UAV Based Monitoring of Adatepe Landslide, Canakkale, NW Turkey

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SUMMARY

Unmanned Aerial Vehicle (UAV) based photogrammetry has been studied for many years in order to monitor and analyze of changes in the surface characteristics and topography of landslides between different dates. We can easily obtain the displacement rate and extend by the comparison of digital surface models of landslide area derived from UAV based photogrammetry. Furthermore, the precise 3D surface models provide opportunities for analyzing sliding materials and also fissure structure of landslide.

In this study, we used a low-cost UAV equipment and digital cameras. The Adatepe Landslide is one of the active landslides in Canakkale and the last activity is occurred on November 15th 2013. The landslide is with an average of 22° slope. We took significant numbers of aerial photographs of the Adatepe Landslide (Canakkale, NW Turkey) during campaign of the UAV based photogrammetry. Using plane image rectification methods, we combined these photographs to an ortho-mosaic. The number of photographs is 42 and 367 for toe region and entire landslide. Note that we obtained two different digital surface models of the Adatepe Landslide by merging aerial photographs to a digital surface model by using plane rectifications, i.e. one of the entire landslide and one of the toe region. Finally The generated ortho-mosaic covers the entire sliding area of the Adatepe Landslide with a resolution in level of cm. According to the results, the density of point of our model changes from 0 to 50 points per m^2. The density of point of the digital surface model of the entire landslide can be shown in the prepared thematic maps. In digital elevation models, displaced sections are successfully modeled by scaling discrepancies, protuberances, ridges and grooves on surface. We propose to use the UAV based photogrammetry for analyzing and monitoring the active landslides. As a future work, we plan to extend this approach with GNSS control points by comparing digital surface models for different dates.

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1. INTRODUCTION

1.1 Study Area

This study was carried out on the Adatepe Landslide (Lapseki, Çanakkale, Northern West Turkey). The landslide is located on the North-facing slope of the Adatepe Basin. The landslide is one of the persistently active landslides at Canakkale Bosphorus Region (since the 1960's). It extends over a horizontal distance of 400 m and occurs between an elevation of 60 m at the crown and 20 m at the toe with an average of 20° slope. Its total volume is estimated to be 20.000 m³ and velocities range from 0.001 m up to 0.1 m per day (Erenoglu et al., 2013).

