Kria
KNOWLEDGE RESEARCH IN IMAGING APPLICATIONS

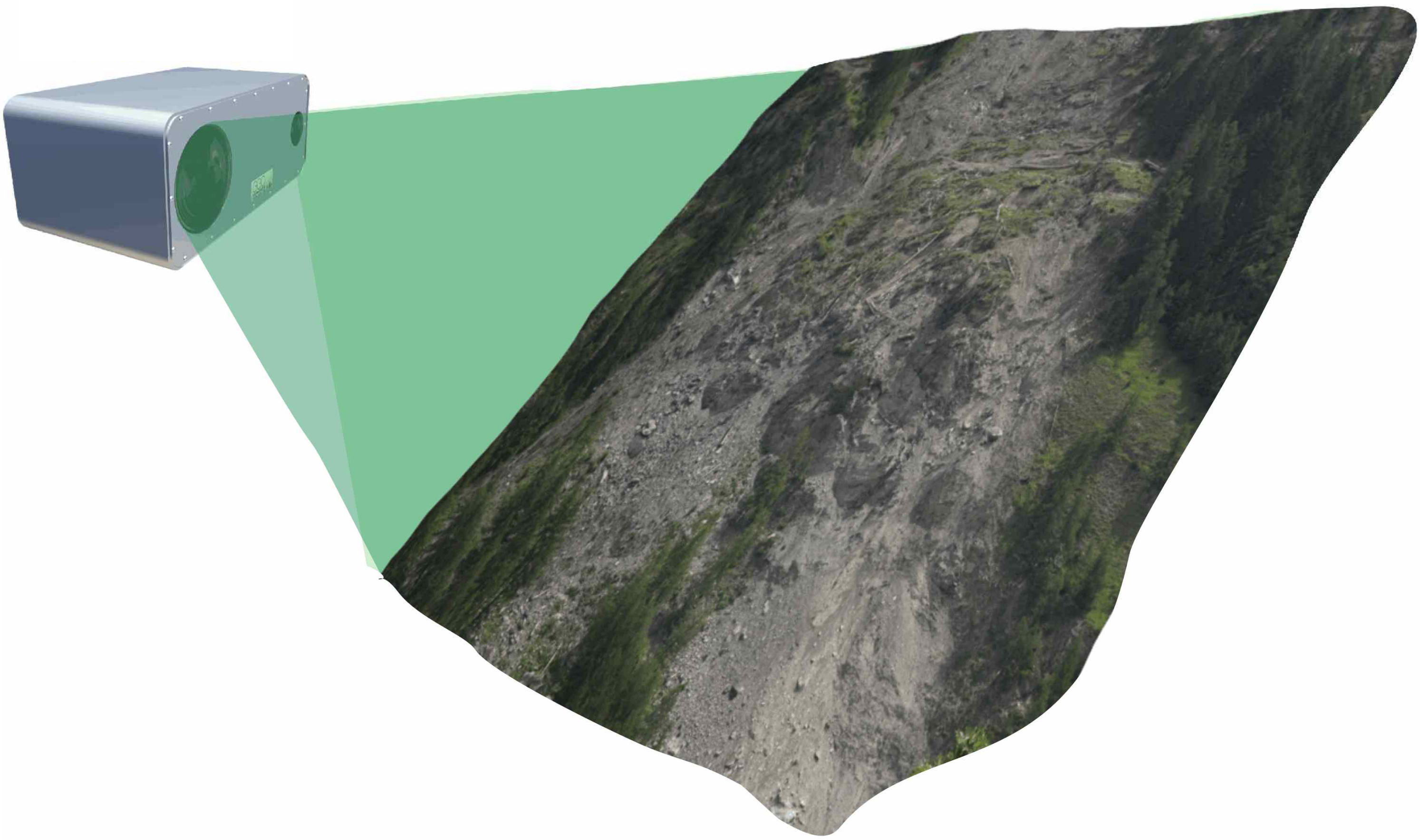
GEO SURVEYOR

Computer Vision System
Large area monitoring
Dense 3D surface
Structural deformation
Real time motion detection and recognition

Introduction

GEO surveyor is a new type of 3D measuring device designed for close-range photogrammetry and motion detection applied to environmental and infrastructural monitoring, providing with information not available with other traditional techniques.

