

# Modern Acquisition Technology of Spatial Data as a Basis of Environmental Engineering and Planning Projects

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**Key words:** orthophoto map, remote sensing, digital terrain model (DTM), laser scanning, UAV system

## SUMMARY

This work presents a summary of the possibility of advanced geodetic technologies for creating 3D digital topography maps for use in spatial and urban planning and for all other spatial related activities. The paper also gives a detailed review of:

1. Creating orthophoto maps and digital elevation models from high resolution satellite images;
2. Advanced methods for data acquisition using mobile LIDAR system from the air, and Mobile Lidar DynaScan for spatial forms mapping;
3. Application of SenseFly eBee UAV system for photogrammetric measurements areas covered by Civil and Environmental Engineering, Regional and Urban Planning projects.

All modern acquisition technologies will be presented with their applications on realized projects in Nigeria, Qatar and Serbia. On the basis of this presentation will be to show that they provide multiple savings in time and labor resources in the realization of a 3D digital maps and models as the basis of design in Civil and Environmental Engineering, Regional and urban projects.

## SUMMARY

U radu su predstavljene mogućnosti primene naprednih tehnologija za generisanje 3D digitalnih topografskih podloga za potrebe prostornog i urbanog planiranja kao i za srodne discipline. U radu se daje pregled sledećih postupaka:

1. Generisanje orto-foto planova i digitalnog modela visina sa satelitskih snimaka visoke rezolucije;
2. Napredne metode za prikupljanje podataka primenom LIDAR tehnologije iz vazduha i mobilnog laserskog skeniranja sistemom DynaScan za kartiranje prostornih formi;
3. Primena SenseFly eBee UAV sistema za fotogrametrijska merenja područja za potrebe projekata iz oblasti građevinarstva i regionalnog i urbanog planiranja.

Savremene tehnologije koje su razmatrane u radu su primenjene na realizovanim projektima u Nigeriji, Kataru i Srbiji. Primenom ovih tehnologija postužu se višestruke uštede u vremenu i radnim resursima u postupku realizacije 3D digitalnih podloga i modela za potrebe projektovanja u građevinarstvu i regionalnom i urbanom planiranju.

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## **1. INTRODUCTION**

During the last ten years the possibilities for data acquisition in geodesy have been rapidly improved. The devices become cheaper, smaller, more accurate and, on the other hand, they are capable of gathering a large number of data within a very short time interval. Also, mobile platforms have been developed as carriers for different devices LIDAR (Light Detection and Ranging) platforms, platforms for cameras, etc. Unmanned aerial vehicles (UAV) are of special interest. Their primary use concerns the three-dimensional terrain mapping and they are applied in various domains, among which is geodesy. These devices are light, mobile, completely automated, providing access to even most unavailable terrains. The satellite high-resolution frames have demonstrated a high potential in forming the frames to national maps (charts) of all kinds and purposes. In addition to geometric data offered by the digital terrain model for the necessities of determining spatial form of urban planning, a very important role belongs to the orthophoto map as a geocoded digital raster photograph, on the basis of which different space forms can be identified. The satellite high-resolution frames have demonstrated a high potential in forming the frames to planning and designing of various kinds and purposes. What is attractive to many potential users is just the meter resolution which, practically, makes it possible to extract the objects appearing in the majority of digital cartographic products. The technology of preparation of digital topographic layouts in vector and raster format is in expansion, great number of satellites with sensors for remote sensing provides the resolution better than 1 meter. Also, laser scanning technology is often used in urban design and space planning project.

## **2. TECHNOLOGY OF LASER SCANNING OF TERRAIN AND BUILDINGS**

For the purpose of solving practical problems in many branches of engineering industry, there is a need for measuring and modeling of measured data as much as possible real display of spatial surroundings. By development of laser scanning technology the conditions for application of 3D measuring of points of very high density have been met in a way that modeling of subject survey can be carried out by using this data. The necessity for highly detailed 3D terrain and building coordinates occurs in different engineering disciplines, such as [3]:

- Quality control, supervision and comparison of construction with plans, especially on complex construction sites
- Virtual planning, analysis of spatial relations between buildings themselves, but also between a building and surroundings (complex buildings)

