IOP Conf. Series: Earth and Environmental Science **90** (2017) 012113 doi:10.1088/1755-1315/90/1/012113

Rainwater harvesting and green area retention potential detection using commercial unmanned aerial vehicles

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Abstract. The objective of this work is to use simple photogrammetry to evaluate rainwater harvesting and green area retention potential in Maribor, Slovenia city centre. Several sources of remote sensing data have been described and a field test with semi-professional drone was performed by means of computer evaluation of rainwater harvesting and green area retention potential. Some of the most important design parameters for rainwater harvesting systems as roof area and slope and available green areas were identified and evaluated. The results have shown that even semi-professional low budget drones can be successfully used for mapping areas of interest. The results of six-minute flight over twelve hectares of Maribor city centre were comparable with professional results of plane remote sensing. Image segmentation from ortho-mosaic together with elevation model has been used to detect roofs and green areas.

1. Introduction

Remote sensing techniques in mapping and data acquisition such as satellite or aerial imagery or geophysical research, urban studies, hydrological modelling and floodplain, vegetation covering, military use, film industry, dangerous situations, fires, accidents provide non-invasive alternatives to acquire information about terrain. There is satellite sensing starting with Landsat (1972), plane sensing from simple orthographic photos of some area to the multi-sensor and laser scanning [1]. In past years the use of Unmanned Aerial Vehicles (UAV) based on remote sensing has generated low cost monitoring, since the data can be acquired quickly and easily with a low cost UAV [2]. There also a lot of other uses well described in papers such on geophysics [3-4], on satellite imagery [5], on passive aerial photography [6], on active aerial photography [7]. The drones are also used in extreme environments.

This paper reports the experience related to quick assessment of urban rainwater harvesting and green area retention potential with consumer drone. The data were processed with traditional photogrammetric data flow and data extraction techniques were applied to extract data regarding roofs and green areas. The fusion of photogrammetry, computer vision, image segmentation and point cloud data use leads to interesting results.

We asked ourselves, if we can obtain data needed for assessment of urban rainwater harvesting and green area retention potential with consumer drone, and process data in reasonable time.

2 Remote sensing in Slovenia

2.1 Remote sensing overview

Satellite imagery and aerial photography play an important role in environmental and urban area monitoring, however there is a limitation; free sources of satellite imaginary usually do not provide images with enough spatial resolution as those given by planes or by UAV's as we can see in Figure 1.

Figure 1. Public satellite image of our area of interest [8]

Aerial photography scan from commercial provider can be ordered, but with high costs. We can get results of high quality as we can see on Figure 2 and Figure 3 where city of Izola, Slovenia has been photographed orthographically in resolution of 5 cm with high details and in scale.

Figure 2. Orthophoto of Izola [9]

Figure 3. Orthophoto zoom – high details resolution of 5 cm [9]

Usable and free source of geospatial data in Slovenia is our public environmental agency ARSO, where free aerial photography and DEM database of whole country in high resolution and maximum height error of 15 cm can be obtained [10]. Plane is flying about 1200-1400 m above sea level with several sensors such LIDAR and cameras with spatial precision of 0.03/0.03/0.025 m, 5 points per sqm. Final result is processed digital terrain model DTM of 1m/1m accuracy (Figure 4a). The data can be downloaded in *.OTR, *GKOT or *.DMR format. A shadows can also be obtained from ARSO web page (Figure 4b).

Figure 4a. Orthophoto with cartographic data

Figure 4b. Shadows on the terrain

2.2 Some commercial UAV measurements in Maribor centre

Digital Surface Model - DSM is a 3D model generated from Airborne Laser Scanning ALS through Light Detection and Ranging LiDAR, which delivers a massive point cloud filled of varying elevation values. These elevation values can come from the top of buildings, tree canopy, powerlines and other types of features on the terrain. A DSM captures the natural and built features on the Earth's surface when digital elevation model DEM exclude vegetation and buildings [11].

Photogrammetry is the science of making measurements from photographs. The input to photogrammetry is photographs, and the output is typically a map, a drawing, a measurement or a 3D model of some real-world object or scene. In aerial photogrammetry, the camera is mounted in an aircraft and is usually pointed vertically towards the ground using the gyroscope. Multiple overlapping photos of the ground are taken as the aircraft flies along a flight path. Traditionally the aerial photogrammetry has been done with manned aircrafts but many projects now are done with drones and other UAV [12].