The device is able to monitor wide areas (e.g. hundreds meters) and to provide real-time dense information with few millimeter spatial resolution. The device is based on high definition 29Mpixel CCD, grabbed and processed at 4 fps automatically detecting and recording any kind of motion event occurring in the monitored area occurring at different time scales from seconds to years.



GEO SURVEYOR

Technology

The **GEO- Surveyor** automatic detection system is based on the principle of short-range terrestrial photogrammetry. In such approach, two high-resolution cameras continuously observe a site where terrestrial movements occur at different time scales. Such events are characterized both temporally and spatially through the comparison of images taken from different angles and different times (stereometric analysis and flow control) . The precise correspondence among different images allows the use of the system as an optical three-dimensional detector capable of measuring both the 3D surface shape and its variation over time.

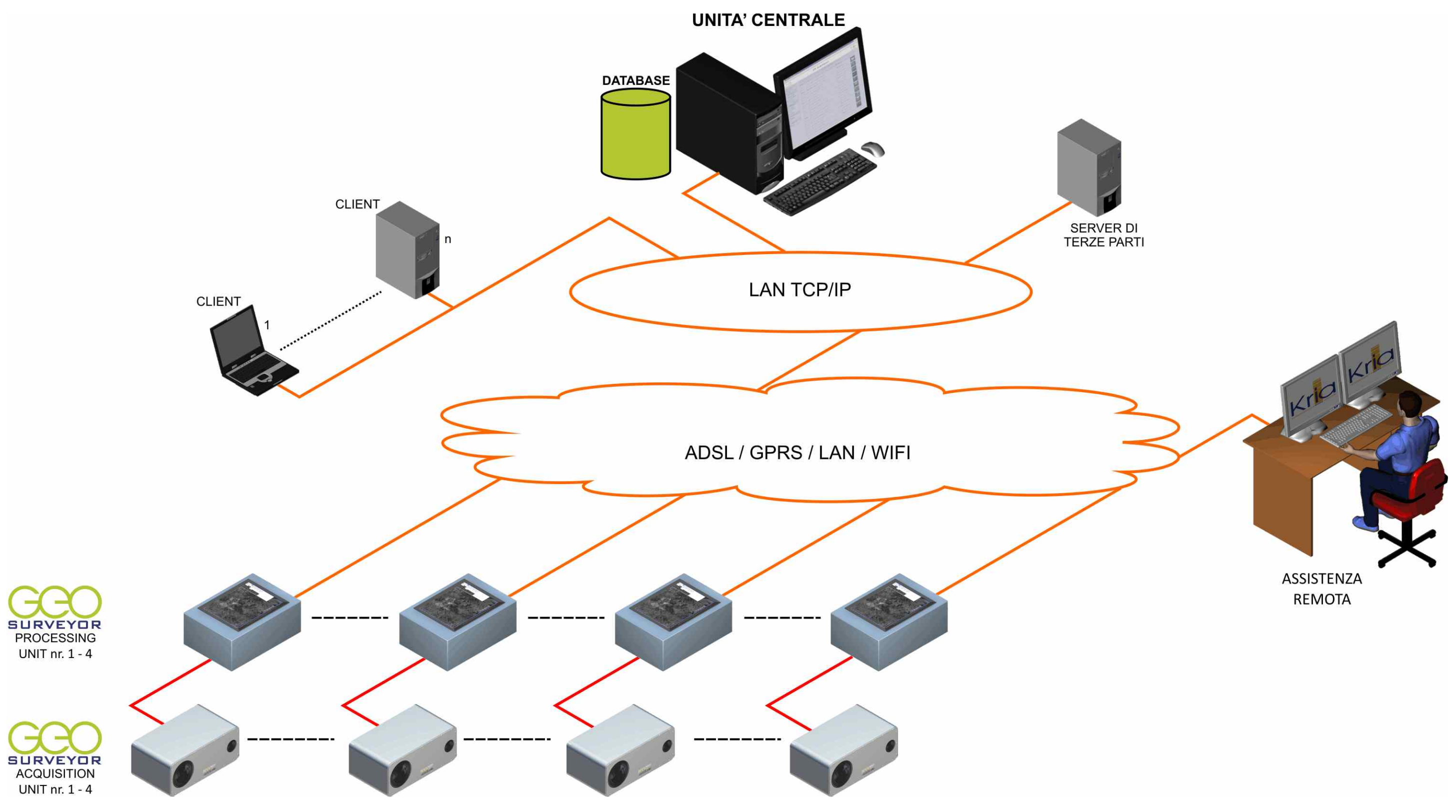
The output data can be made available in order to highlight different events, from fast and localized motions to slow and distributed motions, both in terms of qualitative maps of immediate understanding of both quantitative measures useful for further investigation.