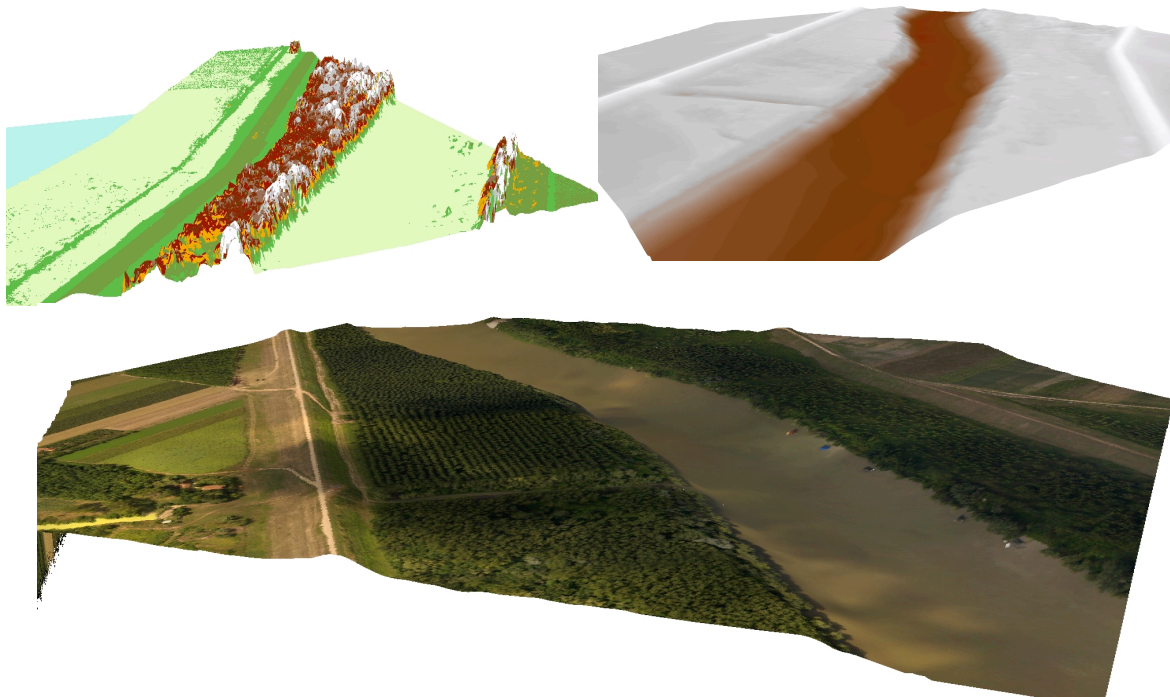
- Digital archiving of infrastructure (tunnels, bridges and road network) in order to provide the basis for efficient management
- Control of different deformations on construction sites (landslides, strains, faults on facilities), surveying of entire construction sites, not only the previously determined selected points.

Detailed survey of culturally significant buildings, monuments, churches, towers with very accurate documentation of their condition (interior and exterior) in order to repair them in case of collapse or destruction of any kind.

## 2.1 Laser Scanning LIDAR

Laser scanning of the terrain from the air (LIDAR) today represents one of the most contemporary technologies which is used in surveying and preparation of topographic plans and maps for different purposes. Laser scanning data can be combined with satellite images in order to make 3D terrain model and creating a photorealistic view of the terrain (Fig 1).

The technology is based on gathering three different sets of data. The position of a sensor is determined by the use of Global Positioning System (GPS) using a phase measuring in the regime of relative kinematics, and the orientation is determined by use of Inertial Measurement Unit (IMU). A laser scanner is the last component. The laser sends an infra red beam to the earth and it reflects to the sensor. Time lapsed from emission to reception of signal with knowledge of sensor and orientation position, enables for the three dimensional coordinates on the Earth to be calculated [1], [2].



*Figure 1. Products of laser scanning of Tisa river in Serbia (Digital Surface Model - top left, Digital Terrain Model - top right, Orto-foto map on DTM - down), [1], [2]*

