COMPARING TERRESTRIAL LASER SCANNER AND UAV-BASED PHOTOGRAMMETRY TO GENERATE A LANDSLIDE DEM

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ABSTRACT

Gravitational mass movements like landslides are natural destructive processes that can cause enormous losses. Although crucial, identification and monitoring of such areas is time consuming and costly. New technologies such as laser scanning, unmanned aerial vehicles (UAV) and Structure-from-Motion – Multi-View Stereo (SfM-MVS) photogrammetry provides an alternative to conventional mapping methods. A hill with a landslide located in the city of Cunha - SP was surveyed by terrestrial laser scanner (TLS) and UAV-based SfM-MVS. The cloud-to cloud distance was calculated. SfM-MVS point cloud covers a larger area and point distribution is more homogeneous while TLS points have an uneven distribution. Small distances were predominant in the vicinity of the landslide and greater differences only occurred on the scene edges. We conclude that both TLS and UAV SfM-MVS are suitable for landslide investigation according to terrain conditions and other visible limitation factors.

Key words – *Laser scanning, Photogrammetry, Landslides, TLS, DEM.*

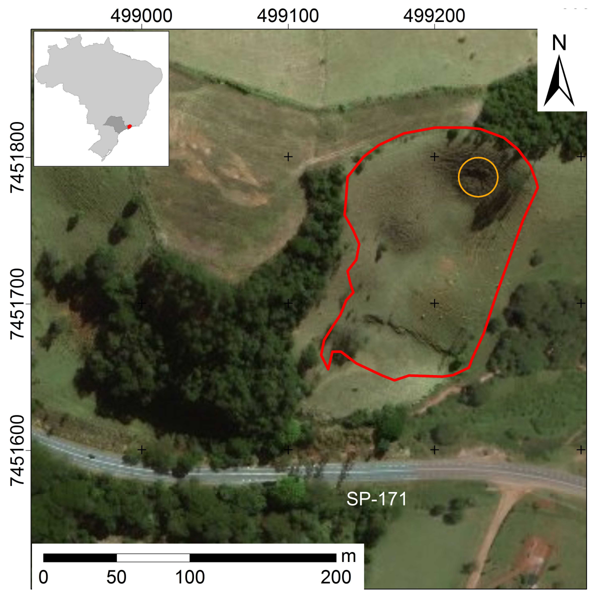

Figure 1: Location map of the Cunha City (left) and of the study area (right). The red line represents the survey boundary and the orange line the area affected by the landslide. Satellite imagery ©2017 Digital Globe, powered by Google. UTM coordinates, zone 23 (South), WGS84.

1. INTRODUCTION

Hill slopes, mainly unvegetated ones, undergo several erosive processes that can compromise their stability. The occurrence of gravitational mass movements in these slopes is usually triggered by natural phenomena such as rains and earthquakes, which when near to highways or inhabited areas can cause enormous economic losses, environmental harm and deaths [1]. Therefore, identification and monitoring of such areas are of high importance for governmental purposes.

Both terrestrial (TLS) and aerial (ALS) laser scanning applied to landslides mapping offers many advantages over traditional methods such as fieldwork, topographic map digitization and aerial photography [2–5]. It allows generation of three-dimensional topographic models, being a more precise method and with little human interference in data acquisition [6]. Rapid data processing with repeated scans and high precision enhances morphometric changes in topography which may indicate sliding process. The combination of Unmanned Aerial Vehicles (UAVs) and Structure-from-Motion–Multi-view Stereo (SfM-MVS) photogrammetry is becoming an increasingly effective tool to gather outcrop data, particularly in the small- to intermediate-scale range and in areas of difficult access [7]. Photogrammetry was pioneer in the development of new methods for topographical surveying and processing, using digital cameras for data collection and softwares for 3D modelling [8].

Both TLS and UAV SfM-MVS methods have been used for landslide monitoring, mapping and 3D surface reconstruction [9–13]. This methods shows great advantages over conventional, costly and time consuming methods but also have their own cons which can compromise the entire project.

