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CHARTING TOPOGRAPHIC MAPS BASED ON UAV DATA USING THE IMAGE CLASSIFICATION METHOD

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Summary

A topographic map is a representation of the terrain, its landform and spatial elements present therein. Land surveying and photogrammetric measurements must be conducted in order to produce such cartographic document. The following must be done while obtaining information on topographic objects: determine the character and type of an object or phenomenon; determine the range of its occurrence; indicate a precise location. The next stage involves classification of objects into relevant classes and categories, i.e. arable land, pastures, forests, water basins, technical infrastructure, buildings, and other. Then, the determined classes undergo the process of cartographic generalization by combining smaller elements into a single complex, determination of a common border of their occurrence, and application of relevant graphic symbols and colours.

The measuring technique which provides quick and accurate topographic information about the surrounding area is the one that uses Unmanned Aerial Vehicles (UAV). Digital photographs taken during the flight are the basis for generating a high-quality orthophotomap. Accurate determination of the location of individual spatial elements allows large-scale cartographic documents to be developed. This paper will present the method of charting topographic maps of rural areas based on orthophotomaps made from the photographs taken during the UAV flight. Supervised and unsupervised methods of object classification will be tested in order to increase the effectiveness of determination of types and occurrence range of individual topographic objects, and the obtained results will be used to chart a topographic map of the studied area.

Keywords

topographic map geospatial data • UAV • photogrammetry • large-scale cartographic studies

1. Introduction

A topographic map is a representation of the Earth's surface in the form of a topographical drawing. It presents the terrain and the spatial elements that can be found therein. Such a cartographic document is the type of a general geographic map, drawn at scale of 1:200 000 or larger. The content of a topographic map includes not only geographic elements (natural features of the terrain), but also mathematical ones, i.e. the scale of the map or the coordinate system, as well as any marginal data. Obtaining information for cartographic purposes is effected by conducting geodetic and photogrammetric surveys, as well as by means of other thematic maps. Assigning attributes to objects on the map involves defining the nature and the type of an existing object or phenomenon. Its range and exact location need to be determined. Having known the parameters, the objects are classified into thematic groups, which are then subjected to cartographic generalization processes, intended to combine individual elements into one complex, as well as to define common boundaries of their occurrence, and to apply appropriate graphic symbols and colour codes.

Topographic maps have a wide spectrum of applications: ranging from geodesy, cartography, spatial planning and land management to uses in forestry, agriculture and many other natural and technical sciences. They are also used as background maps for developing derivative cartographic documents. Topographic maps for geodetic purposes and any work related to space management should be characterized by high accuracy of the richly detailed compilation. Therefore, the maps should be drawn in large-scale forms, for example 1:10 000 and larger. The objects on such maps are represented either directly on one plane, or in the form of numerous thematic layers overlapping each other in order to improve the visibility of key objects. Both the generation, and the constant updating of topographic maps constitute extremely important tasks, mainly needed for geographic information systems (GIS) [Höhle 2017]. To preserve the consistence in the way phenomena and objects are presented on the map in the form of symbols, topographic databases are used. In addition to the collected databases, the number, quality and accuracy of the spatial information are analysed as well. [Ślusarski and Siejka 2017]. Data contained in topographic databases can be used in further works as source material for object-relational analysis, where the methods of classification and valorisation of the area are used based on the modification of the selection of appropriate classes of topographic databases [Cegielska et al. 2017].

In recent years, the use of three-dimensional space mapping technique with the application of laser scanning and Unmanned Aerial Vehicle (UAV or “drone”) has become an increasingly frequent method for obtaining information about the environment, monitoring topographical changes, and creating maps [Tong et al. 2015, Santagata 2017]. UAVs are tools that have been used for many years by engineers to perform photogrammetric measurements (Due to formal and legal regulations applicable in many countries, performing the flights is reserved solely for people with proven qualifications). This tool has become an inexpensive photogrammetric resource for people dealing with cartography, especially with elongated sections, and in the cases when checking the conditions of facilities requires routine observation, for instance, a sea-coast [Gonçalves and Henriques 2015, Turner et al. 2016].

