11TH INTERNATIONAL SYMPOSIUM FIELD MONITORING IN GEOMECHANICS

PhotoMonitoring™ as innovative solution for landslide monitoring: the IRIS tool

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Abstract

In the latest years, thanks to the increasing use of technological devices, Remote Sensing techniques have become crucial tools providing useful data suitable for monitoring purposes. PhotoMonitoring™ technique, using advanced algorithms on multi-temporal images, represents an innovative remote monitoring option obtaining accurate data about unstable slopes, embankments, etc. in terms of changes and displacements.

In this framework, this paper focuses on IRIS software (developed by NHAZCA) implemented with embedded advanced image analysis algorithms of pre- and post-processing. This software is conceived to operate with different types of images (e.g., optical, thermal, SAR amplitude, etc.) acquired by different platforms (e.g., ground, aerial, satellite). This allows to manage and analysis a large amount of available data.

Thanks to recent testing conducted both in lab and on the field, it was proved that the software can detect a surface deformation with an accuracy ranging from 1 to 1/100th of a pixel, meaning sub-millimetric accuracy in case of high-resolution acquisitions.

Thus, the use of such image-processing software represents a suitable solution. A clear advantage is represented by the use of low-cost equipment in terms of sensors (Digital Single-Lens Reflex) and platforms (drones) which makes the deployment very affordable. The advantages of IRIS are also represented by its scalability (both spatial and temporal) that allows a wide variety of applications: from laboratory scale (e.g., compression test in rock mechanics) to large regional scale (e.g., landslides mapping).

Keywords: Photomonitoring, Landslide, Monitoring

1. Introduction

Landslides are one of the most common Natural Hazards, leading to severe human and economic losses worldwide. Geomorphological and topographic changes represent the most evident consequences of landslides. In this perspective, Remote Sensing techniques are able to collect data of the ground surface (e.g. digital images), having a great potential for landslide assessment and monitoring purposes. In the latest years, thanks to the increasing use of technological devices, Remote Sensing techniques have become crucial tools providing qualitative and quantitative data suitable for landslide assessment and monitoring. This is particularly true during emergencies, when it is crucial to acquire data and provide useful information as quickly as possible.

Among Remote Sensing technologies, such as SAR Interferometry and Laser Scanning, PhotoMonitoring™ is becoming a robust method to analyse ground deformations. In fact, the increasing availability of digital images (e.g., panchromatic, multispectral, hyperspectral, etc.) from different platforms (satellite, aerial, terrestrial) is paving the way to new applications and solution, for monitoring purposes too.

PhotoMonitoring™ is based on the concept of "digital image processing", i.e., the manipulation of digital images to obtain data and information. Analyses can be carried out on datasets of images acquired from the same type of platform, on the same area of interest, at different times, and can be conducted using specific algorithms that make it possible to assess any variation in radiometric characteristics (Change Detection) and/or the shift that has occurred in the time interval covered by the acquisition of the images (Digital Image Correlation). Through these applications it is possible to study the evolution and significant changes of the observed scenario, therefore, if applied to Earth Observation they allow to better map geological and hydrogeological hazards, understanding the evolution and causes of the processes in place.

2. Material and Methods

In image analysis, Change Detection (CD) refers to the capability to identify the location and magnitude of changes between a couple of images acquired at different times. Several analytical unsupervised methods have been proposed and used over time to assess changes in images, ranging from simple image difference to MSE (Mean Squared Error) measures, however most of these fail in accurately identifying perceived changes at a human vision level.

Digital Image Correlation (DIC) is an optical-numerical measurement technique capable of providing full-field 2D surface displacements or deformations of any type of object. The deformations are calculated by comparing and processing co-registered digital images of the surface of the same "object" collected before and after the deformation event (Fig.1). Digital Image Correlation allows to evaluate, in a quantitative way, the displacement and deformations occurred between two images acquired at different times by analyzing the different pixel blocks and allowing to obtain a resolution that can go up to 1/100 of a pixel.