In this work we compare point clouds generated by TLS and UAV SfM-MVS for the same area and evaluate which one is more accurate, thus providing better results and allowing more consistent surface interpretation.

2. MATERIAL AND METHODS

2.1. Study area

The surveyed area is located in Cunha City (São Paulo State, southeastern Brazil), at the roadside of km 40 of the Paulo Virgínio Highway (SP-171), and has approximately 15.000 m^2 in area (Fig. 1). The landslide is 14,5 m long and 10 m wide, totaling an area of 145 m^2. The volume displaced from the hill is of 77 m^3 and the main scarp is almost 2 m high. The area presents sparse vegetation, mainly constituted by grass, and soil are partially exposed.

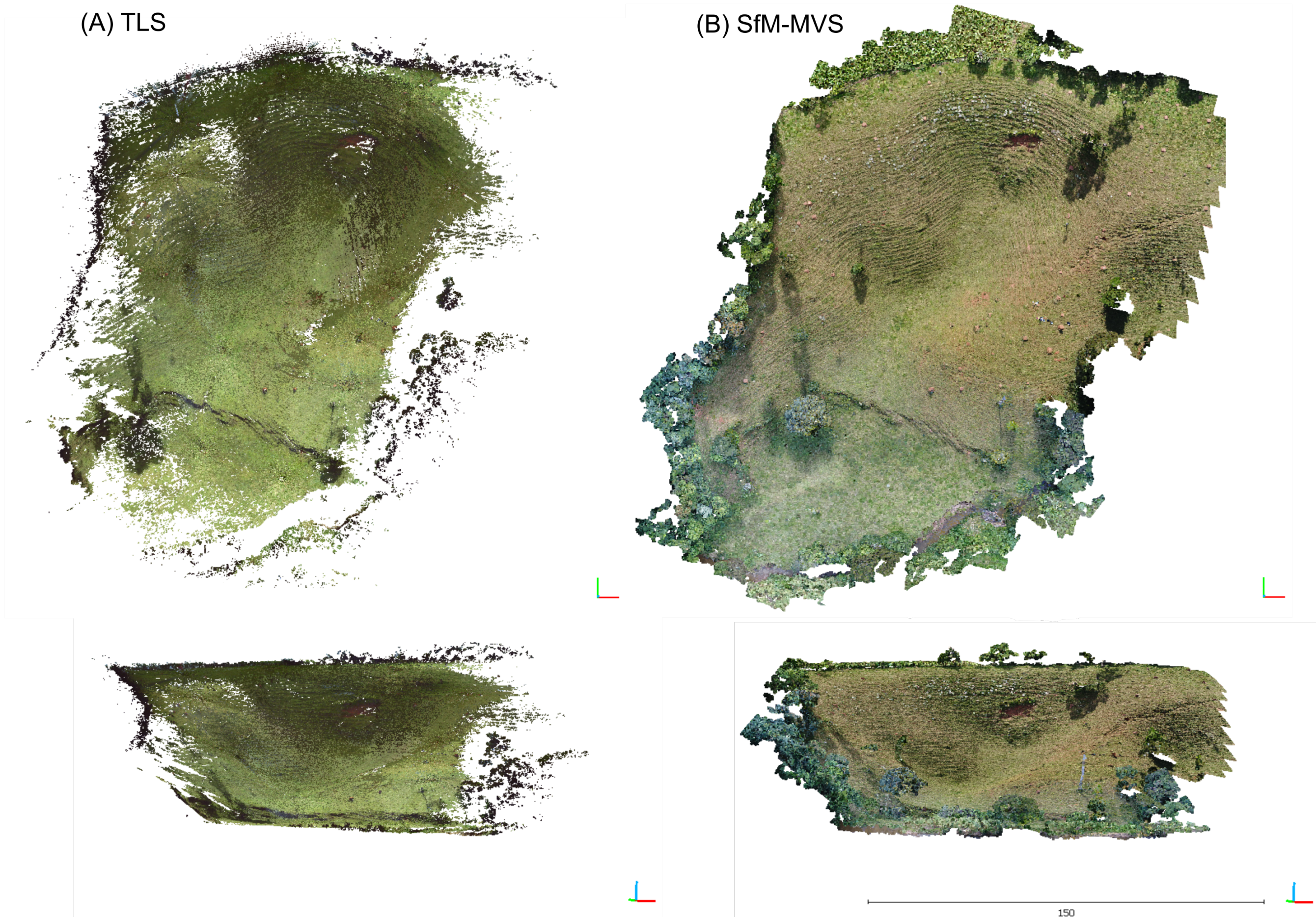

Figure 2: TLS (A) and SfM-MVS (B) point clouds.

2.2. Terrestrial Laser Scanner

A 360° survey was performed from 11 stations allocated around the slide area to generate the TLS point cloud, using a FARO Focus^S 150 Light Detecting and Ranging (LiDAR) equipment. For georeferencing, 8 printed targets were evenly distributed around the landslide and surveyed by irradiation using a total station (TS). Coordinates were collected in field by a Spectra Precision 60 (SP60) equipment and geodetic GNSS post-processing in SPoffice software was used to obtain precise coordinates.

2.3. UAV-based photogrammetry

The image acquisition was made using a DJI Phantom 4 Pro UAV. The onboard digital camera has an 1" CMOS 20MP sensor, with FOV of 84° and 8.8 mm focal distance (24 mm at 35 mm equivalent). The UAV autonomous mission was programed with the MapPilot App [14] which allows the flight height to be set as a constant value above a reference DEM (SRTM), resulting in more consistent pixel size values across the imaged area, even in situations of high relief.

Two missions were flown to cover the entire hillside, both at 40 m above the terrain and with lateral and frontal overlap of 80% beteween photos. For georeferencing, the same targets and coordinates used for the TLS point cloud were applied.

3. RESULTS AND DISCUSSION

TLS raw data is a point cloud with 128,513,743 points (Fig. 2A). FARO SCENE and CloudCompare [15] were used for processing and georeferencig the point cloud. All the markers were automatically recognized by FARO SCENE.