For several years, aerial photographs acquired via the UAVs have been used for drawing and updating topographic maps. The adjustment of the orthophotomap created on that basis involves the indication of known coordinate points, i.e. Ground Control Points. Their number and location have a significant impact on the quality of the compilation and the accuracy of georeferencing [Agüera-Vega et al. 2017]. In order to improve the quality and accuracy of the photos, the series are created in the following layout: nadir, oblique and horizontal. Such a combination minimizes the errors of geometry, and facilitates obtaining topographic data concerning the non-visible areas, for example those under the tree crowns [Rusnák et al. 2018]. Proper data preparation, mapping a large degree of land cover, makes it possible to develop a valid, accurate and high-quality topographic map. While processing photographs for the needs of topographic maps, it is necessary to classify the image with its spatial elements, and present them with the use of conventions, indicating the areas and locations of occurrence, as well as by means of appropriate colours to reproduce the phenomena and objects occurring in the area.

Classification of images involves grouping pixels into areas that are relevant to the analysis for which the image is classified. The areas are called classes [Abburu et al. 2015]. Depending on the manner of classification, both the classes themselves and the affiliation of individual pixels to classes can be determined using the following image classification methods [Horning 2004]: manual, automatic, and mixed classification. The manual classification relates to photo interpretation of aerial photographs. Based on his or her own experience, the operator who carries out the classification, having observed the colours, structure, texture and other factors that distinguish the classes from each other, indicates the areas belonging to the assumed classes. Automatic classification consists in automatically assigning pixels of the image to classes by means of specialized software that examines image pixels in statistical terms or uses more advanced mechanisms, such as machine learning, artificial neural networks, decision trees and split algorithms dividing the image into smaller sections, which is called image segmentation. Classes can be determined by the operator, or they can be created automatically by the software based on statistical analysis of pixels. However, in the case of mixed (hybrid) classification, the image is pre-classified automatically, then the operator improves the classification results manually, by virtue of his or her own experience, to remedy imperfections in those areas where the automatic software struggles to assign pixels to a particular class.

In view of the widespread computerization, automatic methods are usually used for image classification. The two most important approaches to statistical automatic classification pixel by pixel include supervised and unsupervised classifications. The supervised classification involves assigning image pixels to classes pre-defined by the operator. For each of the assigned classes, the operator indicates the representative areas on the analysed image. The areas called training fields have been already assigned to a particular class based on photo interpretation of the image, they could have been read from the map or obtained in a different way. The classification software performs statistical analysis of the pixel brightness contained in the training fields in all channels (e.g. spectral) of the image forming the so-called feature space and determines for each class the parameters that describe it mathematically (e.g. average, standard deviations, etc.). In the case of unsupervised classification, the class remains unknown at the beginning of the process. The software automatically classifies groups of pixels (so-called clusters) without using training data, on the basis of statistical analysis of randomly chosen pixels, and then, in a similar way, assigns the other pixels to such statistically differentiated classes. The operator's task after the classification is to differentiate (e.g. based on photo interpretation of the image) the clusters identified by the software and to name them [Abburu et al. 2015]. After classifying a supervised satellite image, it is often necessary to assess the correctness of this classification [Smits et al. 1999]. The classification may also include a point cloud from LIDAR or generated based on aerial photographs. To increase the accuracy of the image and thematic maps, the point clouds from LIDAR and the photos are integrated to improve the accuracy and land cover representation. The losses associated with the objects being covered are minimized, too. In such works, in order to automatically indicate the scope, shape and location of objects (e.g. buildings), algorithms that detect and fit lines, shapes and points are used [Awrangjeb et al. 2010].

The composition created as a result of the classification of aerial satellite photographs or point clouds do not yet constitute the content of topographic map. The use of the classification results as a source of data for maps requires the improvement of cartometry and checking the geometrical accuracy of objects, as well as the use of measures that generalize sets of objects into complex elements. In the process of creating cartographic studies, it is necessary to maintain appropriate accuracy level, as well as the rapidity and ease of updating its objects [Höhle 2017].

2. Materials and methods

The research work was carried out in of Kobylany (in the Małopolska region – Poland). The work included flying an Unmanned Aerial Vehicle and taking four series of photos with a ground pixel of around 2cm. It was done with the DJI 1000 drone using a Sony ILCE – 7R digital camera with 35mm focal length. The acquired photos were processed in the Agisoft PhotoScan Professional software, and the tasks included: importing the taken photos and correlating them using 5 common points – GCP (Ground Control Point). The accuracy of the photo was down to 0.2 pixel. A dense cloud and orthophotomap was generated on the basis of the correlated images. The orthophotomap, the image correlation, GCP location and the generated point cloud are shown in Figure 1a, b.

