Using Low-cost Unmanned Air Vehicle (UAV) for Landslide Monitoring – Case Studies from the Moravian-Silesian Region, the Czech Republic

Jakub Seidl[1], Michal Kačmařík[1], Petr Šádek[1], Vlastimil Kajzar[2]

[1]Department of Geoinformatics, VŠB-Technical University of Ostrava, 708 00, Czech Republic

[2]Institute of Geonics, Czech Academy of Sciences, Ostrava, 708 00, Czech Republic

Correspondence to: Michal Kačmařík[1] (michal.kacmarik@vsb.cz)

Abstract

Unmanned Air Vehicles (UAV) proved to be an efficient tool for mapping and monitoring of various environmental phenomena including landslides. In this study a utilization of a low-cost multi-copter UAV for monitoring of two active landslides in the Moravian-Silesian region of the Czech Republic is presented. Time series of 3D point clouds reconstructed from RGB images using Structure-from-Motion (SfM) photogrammetry and derived raster digital terrain models are used to evaluate landslide dynamics and also their own quality and reproducibility. At one of the studied landslides, 3D point cloud acquired by an UAV is also confronted with a 3D point cloud collected by a terrestrial laser scanning. Realized analysis show that an accuracy of 3D point clouds acquired by a low-cost UAV can reach up to several centimetres in non-vegetated areas.

Keywords: UAV, landslide, dynamics monitoring, 3D point cloud, terrestrial laser scanning

INTRODUCTION

Unmanned Air Vehicles (UAV) have been already proved by several authors to represent an effective and accurate tool for landslide mapping and monitoring. Most of the authors (for example Niethammer et al. (2012), Lucier et al. (2014), Turner et al. (2015), Fernández et al. (2015), Peppa et al. (2016) or Rossi et al. (2018)) studied dynamics of landslides by evaluating differences in digital terrain models (DTM) obtained at multiple epochs from RGB images processing based on Structure-from-Motion (SfM) photogrammetry. On the other hand, Rau et al. (2011) used also an analyses of ortho-images from an UAV to identify new landslide regions after a typhoon in Taiwan. Both multi-rotor and fixed wing types of UAVs were reported to be applied in the landslide mapping. A comprehensive general overview of current remote sensing techniques suitable for landslide mapping and monitoring including UAVs can be found in Casagli et al. (2017).

Within this study, two active landslides in the Moravian-Silesian region of the Czech Republic were repeatedly mapped by a quad-rotor UAV equipped with a RGB camera. Realized evaluation of landslide dynamics as well as a quality of the UAV-based outputs is based not only on a comparison of high-resolution DTMs from subsequent epochs, but also on a direct comparison of 3D point clouds while we assess advantages and disadvantages of both these approaches. Moreover, at one of the landslides, a 3D point cloud from UAV is compared with a 3D point cloud from a terrestrial laser scanning (TLS).

STUDY AREAS, DATA COLLECTION AND PROCESSING

As already mentioned above, two landslides were included in the presented study. The first one named Kozinec is located near village Doubrava and spans over an area of about 500x350 m. Past and current underground deep coal mining activities led to a development of a large subsidence basin which contains also an unstable slope where the landslide was activated. It can be classified as a slow translational slide of soil masses of low thickness. Height of the main scarp (see figure 1 and 3) was about two meters when UAV was firstly used to collect the data in 2018. In total, images from UAV at this landslide were collected three times in year 2018 (January 11, April, 13 and November 23) and once in year 2019 (November 26). It is necessary to note that during the first half of year 2019 a complex reclamation of upper and lower part of the landslide area was performed in order to stabilize its activity. Due to this reason data collected during the 2019 flight can be used only for an evaluation of non-active areas above the main scarp.