Normalised difference vegetation index (NDVI) is another important term. The normalised difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyse remote sensing measurements, typically, but not necessarily, from a space platform, and assess whether the target being observed contains live green vegetation or not. Example of NDVI analyse of our area of interest is on Figure 5.

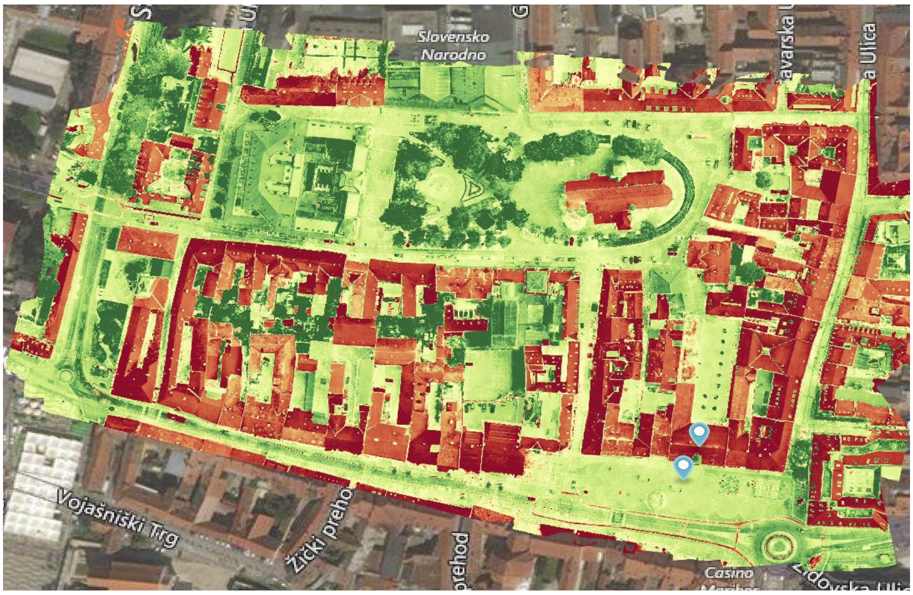

Figure 5. NDVI of observed area

3. Assessment tool of urban rainwater harvesting and green area retention potential

Growing water scarcity and global climate change call for more efficient alternatives of water conservation; rainwater harvesting (RWH) is the most promising alternative among others. However, the assessment of RWH potential and the selection of suitable sites for RWH structures are very time consuming especially on larger scales [13]. This work addresses this challenge by presenting an example of quick and low cost tool for evaluating RWH potential and identifying zones for different RWH structures and green areas with retention potential using drones, photogrammetry and image segmentation.

An area in the centre of the city Maribor, Slovenia was selected for which also geospatial data from professional areal scan done by plane for comparison and test were obtained. A Mavic PRO drone with 12 MP camera, 1/2.3” sensor size, 78° field of view and rolling shutter type was used. A flight plan was set (Figure 6) using DroneDeploy software. The area of interest has been 12 hectares of Maribor city centre. It is a highly urbanised old town centre with also some green areas.

Figure 6. Flight plan

Flight was taken about 6 minutes. With one flight whole area of 12 hectares with planned precision of 3.9 cm per pixel was covered. 63 photos have been taken from the height of 90 meters in high resolution and with overlapping of 60% (Figure 7). Photogrammetric processing has been done in the cloud by DroneDeploy. Using of 12 MP P3P camera yielded an average margin of error of approximately 20 cm. The use of 20 MP pixel camera would produce 0.33% less measurement error of course dependant of the flight height [14].

Figure 7. Map of taken photos

The result is high resolution ortho-mosaic photo and 3D DSM model with tolerances in centimetres (Figure 8). Such a results can be useful in variety of applications of mapping and detection purposes [15].

Figure 8. Ortho-mosaic with resolution 5 cm

Besides ortho-mosaic cloud of points can give us an elevation model (Figure 9) of area needed for RWH potential assessment [16].