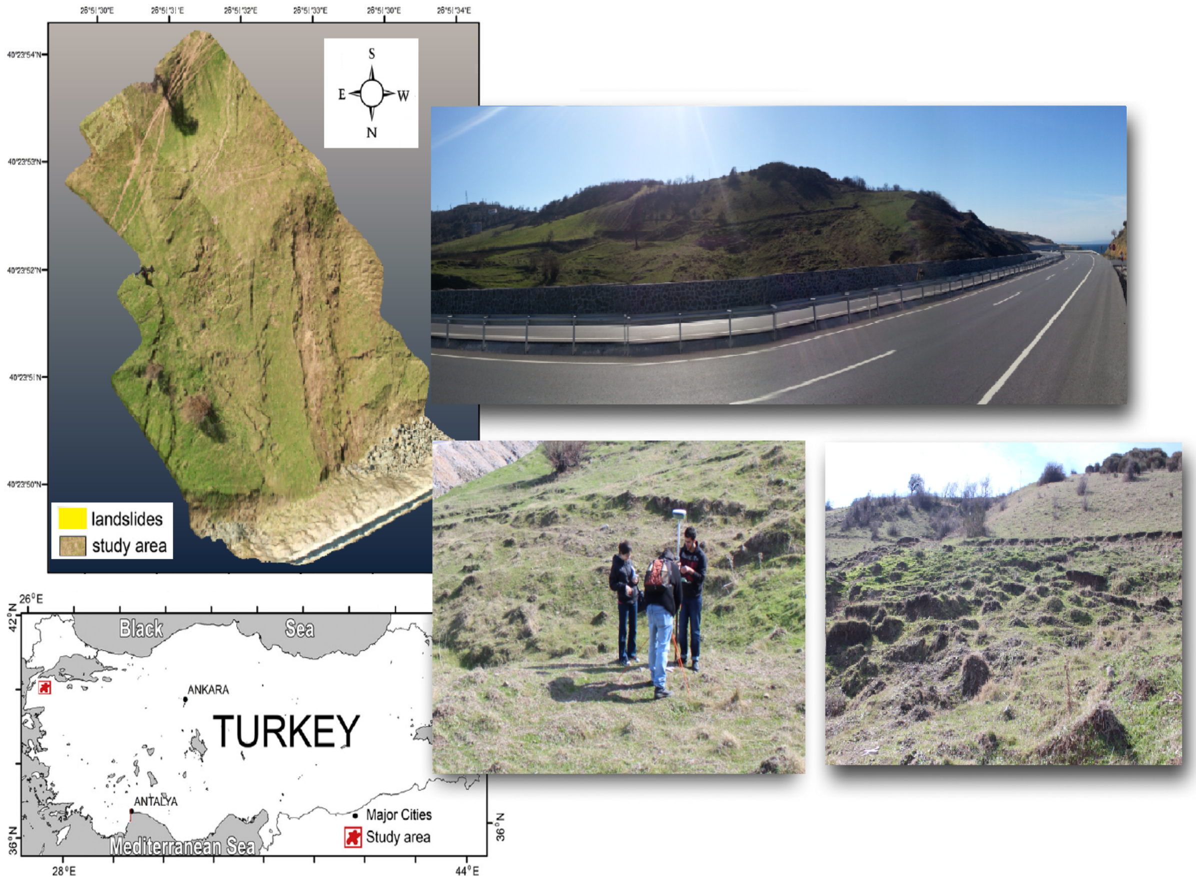

Fig. 1: Studying Area

1.2 UAV-based Photogrammetry and Remote Sensing

Many scientists have been performed UAV-based photogrammetry and remote sensing for many decades. As the first motorized UAV photogrammetry workings, fixed wing remote controlled air vehicles have been developed in 1970's (Przybilla and Wester-Ebbinghhaus, 1979). The first high-resolution digital elevation models was produced by Eisenbeiss et al. (2005) using autonomously UAV helicopter. Nowadays, there are many other UAV-systems for using (Jütte, 2008, Gomez-Lahoz and Gonzalez-Aguilera, 2009, Fotinopoulos, 2004, Aber et al., 2002). If we compared to commercially existing UAV-systems, the costs of such open source systems are so suitable and all software source codes are available in the public domain.

2. UAV SYSTEM

2.1 Eight-Rotor Oktokopter UAV

When compared to conventional helicopters, quad-rotor systems are more stable in flight with reduced vibration and have the mechanical advantage of not requiring a large, variable pitch rotor-unit. Our in-house developed quad-rotor system is stabilized by inertial measurement units (IMU), including three acceleration sensors, three gyroscopes, a three-axis compass, a pressure sensor, and is regulated by basic PID (proportional integral differential) loops. A quad-rotor open source project (Mikrokopter, 2009) has been used and improved by modifications of the software and the electronic circuit in order to comply with the requirements for landslide studies. Technical data of Oktokopter XL can be summarized as follows:

- Dimensions 73x73x36 (BxLxH)
- Payload: recommended max. payload = 2500g
- Max. altitude: Line of sight (several 100m)
- Max. distance: Line of sight (several 100m)
- Flight time: max. 45min at full battery load (30Ah)
- Realistic flight time: 18-28Min (10Ah) See tables below
- Telemetry with speech: Voltage, capacity, current, altitude, distance, direction, speed, temperature

Fig. 2: UAV Okto XL Mikrokopter Full Ready to Fly

Flight time over capacity for UAV Oktokopter is as (See Figure 3):
There are three different curves below
Hoovering -> with no wind and e.g. position Hold
Normal -> in light wind and normal flight
Sportive -> high winds or fast flight