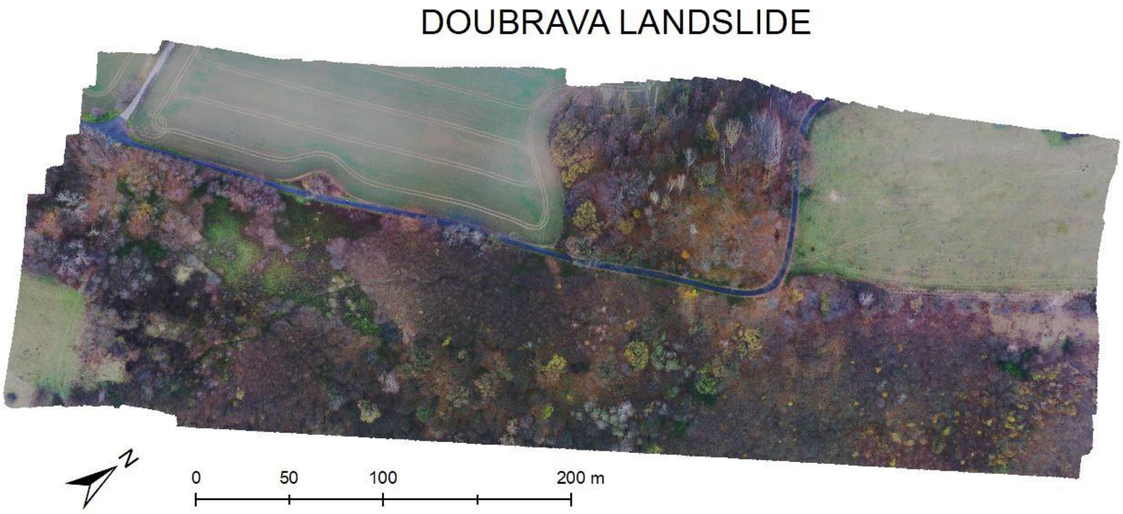

Fig. 1. Orthophoto map of the Kozinec landslide captured by UAV on November 23, 2018.

The second landslide named Gírová is situated along the south-western slope of Gírová mountain close to the Jablunkov city. After a heavy rainfall spanning over several days a large deep-seated gravitational slope deformation was activated on May 19, 2010 and within several days a sliding mass with a total volume of about 2.8 million cubic meters was moved (Baroň et al., 2011, Pánek et al., 2011). The landslide has characteristics of a wedge-like translational rockslide (deeply weathered claystone/mudstone-dominated flysch) and is current horizontal length is around 1100 m and width around 300 m. Within this work only an upper part of the landslide with an approximate size of 300x200 m is studied since it contains up to 30 m high fault-predisposed head scarp which is continuously being eroded and which is mostly not covered by a (dense) vegetation. UAV was used to collect images at this site during the year 2019 on March, 22, June 06 and November 15. Campaign in June was realized shortly after a heavy rainfall with a total precipitation of around 150 mm during three consequent days.

Fig. 2. Orthophoto map of the Girova landslide captured by UAV on June 6, 2019.

For all data acquisition campaigns, a DJI Phantom 3 Advanced quad-copter was used to collect RGB images with its built-in 12 MPix camera. In order to ensure a high quality of 3D reconstruction, two types of images were always gathered. Firstly, orthogonal images with an overlap between 75% and 85% were taken from flight heights of around 60 to 90 m and saved to JPEG format. Secondly, additional RAW images with orthogonal and side-looking camera were collected from lower flight heights of around 30 to 50 m. Ten ground control points (GCPs) were always temporarily placed in the landslide area and their position measured with a GNSS Real-Time Kinematic (RTK) technique to allow an accurate georeferencing. Images from all campaigns were processed in Agisoft Photoscan (Metashape) software with a same workflow and settings. Obtained dense 3D point clouds were filtered in order to eliminate noise and vegetation using semi-automatic tools in Agisoft Photoscan (Metashape) and manual point cloud editing. For TLS data acquisition at the Gírová landslide, a Leica ScanStation C10 device was used. Scanning of selected part of the landslide characterized by a steep slope was performed from 4 scanning positions with 5 cm/100 m resolution. Obtained point cloud data were processed in Leica Cyclone and CloudCompare software.

RESULTS

Due to a limited length of this extended abstract and still ongoing work, only a summary of realized activities is given here and a small set of selected results visually presented below.