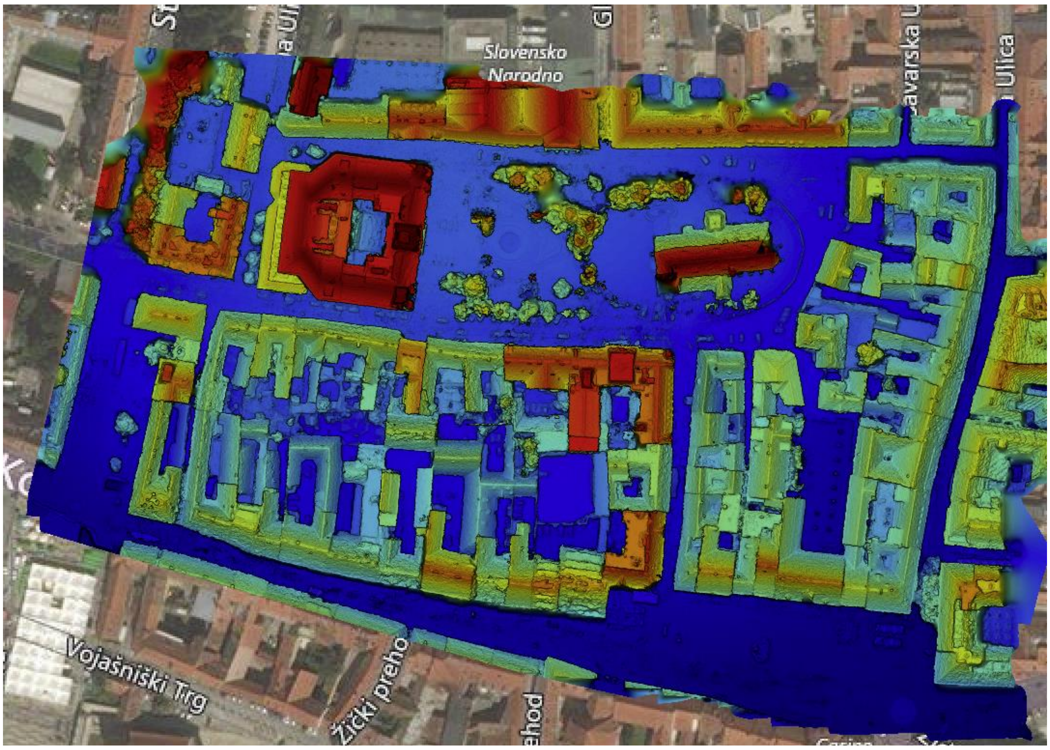

Figure 9. Elevation model map

The results where comparable and almost identical to those from DSM made by plane (Figure 10, Table 1). In Table 1 we can see almost identical coordinates obtained from the DSM made by professional aerial photogrammetry compared with coordinates obtained from UAV DSM model.

Table 1. Coordinates of selected point

Point	Professional Lidar DSM		Mavic Pro DSM	
	N [°]	E [°]	N [°]	E [°]
1	46.5577	15.6454	46.55769	15.64543