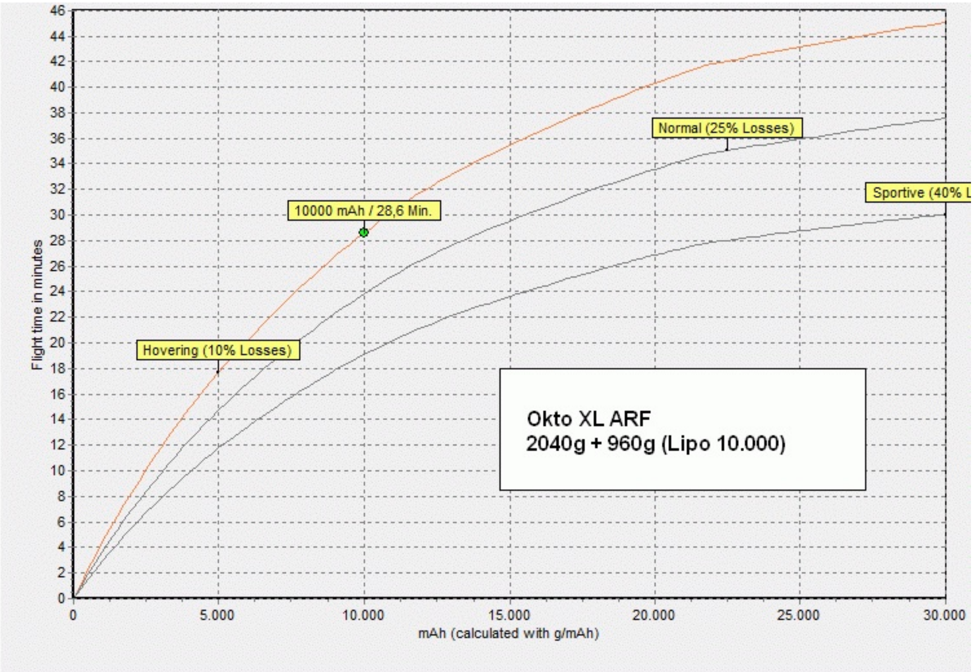

Fig. 3: Calculation of flight time with increasing battery capacity, account for battery weight

2.2 Camera- Systems

For optimum flight time, the eight-rotor UAVs should be equipped with lightweight low-cost digital compact camera, which support manual camera settings. In this study, we used Canon EOS-M Mirrorless Digital Camera. For all flights the camera settings were fixed to ISO 200 at F2.8 and a focus of 18 mm. These settings enabled an average shutter speed of 1/800 s which was necessary to avoid blurred photographs.

Fig. 4: Canon EOS-M Mirrorless Digital Camera

Specifications:
Type: Digital single-lens non-reflex, AF/AE camera
Image Format: 22.3 x 14.9 mm (APS-C size)
Compatible Lenses: Canon EF-M lenses, Canon EF lenses including EF-S lenses (35mm-equivalent focal length is approx.1.6x the lens focal length)
Lens Mount: Canon EF-M mount (Canon EF-M lenses can be mounted directly to the camera. Canon EF lenses (including EF-S lenses) can be attached by using the optional Mount Adapter EF-EOS M.)

Lens System:
Type: Wide-angle lens - 22 mm - F/2.0 STM Canon EF-M
Focal Length Equivalent to 35mm Camera: 35 mm
Focus Adjustment: Manual/Automatic
Min Focus Range: 5.9 in
Max View Angle: 63.5 degrees
Lens Construction: 6 groups / 7 elements
Filter Size: 43 mm
Lens System Mounting: Canon EF-M

3. CAMERA CALIBRATION SCHEME

Camera calibration determines information about the camera that improves accuracy in subsequent studying projects. Calibration process calculates the camera's focal length, lens distortion, format aspect ratio, and principal point. The resulting calibration data file can be saved on disk for use in all the projects that involve photos taken by that camera. High accuracy works, e.g., digital surface modeling, require a well calibrated camera. Various calibration algorithms have been developed and improved over a period of more than decades. Some automatic camera calibrator are fully automated and very accurate, plus it is included at no extra charge as part of the basic software package. It is designed to be so practical to use and suitable for the broadest range of automatic camera calibrator users. In this study, we used PhotoModeler's camera calibrator. To do it, we have performed the field calibration project using calibration sheets including the coded targets, see Figure 5. The calibration status report is given in Figure 6.

