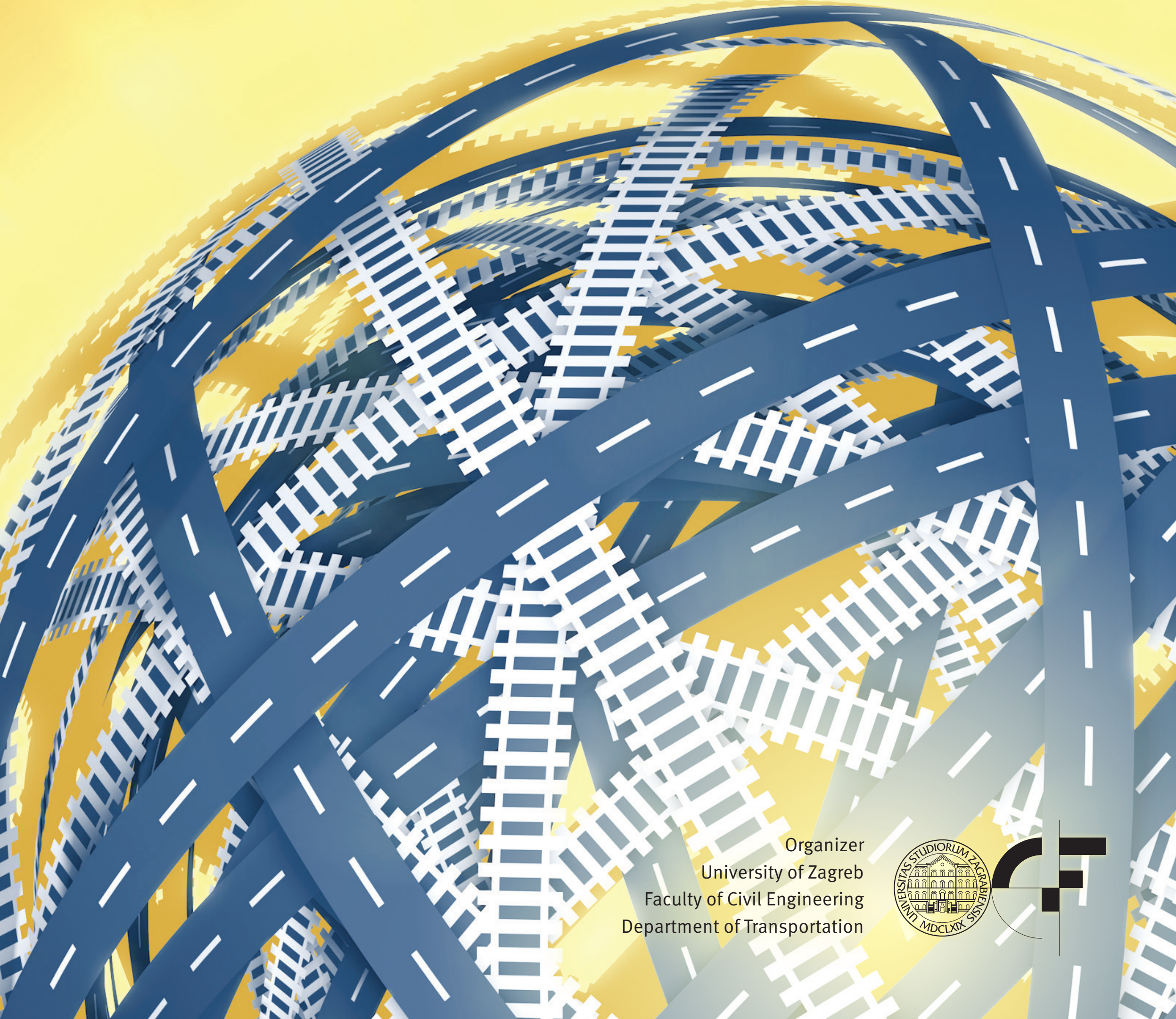
CETRA[2016]

