The use of UAV Point Cloud Object-Based Classification in the Agricultural Land Consolidation

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Key words: UAV, point cloud classification, object-based classification, structure-from-motion, land consolidation

SUMMARY

Development of unmanned aerial vehicles and automated processing (structure-from-motion technique) of photogrammetric measurements led to a large number of different spatial datasets, obtained by using various sensors. In order to use them in various land management tasks, they need to be further processed and/or adjusted. Land Consolidation is the agrarian and technical operation that aims to group and collect the segmented and fragmented holdings into one or more rounded holdings to achieve a more rational agricultural production. As the procedure of LC is a comprehensive, long-lasting and expensive operation, it needs careful and responsible planning. These plans should take into consideration the ratio between consolidation costs and benefits from improved conditions for agricultural producers. To ascertain that, it is necessary to determine areas suitable for consolidation and express their qualitative features in a quantitative manner. This database needs to include a cadastral dataset, physical planning documentation, land use, dry stone wall structures, digital terrain model, pedological and other spatial or non-spatial datasets. That makes possible to determine various indicators and measures to be used in a multi-criteria analysis to make a decision on size, coverage, comprehensiveness, costs and benefits as well as other characteristics of selected land consolidation procedure. Although the use of multispectral and hyperspectral sensors allows relatively simple and reliable classification of natural and artificial surfaces, the paper discusses application use of a UAV point cloud object-based classification of the most widespread UAV sensor - imaging sensor in the visible spectrum range. The comparison of classified data obtained by surveying at different height was done at the case study of UNESCO's World Heritage Site Stari Grad Plain in Croatia.

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1. INTRODUCTION

Agricultural Land Consolidation is the agrarian and technical operation which aims to group and collect the segmented and fragmented holdings into one or more rounded holding in order to achieve a more rational agricultural production (Medić, 1978; Vitikainen & Tech, 2004). Land consolidation is a comprehensive procedure that requires careful planning in order to better utilize rural areas ((UN FAO, 2003, 2004)). Land consolidation on Croatian territory was carried out in the past, but for a long time there were no such projects. Start of the Land Consolidation procedures on a national level requires preparatory activities in order to determine the priority areas, i.e. areas for which it is assumed that redistribution of land is most needed and there are certain prerequisites for successful agricultural production together with the interests from people and state. This can be done by Land Consolidation Programme which should be done based on measurable indicators, specific to a representative sample.
Agricultural land consolidation procedures were implemented on the Croatian territory in the past. Those procedures were focused on agricultural development, which is visible from the land fragmentation indicators. Most of the land consolidation works refer to the eastern part of the country (Eastern Slavonia and Baranya) (Odak, 2017). However, the concept of rural development has changed over time and it now includes the environmental awareness and a range of non-agricultural applications (Food and Agriculture Organization of the United Nations, 2008). Current Croatian land policy includes a rural development policy as an integral part of the EU's Common Agricultural Policy (CAP). Within its framework, Rural Development Plans (RDP) are guiding policy to support the development of agricultural competitiveness, together with the sustainable management of natural resources and balanced territorial development (EC/COM, 2010).
Development of unmanned aerial vehicles and automated processing (structure-from-motion technique) of photogrammetric measurements led to a large number of different spatial datasets, obtained by using various sensors. In order to use them in various land management tasks, they need to be further processed and/or adjusted.
As the procedure of LC is a comprehensive, long-lasting and expensive operation, it needs careful and responsible planning. These plans should take into consideration the ratio between consolidation costs and benefits from improved conditions for agricultural producers. To ascertain that, it is necessary to determine areas suitable for consolidation and express their qualitative features in a quantitative manner. This database needs to include a cadastral dataset, physical planning documentation, land use, dry stone wall structures, digital terrain model, pedological and other spatial or non-spatial datasets. That makes possible to determine various indicators and measures to be used in a multi-criteria analysis to make a decision on size,

coverage, comprehensiveness, costs and benefits as well as other characteristics of selected land consolidation procedure.
Although the use of multispectral and hyperspectral sensors allows relatively simple and reliable classification of natural and artificial surfaces, the paper discusses application use of a UAV point cloud object-based classification of the most widespread UAV sensor - imaging sensor in the visible spectrum range.

