Terrain Mapping by Applying Unmanned Aerial Vehicle and Lidar System for the Purpose of Designing in Serbia

Vasić, D., Ninkov, T., Bulatović, V., Sušić, Z. and Marković, M.

University of Novi Sad, Faculty of technical sciences, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia, Web site: www.ftn.uns.ac.rs, E-mail: vasic.dejan@gmail.com

Abstract

In the paper the results of terrain mapping by using an unmanned aerial vehicle are presented. By applying this methodology one obtains orthorectified frames and the possibility of generating a precise digital terrain model. The advantages of this methodology of terrain mapping are its practicality and a rapid and efficient mapping of rather large areas for terrains usually unavailable to conventional mapping methods, automatic data treatment. It has found application in various kinds of designing, as well as in engineering geodesy. In the paper the results of measurements, data treatment and accuracy analysis, concerning the locality ”Beogradska Tvrdjava - Kalemegdan, Beograd” (Belgrade Fort - Kalemegdan), are presented. By treating the generated digital model of the terrain, using the obtained frames and combining with additional measurements (LIDAR) it is possible to obtain a high-quality topographic maps for different kinds of designing.

Key words: UAV, LIDAR, digital terrain model, ortophoto map, topographic map.

1   INTRODUCTION

During the last ten years the instruments 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 (Fig. 1), 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. 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 designs. 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 and MDL-LIDAR systems. We analyse the idea of combining these two systems. What appears as a problem is the treatment of obtained data and providing the necessary elements to make a topographic map. We got the described devices and analysed data with assistance of the GeoGIS Consultants Company from Belgrade.

2   THE LIDAR AND UAV SYSTEMS

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. Its flexible foam airframe and rear-mounted propeller are designed to ensure the safety of both the drone and the people on the ground.

Figure 1 LIDAR and UAV systems

Figure 2 SenseFly-eBee

The eBee takes off, flies and lands autonomously. The vehicle gathers photographs from the air, its range is 1-10 km^2 for a single flight and it reaches a precision up to 5 cm. The maximum duration of its flight is 45 minutes. Its 16MP RGB camera produces photographs from the air with a resolution of 3 cm per pixel. The images can be used in creating maps and digital elevation models with a precision attaining 5 cm. Its reverse thrust technology and innovative ground sensor allows the eBee to land precisely even in confined spaces. 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 orthophotomosaics 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.

On the other hand, a system for 3D scanning of roads, buildings and trees from vehicles MDL-LIDAR (Fig. 3) is also used.

Figure 3. "MDL Dynascan" model S250

This device utilities several laser scanners with a system of high-precision navigation where each scanner performs up to 36,000 measurements per second with a speed up to

100 scans per second. In this system different scanners, distributed at different places on the automobile platform, can be used. The technology of mobile laser scanning with the MDL Dynascan System model S250 is presented in Fig. 3.

The use of a rotating laser head makes it possible to scan fully, 360°, without "blind points". The system is suitable for gathering 3D data for topography, urban development, industrial plants (including superterranean cables, bridges, dams, shores and rivers), canal banks, mapping of motorways, roads, runways, railways, infrastructural objects, etc. Such a system makes it possible to scan any detail along the scanning corridor, including central reservations, traffic signs, superterranean lines, object facades and anything which falls in the view field of the scanner. By combining the data scanned with laser with video and photographs it is possible to obtain a very precise 3D model. The small size and weight of the device offer the possibility of putting it on small (land) vehicles or boats. In this way one can reach hardly accessible regions (those along steep narrow paths, parks, small rivers being tributaries, narrow water passages, ...).

