Utilization of Digital Photogrammetry in Spatiotemporal Knowledge of Landslides

M. MASTERE*[1 2 3], L. AÏT BRAHIM[3], B. VAN VLIET-LANOË[1 2], N. ELFAHCHOUCH[3], E. GUELZIME[4], H. JIRARI[5] and A. ABDELOUAFI[3]

(1*) Université Européenne de Bretagne, France. Mohamed.Mastere@univ-brest.fr
(2) Université de Brest, CNRS, UMR 6538 Domaines Océaniques, Institut Universitaire Européen de la Mer, PlaceCopernic, 29280 Plouzané, France.
(3) Faculté des Sciences de Rabat, Laboratoire GEORISK, Av Ibn Batouta B.P. 1014, Rabat-Agdal, Maroc.
(4) Mastère de la Conférence des Grandes Ecoles : SILAT Maison de la Télédétection AgroParisTech/ENGREF-UMR TETIS 500, rue Jean-François Breton F-34093 MONTPELLIER CEDEX 5, France.
(5)Institut scientifique de Rabat, Laboratoire de Géophysique. Av Ibn Battouta, B.P. 703, Agdal 10106 Rabat – Maroc.

Summary

Mapping of landslides involves providing informations about the spatial distribution, the type and the lateral borders, the upstream and the downstream of these phenomena, for a proper understanding of their dynamics. Remote sensing imagery and GIS technology are powerful tools for monitoring landslides, because they offer the possibility to have a synoptic view that can be repeated at different times intervals, and their integration into a GIS allowing a multiple layers data superposition to characterize the geometry and follow the evolution of a landslide. Combination of the spatial airborne and the satellite imagery is a promising method for the study of landslides. Airborne data, is then used with a new method of digital elevation model (DEM) calculation from aerial photographs, and apply this method to the Bou Halla landslide in the central Rif in Morocco. The method uses new techniques of image correlation, restitution of camera parameters, allows reconstitution of the topography, and orthorectification of aerial photographs with metric precision and spatial resolution.

1. Introduction

Analyses of spatio-temporal evolution of landslides in recent decades and related landform evolution are often based on the use of aerial photographs. The use of detailed digital photogrammetric techniques offers the possibility to obtain more precise landslide inventories as well as quantitative data to characterize its geometry and landform evolution. Landslide activity is controlled by external parameters like slope, precipitations, erosion or run-off and internal parameters, among which the fracturing, the geotechnical characteristics, the geometry of the slip surface and its spatial and temporal evolution play an important role. Displacements and topographic variations traduce this activity at the surface. The depth and the geometry of the slip surface are usually deducted on boreholes, or by geophysical investigations (Henry et al 2002). However, these techniques are very expensive and very difficult to be available to us in Morocco and difficult to apply on unstable area. Moreover, they give limited results to the area and to the period of investigation (Meric et al 2007, Ait Brahim et al., 2003). Nevertheless, remote sensing presents an alternative, and a very powerful tool, for improving the spatial resolution of measurements, without in situ investigations, when we can use multitemporal aerial photographs in spatiotemporal knowledgement of landslides. This technique is based on the use of images with a temporal and a spatial resolution adapted to landslide studies. Moreover, these kinds of images are acquired about 30 years. They are currently used to generate Digital Elevation Models (DEMs), and orthorectified images in order to detect and follow landslide activity (Weber et al 2000; Casson et al., 2003; Van Ash et al 2006). This paper presents a methodology of slip surface characterization using surface measurements. The processing of surface data generation is also detailed. Then, a qualitative analysis of these multitemporal remote sensing data is realised to characterize the spatiotemporal of the Bou Halla landslide (Central Rif in Morocco).

2. Methodology

For the purpose of spatiotemporal evolution knowledgement and geometric characterization of landslide, we developed a new method of digital elevation data (DEM) calculation from aerial photographs (called stereoscopic couples) and complementary derived products in terms of orthorectifed images and perspective views. These treatments were realised with three software packages whose use and sequencing are shown below (Figure 1).

2.1. Data set traitment

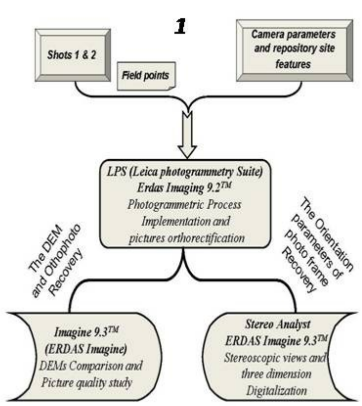
Four aerial stereoscopic photographs acquired in1965, 1978, 1988 and 1995, that were selected from database have been used in this study. These images were acquired above the Bou Halla Jbel. They cover a period of 30 years, with a temporal resolution ranging from 7 to 13 years. The analog images are scanned to obtain a spatial resolution about 1m . For each year, DEM and orthorectified images are generated. Then, DEMs and various orthorectified images are compared to monitor the Bou Halla landslide.