The whole process is made completely automatically by the use of image processing algorithms and three-dimensional artificial vision techniques, all well-established and already in use in other application areas.

In summary the benefits produced by this technology compared to conventional techniques of geological survey are:

- parameters of the system (up to a few millimeters at 100m away);
- gathered data are immediately comprehensible to both experts and operational staff (image-like outputs such as photos and video clips);
- very low costs of setting up and management, compared to other technologies (e.g. the aerial survey)
- minimum energy consumption (passive sensors, night lighting required only in the case of 24-hour monitoring);
- high degree of automation of the on-line and off-line processing tasks;
- simple calibration of optical devices (cameras);
- wide availability of more powerful and accurate image processing algorithms applicable on historical archives of calibrated images previously stored by the system

Architecture



Applications

GEO-Surveyor can be applied to different sectors, in order to provide fundamental information for environmental monitoring and infrastructures maintenance.

Application sectors

- Active landslide monitoring (e.g. safety check for roads and cities)
- Long-time evolution of icefields
- Geologic surveillance (e.g. surface mines)
- Stability check for civil infrastructures (bridges, dams, buildings, etc.)
- Deformation analysis of industrial structures (oil tanks, hydro plants, electric or nuclear power plants)

Functions

The device can send alarms in different cases: wideness of the affected area, intensity of the motion, frequency of occurrences. For instance, in active landslide monitoring, alarms are generated for the fall of single of rocks with consistent volume, or for the continuous fall of debris of lesser volume.

Alarms include high resolution videos in Full-HD (1920x1080 pixel) of the interested area, cropped from the whole image at full resolution (6573x4384 pixel).

The device archives very detailed images (29Mpixel) at a predefined frequency, for instance once a minute, to realize all the a-posteriori analysis, typically related to events with a long time evolution (e.g. detection of small structural modifications).

The software installed on the central server analyzes al the archived images and generates different maps (motion, oscillation, vibration) showing in false color the most critical areas. For instance, maps of small displacements of a landslide, or small deformations of a structure, can be generated with a weekly/monthly cadence.

Thanks to the availability of 3D data, such maps can show quantitative information, expressed in metric units. It is even possible to realize Full-HD videos of interesting areas in time-lapse mode (accelerated time video recording), in order to get in a few seconds the visual evidence of displacements observed during a very long time interval.

Three components for independent 3D data survey

The most important optical component is characterized by a set of cameras in stereometric configuration, all synchronized and continuously operating. It allows the real-time processing algorithms to employ a coarse level of 3D information in order to guarantee a very high alarm reliability. More specifically, the system does not generate alarms for false motions and for the presence of interfering objects along the optical path between the device and the target surface (birds, rain, particles, etc.).

An external camera, not related with the main stereometric component, can be used to get a periodic survey of the whole controlled area. Adopting computer vision 3D reconstruction algorithms a dense high resolution 3D map of the area is generated (DEM), in order to use it in the system processing. The survey can be repeated with a suitable frequency, for instance after significant modifications of the target surface.