The SfM-MVS point cloud (Fig. 2B) was generated with Agisoft Photoscan [16] using 315 images. The complete SfM-MVS workflow, using the 'high quality' setting of Photoscan, produced a dense cloud with 93,245,315 points. Only 7 markers were identified in the image set, as their vertical positioning - specially the one at a tree trunk that was covered by its crown on the images - makes location difficult.

Visually inspecting both point clouds some contrast is clearly noticed. TLS point cloud, despite having a larger number of points, does not reflect the entire area equally. The point distribution is noticeably denser in areas near the scans positions, gradually losing density with increasing distance due the equipment technical features. Blank spaces in the point cloud are common, mainly further the slide area where points are sparsely distributed. It concentrates points near the scan and even the landslide area has some holes itself, some other viewpoints should be done to scan at least once this blank areas inside the slope.

SfM-MVS point cloud has a more uniform appearance, as points are homogeneously distributed and there are no significant voids. The slope is entirely comprised within the point cloud and the landslide can be clearly identified. This point cloud has approximately 30 million points less than TLS point cloud but covers a larger area.

The difference between the two clouds was computed using the “Cloud-to-Cloud distance” tool in CloudCompare [15] with a threshold of 1 m (Fig. 3). Short distances occur in almost the entire slope and larges distances are predominant in the borders. TLS dod not acquired points so far from the scan positions, concentrating them within the slope, while UAV captured a wider area and SfM-MVS generated a homogeneous point cloud. The greater point clouds distances occur at the borders of the surveyed area, probably beyond TLS scan range or due the presence of ground obstacles blocking the laser beam path. However, points within the slope are very similar even though TLS point cloud being denser than SfM-MVS.

Small differences could be related to georeferencing problems as the UAV does not image vertical targets precisely, like TLS does from the ground position. Fig. 4 shows an example of how the UAV imaged vertical markers. This marker was placed over a termite mound and was in a near vertical position, hindering the correct positioning of its center. Some markers were not visible, affecting the distribution of ground control information and thus affecting georeferencing.