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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Road and Rail Infrastructure IV

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VOLUME MEASUREMENTS OF ROCKFALLS USING UNMANNED AERIAL VEHICLES

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Abstract

Abrupt climate changes cause increasing occurrence of rockfalls which are significant and ongoing threat to infrastructure network, particularly for those located within steep terrain. Better understanding and timing where to focus attention for this matter is crucial for the infrastructure companies, which can avoid high cost of damages caused by rockfall hazards. Hazard analysis has historically relied on visual inspection of experienced field engineers assessing each site, which is not time or cost effective. In recent years, the usage of unmanned aerial vehicles (UAVs) is becoming increasingly common, especially for applications concerning natural disasters. By using unmanned aerial vehicles the traditional methods of mapping, determining the volume, cross-sections, contours and other parameters that are required for rockfall engineering analysis can be altered, improved, or even completely replaced. The paper presents the legislation and scientific research initiatives for determining the volume of boulders with unmanned aerial vehicles.

Keywords: boulder, ortophoto maps, point cloud, rockfalls, transport infrastructure, Unmanned Aerial Vehicles

1 Introduction

Rockfalls are a major threat in areas characterized by highly diversity of lithostratigraphic soil compositions [1], high degree of tectonic and seismic activity, complex geological characteristics, various relief features, unfavourable climatic conditions, water network development and significant anthropogenic influence on relief shaping. During the last decade a large number of rockfalls occurred on the steep karst slopes along the Adriatic Coast of Croatia, causing serious damages to buildings and transport infrastructure, which resulted with traffic delays on roads and railways with expensive remediation measures [2].

A rockfall is defined as a rock mass that has detached from a steep slope or cliff along a surface with little or no shear displacement and descends most of its distance through the air [3]. Once a rock block has detached from the steep slope, it will free fall, topple, bounce, roll or slide along the slope surface at a high speed, which can cause significant damages to the facilities at the bottom of the slope.

Investigation of rockfall hazards and rockfall hazard mitigation requirements in Croatia were increased during the last decade after large rockfoils occurred on the steep karst slopes along the Adriatic Coast of Croatia [4]. Majority of sections of Croatian Highways A1, A6 and A7, in total 570 km of length and Croatian Railways, round 650 km of length are situated in the karst terrain with numerous slopes cut in the karstic rock (Figure 1).

Karst takes more than a half of the Croatian area (52%) and over 70%, if Croatian Adriatic seabed is taken into consideration [5]. It is located from Slovenia in the northwest, to the southeast of Montenegro and his northern border goes south from Karlovac to the east where it crosses into Bosnia and Herzegovina. Karst morphological form is including skraps, valleys, pits, sinkholes, coves, fields, caves, caverns, etc. and his hydrological forms includes confluence with rapid drainage, underground rivers, estavelles, surface springs and submarine sources.