Finally, special optical markers placed in a fixed way over the target surface, and efficient IR lights installed in the device, allow the processing algorithms to provide a point spatial accuracy up to 10 times higher. The optical markers can be placed near the most important points of the target surface, and they are allow the main control function even in absence of ambient or artificial lighting.

Architecture and availabe versions

The system is composed by the stereometric monitoring device, the external survey camera, the local server and the central server. Both cameras are available in 50 and 135 versions, to be selected according with different area coverage, distance and spatial resolution over the observed surface.

Versions and positioning

The stereometric camera must be installed at a distance between 100m and 500m to the controlled area.
The observed area size and resolution depend on the installed version:

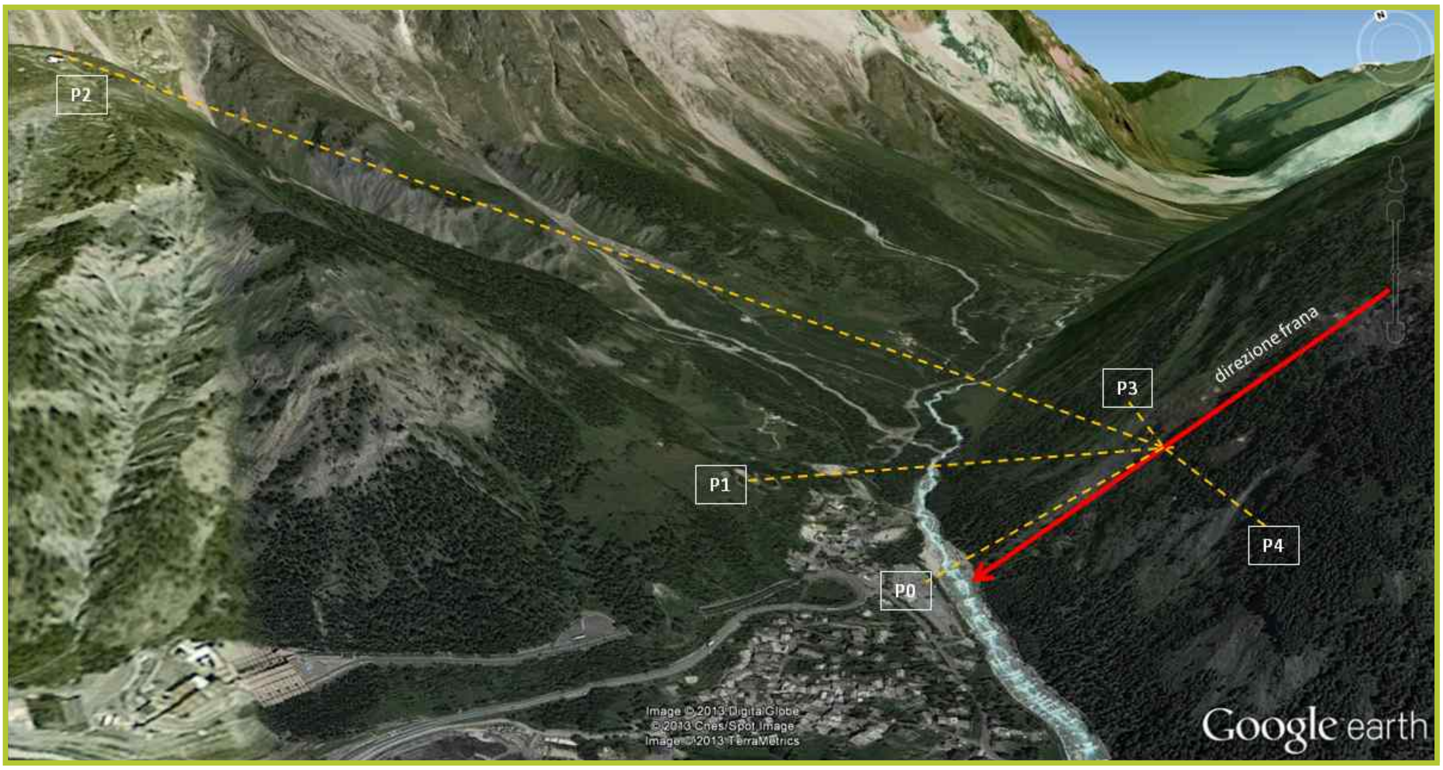
GEO-Surveyor Type 29-50	
Minimum distance Field of view Accuracy	100m 78m x 52m 11mm
Maximum distance Field of view Accuracy	600m 391m x 260m 65mm
GEO-Surveyor Type 29-135	
Minimum distance Field of view Accuracy	100m 29m x 19m 4,5mm
Maximum distance Field of view Accuracy	600m 144m x 96m 24mm