During flight speed of approximately 250 km/h and altitude of approximately 1000 meters with standard characteristics of a sensor (130000 emissions / second), the data on position of points on the ground with density of up to 100 dots/m<sup>2</sup> have been gathered. Usual relative accuracy of a model with calculated omission of GPS and inertial system amounts to 5-7 cm. Absolute error is always better than 15 cm and it can be significantly reduced by use of control points on the ground. Almost all modern LIDAR systems, next to GPS, IMU and laser scanner also integrate RGB/NIR (Red – Green-Blue, Near Infra Red) cameras of high resolution which enable the making of quality ortho-photo plans of resolution of up to 2 cm (depending on the height of over flight). Survey with LIDAR is carried out while moving and the system can be mounted to a vehicle in the aim of scanning corridor such as roads or similar line facilities or to an aircraft for scanning the corridor from the air. LIDAR has a very simple principle of measuring. The scanner emits the high frequency impulses and it reflects from the surface to the instrument. The mirror inside laser transmitter moves by rotating perpendicular to the flight direction which enables the measuring in wide belt. Time elapsed from the emission to the return of each impulse and angle of divergence from the vertical axes of the instrument are used for determining relative position of each measured point. Data from laser scanning are combined with scanner position and orientation in order to obtain three dimensional coordinate of laser print on the surface of the terrain [3].

After the processing of GPS vector from base stations to each measured sensor position, orientation and determining relative position on the ground in regard to the sensor, the following data are obtained:

- The cloud of points of first and last echo
- DSM first and last echo
- RGB and NIR recording

## 2.2 Technique of Mobile Laser Scanning

The implementation of the most recent laser scanning technique combined with the high-precision navigation system, yields a system for 3D scanning of roads, buildings and trees from moving vehicles. The device utilises several laser scanners where each of them performs up to 10.000 measurements per second with a scanning speed of at most 100 acts of scanning per second. In the case of this system different scanners, located at different places of the car platform, can be utilised.



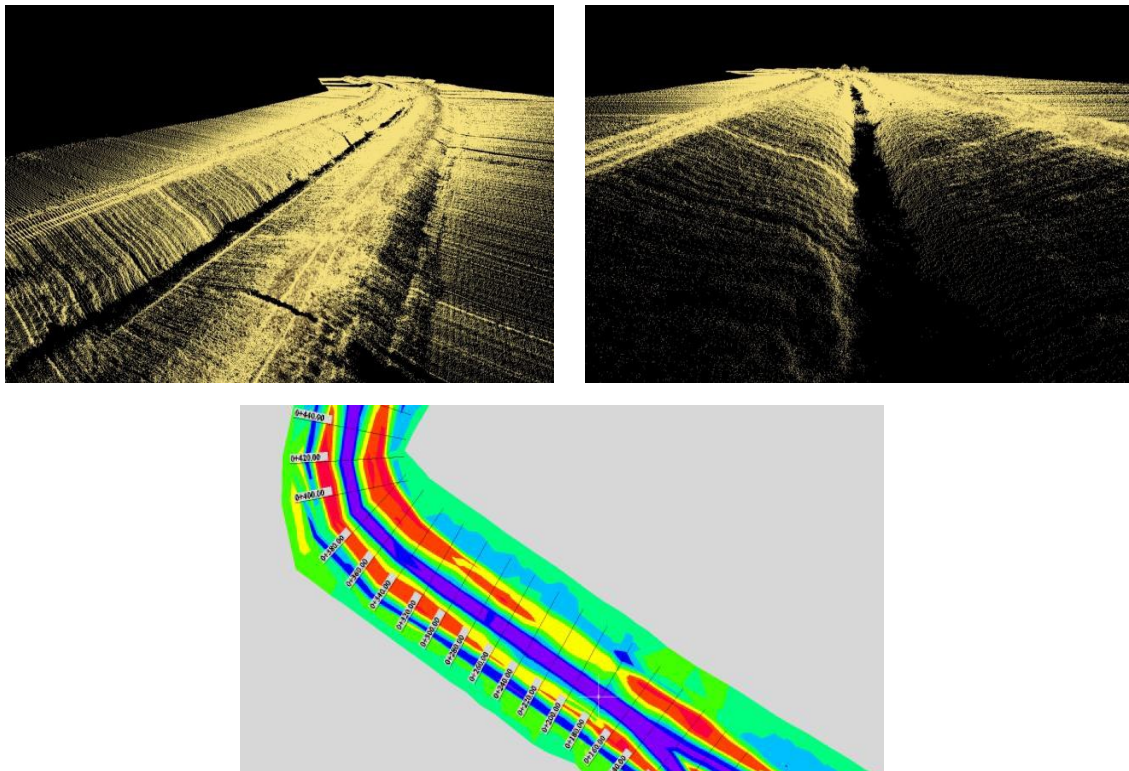
*Figure 2. Mobile mapper system MDL DynaScan model 250*

In Fig. 2 the technique of mobile laser scanning by using the "MDL Dynascan" system, model 250, is



presented.