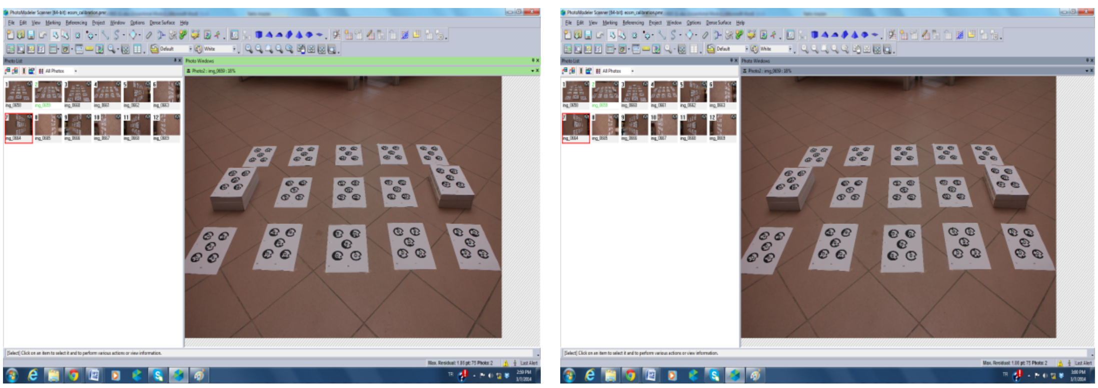

Fig. 5: Calibration process using calibration sheets.

```
Status Report Tree
   Project Name: eosm_calibration.pmr
   Problems and Suggestions (1)
      Project Problems (1)
         Problem: A large percentage of your points are sub-pixel marked
so it is assumed you are striving for a high accuracy result. The largest
residual (Point75 - 1.86) is greater than 1.00 pixels.
            Suggestion: In high accuracy projects, strive to get all
point residuals under 1.00 pixels. If you have just a few high residual
points, study them on each photo to ensure they are marked and referenced
correctly. If many of your points have high residuals then make sure the
camera stations are solving correctly. Ensure that you are using the best
calibrated camera possible. Remove points that have been manually marked
unless you need them.
      Problems related to most recent processing (0)
   Information from most recent processing
      Last Processing Attempt: Fri Feb 07 16:23:40 2014
      PhotoModeler Version: 2014.0.0.1302 - final,full (64-bit)
      Status: successful
      Processing Options
         Orientation: on
            All photos oriented.
            Number of photos oriented: 12
         Global Optimization: on
         Calibration: on (full calibration)
         Constraints: off
      Total Error
         Number of Processing Iterations: 4
         Number of Processing Stages: 2
         First Error: 41.112
         Last Error: 4.548
      Precisions / Standard Deviations
         Camera Calibration Standard Deviations
            Camera1: Canon EOS M [18.00]
               Focal Length
                    Value: 18.697047 mm
                    Deviation: Focal: 0.003 mm
               Xp - principal point x
                    Value: 11.632606 mm Deviation: Xp: 0.005 mm
               Yp - principal point y
                    Value: 7.782084 mm  Deviation: Yp: 0.006 mm
               Fw - format width
                    Value: 22.768255 mm Deviation: Fw: 0.003 mm
               Fh - format height
                    Value: 15.163800 mm
               K1 - radial distortion 1
                    Value: 4.947e-004   Deviation: K1: 3.9e-006
               K2 - radial distortion 2
                    Value: -8.669e-007  Deviation: K2: 2.9e-008
               K3 - radial distortion 3
                    Value: 0.000e+000
               P1 - decentering distortion 1
                    Value: -6.402e-005 Deviation: P1: 3.7e-006
               P2 - decentering distortion 2
                    Value: 1.169e-004  Deviation: P2: 4.1e-006
```

Fig. 6: Calibration status report

4. IMAGE ACQUISITION

On February 20th 2014, a set of UAV-acquired photographs covering the whole sliding area were taken. The achievable altitude over ground was in the range between 30 m and 60 m. All photographs were taken manually using shooter of remote controller and First Person View (FPV) flying mode. In a first in-situ flight planning step, the desired area and suitable locations for starting and landing were chosen. Then the quadrotor was launched to the maximum flight altitude of about 50 m. At this location the UAV was hovered for about 30 seconds. Note that the pilot initiated vertical landing. After each flight, we downloaded and checked the covered area of the acquired photographs on-site.