The optimal potions for motion detection is with a look

direction orthogonal to the target surface, however even more tilted views (e.g. 30 degrees) allow good results.
Accuracy is evaluated in the ideal case (orthogonal looking) and without the use of optical markers. Optical marker could improve spatial localization up to 10 times.
Besides the standard versions, ad-hoc version can be realized to match special custom needs..
The distance between device and surface depends on terrain and infrastructural constraints (accessibility, safety, broadband connectivity, power energy availability) of the candidate site.
The version is chosen on the base of the required field of view and reconstruction accuracy needed for the application.

CASE STUDY

GEO-Surveyor has been successfully applied in 2013 for the monitoring of one of the largest and more dangerous landslide front in Europe, the one coming from Mount La Saxe, over the village of Entreves in Aosta Valley (Italy).
The device is operating continuously since May 2013 and it archives images and videos analyzed by the staff in charge for the control, the Geologic Area Structure of the Aosta Valley Region Authority..
Due to the extreme dangerousness of the landslide, the device has been installed using existent infrastructures in a position quite far from the optimal one, because the looking direction is nearly parallel to the target surface.



For safety reasons, the system is installed in P1, a better choice may be P2, while a worse is P0.

Nevertheless the positioning was not ideal, the system has proven sufficient to get three type of information:
- a historical archive of the landslide front, about 150m, with a few cm of spatial resolution;
- real-time alarms of falling rocks and debris;
- dense displacement maps of the whole landslide.