The system is specially designed for a rapid 3D mapping of motorways, roads, runways, railways, infrastructure objects etc. The data can be registered in a normal drive speed, the survey of urban environments over a relatively short time is also possible. Such a system makes it possible to register every detail along the scanning corridor, including road verges, traffic signs, surface lines, object facades and everything entering the view field of the scanner. Combining the data scanned with laser with the video and the photographs makes it possible to produce a very precise 3D model [4]. Such a system makes it possible to scan the corridor very quickly (even 60km/h – recommended not higher than 30 km/h) with high precision satisfying various necessities. One of them would also be the canal scanning for the purposes of reconstructing and designing (Damaturu, The State of Yobe, Nigeria) [5]. LIDAR scanning, even 350,000 points per second, a large number of points are obtained with georeference coordinates. Such a set of points is not suitable to any application in the process of designing, consequently, a data treatment is unavoidable. To generate 3D models with all technical characteristics necessary to all kinds of space analyses and new designing is possible by means of a numerico-graphical data treatment, by using a specialised software. One day of scanning requires about 7 days for data treatment in order to obtain the corresponding formats of graphical presentations suitable to standard designing in space planning, urbanism and other engineering branches [5].



*Fig. 3. Cloud of points for scanned canal with 3D model*

By a computer treatment of the collected cloud of points, it is possible to generate a 3D model and from it the characteristic profiles (Fig. 3 and Fig. 4). By comparing them to the profiles generated from the existing topographic documentation or to the profiles from the same measurement after a time interval it is possible to quantify the changes and determine the degree of terrain degradation.

