# EARLY DETECTION OF ROCKFALLS AND TRAJECTORY EVALUATION BY «STATE OF THE ART» COMPUTER VISION TECHNOLOGIES


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## 1. INTRODUCTION

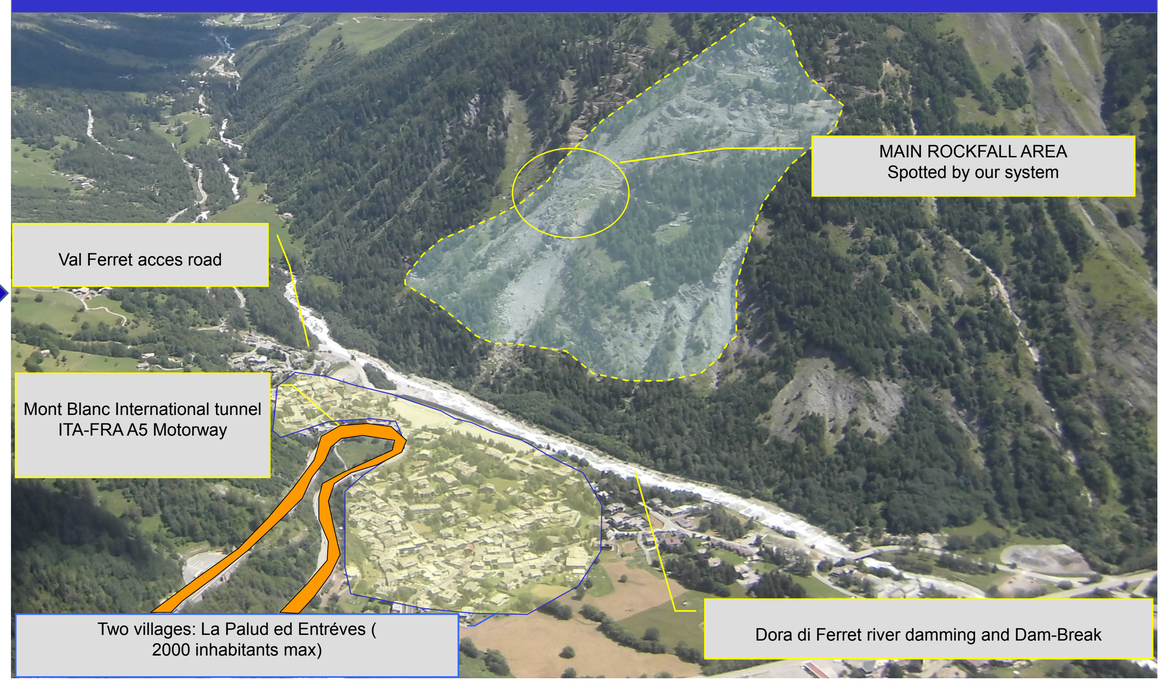
On April 2013 the Mt. De La Saxe landslide in Coumayeur (Valle d'Aosta-Italy) showed its first great activation since it has been continuously monitored (2008). An estimated 650.000 $m^3$ volume from the great unstable $8{,}6x10^6$ $m^3$ body could collapse. About 100 peoples were forced to leave their homes for 40 days. The alert thresholds set at 2 mm/h were surpassed for nearly two months. Another important activation followed during April 2014.

The evacuation of the households had to be maintained but the road closing was to be enforced at last time, immediately before the collapse, in order to prevent heavy economic losses (2M€/day) by the foreclosure of A5 and Mt. Blanc Tunnel.

**Due to the fact that all the threshold had been exceeded, the Geological Survey needed gathering all the signals potentially indicating the impending collapse of the rock mass. Among these signals, a.k.a. as "forerunners" of a great rockslide, the increasing of rockfalls in frequency rather than in magnitude (i.e. volume) is well known, even if it can be considered as a very "qualitative" forerunner.** To detect the rockfalls, a complex device based on spotlights and an h24 guard has been, but the problems were immediately evident, among them the most relevant were the excessive logistical costs to maintain the personnel engaged in the surveillance h24 and the inhomogeneous professionalism in accomplishing the assigned tasks (to detect each rockfall and recording it, dispatching an alert in case of rockfall frequency increasing).