3   DATA TREATMENT AND PROBLEMS

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). A frequent problem is to classify objects, more precisely to discriminate the objects belonging to a whole. Whether the scanning is done by using LIDAR or UAV the problem is the same. In the case of LIDAR (Mobile Mapper) any access to the objects from all sides is impossible so that the information is not complete. In the case of UAV everything is visible, but the problem is due to roofs and roofed constructions. One finds the solution through analysing and treating two clouds of points obtained from two different systems. Namely, from one point cloud we have visible fundaments of objects and parts of roofed constructions, whereas from the other one we have all roofed constructions. On the basis of visible roofed 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, 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   APPLIED SOLUTIONS

The density of a cloud of points which are obtained by using the UAV system depends on the defined resolution of the photographs. By automatic extraction one obtains a cloud of points as a regular grid of points. The problems arising in the treatment are due to the elevating objects (houses, buildings, ...). The solution would be through applying a conventional method. In order to avoid any conventional method, since such a method requires a lot of work and time, and also, if an integrated measuring system is available, it is possible to reach an elegant solution of the problem by combining several devices where the terrain works will be minimal and the stress will be put on the usual (office) data treatment.

By integrating the UAV device and terrestrial LIDAR system, more precisely Street Mapper device, in fact the problem of elevating objects would be solved. This combination is vindicated for sufficiently large objects where it is necessary to scan sufficiently large areas of a building region. A cloud of points obtained by using the UAV system provides us with

reliable data for regions not accessible to the LIDAR system (inner small streets, objects well inside a yard, ...), whereas a cloud of points obtained by using the LIDAR system yields reliable data for streets and street objects.

Among the first procedures on a raw cloud of points is the classification. The classification means to group the points within distinct classes (terrain points, object points, vegetation points, ...). On the market one can find various software packages for the purpose of classifying and treating a cloud of points. However, not seldom in addition to the automatic classification a manual one is also necessary. An experienced operator can very simply on the basis of DTM and control profiles notice any errors due to the automatic classification and reclassify (change the class) them manually. Various algorithms developed for the purpose of classifying are available; some of them are: Classify by Class, Low Points, Isolated Points, Air Points, Ground Points, Below Surface, By Height from Ground, etc. One has often to combine several algorithms in order to achieve a correct classification. One of important procedures is the classification known as "Ground" (Fig. 4) which distinguishes the terrain points iteratively forming the model of the surface. The classification begins with the choice of points done by the algorithm, so-called low points, which are surely on the ground. In the application one specifies Max Building Size, the value on the basis of which, the field of the corresponding size is searched and the point is assumed to be the lowest for the given terrain. The initial model is built from selected low points, to be extended iteratively afterwards with including new points.
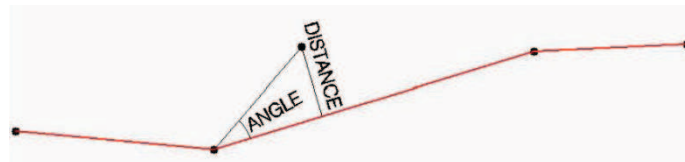

Figure 4 Criterion of Ground Classification

Any new point strengthens the model and contributes to its higher likelyhood. On the basis of the given parameters (iterative angle and length) one determines whether a point should be assumed as a terrain one or not. The given parameters depend above all on the terrain configuration. The iterative angle is the maximal angle between a point and its projection onto the formed model triangle, whereas the iterative length prevents large jumps when the model contains large triangles. In this way by giving the iteration parameters one can exclude low objects from the model. It is recommended to use sufficiently small angles (nearly 4 degrees) if the terrain is sufficiently flat, i. e. a larger angles (nearly 10 degrees) if the terrain is hilly. When the Ground classification is finished and vegetation is assigned to a special class, we shall be sure that the terrain points are terrain points indeed so that a sure group of points concerning the objects will be provided. The same method is applied to two data sets obtained by using two independent systems (UAV and LIDAR).

In the framework of our task a block of objects, where an access with a vehicle from every side is impossible, is analysed. In Fig. 5 a cloud of points generated with LIDAR is presented. After finishing the treatment and classification of the point cloud the class containing the points of the objects only is distinguished. Some parts of the objects are visible, but a bulk inside the block is not (Fig. 5). The problem is just due to the parts of the objects which are not visible. The alternative is to carry out the classical geodetic survey of the objects or their parts which are not visible, or to apply the UAV system which will contribute to a maximal reduction of the terrain work. The scanning by applying the UAV system provides a complete cloud of points for which the objects and vegetation make a problem.