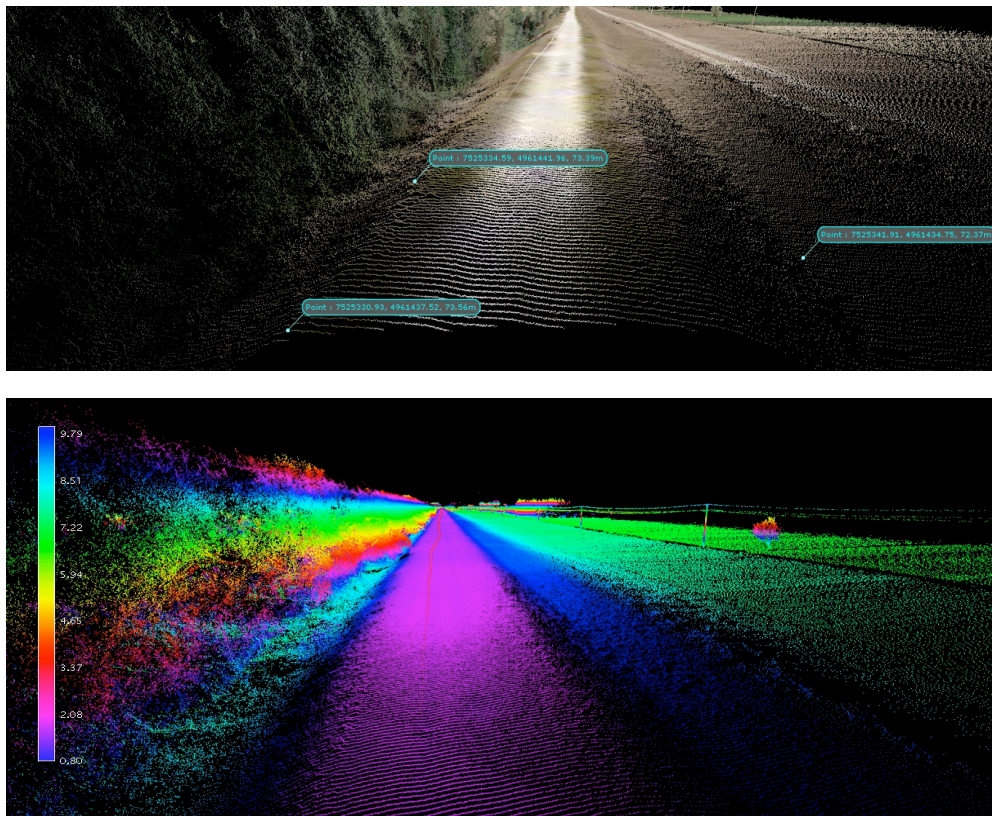


Fig. 4. Surveying the river embankment by using mobile laser scanning technology

### 3. UAV TECHNOLOGY IN REGIONAL AND URBAN PLANNING

Unmanned aerial vehicles (UAV) are of special interest. Their primary use concerns the three-dimensional terrain mapping and they are applied in various domains, among which is geodesy. These devices are light, mobile, completely automated, providing access to even most unavailable terrains. They are simple for use so that, in addition to the mapping, they are also used for various purposes of concept and other kinds of regional and urban planning and design. It is also important to mention its application in engineering geodesy. Here we explain the procedure of creating a digital terrain model and cadastre-topographic map with the minimal application of the conventional measuring methods; we also present a short specification of the eBee SenseFly (Fig. 5). The SenseFly UAV System is exceptionally light, with a mass of 0.7 kg it is one of the lightest UAV systems available on the market. The flexible polystyrene construction and the propeller mounted in the rear part of the construction are designed to provide the security of both the system itself and the people on the terrain. The device takes off, flies and lands fully automatically. The vehicle gathers photographs from the air, its range is 1-10 km<sup>2</sup> for a single flight and it reaches a precision up to 5 cm (Fig. 6). The maximum duration of its flight is 45 minutes which makes it possible to cover even 10 km<sup>2</sup> in a single flight. Its 16MP camera produces photographs from the air with a resolution of 3cm per pixel. The images can be used in creating maps and digital elevation models with a precision attaining 5 cm. The reverse-buoyancy technology and innovative terrain sensor



make possible landing even on limited areas. SenseFly has built an intuitive software "eMotion 2" with which one can plan, simulate, track and control the device trajectory, both before the flight and during it. The artificial intelligence built in the SenseFly autopilot analyses the data from the inertial measuring unit and GPS incessantly and takes care about all aspects of the flight mission. The Ebee autopilot saves all data and gathered images of the flight trajectory. These data can be taken by use of a USB. They are directly compatible with the Postflight Terra 3D-EB software. This software offers the possibility of automatic treatment of georeferenced orthomosaics and digital elevation models (DEM) to an accuracy of 5 cm (relative accuracy). The ground control points can be used for the purpose of accuracy improving.



*Fig.5. Unmanned aerial vehicle Swinglet CAM (GeoGIS Konsultanti, Beograd 2013)*



*Fig.6. Point cloud (left) and ortho-photo map by using UAV technology overlapped with cadastral data for the location Kalemegdan fortress in Belgrade*

The main problem arising in the case of treating a large number of points (Point Cloud) is the classification. By classifying the terrain points one can group the points within classes so that it becomes possible to reach a very precise digital terrain model (DTM). In the case of UAV everything is visible, but the problem is due to roofs and roof constructions. On the basis of visible roof constructions one can obtain information concerning the position of the principal axial points of an object. Where the scanning is performed by using the UAV system only, the characteristic object points must be scanned by applying one of the classical methods or by applying mobile laser scanning, whereas in the case of objects for which the details are scanned by using both systems, it is possible to determine the characteristic points by combining the obtained data.

## 4. CONCLUSION

The application of devices for gathering large bodies of data has become very frequent in recent times. The technological development of these devices is very rapid, the accuracy of measurements has been improved, which is followed by an intense software development concerning the data treatment. The conventional manner of the presentation of spatial data in 2D form enriched with information on the sea level of certain points (isohypses) is slowly abandoned and it is replaced by modern concept of 3D presentation of altitude display of the terrain and buildings, where in regard to recent experiences more geometrical and visual information on terrain configuration and artificial buildings on it is obtained by manipulating 3D model in suitable software surroundings. For that purpose, UAV technology and the technology of laser scanning of the terrain and buildings is becoming more and more dominant technique of mass gathering of spatial information in regard to recent techniques, with great saving in time and money. Modern data-collecting methods can to a high extent quicken and improve the formation quality for 3D topographic frames which are necessary, because the quality of the urban planning carried out depends on the quality of geodetic maps. Modern technological procedures of gathering and processing of spatial data enable 3D display of spatial forms (terrains and buildings) in full-color regime. Practically all most recent geo-information systems have an integrated module for 3D visualization which enables a 3D positioning of the buildings in relative and absolute model, i.e. coordinate system. Many of them have some additional possibilities such as the extraction of the building height, flight simulation over the digital terrain model etc. Engineers of different professions connected with spatial planning shall consider this 3D analysis as extremely useful for regional and urban planning, design the transport and telecommunications, environment protection, etc.

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## BIOGRAPHICAL NOTES

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