2. MATERIALS AND METHODS

The purpose of the paper is to analyse the possibilities of object-based classification using point cloud data measured by UAV to help make desicion based on coverage, costs, benefits and other characteristics of selected Land Consolidation procedure.
The study was conducted based on datasets of point clouds and digital orthophoto maps collected by UAV survey from the different heights on the island of Hvar in Croatia, known as UNESCO's World Heritage Site Stari Grad Plain (**Fig. 1**). In this study area the ancient Greek division of land is preserved and shape of the parcels are defined by stone walls that have protection regimes, as it requires careful detection. In order to detect ancient stone walls and other land cover of the study area from the collected datasets we used object-based classification. Results of classified datasets were used as a input data for measure of land consolidation suitability.

Land use can be determined using land cover classification based on the Vegetation Index – VI. The VI is an indicator which assess whether the target being observed contains live green vegetation or not. The VI can be determined based on (visible) red and near-infrared (NIR) spectrum channel of multi-spectral image. In this case the data was recorded using a camera with an RGB sensor which made the NIR channel values unavailable. In order to recognize vegetation better than other objects, a two-band simple ratio index was calculated using channels with extreme values of vegetation – green and blue channel.

Classification of collected point cloud datasets was done using RGB picture, two band simple ratio index and Digital Surface Model – DSM, and classification of collected raster image was done using only RGB picture and two band simple ratio index. Classification process was done using eCognition software.

Research methodology included detailed literature review to assess possible solutions and best practices in the process of the point cloud object-based classification (Antonarakis et al., 2008; Che et al., 2019; Jia, 2015; K. F. Lin et al., 2013; X. Lin et al., 2011; Ni et al., 2017; Xiang et al., 2017). Those findings were used to analyse process of multiresolution segmentation and classification by attributing classes.

2.1. Study area

The study area is located on the Island of Hvar in Croatia. The Stari Grad Plain (Fig. 1) represents a comprehensive system of land use and agricultural colonisation by the Greeks, 4th century BC. The criteria for the inclusion in UNESCO are: the land parcel system bears witness to the dissemination of the Greek geometrical model for the division of agricultural land

(Criterion II), the plain has remained in continuous use with the same initial crops being produced for 2400 years (Criterion III), and the plain is an example of very ancient traditional human settlement which is today endangered by modern economic development, especially by rural depopulation and the abandonment of traditional agricultural practices (Criterion V).

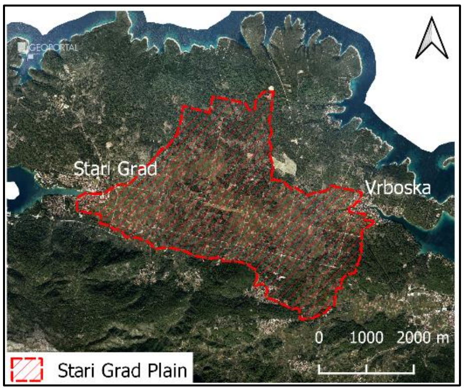

Figure 1 UNESCO World Heritage Site "Stari Grad Plain" location

The area covers 13,77 km2, the altitude ranges between 1 and 86 meters above the sea level and it is gently sloped – more than 95 % of the area has the slope less than 10 %. The main characteristics of today's landscape (Andlar et al., 2014) are low intensity, mixed agriculture (dominated by olive groves and vineyards), high density of stone wall enclosures, terraces, channels, dwellings, shelters etc.

The area was measured from two different heights (40 m and 80 m) with UAV DJI Phantom 4 using RGB senzor. Due to huge area of measured data it was decided to execute classification process of the collected data on the selected area (Fig. 2) with the largest number of stone walls and stone structures in order to present the classification result of these two classes as better as possible.

