About prospects for the air laser scanning technology implementation for obtaining a digital model of densely built-in territories

D A Gura 1*, I G Markovskii1, B A Hahuk 1, S K Pshidatok 2

1Kuban State Technological University, Department of Cadastre and Geoengineering, 2, Moscowskaya str., Krasnodar, 350000, Russia
2Kuban State Agrarian University named after IT Trubilin, Department of Geodesy, 13, Kalinina str., Krasnodar, 350000, Russia

E-mail: gda-kuban@mail.ru

Abstract. The work raises the question of the urban development using a digital model based on the results of airborne laser scanning for the municipality administration needs. The processes of air laser scanning and subsequent cameral processing of the results are described. Specialized software for analyzing the information received and authors’ methods for classifying the objects are considered. The available achievements analysis in the field of city models compilation and the analysis of natural and man-made objects obtained from aerial surveys of urban areas is carried out. The conclusions are drawn about the prospects for the application and development of this technology for the purpose of accounting and monitoring the urban areas in terms of its impact on the urban economy, the quality of the population life and forecasting emergencies.

Introduction
Laser scanning technology is increasingly used in various sectors of the economy and production. It is used to obtain the data on the Earth’s surface and the objects located on it, for the purpose of mineral exploration [1], monitoring natural and man-made objects [2], studying the water bodies and coastal territories bottom topography, accounting and analyzing the forest resources development [3]. In addition, this method of obtaining and collecting data is increasingly used for the purpose of creating the basis of geographic information systems of various enterprises and other real estate objects. This allows to have in the arsenal a real three-dimensional enterprise model, which facilitates the process of managing it and finding the best ways to modernize it to increase the overall production efficiency.

Immersed in the structure of a large enterprise, it is possible to notice that it is very similar to the city structure, where the administration is divided into departments (structured), each of which is engaged in a certain range of tasks in a particular direction, responsible for its management and development. Together, this leads to the most promising economic and social growth of both the municipality and the enterprise.

In this paper, we analyze the existing methods for creating three-dimensional models of cities based on the method of obtaining information about the terrain and buildings using laser scanning.
The conclusions are drawn about the impact of this approach taking into account the urban areas on the urban economy, the quality of life of the population and on forecasting emergencies.

**Analysis of obtaining information means about the urban areas**

The task of accounting for urban areas is always important for each municipality administration. The future rational development of the city depends on its solution completeness degree. In some concepts of smart cities, a ready-made methodology, which implies the use of a whole set of means for sensing the Earth’s surface is given [4]. In order to obtain the data on urban areas, the use of the following instruments and technologies is described: total stations, global navigation satellite system (GNSS), ground-based laser scanners, mobile laser scanners, airborne laser scanners. However, most scientific teams in their work agree on the superiority of the airborne laser scanning method over these analogues. Such conclusions are due to a combination of high accuracy and high speed of obtaining data on the terrain in this way.

Speaking about the procedure for conducting airborne laser scanning, it is necessary to mention that there are airborne laser scanners designed specifically for use with unmanned aerial vehicles. However, their use is most often advisable only to obtain information about individual real estate objects, their group or a small area due to the short flight time of these air assets. Therefore, it is best to use airborne scanners mounted on manned aircraft, the most modern of which can cover an area of 150 km² in 1 flight. In addition, there are specialized solutions in the field of air scanning designed to obtain information about the territory with dense buildings, for example, Leica Terrain Mapper or Optech Galaxy. They are optimized for shooting urban lands, which is reflected in the received laser reflection points increased density, increased flight altitude, the ability to display power lines and other objects in detail above the surface of the Earth.

**The procedures for obtaining and subsequent processing of the Earth surface data**

The scanning procedure itself consists in carrying out the flight of an aircraft with equipment installed on board - a laser scanner over the study area. To compensate for errors accumulated during scanning and to speed up the process of decrypting the received data, digital survey specialists, together with the scanning unit, use a digital wide-format aerial camera, a GPS receiver and an IMU module [5]. Then the process of the results camera processing begins, which consists in stitching (if it is not provided for in the scanning system) clouds of laser reflection points and creating in specialized software solid objects from individual points.