Subsequent work was carried out in the MicroStation V8i environment using the TerraScan and TerraModeler overlays, by means of which the created point cloud was classified (Fig. 2a). The following classes were established during the classification process: ground, low, medium and high vegetation as well as technical infrastructure. Then, the cloud point was processed, which entailed the creation of a normalized point cloud (Fig. 2b). New altitude coordinates have been calculated for points in the database. They were determined in relation to the points representing the ground level, of the altitude equal to zero. For that purpose, tools developed using the Python language were used. The next stage involved creating a raster with an eyelet of 0.04 cm.

During the work in the AgiSoft Professional software, an orthophotomap was also generated, which then served as a background for the topographic map (Fig. 1b). The content of the map was determined on the basis of the classification of the composition, obtained through the use of orthophotomaps and point cloud acquired from the UAV images. The orthophotomap was divided into red, green and blue channels and the NDSM (Normalized Digital Surface Model) was created. The composition from red, green and NDSM channels was created.

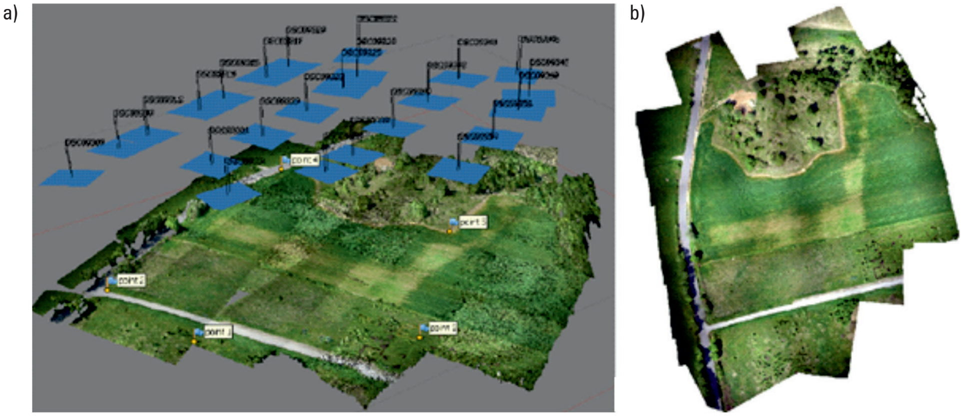

Fig. 1. a) image correlation from the UAV with GCP marked and the generated dense cloud; b) orthophotomap generated from UAV images

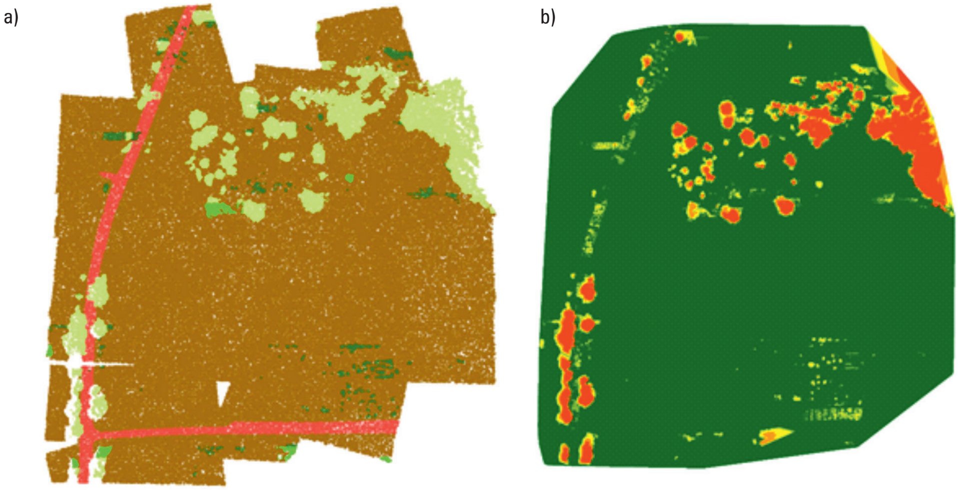

Fig. 2. a) classified point cloud; b) normalized point cloud – nDSN

The next step was related to the classification of Band Red, Band Green, and NDSM. The supervised classification was applied, and training samples of the area represented by different land use cover classes were indicated. The Vector Support Machine algorithm was applied. Two classifications were performed, the first one was to classify each pixel – pixel-based classification (Fig. 3a), the second one aimed to group pixels into objects, and then to classify them – object-based classification (Fig. 3b).