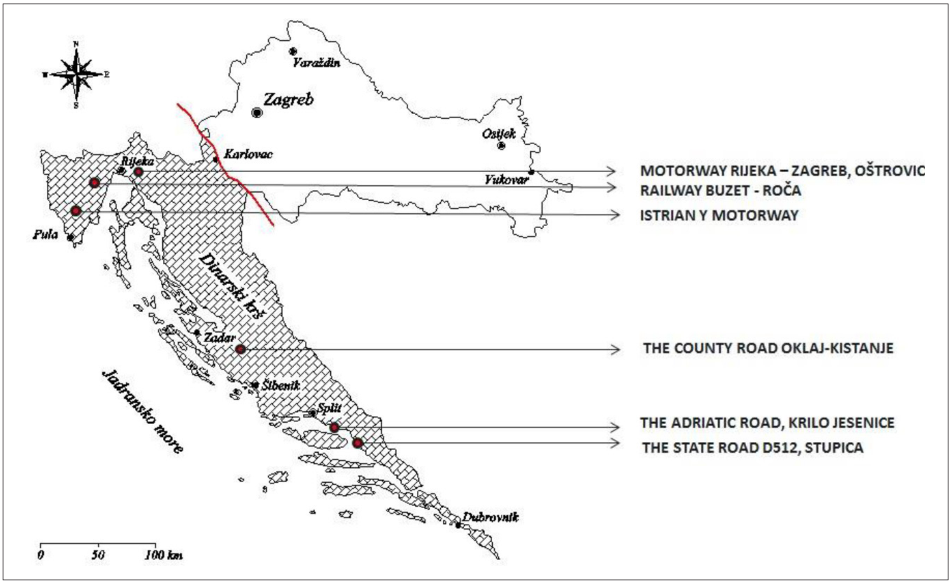

Figure 1 Map of Croatian karst area with some rockfall locations

2 Jurdani rockfall survey with UAV

Accessing and mapping rockfal locations with Unmanned Aerial Vehicle (UAV) can be used to collect series of high resolution images from which is possible to create Digital Terrain Model (DTM) of a rockfall area. By using such models it is possible to generate very accurate data of volumes, areas, surfaces, cross sections and contour lines in a very short time and replace traditional methods of mapping such areas.

On the railway line M203 between stations Jurdani and Matulji is a location of potential rockfall and it was photographed with UAV DJI Phantom 2 Vision+ [6]. With this type of Unmanned Aerial Vehicle it is possible to take a lot of pictures in very short time, which depends on the experience of the pilot. In this case 69 pictures was taken. which were used latter on in mapping software Pix4Dmapper Pro [7]. Combination of such UAV and mapping software is a powerful tool which can generate data for all computer programs who are used for rockfall simulations, an one of them is Rocfall [8].

It is a computer program easy to use, which performs probabilistic simulation of rockfalls or landslides and can be used for designing barriers and testing their effectiveness. Rocfall based on input data (slope geometry, characteristics of slope materials, block size, block starting position and starting speed) calculates the trajectory of a block and as output data gives speed, position and kinetic energy of block. Output form also gives a histogram showing distribution of velocity, kinetic energy and stepping height of the blocks in relation to any location along the slope profile.

2.1 DJI Phantom 2 Vison+

Company DJI [6] is one of global leaders in the development and production of simple to use and reliable small unmanned aircraft for commercial use and recreation. Model Phantom 2 Vison+ is one of the top sellers, most simple and very easy to use. Unfortunately his production has been terminated, but was replaced with newer versions like Phantom 3 and Phantom 4, while technology and other operating principles on new drones remains the same or slightly enhanced. This UAV (unmanned aerial vehicle) has four propellers (quadcopter) and is equipped with a camera attached to the bottom that can record high-resolution images or high-definition video (Figure 2). It also comes with many other features for recording digital imagery. A user can control the device using a remote control connected to almost every smartphone, where live video from the drone's camera can be streamed. By using images supplied to the smartphone, pilots can navigate the drone even when it is out of a direct line of sight.