- DTMs with a 10 cm resolution and 3D point clouds from individual epochs were statistically and visually compared at both landslides for a) complete mapped areas; b) selected multiple zones representing various surface types in non-active and active areas of landslides. An evaluation of outputs from different epochs in non-active areas of landslides showed that an accuracy of UAV outputs is at the order of 5 to 10 cm in the vertical direction what is in accordance with results presented by other authors in some of the above cited studies. While both used approaches (DTMs comparison versus direct point cloud to point cloud comparison) generally provided similar results in the statistical evaluation, comparisons of 3D point clouds allowed a better visual inspection making easier to identify small structure changes. Differencing of 3D point clouds was done using a M3C2 algorithm (James et al., 2017) implemented in open source software CloudCompare.
- At the Gírová landslide, UAV 3D point cloud from March 22, 2019 was compared with a TLS 3D point cloud obtained on the same day for a selected area of studied landslide with a steep slope. Since TLS 3D point cloud was available only in a local coordinate system, it was firstly aligned to the UAV point cloud. An Iterative Closest Point (ICP) algorithm implemented in CloudCompare software was used for this task. A result of differencing of both point clouds is presented in Figure 4. While minimum (maximum) differences reach -3.25 (0.87) m respectively, mean value is -0.01 m and standard deviation 0.09 m. Locally present values with high differences are mainly caused by a rests of non-filtered vegetation remaining in the data. Although the 3D point cloud derived from UAV photogrammetry seems to be comparable with the one provided by TLS in terms of accuracy, the level of detail cannot be surpassed since point density from TLS is three times higher the UAV one.

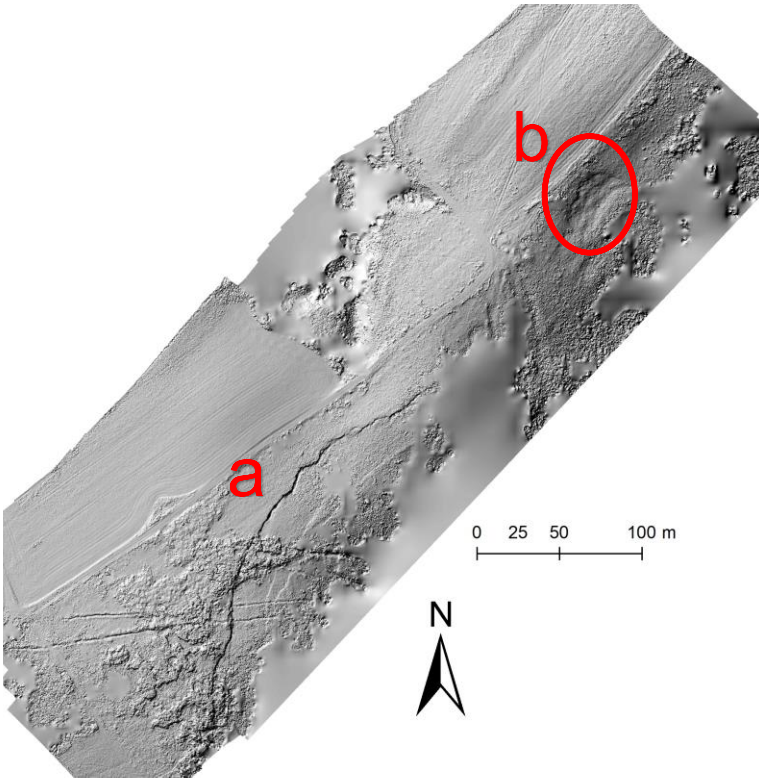

Fig. 3. Hill shade visualization of a DTM from the landslide Kozinec with a well visible main scarp (a) and a new secondary small landslide (b) which was firstly identified from this UAV output and not from a visual terrain inspection regularly realized by a geologist.