The selected area represents the case of overlapping of several different protection regimes, creating problems in administration and management. This leads to abandonment of land, and, in general, abandonment of rural communities. The abandonment and depopulation are two closely connected problems that can lead to devastation of natural resources and potentials.

Figure 2 RGB image of the selected classification area

3. RESULTS AND DISCUSSION

In this chapter, the classification results of different input data with different resolution will be presented, compared and discussed. The input data are point clouds that have been made from images measured from 40 m and 80 m height and digital orthophoto maps that have been made from images measured from 40 m. The comparison of the results will be done by presenting land cover details where classification results of two datasets are different. Due to particular importance of stone walls and stone structures, comparison of the classification results will focus on these classes.

First comparison analyzes classification of point cloud and digital orthophoto maps **(**Fig. 3). It can be seen that stone walls and stone structures are properly separated in the classification of point clouds while this is not case with classification of digital orthophoto map. The reason of this classification imparity is that digital orthophoto maps don't have height data so the entire stone surface was merged into one object. It is also noticeable that other stone objects and driveways are classified clearly when point clouds were used as an input data.

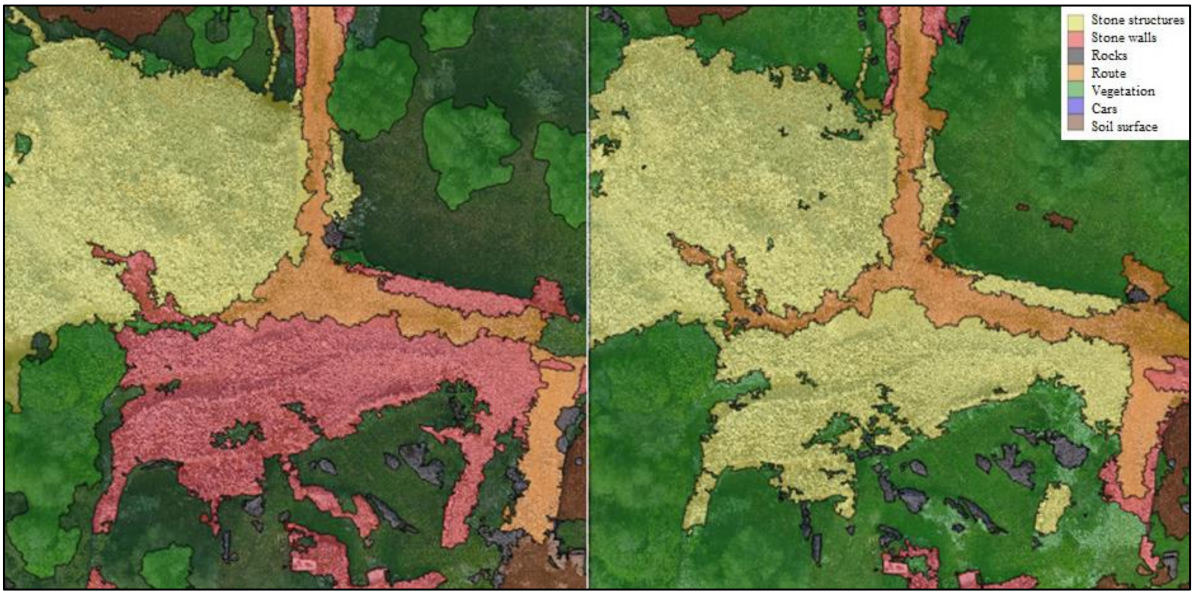

Figure 3 Comparison of point cloud (left) and digital orthophoto maps (right) classification results, detail 1

The same problem is shown in Figure 4, the height information allowed the separation of the stone structures from the stone walls in the classification of poin clouds while in the classification of digital orthophoto map both object were classified as stonewalls. Another benefit of using DSM as input data in classification of point clouds is ability to separate high and low vegetation. Comparing the classification results of point clouds and digital orthophoto maps, it became clear that the height information is very useful in the classification of different stone objects.

