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Using a Remotely Piloted Aircraft System (RPAS) to analyze the stability of a natural rock slope

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This paper describes the application of a rotary wing RPAS for monitoring the stability of a natural rock slope in the municipality of Vecchiano (Pisa, Italy). The slope under investigation is approximately oriented NNW-SSE and has a length of about 320 m; elevation ranges from about 7 to 80 m a.s.l.. The hill consists of stratified limestone, somewhere densely fractured, with dip direction predominantly oriented in a normal way respect to the slope. Fracture traces are present in variable lengths, from decimetre to metre, and penetrate inward the rock versant with thickness difficult to estimate, often exceeding one meter in depth. The intersection between different fracture systems and the slope surface generates rocky blocks and wedges of variable size that may be subject to phenomena of gravitational instability (with reference to the variation of hydraulic and dynamic conditions). Geometrical and structural info about the rock mass, necessary to perform the analysis of the slope stability, were obtained in this work from geo-referenced 3D point clouds acquired using photogrammetric and laser scanning techniques. In particular, a terrestrial laser scanning was carried out from two different point of view using a Leica Scanstation2. The laser survey created many shadows in the data due to the presence of vegetation in the lower parts of the slope and limiting the feasibility of geo-structural survey. To overcome such a limitation, we utilized a rotary wing Aibotix Aibot X6 RPAS geared with a Nikon D3200 camera. The drone flights were executed in manual modality and the images were acquired, according to the characteristics of the outcrops, under different acquisition angles. Furthermore, photos were captured very close to the versant (a few meters), allowing to produce a dense 3D point cloud (about 80 Ma points) by the image processing. A topographic survey was carried out in order to guarantee the necessary spatial accuracy to the process of images exterior orientation. The coordinates of GCPs were calculated through the post-processing of data collected by using two GPS receivers, operating in static modality, and a Total Station. The photogrammetric processing of image blocks allowed us to create the 3D point cloud, DTM, orthophoto, and 3D textured model with high level of cartographic detail. Discontinuities were deterministically characterized in terms of attitude, persistence, and spacing. Moreover, the main discontinuity sets were identified through a density analysis of attitudes in stereographic projection. In addition, the size and shape of potentially unstable blocks identified along the rock slope were measured. Finally, using additional data from traditional engineering-geological surveys executed in accessible outcrops, the kinematic and dynamic stability analysis of the rocky slope was performed. Results from this step have indicated the deterministic safety factors of rock blocks and wedges, and will be used by local Authorities to plan the protection works for safety guarantee. Results from this application show the great advantage of modern RPAS that can be successfully applied for the analysis of sub-vertical rocky slopes, especially in areas either difficult to access with traditional techniques or masked by the presence of vegetation.

KEY WORDS: 3D point cloud, RPAS photogrammetry, Terrestrial laser scanning, Rock slope, Fracture mapping, Stability analysis