If we take a look of the perspective view of the point cloud generated by the Mobile Mapper System (Fig. 5), we can see that in most cases the lateral sides of the objects are not

visible. In Fig. 6 we present the perspective view of the point cloud generated by the UAV system. It is clearly seen that the roofed constructions can be noticed. By overlapping the two clouds of points we can obtain the complete data. Where the characteristic points of the objects are not visible, we use the data from the other point cloud (UAV).
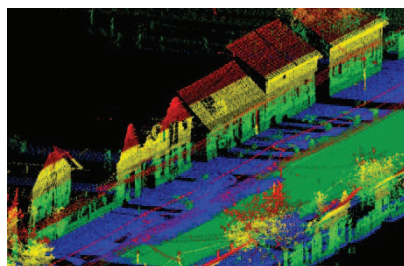

Figure 5 Perspective view of the point

Figure 6 Perspective view of the point cloud (UAV) cloud (Mobile Mapping System)

On the basis of the visible roofed construction and knowing the width of the roof overlay we can determine the characteristic points of the object. For a number of objects one must gather information about the roof overlay.

5   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.
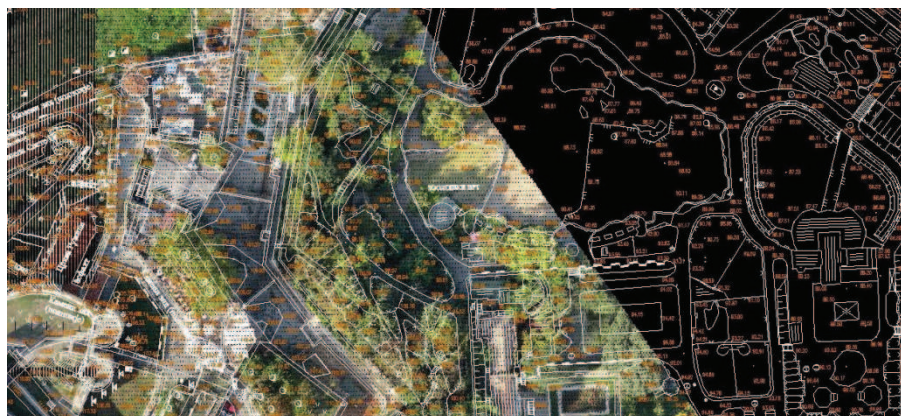

Figure 7 Topographic map

Nevertheless, the methods of data treatment and specific requirements cannot be fully automated. One often apply special methods in order to realised all kinds of requirements. Combining two data sets obtained with different devices appears to be one of the methods aimed at resulting in a cadastre-topographic map (Fig. 7). The data generated by use of the Mobile Mapping System do not yield a complete information about the objects (inaccessible parts), whereas the ones generated by use of the UAV system cover also the inaccessible parts, but do not yield any information concerning the points under the roofed construction. Nevertheless, by merging these data sets into one body of data and by analysis through suitable software solutions it is possible to find out the desired information.

REFERENCES

NINKOV, T., BULATOVIĆ, V., VASIĆ, D., SUŠIĆ, Z.: Modern methods of collecting and processing geodetic data in hydro technical projects, "FIG Working Week 2013- Abuja, Nigeria, 6 – 10 May 2013"

NINKOV, T., VASIĆ, D., MARKOVIĆ, M., BULATOVIĆ, V., SUŠIĆ, Z.: Značaj i uloga karata plavnih zona reka u Srbiji na optimalno uređenje prostora. "Letnja škola urbanizma", Tara 30.05-01.06.2013.

VASIĆ, D., BULATOVIĆ, V., NINKOV, T., SUŠIĆ, Z.: Development of 3d topographic layouts for the design of rain sewerage for the city of Damatur in Nigeria. International scientific conference and XXIV meeting of Serbian surveyors″ professional practice and education in geodesy and related fields″, 24-26, June 2011, Kladovo - „Djerdap" upon Danube, Serbia.

NINKOV, T., BULATOVIĆ, V., SUŠIĆ, Z., VASIĆ, D.: Application of laser scanning technology for civil engineering projects in Serbia. FIG Congress Sydney, Australia, 11-16 April 2010.

http://www.terrasolid.com

http://www.mdl-laser.com

https://www.sensefly.com