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Building a virtual outcrop, extracting geological information from it, and sharing the results in Google Earth via OpenPlot and Photoscan: An example from the Khaviz Anticline (Iran)

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ABSTRACT

Photogrammetry is becoming a highly efficient alternative technique to laser-scanning for creating virtual outcrop models. It is easy to create a 3-dimensional digital model of an outcrop and extract geological information contained in it by using photos taken from different locations and integrating few free and/or cheap software. Subsequently, both the virtual outcrop and the geological data can be easily uploaded into Google Earth for sharing purposes. This is opening a door to the use of virtual outcrops in geology, for both research and teaching, which due to the costs and computers' skill requirements, was limited to a few.

The aim of this paper is to present methodologies involved in the creation, analysis and sharing of low-cost easily-built virtual outcrops, which can be extensively used for the introduction to the 3D geology. An example from the Khaviz Anticline (Iran) is used to create a 3D digital model from a set of non-oriented images, using Agisoft Photoscan photogrammetry software. The obtained geopositioned model is then imported into OpenPlot, from which geological surfaces can be extracted. These data, together with the 3D model, can be later exported in Google Earth format.

1. Introduction

Virtual globes, such as Google Earth (GE), provide popular and useful platforms to integrate and share geospatial data (Butler, 2006; Chen et al., 2009; Tiede and Lang, 2010; Blenkinsop, 2012). In GE, three-dimensional (3D) surface models with associated textures can be uploaded as COLLADA file, offering the opportunity of sharing virtual outcrops (Xu et al., 2000; Pringle et al, 2001; Bellian et al., 2005; Clegg et al., 2005; McCaffrey et al., 2005, 2008; Trinks et al., 2006; De Paor and Whitmeyer, 2011; De Paor et al., 2012; Hodgetts, 2013), created by laser-scanning (Buckley et al., 2008; Garcia-Sellés et al., 2011) or stereo-photogrammetry (Haneberg, 2008; Gessner et al., 2009; Favalli et al., 2012). In addition, GE KML files allow to handle 3D georeferenced objects (i.e., polygons) which can be displayed together with the COLLADA 3D models. These objects may be used to upload geological information, namely any geological surface (e.g., bedding planes, faults, fractures) that can be extracted from the virtual outcrop with different tools. Although several software for managing 3D geospatial data – for different purposes – have been created during the last twenty years (e.g. Petrel, GoCad, 3DMove, 3D Data Viewer), the introduction to the 3D virtual world for the current generation of researchers and students passes (or has passed) through GE Accordingly, making virtual outcrops easily compatible with GE is key for teaching and making geological virtual outcrops popular and accessible. In order to popularise the technique among a non-expert audience, two important additional requirements are needed: (1) providing entry-level software for making fast and easy the creation of virtual outcrops and (2) making easy and useful the extraction of geological data from virtual outcrops. All these requirements are presently satisfied, as they involve the use of existing cheap and/or free software and tools.

Low-resolution digital cameras and ordinary computers (i.e. less than 4GB of RAM), can be used for the 3D photogrammetric reconstructions of outcrops (e.g., Sturzenegger and Stead, 2009; Lato et al., 2013). The recent advances in both computational speed and resolution of digital imaging devices allows for amateur photographers to easily and rapidly produce 3D digital outcrop models (Pringle et al., 2001; Lebel et al., 2001; James and Robson, 2012; Favalli et al., 2012). As a consequence, phogrammetry has become a valid alternative to the more accurate, but yet limited to a circle of "experts", light detection and ranging technique (LiDAR, or laserscan). In fact, although LiDAR is the most popular technique

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for producing accurate 3D digital outcrop models (Buckley et al., 2008; Garcia-Sellés et al., 2011; Hodgetts, 2013), its use still has many limitations in terms of logistics and costs. Hence, preventing its widespread use within the geoscientist community.

Moreover, the lack of software tools to analyse geological data extracted from virtual outcrops is presently a critically missing component. This apparently easy task, in fact, cannot be achieved within a single software. On the contrary, extraction and analysis of geological data require multiple steps through different tools. This prevents the use of virtual geological outcrops at the teaching and research levels, limiting their application to a restricted number of research or industry institutions. The main goal and novelty of our work is the unification of these steps into a single user-friendly, open-source software, integrating exporting tools for GE file formats. Such unification has led to the development of a simple, easy, and cheap workflow for virtual outcrop creation, analysis, documentation and sharing, which has the potential to revolutionise the geological documentation of outcrops, particularly on the teaching side.

In this contribution, it is first illustrated how to create a virtual outcrop by means of PhotoScan photogrammetry software (Verhoeven, 2011; Arbués et al., 2012). Then, the geological data extraction from a virtual outcrop using the OpenPlot software 3D tools (Tavani et al., 2011) is explained. Finally, it is shown how PhotoScan and OpenPlot allow to export the virtual outcrop and the extracted geological information in a format readable by GE. For this purpose, data from the Khaviz Anticline of the Zagros fold belt of Iran are used.