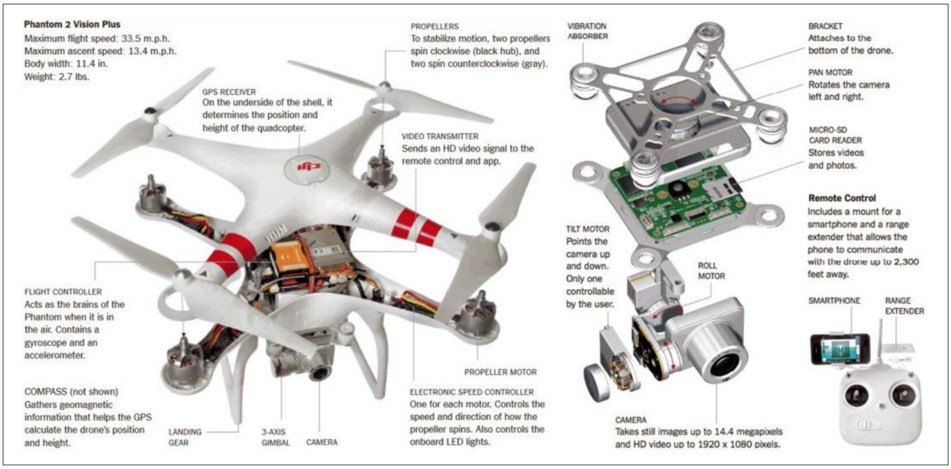

Figure 2 Parts of DJI Phantom 2 Vison+

2.2 Pix4Dmapper Pro

Pix4Dmapper Pro is software that automatically processes the images that were taken from the air using unmanned aircraft, or from the ground with digital camera. It uses technology that works on the principle of recognizing the image content (pixels) in order to make a complete 3D model of the subject (Figure 3). The software is completely adaptable to all types of cameras and image processing results can be converted and used by any GIS or CAD applications. Pix4Dmapper Pro can be used in many different branches of industry and science, such as mining, agriculture, geodesy, civil engineering, management of natural resources and emergency services, and allows following:

- line and polyline measurement (break lines), making longitudinal and cross sections, contour drawing, measuring areas and volumes directly in the model and their export to other different formats
- generating 3D point cloud, true orthomosaic and orthophoto maps, 3D textured models, DSM (Digital Surface Model), NDVI Maps (normalized difference vegetation index) from vertical and oblique aerial or terrestrial photos
- it uses a fully automated flow of data processing and calibration of each photo in order to achieve a satisfactory level of accuracy, but also the “Rapid Check mode” for checking the quality of recording directly on the field

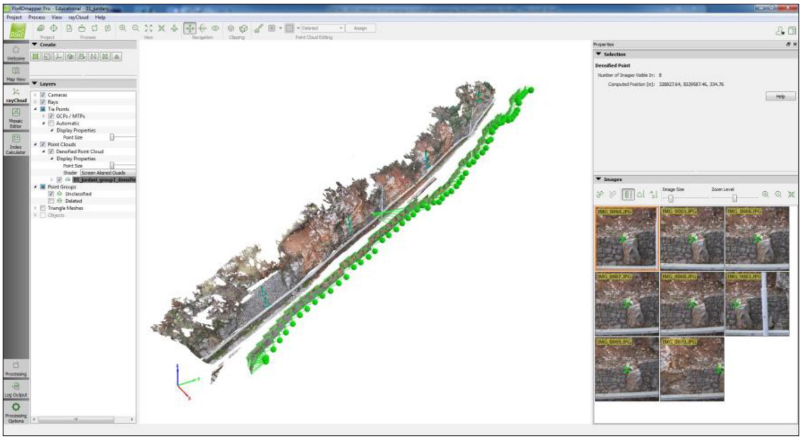

Figure 3 Pix4Dmapper Pro user interface

2.3 Flight preparation

Upon arrival at the location the first step is to prepare flight of aircraft which is done by connecting smartphone with UAV through wireless connection, and upload the map of the location to the smartphone. To prepare a flight it is needed to set up dimensions of mapping area in Pix4D capture [9] application, flight orientation and altitude as well as drone airspeed. In this particular case, flight was carried out in "free flight mission" mode which means that one set of parameters had to be added. Horizontal and vertical change of camera position through GPS (Global Positioning System) were set in the way that when camera moves by 2 meters (Figure 4) it will automatically take a photo and save a GPS coordinate of a photo position.