This is a very time-consuming task, which when done in manual mode takes a lot of time, therefore, there are programs that partially automate this process. In addition, the scanning systems manufacturers often offer their own software, the scope of which varies from solving specific application problems to assisting in the entire project development. Such programs greatly accelerate the work of cameral processing specialists, as they have many functions that automatically classify various elements of a point cloud obtained by scanning, such as: automatic detection of the earth's surface, grass substrate, crowns and tree trunks, and others.

In addition to these methods of processing airborne laser scanning data, there are also various proprietary techniques. The work of scientific teams from various countries describes the methods for deciphering laser reflection points by creating add-ons to existing software or without them [6, 7, 8, 9]. In addition, there are techniques that automatically classify buildings, parts of which are hidden from the laser beam under the crowns of trees. The operation principles of such techniques are mainly based on the difference between the characteristics of buildings and vegetation: by classifying points belonging to trees from the cloud, the program removes them and, according to the laid down algorithms, completes the missing elements of houses [10, 11].

**Results**

There are currently ways to solve almost all of the applied problems encountered by the specialists in cameral data processing of airborne laser scanning in the process of their work. Knowledge of the
necessary programs and methods, as well as their competent application, will provide a quick and accurate representation of almost any amount of data in informative three-dimensional models for subsequent work with them.

A large amount of data from the studies related to the urbanized areas study by means of their airborne laser scanning has now been accumulated and systematized. The main feature of such approaches to mapping urban lands is the cities digital three-dimensional models unprecedented detailing, the resolution of which can reach up to 1 m² [12]. This allows to measure and calculate not only the area of each individual building, but also its height and volume. Such an approach to accounting for real estate construction projects, where it is possible to scale a detailed city map from a panorama of the entire municipality to a model of a specific building, opens up new possibilities for the administration, allowing a better analysis of the urban morphology that makes up the real estate cadaster. In the aggregate, all this will help to more rationally and competently design a new and modernize the existing infrastructure, which will positively affect the road situation in the entire city.

The final result of such work is this technology testing for the city administration needs. An example is the work aimed at testing the possibility of classifying land use in municipal territories [13, 14]. In particular, there is a land analysis method where information about them is obtained by conducting airborne laser scanning in conjunction with the Google Street View database [13]. It shows high potential for their accurate classification, which opens up the prospects for its widespread use.

Summary
Over the decades of its existence, airborne laser scanning technology has proven itself as one of the best ways to obtain information about the Earth’s surface. It is important to understand that the data obtained by the digital research method which has a very wide range of applications beyond the boundaries of photogrammetry. Numerous studies prove the undeniable benefits that this technology can bring in combination with other methods of extracting and processing data on the earth’s surface, for the needs of cities and other municipalities. Subsequently, the obtained information and knowledge can be used to monitor the proper use of land, register land resources, search for and eliminate unauthorized landfills for household and industrial waste, environmental monitoring of green spaces, analyze existing buildings and urban infrastructure, the security of infrastructure facilities and much more. Together, this will give the administration a tool for a more rational and competent arrangement of urban life, development of the city’s infrastructure network, zoning of territories and maintaining the ecological balance, and creating a comfortable urban environment. Integrating the achievements of various scientific and technical spheres into urban life is the key to the modern sustainable development of urban areas.