Historical archive

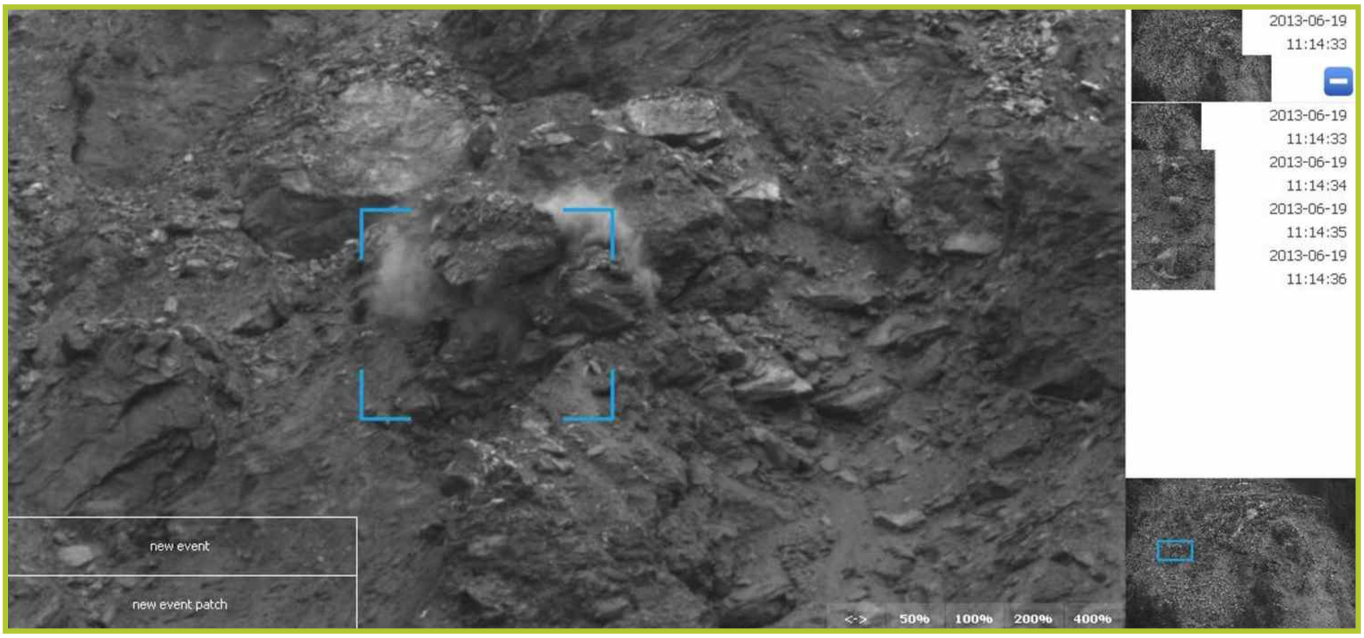
The archived image documentation has a very high resolution (29Mpixel), using the state-of-the-art of matrix image sensors, and it is not easy to show it on a computer display or a piece of paper. For this reason, it has been installed a software able to zoom in the images up to the maximum resolution on standard PC display, and it has been proposed also a video-wall of suitable dimension to represent the whole landslide front with the maximum available detail.
In the above simulation a possible realization of the central control room is depicted. The graphical interface is installed both on the PC located at the La Saxe site and remotely at the central room in Aosta. In the following it is showed, as an example, a coarse-to-fine sequence of images at variable resolution, in order to demonstrate the level of available detail.

Di seguito è fornita a titolo di esempio una sequenza a risoluzione variabile dall'immagine intera alla più ingrandita a dimostrazione del livello di dettaglio delle immagini.

Complete image 6573 x 4384 pixel

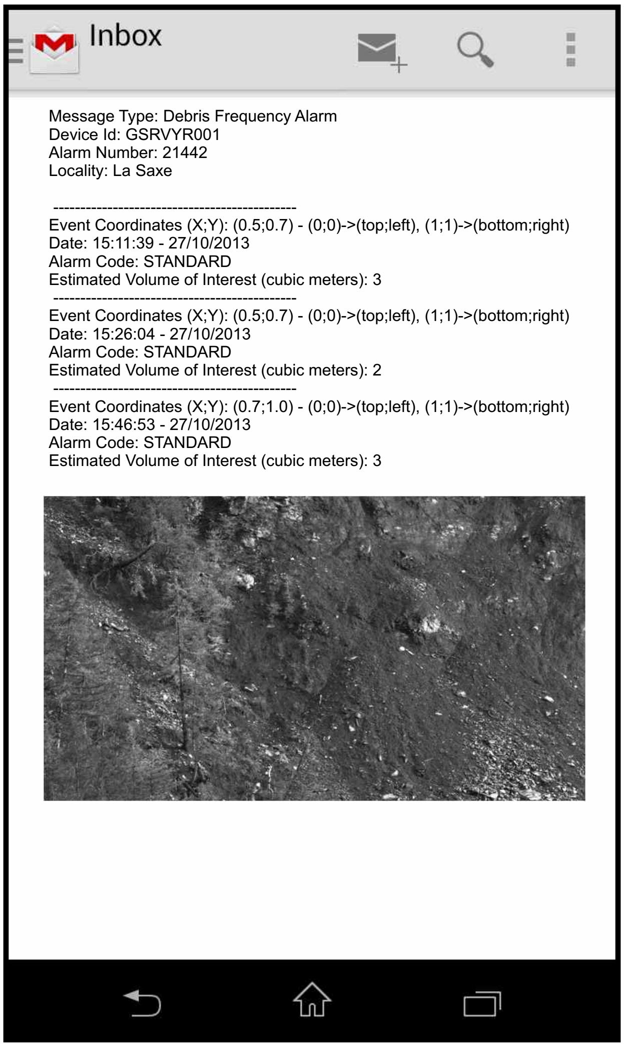
Cropped image for video FULL HD 1920 x 1080 pixel

Alarms are provided in real-time on the AU, on the Central Server and sent to smartphones if required. Messages are formatted accordingly to the reception device and carry both textual and visual information related to the spatial location of the event and its dangerousness.