**The Authors propose to call these Computer Vision-based Optical System applied to these geological issues as "Early Rockfall Detection System" using the Acronym (ERDS).**

## SITE AND TARGETS

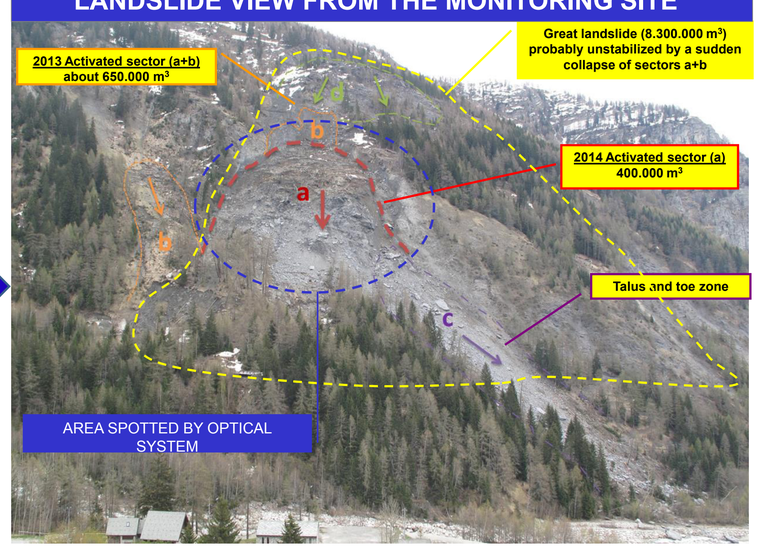



## 2. SYSTEM IMPLEMENTATION

RAVA Geological Survey, being aware of the progresses in the field of computer imaging for safety and security in tunnels and other environments, asked KRIA s.r.l. to develop an experimental Computer Vision-based Optical System for early detection and counting of the small rockfalls that are supposed to precede a major collapse event. Thus a developing and experimental activity between RAVA Geological Survey and Kria led to the implementation of a first-stage system that was activated during may 2013.

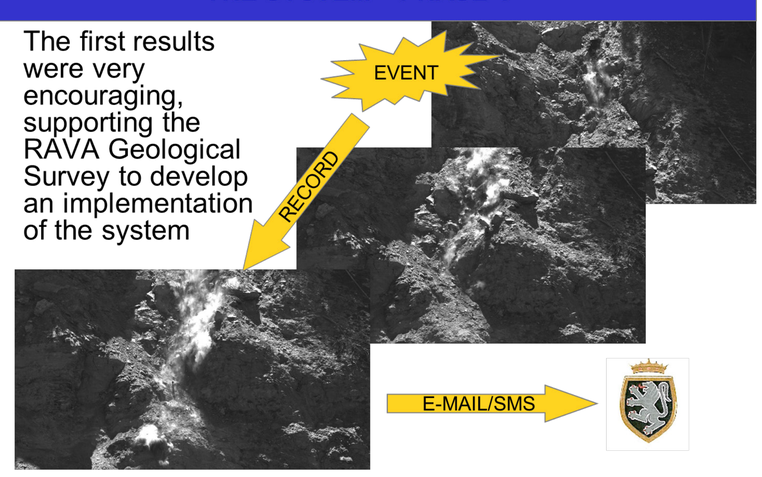
The first results were very encouraging, supporting the RAVA Geological Survey to order the implementation of the system during 2013 and 2014. As a matter of fact, **the first-stage system (release 1) acted mainly as an "evolute and robotized rockfall counter"**, recording all the rockfall trajectories, dispatching an alert to the Geological survey and saving a multi-frame record of the rockfall event. It was obviously an experimental system, that had to be strengthened both in performance and reliability. **Thus, the upscaling to a second stage was decided in order to achieve these goals.** The main features under implementation since August 2013 consist of acquisition of the images during the night in order to extend the monitoring even in those periods, acquisition in stereoscopy for the removal of sources of error arising from dust, pollen, insects, etc... Another task is the hardening of the acquisition platform HW/SW and storage through remote data collection, return the data to an user-friendly interface for faster data interpretation.

