Kria
KNOWLEDGE RESEARCH IN IMAGING APPLICATIONS

GEO SURVEYOR

Computer Vision System
Large area monitoring
Dense 3D surface
Structural deformation
Real time Rockfall and Avalanche detection
Photo and Video Documentation

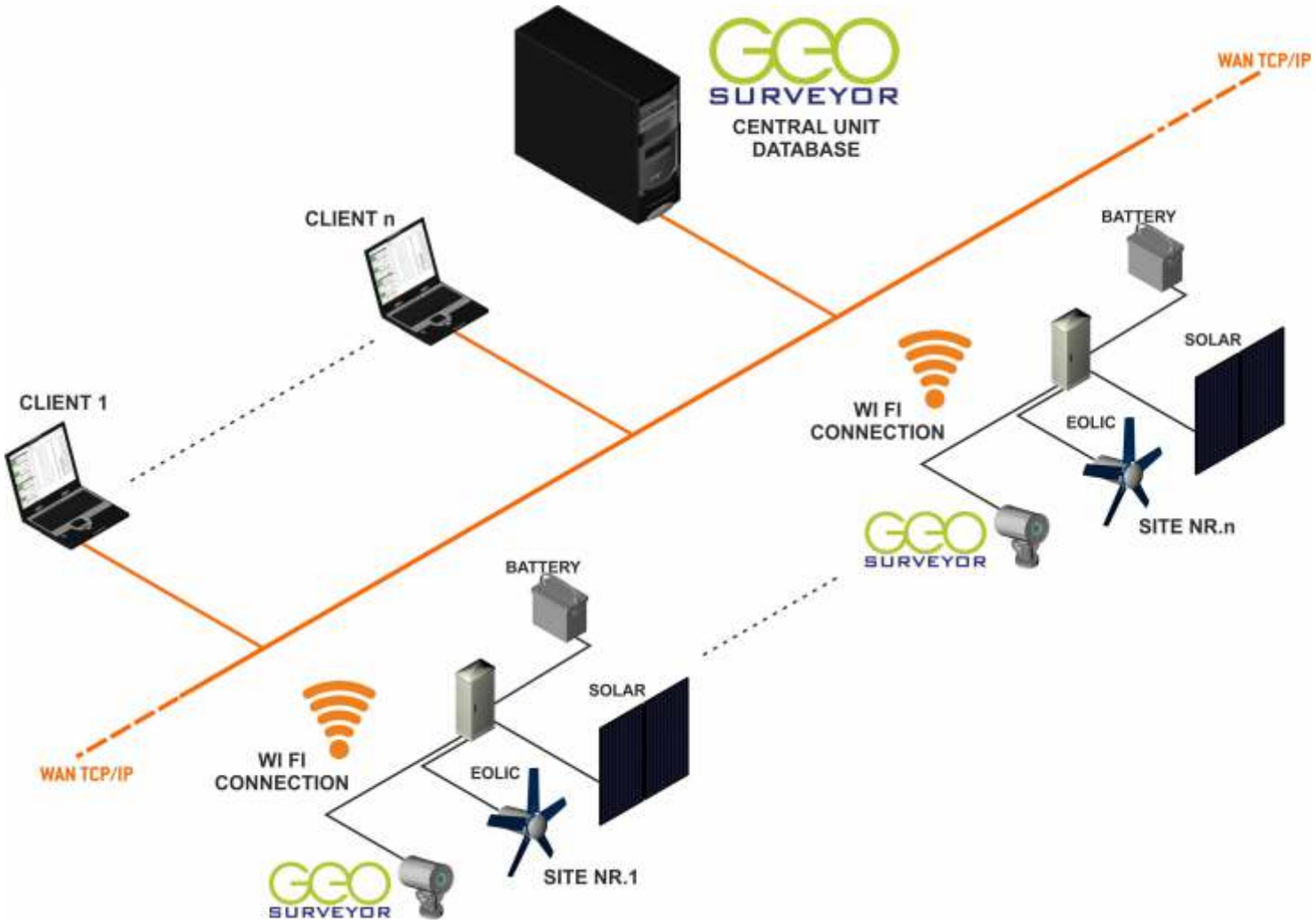
Introduction

GEO-Surveyor is an environmental monitoring and measuring system based on Computer Vision technology. The device is designed for close-medium range photogrammetry and environmental event detection, providing information unavailable with other techniques traditionally applied to geological and infrastructural monitoring.