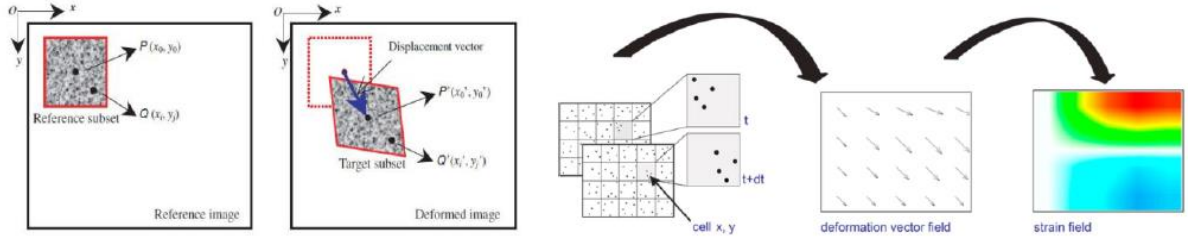

Figure 1: Digital Image Correlation (DIC) process.

These techniques could be affected by environmental effects caused by different atmospheric and illumination conditions, temperature changes and inherent problems with the camera's viewing geometry. Using high resolution, accurately positioned and aligned images, it is possible through CD and DIC to identify differences, deformations and changes in the observed scenery with high precision.

Recently, several authors have presented interesting results derived from the application of CD and DIC analysis with terrestrial, aerial and satellite imagery for landslide displacement studies. The use of these data processing procedures is currently not very widespread, although there is a lot of availability of images coming from different remote sensing sensors (Optical, RADAR, LIDAR). In this context, NHAZCA S.r.l., a Startup of Sapienza University of Rome, has developed IRIS, an innovative software designed for PhotoMonitoring^{TM} applications. The software provides different types of processing procedures for remote sensing images, allowing to carry out change detection and displacement analysis. The Change Detection method implemented makes use of Structural Similarity Index Measure, an algorithm originally developed to evaluate the perceived quality of digital television and film images in which the measurement of image quality is based on an initial image taken as a reference. The method here is used on a local scale, iteratively assessing image similarity over a small subset of image pixels using a sliding window approach, allowing the identification of portions of the scene that have undergone alterations and the precise definition of the edges of those changes. The Displacement Analysis method implemented makes use of different types of algorithms that exploit different analysis techniques (e.g., Feature Tracking; Template Matching).

3. Result and Discussion

Here are presented and discussed the results obtained from the analysis carried out on different application cases that show the full potential of Earth Observation techniques, and more specifically of IRIS and PhotoMonitoring^{TM}, a reliable and versatile tool for landslide analysis and monitoring.

The study was carried out on two main sites using of different pairs of images. In particular, the analysis was carried out on:

- landslide affecting a transportation asset in Southern Italy using images collected by a Digital Single-Lens Reflex (DSLR) from 900m away (terrestrial images, Fig.2 up);
- landslide in Washington State (US) using the available stack of PlanetScope images (satellite images, Fig.2 down).

The results obtained are displacement maps representing the movement pattern including the magnitude (depicted according to a metric colour scale) and direction on the focal plane (represented by arrows) of the landslides under study (Fig. 2).

