands to computational resources do not allow full use of the capabilities of the technologies [18]. Today processing of laser scanning results (point clouds) are often associated with providers of equipment [19]. But there are almost no universal tools for processing and exchanging of the point clouds from different sources [9 ,20].

Laser scanning point clouds are currently collected and processed individually on specific objects and territories, according to the technological requirements (Xu et al., 2017). Automatic or semi-automatic segmentation and objects detection in 3D laser scanning data is the most resources-consuming step. There are also special software packages developed for creation of specific models types from laser scanning data such as Cyclone, RapidForm, 3Dipsos, they are all designed to work in 3D [4]. Also laser scanner providers have proposed to import point clouds into most popular CAD systems AutoCAD (Autodesk) and Microstation (Bentley). However, processing of raw 3D laser scanning data in CAD environment is inconvenient, especially if creation the 2D plans are required [21].

The complexity of historic buildings, with irregular geometry poses numerous challenges in the computer modelling and simulation of structural elements under different types of loads [22]. The responsible persons must take into account a range of possible and compatible solutions that avoid endangering the cultural significance of the historical building [9]. Nowadays, in many publications for solving the mentioned problems it has been proposed to use an approach based on HBIM. The first step of the modern HBIM usually is remote collection of survey data using a laser scanner technologies combined with digital photos [12, 22]. Therefore, there are many applications of the laser scanning technologies for data collection about historical buildings worldwide [9]. In papers has been discussed the usage of innovative laser scanning surveying technologies for modelling and monitoring of heritage buildings to forecast their behavior during the life cycle management.

5 Conclusions

Unified hybrid technology for the processing, storage and visualization of laser scanning and photography data about historical buildings based on decoding and vectorization algorithms was proposed. It is an information framework for HBIM of heritage resources in St.Petersburg, Russia. The first result of application the technology to historical building (Water Supply Tower of Peter the Great St. Petersburg Polytechnic University) shows the reliability of the proposed technology. The developed technology also can be useful for processing laser-scanning data during engineering survey of roads and existing building.

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