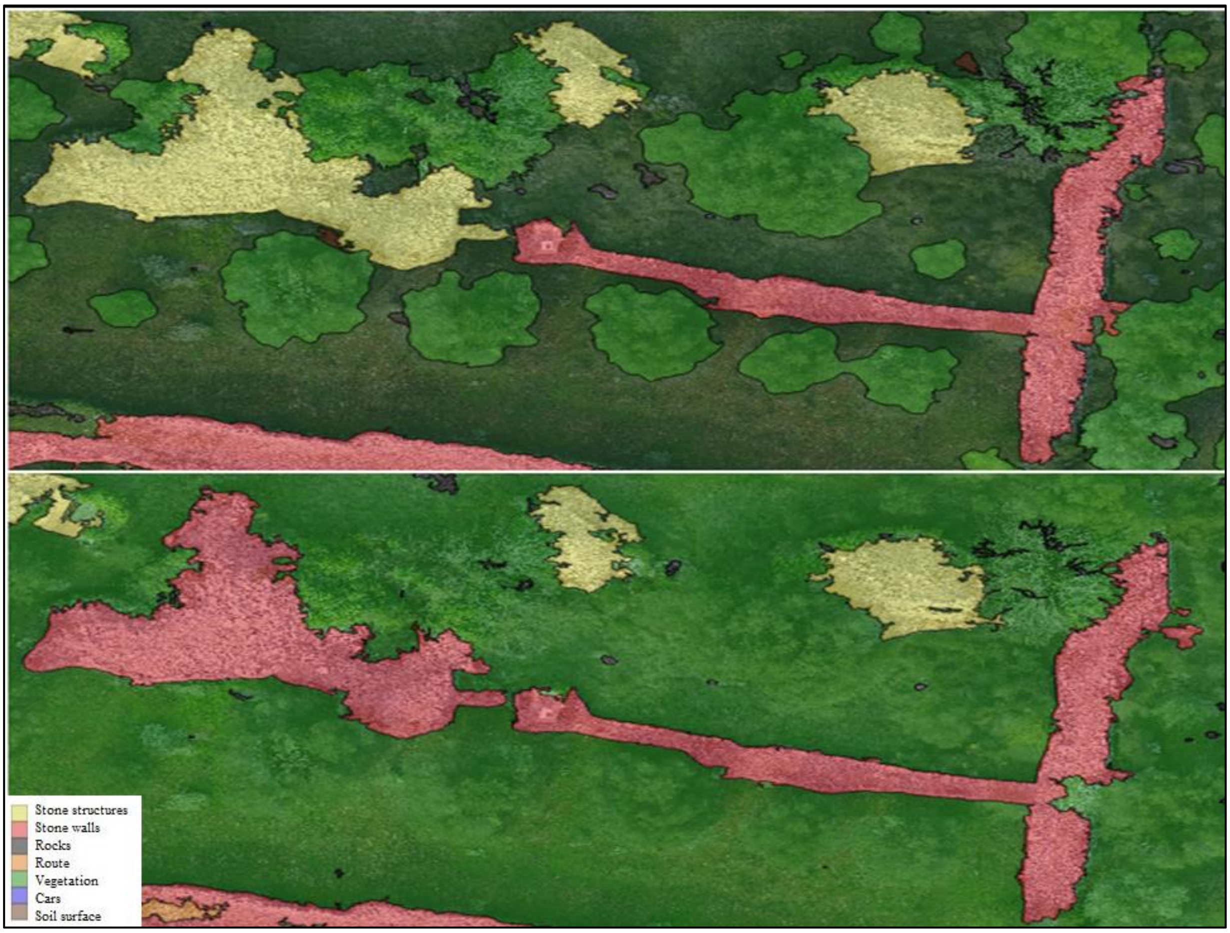

Figure 4 Comparison of point cloud (up) and digital orthophoto maps (down) classification results, detail 2

