Geophysical Research Abstracts
Vol. 13, EGU2011-9856, 2011
EGU General Assembly 2011


# Object-oriented analysis of unmanned aerial vehicle (UAV) imagery for mapping and monitoring fissures in landslide bodies

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The availability of optical remote sensing products exploded in recent years, with very-high resolution (VHR) sensors and flexible platforms providing new data sources for the monitoring of active landslides and rapid mapping of inventories after major events. Low-cost Unmanned Aerial Vehicles (UAVs) readily allow to record optical images over large areas at ground resolutions of 5-10 cm and provide unprecedented details of the geomorphological surface features. This study focuses on the adaption and application of advanced image analysis techniques and machine learning algorithms to this new kind of image data and thereby targets an efficient semi-automatic mapping and characterization of geomorphological features.
Multi-temporal VHR optical images of the Super Sauze landslide (South French Alps) were acquired with an UAV for the period 2008-2010 and reveal the pattern and development of geo-indicators of landslide activity. Especially, surficial fissures are expressions of the distribution of stress and strain within the landslide and proxies for analyzing the kinematics and rheology of the material.
The highly textured landslide surface (composed of blocks of different sizes, of small gullies and open channels, and of lobes) creates a challenging domain for the application of automated fissure detection. Based on well known algorithms for edge detection, morphological filtering, texture analysis, image segmentation and shape analysis, an image processing chain that enables the semi-automated mapping of surface fissures is proposed. Topographic information and generic knowledge on the geomorphological processes are incorporated in the workflow to efficiently distinguish the different structures.
Three detailed fissure maps (1:500 scale) produced for the period 2008–2010 through geomorphological field mapping are used to validate the automatic detection. Different types of fissure are observed (strike-slip fissures, concentrating fissures in traction, transverse compression ridges and thrust fissures, bulges), characterized and explained from a mechanical point of view. Such fissures must be distinguished from superficial cracking caused by swelling and shrinkage of the clays, which are not part of the analysis.
The processing chain results in multi-temporal fissure maps; the fissure pattern (abundance of fissures, direction of fissures, synthetic of anthitetic distribution of fissures) is portrayed from the main scarp to the toe of the landslide and associated to the topography of the bedrock. All observed open fissures occur at the boundary of in-situ stable crests covered by the landslide material. The high image resolution also allows mapping the vegetation patterns and characterizing the relative distribution of gravel sizes at the surface via windowed measurements of the grey values entropy. In general the semi-automatic analysis of the UAV imagery provides a cost-efficient, objective and transparent way for the monitoring of hazardous sites and geomorphological features in general.