Real-time alarms on the server unit

An automatically detected event



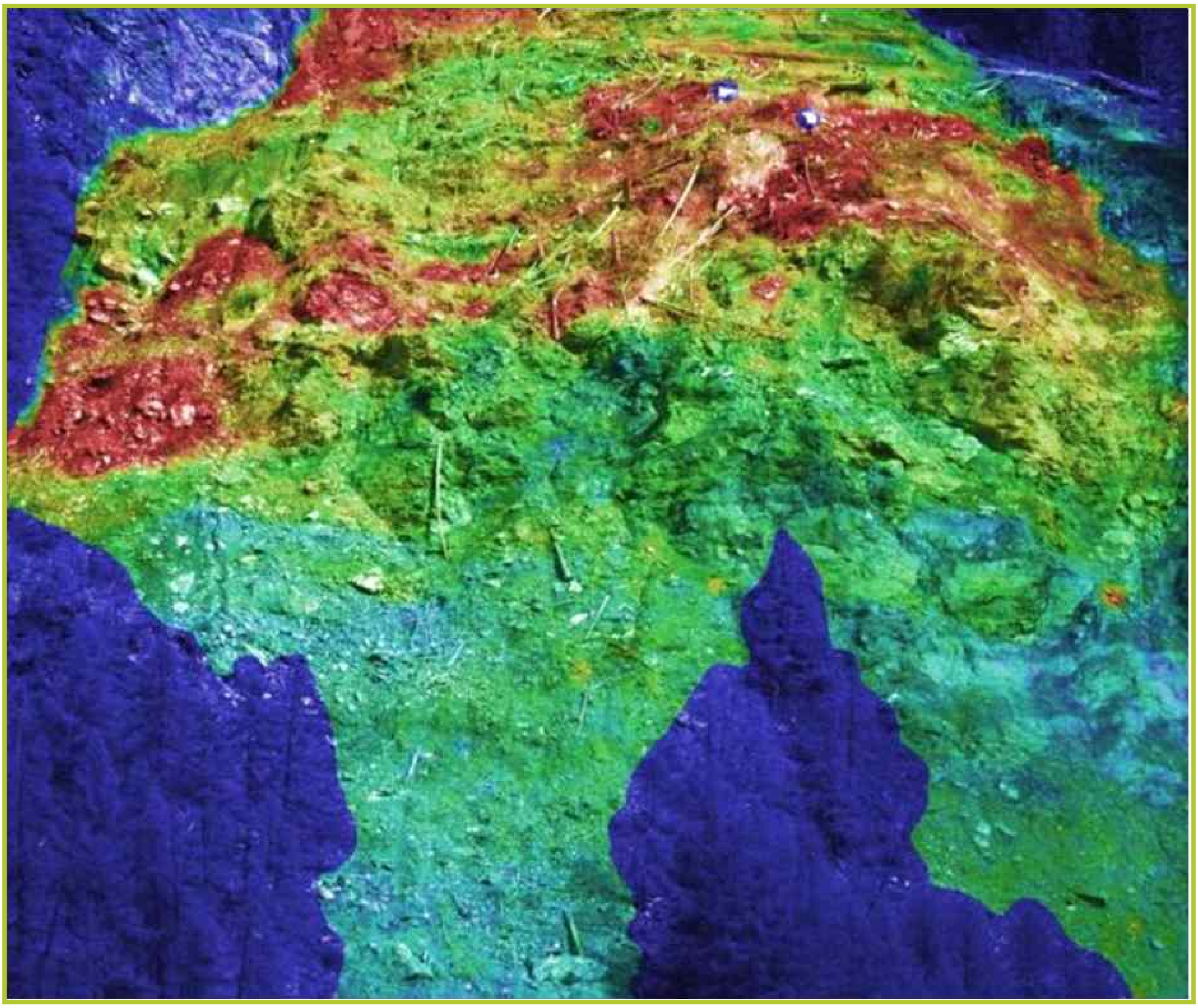
A typical real-time alarm sent through e-mail to a smartphone