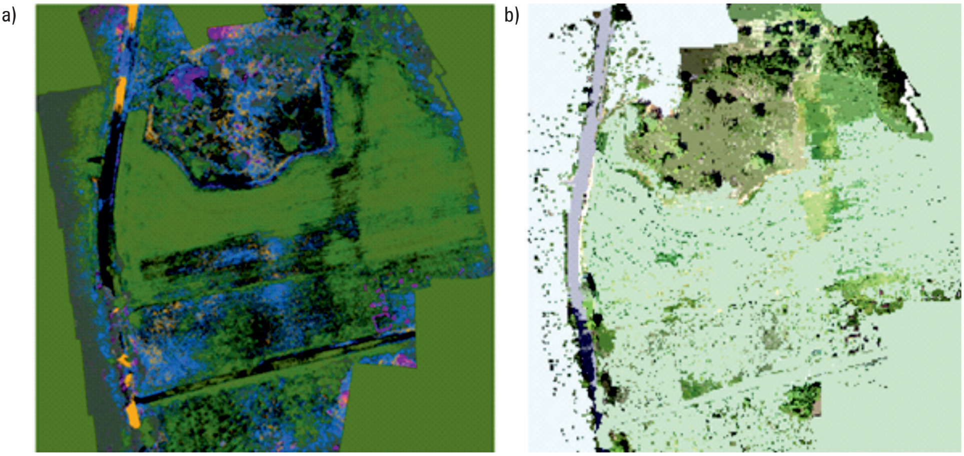

Fig. 3. Classification based on: a) pixels, b) objects

3. Discussion and results

The classification results have been subjected to vectorization. The class boundaries were vectorized using ArcGIS tools (Fig. 4). In this process, the classes established using the OBIA classification were adopted, and the results of the supervised classification for pixels did not allow the vectorization process to be carried out. The vectorization results were combined with the contours obtained from the point cloud. Then, class boundaries and contours were generalized in order to eliminate small objects and simplify the object's geometry.

The presented graphic image (Fig. 4) is a representation of the topography of the examined area. The results of the work related to the classification made it possible to define classes and groups of the objects, for which proper contours were created. The objects drawn on the orthophotomap constitute elements of the topographic map (Fig. 4). At this stage, the graphic elements thus obtained are subject to checking [Smits et al. 1999] in order to assess the quality and accuracy of the information obtained, which is then used in creating a topographic map (Fig 5c).

The cartographic generalization process facilitates generalization of areas obtained during the classification, makes it possible to determine the boundaries within which a particular phenomenon occurs, and enables presenting it on the appropriate thematic layer. The appropriate level of accuracy of the objects presented on the map, as well as respecting the rules that guarantee proper cartometry of a given compilation, are also of high importance [Höhle 2017]. Figure 5 presents the scheme of applying, to orthophotomap, the ranges of areas generated in a semi-automatic manner of thematic layers (Fig. 5b) (generated on the basis of object forms obtained from image classification). Consequently, a fragment of the topographic map is obtained (Fig 5c).

Fig. 4. Topographic elements vectorized according to the results of the OBIA classification on the orthophotomap

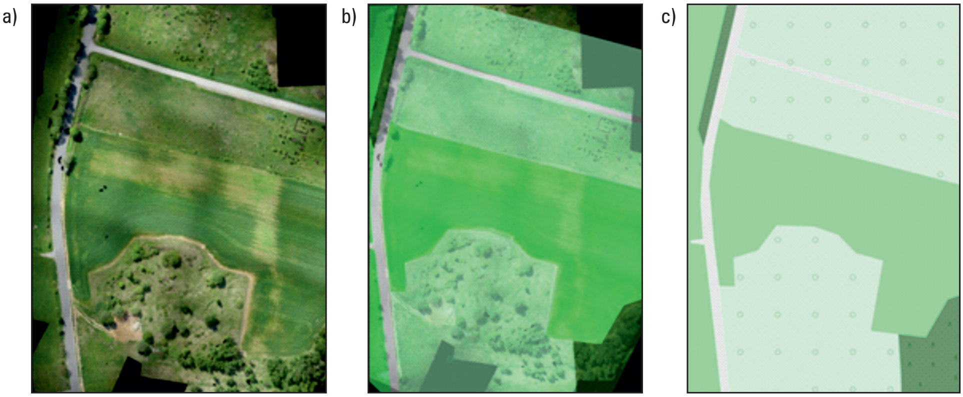

Fig. 5. Semi-automated (supervised) creation of a topographic map: a) orthophotomaps, b) orthophotomap with topographic map layers superimposed, c) fragment of the topographic map