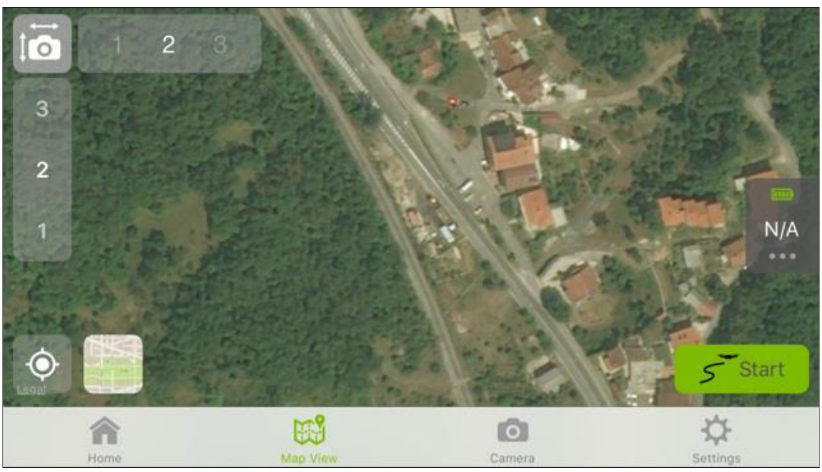

Figure 4 Screen shot of the map location "Jurdani" from smartphone

2.4 Office work

By uploading such geocoded images taken from air in Pix4Dmapper Pro it displays flight path and the position of each photo that was taken (Figure 5).

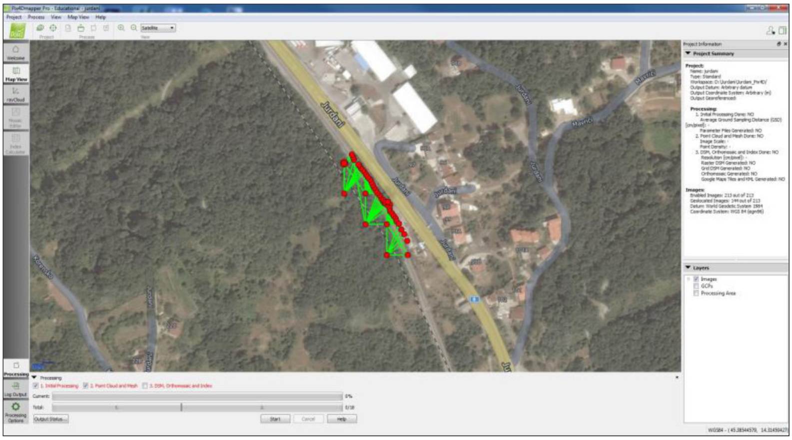

Figure 5 Screen shot of Pix4D mapper Pro with positions where images were taken

Photo processing, generating point cloud and orthophoto map takes place automatically by SFM algorithm (Structure From Motion) [10] by Pix4Dmapper Pro. Depending on the power of the processor and graphics performance of a computer after some time software generates orthophoto map and Digital Surface Model (DSM) (Figure 6) and 3D view of the terrain in the form of a point cloud (Figure 7).

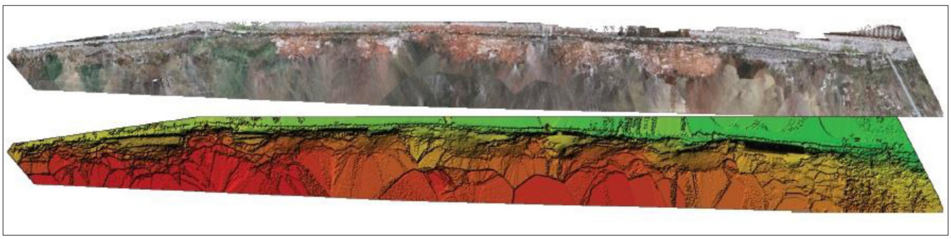

Figure 6 Ortophoto map and Digital Surface Model (DSM) generated by Pix4Dmapper Pro from photos taken from air