References
[1] Wang J W, Zhang C 2017 Separating Coal and Gangue Using Three-Dimensional Laser Scanning (International Journal of Mineral Processing) 169 79-84.
[2] Fabbri S, Giambastiani B M S, Sistilli F, Scarelli F, Gabbianelli G 2017 Geomorphological Analysis and Classification of Foredune Ridges Based on Terrestrial Laser Scanning (TLS) Technology (Geomorphology) 295 436-451.
[3] Adnan S, Maltamo M, Coomes D A, Garcia-Abril A, Malhi Y, Manzanera J A, Butt N, Morecroft M, Valbuena R 2019 A Simple Approach to Forest Structure Classification using Airborne Laser Scanning that can be Adopted Across Bioregions (Forest Ecology and Management) 433 111-121.
[4] Fawzi Al-Hader M 2012 Smart City Infrastructure Monitoring Using LIDAR Technologies (LAP LAMBERT Academic Publishing).
[5] Gura D A, Shevchenko G G, Kirilchik L F 2017 Application of Inertial Measuring Unit in Air Navigation for ALS and DAP (Journal of fundamental and applied sciences) 9 732-741.
[6] Han W, Zhao S, Feng X, Chen L 2014 Extraction of Multilayer Vegetation Coverage Using Airborne Lídar Discrete Points with Intensity Information in Urban Areas: a Case Study in
Nanjing City, China (International Journal of Applied Earth Observation and Geoinformation) 30 56-64.

[7] Ma H, Zhou W, Zhang L 2018 DEM Refinement by Low Vegetation Removal Based on the Combination of Full Waveform Data and Progressive TIN Densification (ISPRS Journal of Photogrammetry and Remote Sensing) 146 260-271.

[8] Liu L, Lim S 2018 A Voxel-Based Multiscale Morphological Airborne Lidar Filtering Algorithm for Digital Elevation Models for Forest Regions (Measurement) 123 135-144.

[9] Kuzyakina M, Gura D, Sekisov A, Granik N 2019 Assessment of Potential Forest Biomass Resource on the Basis of Data of Air Laser Scanning (International Scientific Conference Energy Management of Municipal Facilities and Sustainable Energy Technologies EMMFT) 2 403-416.

[10] Zhou Q, Neumann U 2013 Complete Residential Urban Area Reconstruction from Dense Aerial LiDAR Point Clouds (Graphical Models) 75 (3) 118-125.

[11] Li M, Rottensteiner F, Heipke C 2010 Modelling of Buildings from Aerial Lidar Point Clouds Using TINs and Label Maps (ISPRS Journal of Photogrammetry and Remote Sensing) 154 127-138.

[12] Bonczak B, Kontokosta C E 2019 Large-Scale Parameterization of 3D Building Morphology in Complex Urban Landscapes Using Aerial Lidar and City Administrative Data (Computers, Environment and Urban Systems) 73 126-142.

[13] Zhang W, Li W, Zhang C, Hanink D M, Li X, Wang W 2017 Parcel-Based Urban Land Use Classification in Megacity Using Airborne LiDAR, High Resolution Orthoimagery, and Google Street View (Computers, Environment and Urban Systems) 64 215-228.

[14] Yan W Y, Shaker A, El-Ashmawy N 2015 Urban Land Cover Classification Using Airborne Lidar Data (A review, Remote Sensing of Environment) 158 295-310.

[15] Volynsky B N 2001 Constructive Solutions for Energy-Saving Building (Energy-saving) 3 (67).

[16] Gagarin V G 2010 Regarding the Rationale for Increasing the Thermal Protection of the Enclosing Structures of Buildings (Stroyiprofi) 1 21-23.

[17] Grabovoy P G, Kharitonov V A 2013 Reconstruction and Renewal of the Existing Urban Development (A textbook. 2nd ed., revised, Prospekt, Moscow).

[18] Zilberova I Y 2000 System-Flow Arrangement of Civil Engineering Production in the Course of Reconstruction of Residential Houses (Author's abstract form PhD Tech. thesis, Rostov-on-Don).

[19] Sheina S G, Cherednichenko N D, Vongay A O 2009 The Choice of the Most Effective Option for Increasing the Thermal Protection of Buildings of Higher Educational Institutions by the Use Criterion Analysis Method (Bulletin of Construction Machinery) 9 55-58.

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