Absence of vegetation also contributes to this smalls differences. UAV images are usually in visible spectral range (RGB) so it has no penetration among leaves. Densely vegetated areas blocks markers from UAV field-of-view (FOV) which increases georeferencing errors and point cloud differences.

Thus, both TLS and SfM-MVS point clouds are suitable for 3D surface modelling in this case. Point clouds differences are minimal in the target area, despite the 30 million points variation between them. Great differences occur only outside the study area and has less influence in modelling process. Absence of vegetation allows digital models generation from both point clouds without significant information loss.

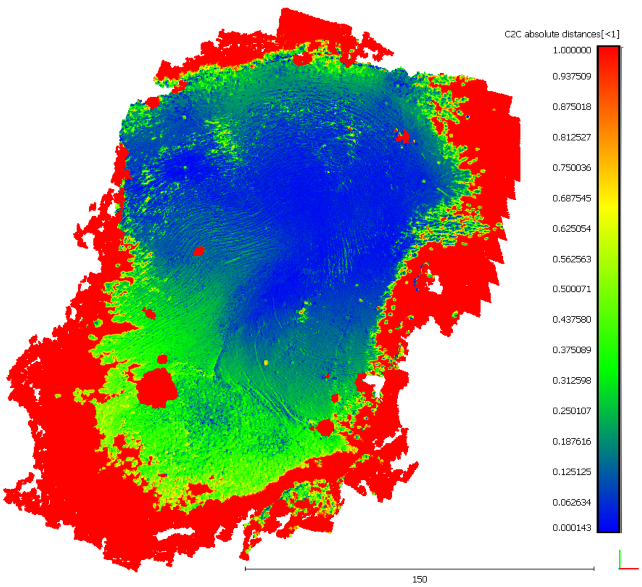

Figure 3: Cloud-to-Cloud distance with 1 m threshold using the TLS as the reference cloud.

Figure 4: UAV image of a printed target.

4. CONCLUSIONS

Laser scanning and UAV SfM-MVS are ultimate tools in evolving surface representation and topographic data acquisition. In the past decades this techniques were used for many applications including landslides mapping and other surface processes monitoring. Both techniques presents pros and cons, but mostly easy handling, high precision and rapid acquisition are great advantages over conventional methods. Knowledge of which technique is more suitable for a specific application is essential for any project, so comparison between TLS and SfM-MVS point clouds are relevant in the choosing process.

A hill slope with a minor landslide within (14,5 m long and 10 m wide), mainly covered by grass and with partially exposed soil was scanned by a FARO TLS and photographed by an UAV. Vegetation absence is critical for comparing both methods once UAV imaging cannot penetrate through the leaves. Final TLS point cloud contains 128,513,743 points while UAV SfM-MVS generates a point cloud with 93,245,315 points, a difference of about 35 million points. “Cloud-to-Cloud distance” tool in CloudCompare was used for comparing both point clouds; it computes the (euclidean) distance between points highlighting their positioning differences. Despite the 35 million points difference in total points, the two point clouds are very similar in the top and center slope areas but present great differences away from these areas. TLS technical limitations and laser beam path obstruction can explain the major differences in the borders of the scene, while georeferencing problems probably causes small differences within the slope. UAV images may have some problems identifying markers in vertical positions, such as in tree trunks or termite mounds, and this can lead to these minor errors in the point clouds.

For this specific terrain conditions, no vegetation cover and few view obstacles, both point clouds are suitable for DEM generation and other surface modelling to identify landslides. TLS majority total points and concentration in target area should provide more detailed DEMs than UAV SfM-MVS, but for local and intermediate scales both methods can be applied with minimal information loss. Choose which method best fit a project depends mainly on personal preferences, budget, mapping scale and study area particulars. Other studies comparing TLS and UAV SfM-MVS in different environments should provide distinct results, and also comparison between ALS and UAV SfM-MVS must yield great results.

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