Fig. 7: Some examples of taken aerial photos by UAV

5. DIGITAL SURFACE MODEL PROCESSING

In order to produce digital surface model, we processed the data in PhotoModeler Scanner software. The photographs of the entire landslide (manually pre-selected by criteria like image quality and covered area size) were computed to digital surface models in 4 sub-areas. First, all photographs were processed to get the image planes from UAV photos and the image frustum plane, see Figures 8 (a) and (b). Then, these data were supplied to the patch based multi view stereo procedure of the software which finally computed a dense point cloud for all supplied photographs. Thereby, we obtained 3D digital surface model including point cloud with single color and point cloud with exact color from photo as seen in Figures 8 (c) and (d). Furthermore, the connectivity among the photos in Figure 9 clearly shows high quality production of digital surface models during software process.

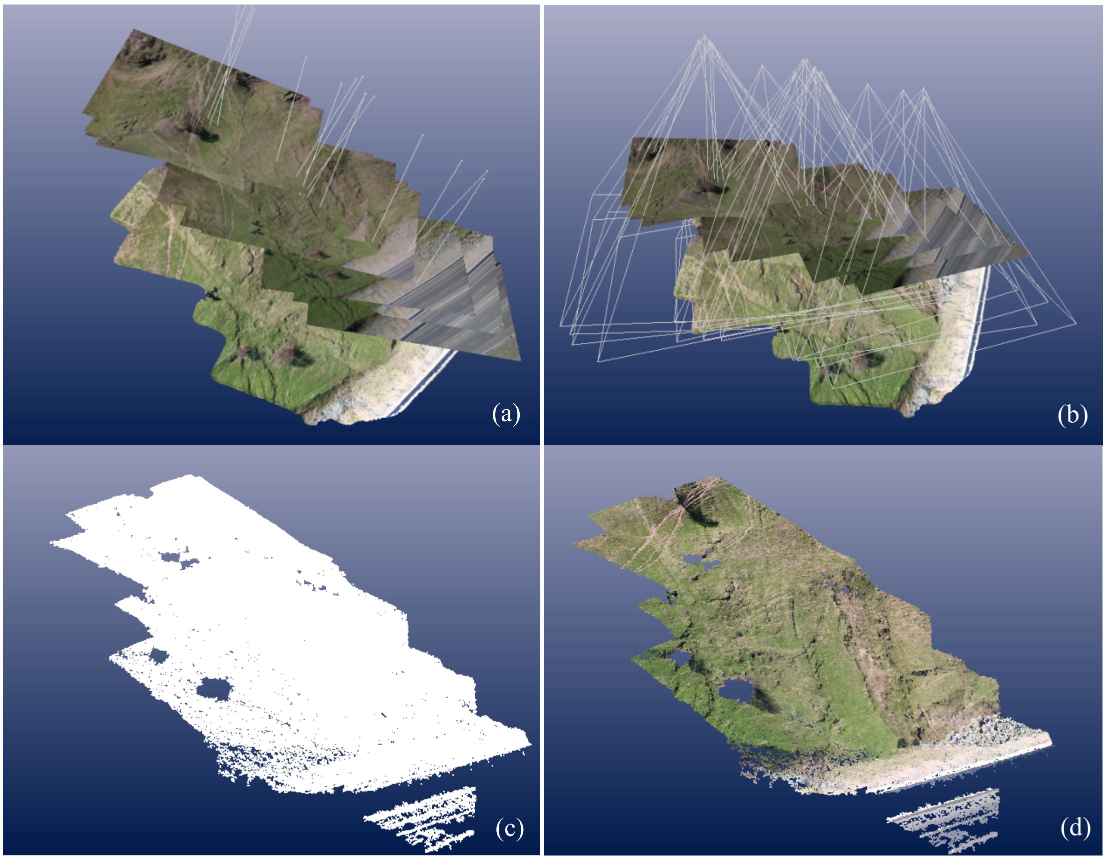

Fig. 8: (a): Image planes from UAV photos. (b): Image frustum plane. (c): Point cloud with single color. (d): Point cloud with exact color from photo.