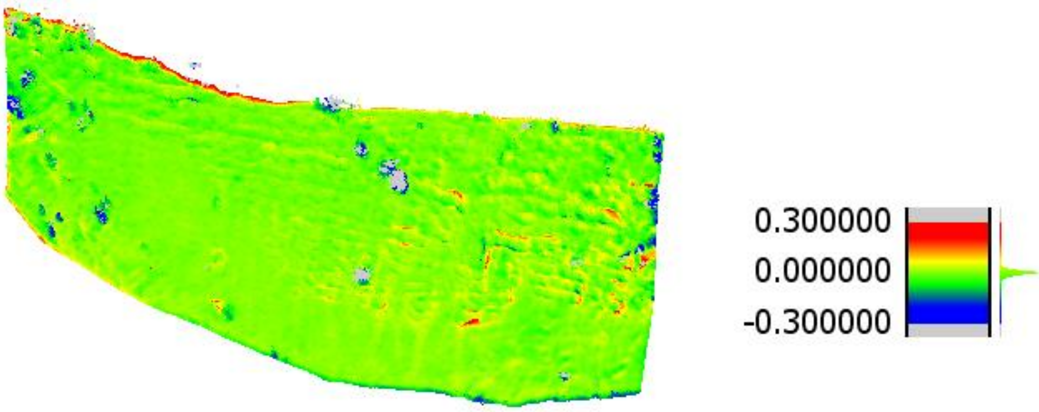

Fig. 4. Difference in meters between a 3D point cloud from UAV and a 3D point cloud from TLS at a small part of the Gírová landslide with a steep slope.

REFERENCES

Baroň, I., Řehánek, T., Vošmik, J., Musel, V., Kondrová, L. (2011) Report on a recent deep-seated landslide at Gírová Mt., Czech Republic, triggered by a heavy rainfall: The Gírová Mt., Outer West Carpathians; Czech Republic. Landslides, 8, 355-361, doi:10.1007/s10346-011-0255-y

Casagli, N., Frodella, W., Morelli, S., Tofani, V., Ciampalini, A., Intrieri, E., Raspini, F., Rossi, G., Tanteri, L., Lu, P. (2017) Spaceborne, UAV and ground-based remote sensing techniques for landslide mapping, monitoring and early warning. Geoenvironmental Disasters, 4, 9, doi:10.1186/s40677-017-0073-1

Fernández, T., Pérez, J.L., Cardenal, F.J., López, A., Gómez, J.M., Colomo, C., Delgado, J., Sánchez, M. (2015) USE OF A LIGHT UAV AND PHOTOGRAMMETRIC TECHNIQUES TO STUDY THE

EVOLUTION OF A LANDSLIDE IN JAÉN (SOUTHERN SPAIN), The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-3/W3

James, M.R., Robson, S., Smith, M.W. (2017) 3-D uncertainty-based topographic change detection with structure-from-motion photogrammetry: precision maps for ground control and directly georeferenced surveys. Earth Surface Processes and Landforms, 42, 12, 1769-1788, doi:10.1002/esp.4125

Lucieer, A., de Jong, S., Turner, D. (2014) Mapping landslide displacements using Structure from Motion (SfM) and image correlation of multi-temporal UAV photography. Progress in Physical Geography, 38, 1, 97-116, doi:10.1177/0309133313515293

Niethammer, U., James, M.R., Rothmund, S., Travelletti, J., Joswig, M. (2012) UAV-based remote sensing of the Super-Sauze landslide: Evaluation and results. Engineering Geology, 128, 2-11, doi:10.1016/j.enggeo.2011.03.012

Pánek, T., Brázdil, R., Klimeš, J., Smolková, V., Hradecký, J., Zahradníček, P. (2011) Rainfall-induced landslide event of May 2010 in the eastern part of the Czech Republic. Landslides, 8, 507-516, doi:10.1007/s10346-011-0268-6

Peppa, M.V., Mills, J.P., Moore, P., Miller, P.E., Chambers, J.E. (2016) ACCURACY ASSESSMENT OF A UAV-BASED LANDSLIDE MONITORING SYSTEM, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLI-B5

Rau, J.Y., Jhan, J.P., Lo, C.F., Lin, Y.S. (2011) LANDSLIDE MAPPING USING IMAGERY ACQUIRED BY A FIXED-WING UAV, International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XXXVIII-1/C22

Rossi, G., Tanteri, L., Tofani, V., Vannoci, P., Moretti, S., Casagli, N. (2018) Multitemporal UAV surveys for landslide mapping and characterization. Landslides, 15, 1045-1052, doi:10.1007/s10346-018-0978-0

Turner, D., Lucieer, A., de Jong, S. (2015) Time Series Analysis of Landslide Dynamics Using an Unmanned Aerial Vehicle (UAV). Remote Sensing, 7, 1736-1757, doi:10.3390/rs70201736