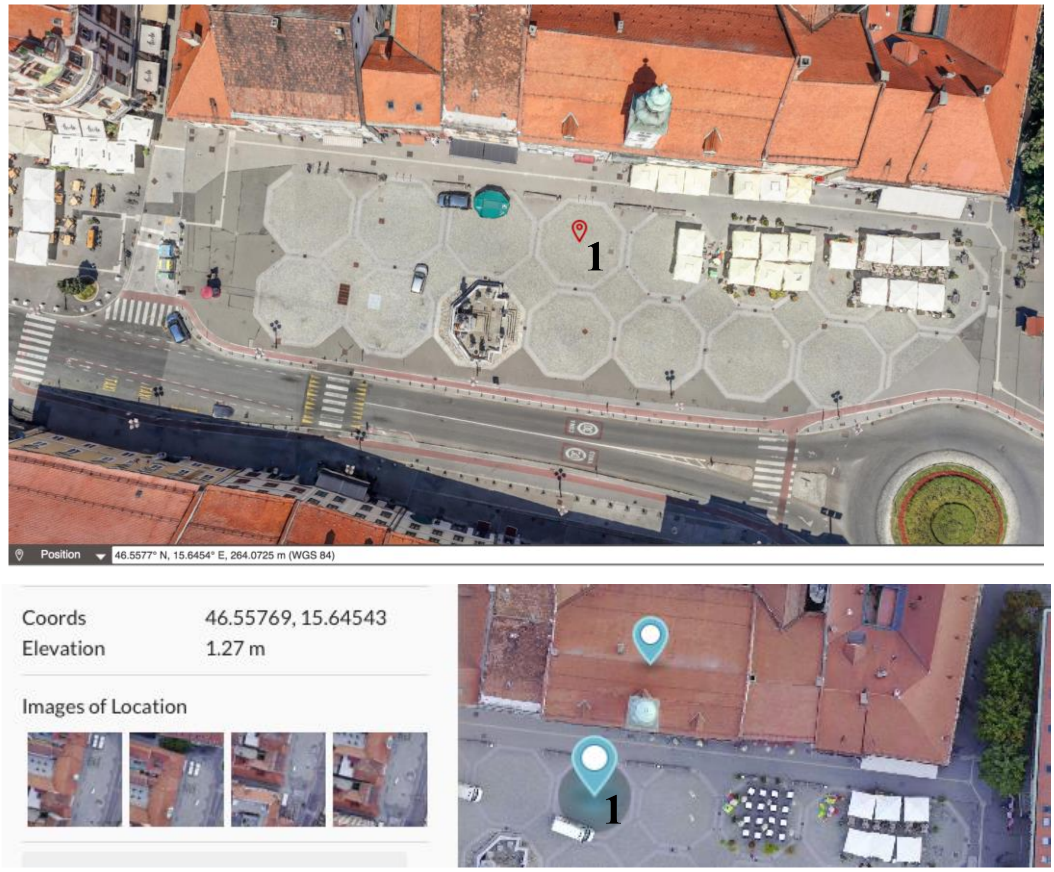

Figure 10. Coordinates and heights as result of professional plane scanning (upper) and our drone scan (lower)

4. Roof and green area estimation

After image segmentation and combination of computer vision and heights information the result is a measureable map of detected roof areas (Figure 11) and detected green areas (Figure 12).
The estimation of roof areas was about 3.9 hectares and green area around 0.8 hectares.

Figure 11. Roof areas of 3.9 hectares

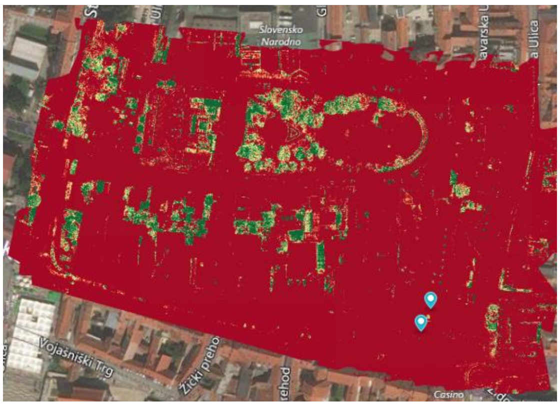

Figure 12. Green areas of 0.8 hectares

5. Conclusion

Without expensive equipment and in a very short time (6 minutes of flight and three hours of post processing) quite good informative results can be obtained. Most surprisingly those results and height model where comparable with professional obtained data. Detection algorithms needs some improvements but results can be used as quick assessment.

While the practice of rainwater harvesting (RWH) can be traced back millennia, the degree of its modern implementation varies greatly across the world, often with systems that do not maximize potential benefits and potentials [17].

More and more need for use of rainwater has been taken into account. Quick assessment tools as ours can be help for decision makers to "see" local RWH potential.

For even better result the use of 20 MP pixel camera is suggested. In that case the measurement error would be better for approximately 0.33 %. Also flying lower and ground control points would drastically improve measurement accuracy. Actually ground control points produces the most consistent, accurate results.

Acknowledgements
The paper is side product from the student project BLAKE which was financed by the European Union (European Social Fund) and the Republic of Slovenia (Javni štipendijski, razvojni, invalidski in preživninski sklad and the Ministry of Education, Science and Sport).

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