2. Virtual outcrop creation via PhotoScan

2.1. An overview on photogrammetry

3D view is ensured by the availability of at least two images of the same scene taken from different positions. Knowing position, orientation, and focal length of each image, allows for the position of any point in space to be computed from its 2D coordinates in the two images (Fig. 1). On the other hand, when camera parameters (i.e. photos' position, orientation and focal length) are unknown, they can be derived by the 2D coordinates of equivalent points in the different photos, which in turn allows for the computation of points' coordinates in the space. From what is stated above, it is clear the importance of detecting the position of a suite of points in different – but overlapping – photos of the same scene. This issue is a matter of study since the dawn of the digital era (Ullman, 1979), with Structure From Motion (SFM) algorithms being designed to correlate points in images of the same scene, taken from different positions and/or in different times (Ullman, 1979; Tomasi and Kanade, 1992; Gruen et al., 2004; Remondino and El-Hakim, 2006; Szeliski, 2010).

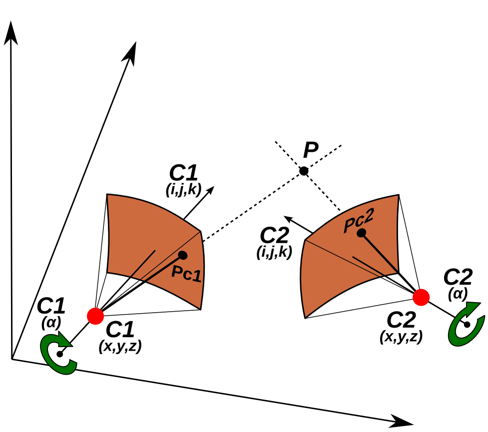

Fig. 1. Scheme showing parameters involved in stereoscopic view. When a point P is photographed from two cameras C1 and C2, the position of P in the two photos (Pc1 and Pc2) depends on the position of the two cameras, on their focal length, and on their orientation, which is defined by 4 parameters (the *ijk* versor and the angle α defining the amount of rotation about the *ijk* axis).

SFM algorithms are presently implemented in various software (e.g. Bundler, Microsoft's Photosynth, Photomodeller, Agisoft-PhotoScan). For a given a set of partially overlapping images, SFM algorithms automatically detect a suite of common points in each image pairs, and subsequently, recognise the camera parameters for each photo. This, in turn, permits the extraction of the 3D coordinates of each point recognised in at least two photos and hence, the creation of a point-cloud representing the surfaces of the objects within the target scene (e.g. Gruen et al., 2004; Verhoeven, 2011; Favalli et al., 2012). Essentially, the overlapping photos should be taken from multiple points of view. It is worthwhile to use the same camera to minimize errors coming from the use of different lenses and camera sensors. It is not mandatory to keep the focal length fixed, but it is strongly recommended. Photos should also be taken consecutively, or at least under the same lighting conditions (e.g., Arbués et al., 2012). These recommendations ensure that each portion of a scene is represented by a similar pixel pattern in the different photos, easing the recognition of points by the SFM algorithms. These procedures ensure and maximise the recognition of points, allowing for the creation of denser point-clouds.

Different photogrammetry packages are available, these having a wide range of costs, ease of installation and use, and ability to export results. Agisoft Photoscan has been chosen in our workflow due to its user-friendly nature, the availability of academic licensing, and tools allowing for the export of results into GE and OpenPlot.

2.2. Building a georeferenced 3D model in PhotoScan

After uploading photos, the to-do list starts with photo-masking (Fig. 2a), which consists in defining areas that will not be involved in the 3D reconstruction (i.e., the sky, vegetated areas, etc.). Photo-masking is not mandatory but it is highly recommended to ensure a substantially faster reconstruction. The subsequent photo-alignment command, attempts to recognise the position of the same points in the different overlapping photos. This allows to compute position and orientation of photos and, in turn, to create the point-cloud. At the end of the procedure, PhotoScan indicates those photos that have been aligned (according to the software) and those that have not, with wrong alignments being recognisable by either unrealistic or wrong photos' positioning (Fig. 2b), and/or by the presence of unrealistic geometries within the point cloud, such as planes or narrow and elongated bands of points converging toward a photo. The latter can occur when two or more photos have been taken from very close locations, however with different focal lengths. Alignment can be improved by: (i) avoiding the abuse of photos taken with very different focal lengths; (ii) manually indicating the same point in the different photos (Fig. 2c); and (iii) removing photos that cannot be successfully aligned.

The subsequent "building geometry" step triangulates the obtained point-cloud and returns a mesh (or a set of meshes) made up of irregular triangles. Memory requirements for photo-alignment and building geometry steps, depends on both hardware and number of photos; details can be found in the software's vendor wiki (http://www.agisoft.ru/wiki/PhotoScan/Tips_and_Tricks#Memory_Requirements). From our experiences building different virtual outcrop models, processing time strongly depends on the hardware but also on the quality of the dataset. Building a