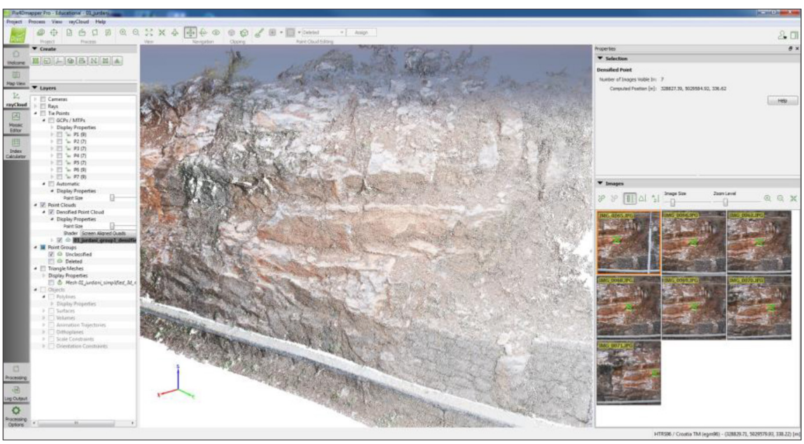

Figure 7 Point cloud generated by Pix4Dmapper Pro from photos taken from air

Result of this way generated point cloud and orthophoto map it that they are fully measurable at every part of the created model. It is allowing us to produce longitudinal and cross sections (Figure 8), contour drawing, measuring areas and volumes (Figure 9) directly in the point cloud model and their export to other different CAD format (Computer Added Design) who are used in most professions related for mapping and design.

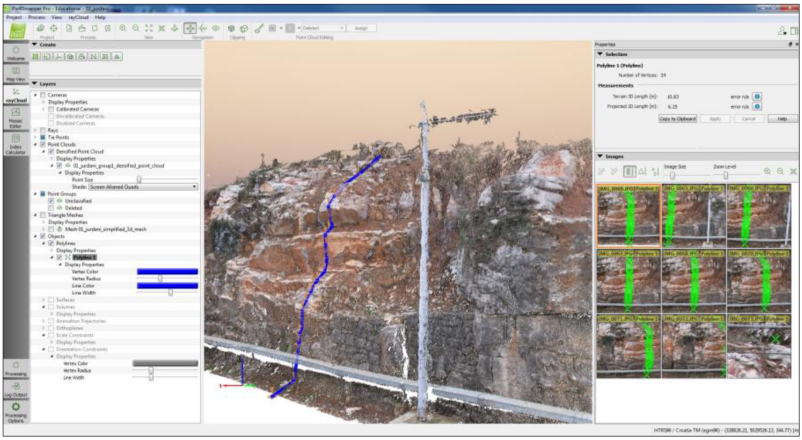

Figure 8 Example of cross section generated in Pix4Dmapper Pro

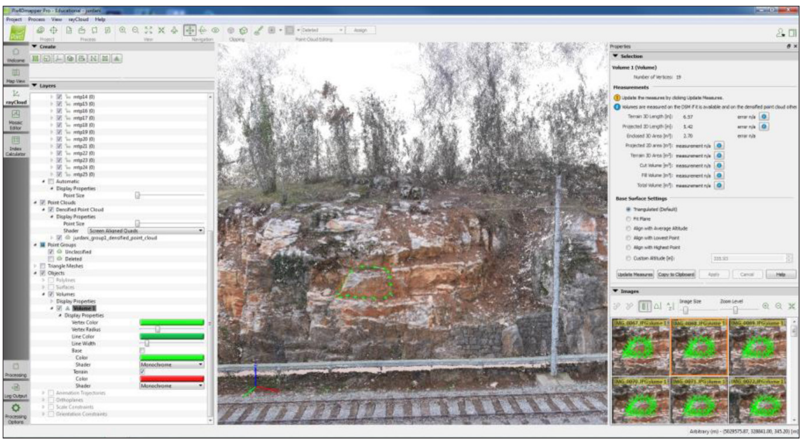

Figure 9 Volume generated in Pix4Dmapper Pro

3 Conclusion

Application of Unmanned Aerial Vehicles (UAVs) can deliver high-resolution remote sensing data on rockfalls which are constantly appearing in Croatian karst. Compared to conventional classical methods for mapping rockfalls, new technologies and software can save a lot of time and money, especially when the area of interest is hazardous, dangerous and inaccessible delivering data which is more than sufficient for rockfall analysis.

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