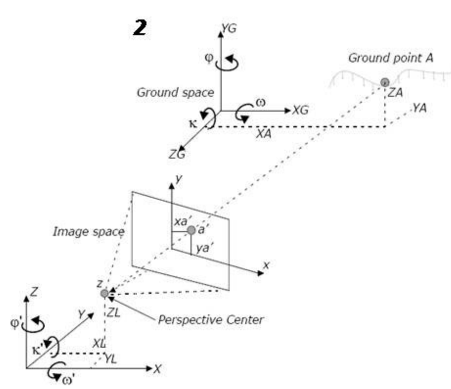
2.2. Aerotriangulation

In this processing, the initial digital pictures were all generated at the same ground resolution of one meter. The digital elevation model calculation from aerial photographs needs two types of informations: the restitution of optical parameters of the different cameras used, and the precise geographical coordinates of a set of connecting points defined in the study area, allowing correction of acquisition distortions. The triangulation operation based on this information, consists in the calculation of mathematical equations linking the real geodetic coordinates of the reference points in the field of their coordinates in the pictures. The image and ground space coordinate systems are right-handed coordinate systems. Most terrestrial applications use a ground space coordinate system that was defined using a localized Cartesian coordinate system. The image space coordinate system directs the z-axis toward the imaged object and the y-axis directed North up. The image x-axis is similar to that used in aerial applications (Van Westen et al 2003, Chaplin et al 1998). The XL, YL, and ZL coordinates define the position of the perspective center as it existed at the time of image capture. The ground coordinates of ground point A (XA, YA, and ZA) are defined within the ground space coordinate system (XG, YG, and ZG). With this definition, three rotation angles ω (Omega), ϕ (Phi), and κ (Kappa) define the orientation of the image. We can also use the ground (X, Y, Z) coordinate system to define directly GCPs. Thus, GCPs do not need to be transformed (Figure 2). Then the definition of rotation angles ω', ϕ', and κ' are different. In our case, initial camera angles are considered equal to zero, because of the near vertical acquisition (Casson et al 2003). These approximate values have to be improved by a least mean squares minimization. Firstly, ground points localized by GPS are identified on images. Then, photogrammetric equation is used to calculate image coordinates of the control points, using initial acquisition parameters and ground positions of the control points. After a first least mean squares minimization, new camera angles and new camera positions are obtained. The convergence is obtained for 15 points equally localized over the whole image. This method is called the absolute orientation of cameras (Mora et al 2003).

Conclusions

Multi-temporal analysis of the four DEMs and orthorectified images allowed to obtain several informations, concerning geomorphologic evolution. It allows in particular, to place the different periods of the Bou Halla landslide reactivation, between 1965 and 1995. 1965 aerial photographs show a sector where the various types of movements in the current side had already started. However, marl accumulations materials did not go below the 700m coast; while breaches and groizes, in the upstream of the road were widely represented. In 1978, two distant movements as the crow flies from 6.5km occurred at the same time. It is the one of P.K29 900 and the J. Akroud casting of stones (Mastere 2008, Mastere et al 2009, Alaoui 2005, Mansour et al 2005). Unfortunately, we could not establish a link between the role of rainfall and landslide triggering at this period, because the study area meteorological stations did not work. Although, we will try to make the relationship between the Bou Halla landslide and the earthquake of 8 magnitude registered on the Richter scale on February 28 at 400km from the coast of Morocco.The sliding of these successive packages of groizes formations landslide was made inward the khandak (ravine) which is increasingly dislocated towards the downstream because of their weak cohesion. These packages see their product spreading on soft slop, and covering a big part of the marly material formerly slid .The continuation of this sliding, a crack appeared at the foot of the massif; cubit to the east (Figure 3), it continues downstream. 1988 DEM and orthorectified image show a landslide which started in the Tangiers marls inside the national road number 2 which it completely took. This landslide was occurred on 4 May 1984 according to the testimony of the inhabitants of this douar. The main escarpment of this movement is about twenty meters and the width to the head did not exceed the originally hundred meters. This movement had the effect of pursuing and increasing the disorders due to the previous movements with the reorganization of deep formations until now saved. 1988 and 1995 DEMs and orthorectified images allowed us to estimate that the front of Bou Halla landslide has reached a width of 300m and the slope of the main escarpment has decreased. This decompression by call vacuum, introducing transverse cracks, is followed by differential collapses of the unwound material. When the hydrique contribution is important, these unwound materials of weak cohesion reach the limit of liquidity. Then, we obtain pasty castings, which become widespread towards the downstream. Gradually, by the importance of the streaming, the finest particles of this weak cohesion material are transported towards the downstream. It enlarge the accumulation zone and leaving in place under chaotic forms of heap, all which was not able to be transported. The accumulation, ended by a frontal bourrelet pushes away towards the downstream almost 400m. The not reshaped Marly mass undergoes at the same time a decompression by the banks sapement, as proving by the transverse cracks . This translationnel movement makes probably on the synsedimentary limestone bench of the Tangier unity. That has been enregistred later than the collection of the soil erosion after the movement. Since 1995 and until now, the Bou Halla landslide shows a stability which risks to be interrupted at any moment.





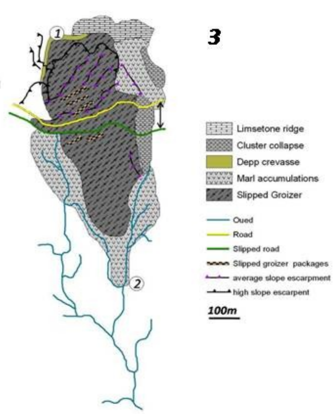


Figure1: Various steps and software's for DEMs and orthoimages construction
Figure2: The image and ground space coordinate systems relationship
Figure3: Final plan of Bou Halla landslide evolution since 1965 until now: 1: Deep crevasse; 2: frontal bourrelet

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