## LANDSLIDE VIEW FROM THE MONITORING SITE




## THE SYSTEM – PHASE 1

The first results were very encouraging, supporting the RAVA Geological Survey to develop an implementation of the system

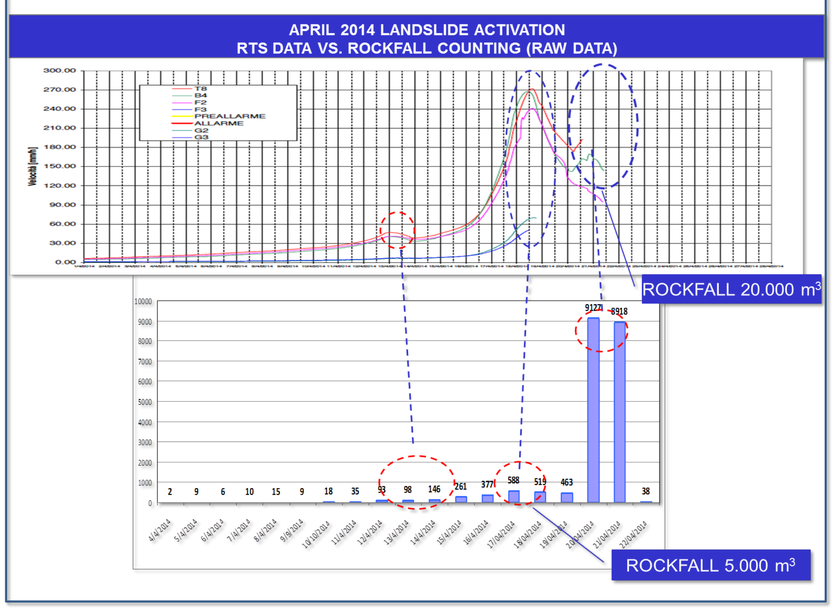



**The rockfalls could be promptly detected by the system, the system could also indentify the trajectories and keep a record of them**

## 3. FIRST RESULTS 2013-2014

The first stage release of the system could count and evaluate each rockfall, as successfully tested during 2014 emergency.

**APRIL 2014 LANDSLIDE ACTIVATION**
**RTS DATA VS. ROCKFALL COUNTING (RAW DATA)**



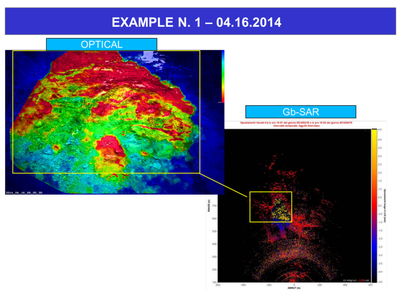

## 4. FURTHER DEVELOPMENTS

The first stage of the system could count and evaluate each rockfall, recording the frames, also giving to the geologists indications in terms of volume and fragmentation, but it was immediately clear that a lot of additional information could be gathered, if all the potential of the system were exploited.

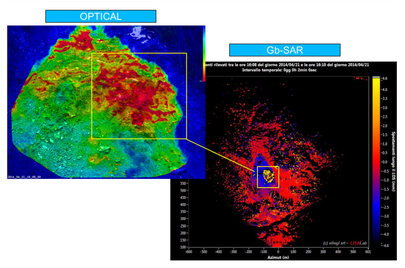
### DISPLACEMENT MAPS

A series of displacement maps has been issued, showing a strong and positive correlation with the other monitoring systems like Gb-SAR.

