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Application of a long-range Terrestrial Laser Scanner to a detailed rockfall study at Vall de Núria (Eastern Pyrenees, Spain)

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Abstract

In this study we show the application of a long-range Terrestrial Laser Scanner (TLS) to a detailed rockfall study in a test zone at Vall de Núria, located in the Eastern Pyrenees. Data acquisition was carried out using TLS-Ilris3D, the new generation of reflector-less laser scanners with a high range, accuracy and velocity of measurements. Eight scans were performed at 3 stations to acquire coordinates of almost 4 million points. The results from the acquired data are a high accuracy Digital Elevation Model (DEM) and the reconstruction of the joint geometry. The former is used for inventory of rockfalls and for more accurate rockfall simulation (trajectories and velocities). The latter allows us to model the geometry and volume of the source area in recent rockfalls. Our findings suggest that TLS technology could be a tool of reference in rockfall studies in the near future.

Keywords: Rockfall; Terrestrial Laser Scanner; DEM; Rock slope; 3D geometry modelling; Eastern Pyrenees

1. Introduction

Rockfall is the relative free falling or precipitous movement of a newly detached segment of bedrock from a cliff or other very steep slope (Bates and Jackson, 1987). Since rockfall is the fastest type of landslide (Varnes, 1984), it presents a common risk to transportation and structures in steep mountainous terrain (Pfeiffer et al., 1995; Corominas et al., 2003).

In recent years considerable advances have been made in the analysis of rockfall susceptibility (Marquínez et al., 2003; Baillifard et al., 2003; Günther et al., 2004), in the modelling of rock trajectories on a 3D slope (Agliardi and Crosta, 2003; Crosta and Agliardi, 2004; Dorren and Seijmonsbergen, 2004), as well as in the risk management of rockfalls (Guzzetti et al., 2004; Copons et al., 2005). Many of these studies use topographical maps and Digital Elevation Models (DEMs) derived from aerial sensors, i.e. aerial photography and airborne LIDAR (Light detection and Ranging). These sensors achieve maximum density of information when the incident ray is perpendicular to topography, typically subhorizontal surfaces. By contrast, the instabilities due to rockfall usually occur on vertical slopes with the result that a greater density of information using terrestrial sensors is obtained.

One of the terrestrial sensors is the new long-range Terrestrial Laser Scanner (TLS). This is a technology

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with considerable potential in the characterization and monitoring of slope instability due its maximum reach (1000 m) and accuracy (4 mm).

TLS was used at Vall de Núria (Eastern Pyrenees), an area currently affected by rockfalls (Rendón and Vilaplana, 2004). In our study we show how TLS can help us to improve the estimation of parameters of interest in rockfall studies: TLS can produce high resolution DEMs, which can be employed for inventory of rockfalls, monitoring of mass movement time evolution and more accurate numerical simulation of rockfall trajectories and velocities. Furthermore, data obtained from TLS allows the reconstruction of joint geometry and an estimation of the volume of blocks that can fall from steep inaccessible rock slopes.

1.1. Study area

The study area is located in a high mountain valley, Vall de Núria, Eastern Pyrenees, Spain (Fig. 1). There is only one form of transport in this area: the rack railway. Vall de Núria is a popular mountain resort, especially with skiers and ramblers. It caters for more than 250,000 visitors annually.

A small test area was selected on the railway track (300 × 500 m) in order to calculate the 3D geometry of the slope using TLS. This area forms part of a steep rock slope made up of heavily fractured Paleozoic gneisses of Núria (Santanach, 1974). This area was selected given its exposure to frequent rockfalls, resulting in considerable damage to the railway in recent years (Rendón and Vilaplana, 2004) (Fig. 2), specifically in 2003: 3 March, 4 April and 15 June (henceforth, events A, B and C respectively). This scenario of natural risk has been the subject of recent studies in an attempt to evaluate the phenomenon of rockfall in the whole valley (Rendón et al., 2004; Fernández and Vilaplana, 2004) and to implement preventive and corrective measures.

1.2. Terrestrial laser scanner

The long-range TLS is a new instrument that massively captures coordinates of ground points in 3D with high velocity and accuracy. TLS began to be used in the 1990s for mobile robot navigation (Singh and West, 1991; Hancock et al., 1998), in the construction of metric scale 3D models, such as sculptures (Beraldin et al., 2000) and industrial applications (Sequeira et al., 2003). Given the rapid development of technology, the maximum distance of the laser is continually being improved. This has been accompanied by an increase in TLS applications, including calculation of 3D models of large surfaces (architecture, archaeology, topography) and recently the characterization and monitoring of natural hazards, e.g. volcanoes (Hunter et al., 2003) and landslides (Rowlands et al., 2003; Bitelli et al., 2004).

TLS consists of an instrument for measuring distance (laser) and a scanner. The laser beam is focused and is reflected directly on the land surface, obviating the need for the existence of intermediate prism reflectors. The

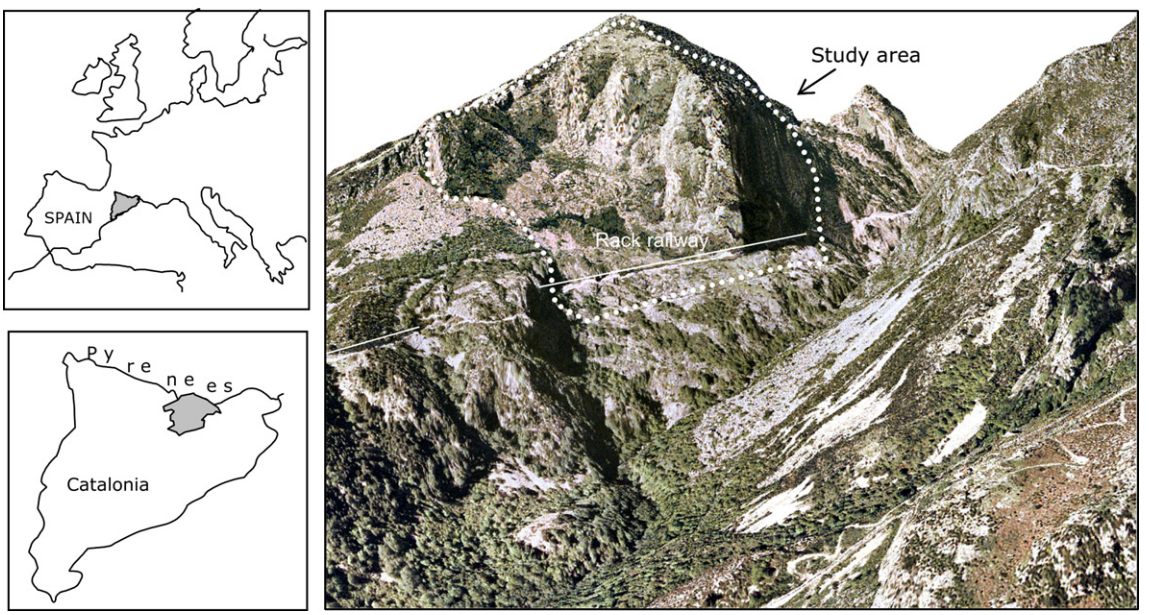

Fig. 1. Study area in Vall de Núria, Eastern Pyrenees, Spain. Pilot area is enclosed by dotted line.