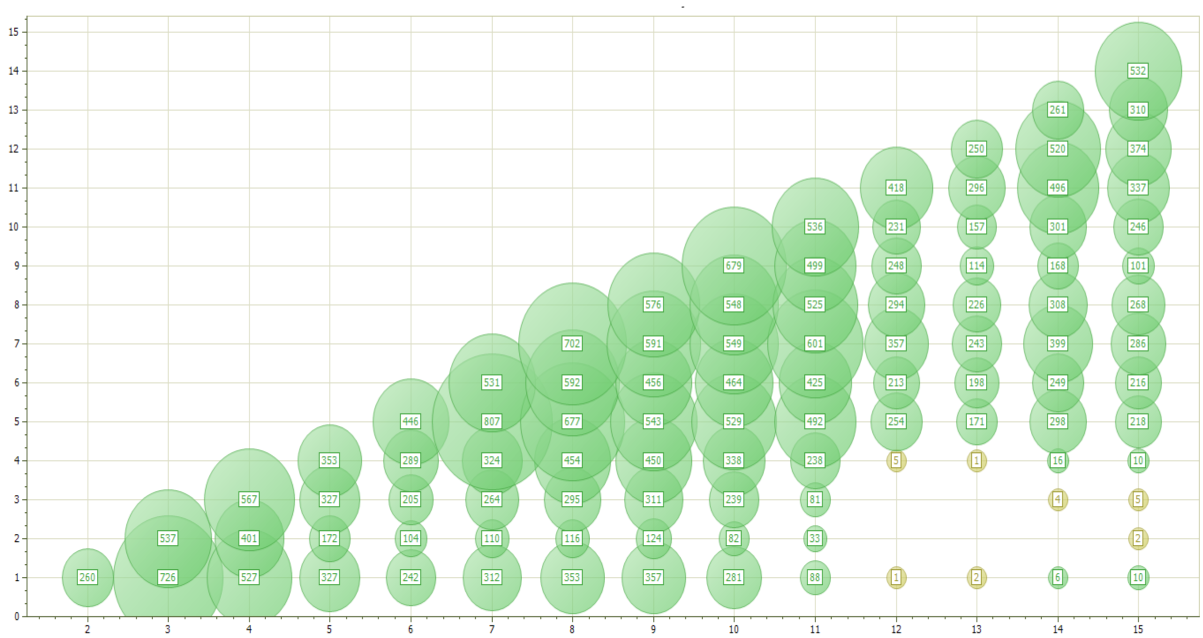

Fig. 9: Photo connectivity during the processing step.