When classifying data with different resolutions, the difference in classification is noticeable already after segmentation process. Although the segmentation and classification of data with different resolutions should be done using different parameters, in this study the same parameters were taken in order to be able to compare the final results. Segmentation of higher resolution data have segments that better reflect objects in the scene (especially their edges) than segments that result from lower resolution data segmentation. In Figure 5 it is shown result of classification point cloud data with different resolution. The left part of the figure shows the results of the classification point cloud data made from images measured from 40 m height, and the right part of the figure shows the result of the classification point cloud data made from images measured from 80 m height. It is noticeable that stone walls on the left part of the figure better reflect objects in the scene than stone walls on the right part of the picture who is interrupted with other classes.

Figure 5 Comparison of classification results of data with higher resolution (left) and lower resolution (right), detail 1

Figure 6 shows example of wrong classification of stone walls. Although objects generated by segmentation of data with higher and lower resolutions don't have big differences in classification result, in this example objects generated by segmentation of data with different resolution have been attribute to different classes. This happened because the edges of an object created by segmentation of lower resolution data are more rounded and because of that object has been attribute wrongly.

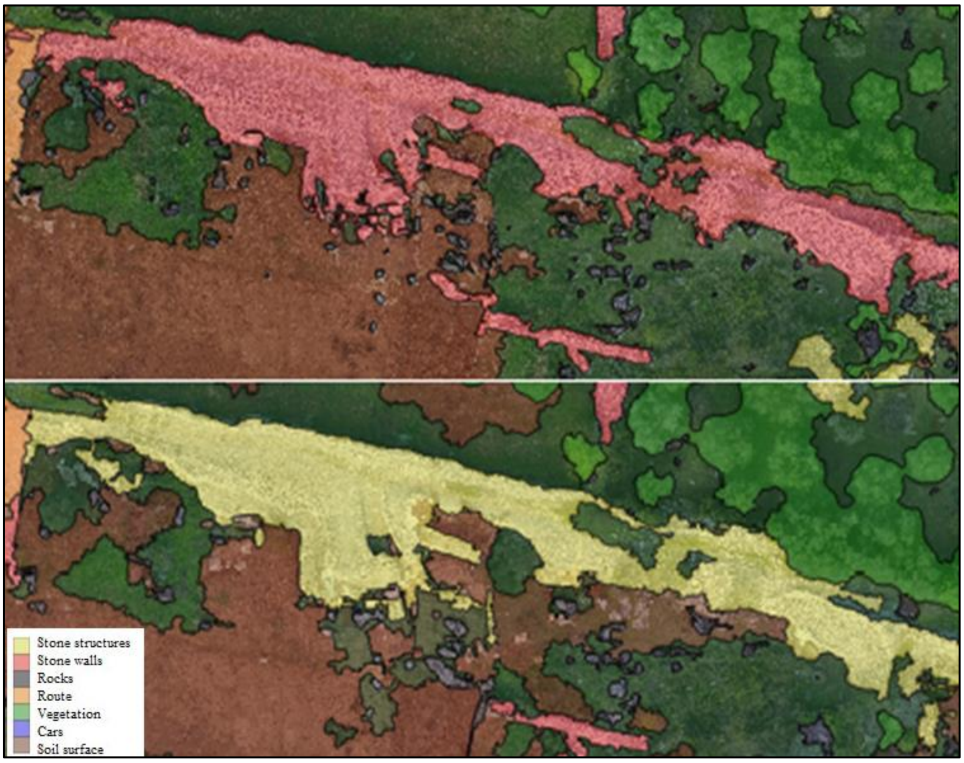

Figure 6 Comparison of classification results of data with higher resolution (up) and lower resolution (down), detail 2

4. CONCLUSION

The results showed that the point cloud classification gives better results than orthophoto map classification. This is an expected result because the inclusion of height data allows better separation of defined classes and clearer representation of land cover details.