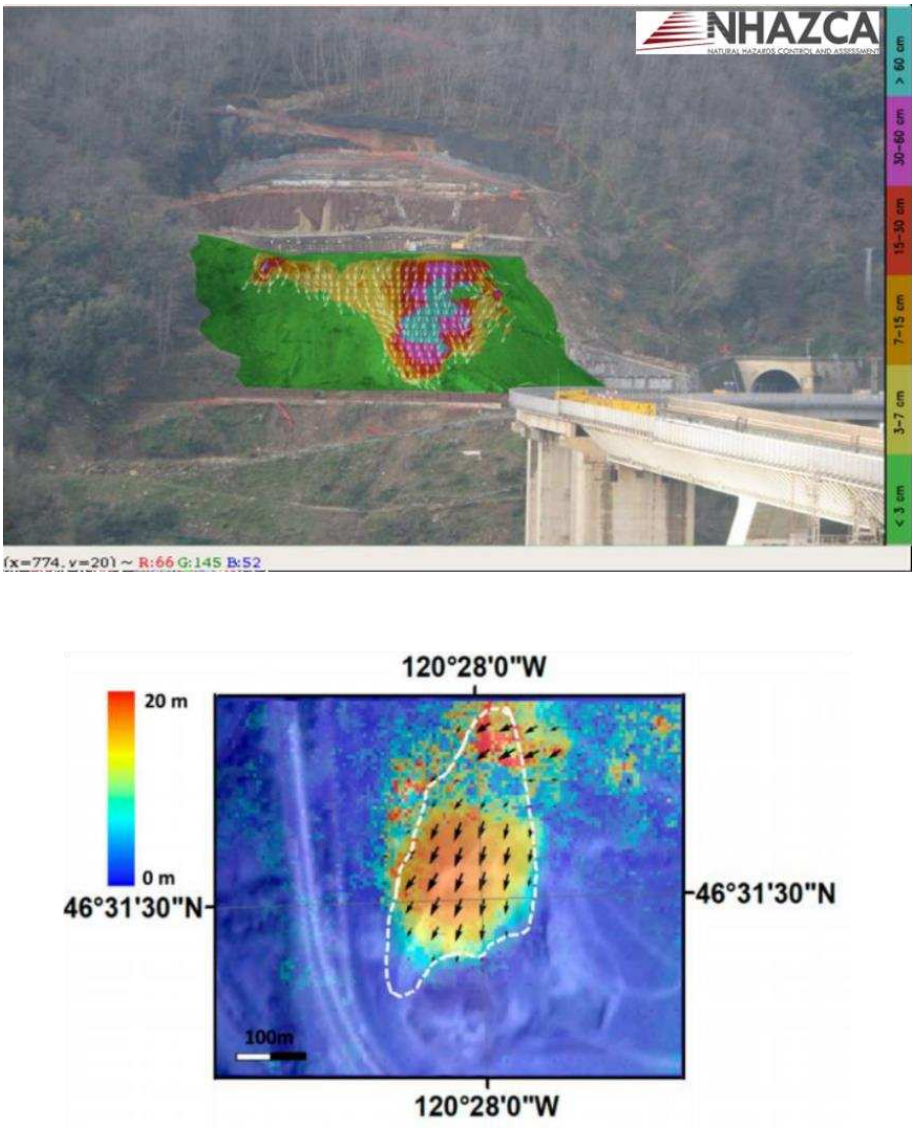

Figure 2: Up. Displacement pattern of a landslide affecting a transportation asset in Southern Italy by using images collected by Digital Single-Lens Reflex (DSLR) from 900m away. Colours indicate the intensity of displacement while white arrows represent the main displacement directions (IRIS software screen). Down. Displacement map (NS-EW components) of a landslide in Washington State (USA) between September 2017 and September 2018. This map was obtained by applying the Sliding Time Master Digital image correlation Analyses (STMDA) processing method to the available stack of PlanetScope images (Satellite images).

4. Conclusions

The PhotoMonitoringTM analyses presented in this paper allowed to study and evaluate the effects, in terms of surface displacement, of two main landslides located in different places. these analyses carried out using terrestrial and satellite images with a new generation software called IRIS, developed by NHAZCA S.r.l. - Startup of Sapienza University of Rome, allowed also to identify, map, and monitor the displacement pattern of landslide interfering with strategic infrastructures. The results obtained allow to fully understand the potential of Remote Sensing techniques, and more specifically of PhotoMonitoring^{TM} technique and IRIS software, a reliable and

versatile tool that allows the study and monitoring of the impact of geohazards such as landslides, through data from different sensors (e.g., optical, RADAR, LIDAR).

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