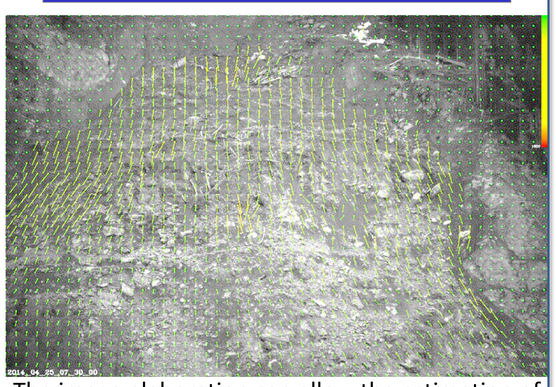
**EXAMPLE N. 1 – 04.16.2014**




**EXAMPLE N. 2 – 04.21.2014**




### OPTICAL FLOW ANALYSIS

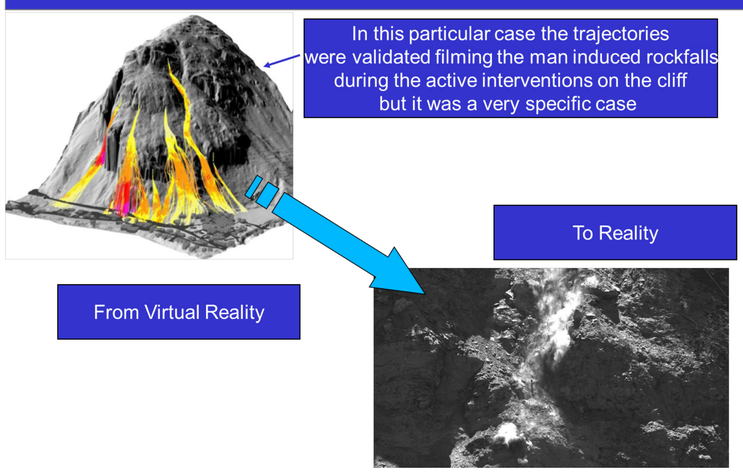


The image elaboration can allow the estimation of "flow" direction intended as vectorial displacement directions. This is a feature that is still being tested but it's very promising for earthflows and glacier monitoring. The Mt de La Saxe monitoring site gave the opportunity to validate the potentialities of the device comparing optical flow maps and displacement maps with similar data obtained by long-range Laser Scanner and Gb-InSAR. The results were impressive, mostly for which concerns the displacement maps, where motion "non-LOS" components can be traced

## 3 a. THE ERDS AS A COMPONENT OF A DECISION SUPPORT SYSTEM

Ogive his reliability and strong correlation of the increasing rockfall trend with the accelerations detected by the other monitoring networks (i.e.: RTS topographic and GB-SAR), the rockfall counter function and trajectories tracing system ERDS gives the technicians engaged in the emergency another very reliable decision support system in evaluating the civil protection alerts dispatching.

### ROCKFALL TRAJECTORY VALIDATION




### ROCKFALL TRAJECTORY EVALUATION


Due to the system capabilities, which allows a continuous monitoring of all the event (the current operative device has a sampling rate set at 4 FPS) it was immediately clear to the Geological Survey that the ADRD has all the potentialities to detect, record and document the trajectories of the blocks falling on a cliff. For this reason the authors think that, referring to the rockfall dynamic studies, the ADRD can bridge the gap, still uncovered, between numerical simulation and back analysis. This allows administrations and professional to increase the reliability of the preliminary studies for rockfall protection structures. Another obvious feature, successfully tested at Mt. De La Saxe site during the winter, is the capability to assess and record snow avalanches. In fact, in some cases, for rockfall defense structures aimed to protect critical sites, the system can be placed in front to the rockslide area in order to validate the estimated trajectories and calibrate the numerical models outputs.