Thematic displacement maps

Displacements maps are generated by the Central Server using the historical archive and automatically selecting daily images for a given time range, typically one month. The selection ensures that selected images were as similar as possible in lighting conditions, and so the comparison should be effective. Using image processing algorithms (optical flow computation), the raw displacement map is computed in pixel-based units. Then, by exploiting calibration information, the map is corrected keeping into account local distance and orientation of the surface, producing the final map in metric units (e.g. millimeter/month). The computation can be repeated at any frequency, in order to observe the slow motion of the surface over a time interval longer than one month.

Maps contain the overlay of the original gray-level image, to allow an immediate location and verification of the more interesting zones of the landslide, and a pre-defined false-color map to visualize the intensity of the observed displacement. The false-color scale may be customized, for instance from 0 to 1000 mm/month.

In specific areas of interest it is possible to activate the time-lapse recording mode. In this mode the software generates a Full-HD video at different sampling rate, in order to observe in a few seconds the events occurred on a very longer time interval. Such video provides an immediate evidence about how a given area has changed over time.



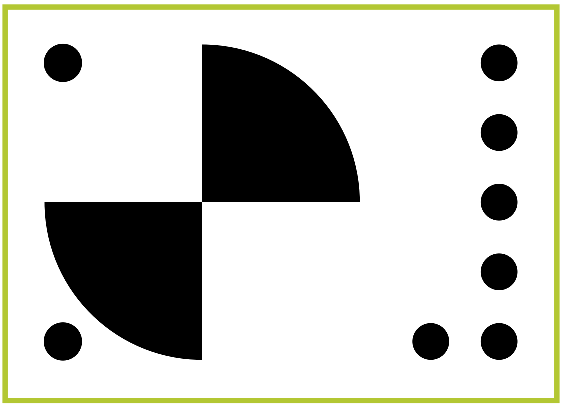
From May to September 2013 the displacement map generation function has been tested. Disable area shown in blue color due to vegetation coverage. Small displacements are shown in green and larger ones in red.

Technology growth and limitations

After earlier tests, the possible improvements of this new technology has proved to overcome its intrinsic limitations; is is sufficient to note that sensor quality, computing power and image processing algorithm capability are all continuously increasing. A few critical points are reported in the following, and they are connected with night-time operation and the occurrence of heavy snow events. However, it necessary to stress that such points are still open due to the limited time and initial budget assigned to the project. The developer (KRIA) and the end user (Aosta Valley Region Authority) are planning some activities to solve the open problems.

Functional improvements

The system works well during daytime, when natural lighting is sufficient, thanks to a dynamic setting of shutter, iris and gain of the optical sensor. Without any lighting it cannot provide any useful data. To this scope some visible lighting systems have been tested and they provide a lighting sufficient for the monitoring. To reduce the ambient impact, some infrared lighting system are under analysis. Special optical markers can be distributed over the landslide to increase its reflectance.
Moreover, in bad weather days, image processing algorithms have proven to be robust to snowflakes or raindrops in suspension between target and the camera. However, with heavy snow events the landslide texture is completely covered and so it is impossible to analyze the small displacements. To overcome the problem it is possible to install special optical markers mounted on structures emerging from the snow, in order to monitor single points instead of the whole surface (in complete analogy with laser-based photogrammetry systems). The cost of the markers is very low if compared with the optical prisms needed by lasers and so many of them could be installed, even in uncontrolled positions.



An optical marker with binary code for unambiguous identification on the landslide.

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