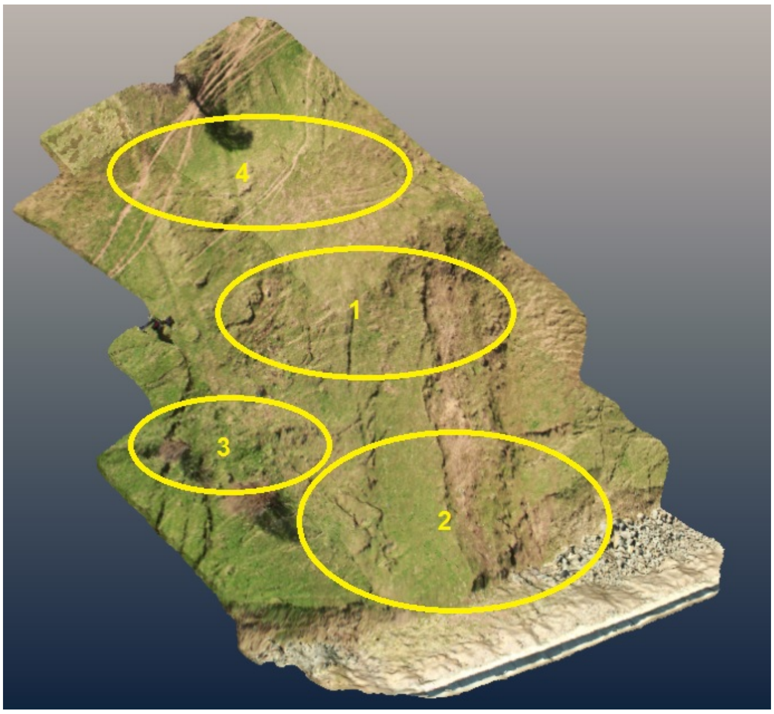

Fig. 10: 3D model of landslide showing the sub-areas

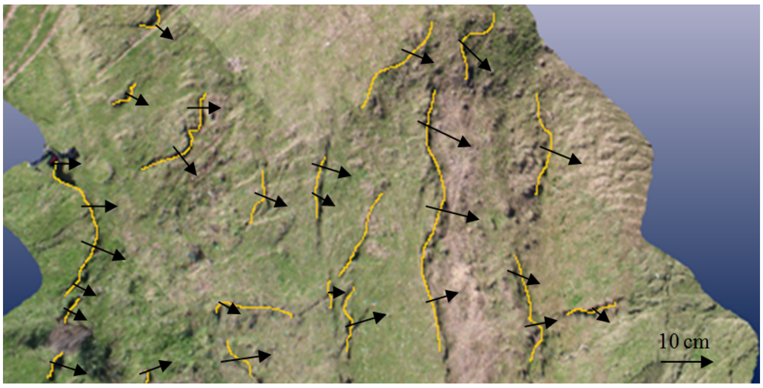

Fig. 11: Sliding locations and velocity vectors in 3D model of sub-area #1

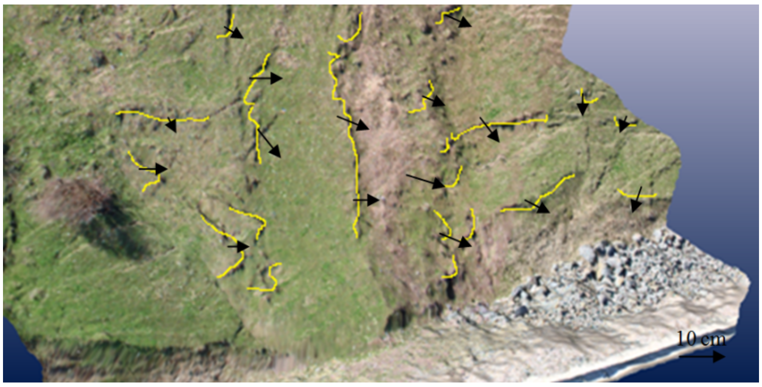

Fig. 10: Sliding locations and velocity vectors in 3D model of sub-area #2

Fig. 11: Sliding locations and velocity vectors in 3D model of sub-area #3

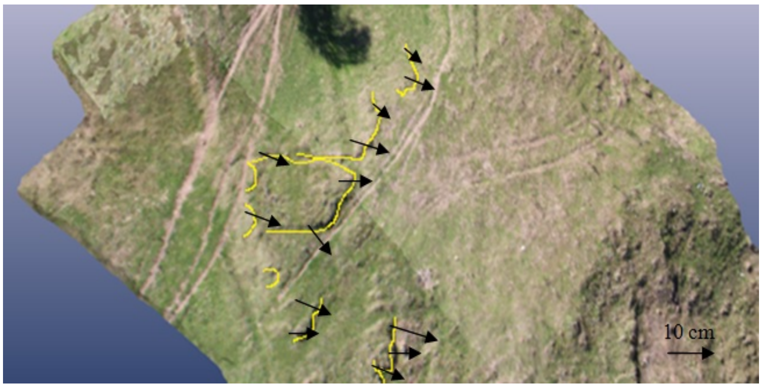

Fig. 12: Sliding locations and velocity vectors in 3D model of sub-area #4

DSM precision analysis; In order to assess the quality of the generated digital surface models, the surface model of the landslide toe-region was compared to the result of terrestrial photogrammetric surveys. Both surface models successfully were computed using the same criterions. Note that all results cannot be presented due to the lack of space.

6. CONCLUSIONS

In this study, we showed that a low-cost UAV-based remote sensing approach reveals high-resolution digital surface models for landslide monitoring. The density of point of the digital surface model of the entire landslide can be shown in the prepared thematic maps. In digital elevation models, displaced sections are successfully modeled by scaling discrepancies, protuberances, ridges and grooves on surface. We propose to use the UAV based photogrammetry for analyzing and monitoring the active landslides. As a future work, we plan to extend this approach with GNSS control points by comparing digital surface models for different dates. The proposed structure from motion method can easily handle unordered image collections and has provided a consistent digital surface model of the Adatepe landslide that is consistent with results from a more traditional photogrammetric approach.

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