The classification results can be used as quantitative land consolidation indicators, meaning extracted dry-walls, permanent crops or other objects could be associated to the cadastral records. The main benefits of using the quantitative indicators are the effectiveness and the increase of information-based decision making.

REFERENCES

Andlar, G., Aničić, B., & Šteko, V. (2014). *Landscape plan as an instrument for revitalisation of the cultural landscape- case of the UNESCO's Stari Grad Plain landscape plan*.

Antonarakis, A. S., Richards, K. S., & Brasington, J. (2008). Object-based land cover classification using airborne LiDAR. *Remote Sensing of Environment*, *112*(6), 2988–2998. https://doi.org/10.1016/j.rse.2008.02.004

Che, E., Jung, J., & Olsen, M. J. (2019). Object recognition, segmentation, and classification of mobile laser scanning point clouds: A state of the art review. *Sensors (Switzerland)*, *19*(4). https://doi.org/10.3390/s19040810

EC/COM. (2010). *The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future* (Vol. 672, Issue 5, p. 18). European Comission. https://doi.org/10.1017/CBO9781107415324.004

Food and Agriculture Organization of the United Nations. (2008). Opportunities to mainstream land consolidation in rural development programmes of the European Union. In *FAO* (Vol. 91, Issue 5). https://doi.org/10.1017/CBO9781107415324.004

Jia, Y. (2015). *Object-based Land Cover Classification with Orthophoto and LIDAR Data*. *February*, 1–75.

Lin, K. F., Wang, C. P., & Hsu, P. H. (2013). Object-based classification for LiDAR point cloud. *34th Asian Conference on Remote Sensing 2013, ACRS 2013*, *2*(1), 1209–1216.

Lin, X., Zhang, J., & Shen, J. (2011). Object-based classification of airborne LiDAR point clouds with multiple echoes. *2011 International Symposium on Image and Data Fusion, ISIDF 2011*, 1–4. https://doi.org/10.1109/ISIDF.2011.6024305

Medić, V. (1978). *Komasacija zemljišta*. University of Zagreb Faculty of Geodesy.

Ni, H., Lin, X., & Zhang, J. (2017). Classification of ALS point cloud with improved point cloud segmentation and random forests. *Remote Sensing*, *9*(3). https://doi.org/10.3390/rs9030288

Odak, I. (2017). *Agricultural Land Fragmentation Analysis of Land Holdings and its Application in the Rural Land Management, doctoral thesis*. University of Zagreb Faculty of Geodesy.

UN FAO. (2003). *The design of land consolidation pilot projects in Central and Eastern Europe*. UN FAO. ftp://ftp.fao.org/docrep/fao/006/Y4954E/Y4954E00.pdf

UN FAO. (2004). Operations manual for land consolidation pilot projects in Central and Eastern Europe. *Organization*, 69.

Vitikainen, A., & Tech, D. S. (2004). An Overview of Land Consolidation in Europe. *Nordic Journal of Surveying and Real Estate Research*, *1*(1), 124–136.

Xiang, B., Yao, J., Lu, X., Li, L., & Xie, R. (2017). Segmentation-Based classification for 3D urban point clouds. *2016 IEEE International Conference on Information and Automation, IEEE ICIA 2016*, *August*, 172–177. https://doi.org/10.1109/ICInfA.2016.7831817

BIOGRAPHICAL NOTES

Josip Šiško graduated in 2017 at the Faculty of Geodesy, University of Zagreb. From 2018 until today he works as an Assistant at Department of Applied Geodesy, University of Zagreb, Croatia. He is a PhD student with particular interests in GIS applications, land management and spatial data infrastructure. Josip Šiško has participated on several projects and has published several papers.

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Iva Vuković graduated in 2019 at the Faculty of Geodesy, University of Zagreb. The title of her Masters thesis was: “Point Cloud Object Classification for the purpose of Real Estate Valuation in the Land Consolidation Process”. She is working as a Professional associate of chartered geodetic engineer at the “GEO-ing d.o.o.” company since September 2019. Her main research interests are land management and engineering geodesy.

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