4. Conclusions

Acquiring images using UAV is an easy and quick way to record spatial information. This data enables the creation of orthophotomaps and point clouds of the observed area. The results of work on the acquired materials provide the opportunity to carry out numerous image classifications, and then use them in order to automate some of the cartographic work.

The use of data from UAV enables the classification of land use methods and then the vectorization of area structures. It brings satisfactory results, but it requires the support of tools that would facilitate generalization. It is possible to improve the classification work results if data representing multispectral data is included, which will improve the classification results and thus allow for better vectorization of the area's structures.

The images obtained as a result of the works make up the content of the topographic map. The combination of these elements on the orthophotomap enables presentation of the image of land and its topography, classified using appropriate thematic layers (Fig. 4). Further work merely requires supplementing the image with marginal data as well as using appropriate graphic symbols and colour codes to obtain a topographic map of the area under study.

The research has been conducted at the University of Agriculture in Krakow, Faculty of Environmental Engineering and Geodesy, Department of Land Surveying and Department of Agricultural Land Surveying, Cadaster and Photogrammetry.

References

Abburu S., Golla S.B. 2015. Satellite Image Classification Methods and Techniques: A Review. International Journal of Computer Applications, 119, 8, 20–25.

Agüera-Vega F., Carvajal-Ramírez F., Martínez-Carricondo P. 2017. Assessment of photogrammetric mapping accuracy based on variation ground control points number using unmanned aerial vehicle. Measurement, 98, 221–227.

Awrangjeb M., Ravanbakhsh M., Fraser C.S. 2010. Automatic detection of residential buildings using LIDAR data and multispectral imagery. ISPRS Journal of Photogrammetry and Remote Sensing, 65, 5, 457–467.

Cegielska K., Salata T., Gawroński K., Różyczka-Czas R. 2017. Level of Spatial Differentiation of Anthropogenic Impact in Małopolska. Journal of Ecological Engineering, 18, 18, 200–209.

Gonçalves J.A., Henriques R. 2015. UAV photogrammetry for topographic monitoring of coastal areas. ISPRS Journal of Photogrammetry and Remote Sensing, 104, 101–111.

Horning N. 2004. Land Cover Classification Methods. American Museum of Natural History. Centre for Biodiversity and Conservation, https://www.amnh.org/content/download/74344/ (accessed: 12.10.2017).

Höhle J. 2017. Generating Topographic Map Data from Classification Results. Remote Sensing, 9(224), 1–24.

Rusnák M., Sládek J., Kidová A., Lehotský M. 2018. Template for high-resolution river landscape mapping using UAV technology. Measurement: Journal of the International Measurement Confederation, 115, 139–151.

Santagata T. 2017. Monitoring of the Nirano Mud Volcanoes Regional Natural Reserve (North Italy) using Unmanned Aerial Vehicles and Terrestrial Laser Scanning. Journal of Imaging, 3(4), 1–10.

Smits P.C., Dellepiane S.G., Schowengerdt R.A. 1999. Quality assessment of image classification algorithms for land-cover mapping: A review and a proposal for a cost-based approach. International Journal of Remote Sensing, 20, 8, 1461–1468.

Ślusarski M., Siejka M. 2017. Model of quality of data collected in the topographic database. Proceedings of International Conference "17th International Multidisciplinary Scientific GeoConference SGEM2017", 17, 23, 595–603.

Tong X., Liu X., Chen P., Liu S., Luan K., Li L., Hong Z. 2015. Integration of UAV-Based Photogrammetry and Terrestrial Laser Scanning for the Three-Dimensional Mapping and Monitoring of Open-Pit Mine Areas. Remote Sensing, 7, 6635–6662.

Turner I.L., Harley M.D., Drummond C.D. 2016. UAVs for coastal surveying. Coastal Engineering, 114, 19–24.

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