The device is able to monitor wide areas (e.g. 300 x 300 m) and to provide real-time information with millimetric accuracy. The device is based on very high definition industrial cameras and lenses. Images are automatically processed in real time in order to detect, transmit and record relevant events.

Geological events may occur at different time scales and GEO-Surveyor can detect different kind of morphological changes lasting from few seconds to years.

Architecture



Technology

The **GEO-Surveyor** automatic detection system is based on the principle of close-medium range terrestrial photogrammetry. In such approach, the high-resolution camera continuously observes the target in order to detected events like rockfalls, avalanches and landslides. A very powerful comparison method applied to consecutives frames detects and localizes any geologically relevant event occurring inside the target area erasing other typical outdoor events (e.g. sun light and shadows, rain, snow, animals, humans and vehicles).

This technology is able to detect fast localized events (e.g. rockfall) as well as slow distributed events (e.g. landslide). Output data are available in different ways in order to highlight specific phenomena in terms of qualitative maps and quantitative measurements.
In summary the benefits produced by this technology compared to conventional techniques of geological survey are:

· immediately understandable data 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. aerial surveys);
· minimum energy consumption (normally 15 W, max 45 W in cold environments);
· high degree of automation of the on-line and off-line processing tasks;
· simple calibration of the optical devices;
· wide availability of more powerful and accurate image processing algorithms applicable on historical archives of calibrated images previously stored by the system

3D Technology

Using two or more synchronized devices installed at a proper distance and framing the same area, the system provides real time 3D information.

The 3D setup of GEO-Surveyor brings benefits like:

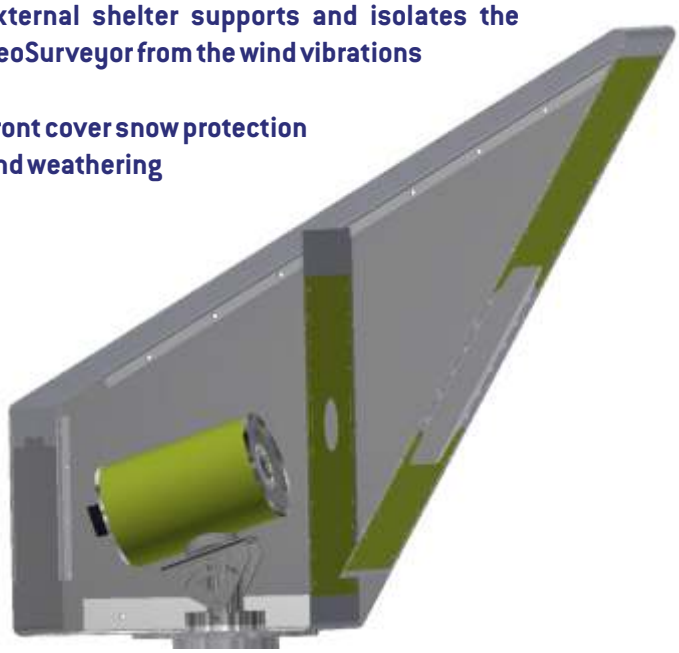
- compute the volume of the event with high accuracy;
- 3D map of the events;
- improvement of the reliability of the monitoring;
- automatic avoidance of false alarm generated by external stuff between GeoSurveyor and the target;
- compute 3D landslide maps, useful for the prediction of the target future dynamic.

The whole process is based on 2D/3D artificial vision techniques developed by KRIA Labs since 2002 for their well-know outdoor traffic enforcement and measurement systems.

Outdoor Housing

External shelter supports and isolates the GeoSurveyor from the wind vibrations

Front cover snow protection and weathering



Ip65 GeoSurveyor Housing

Applications

GEO-Surveyor can be applied to different fields in order to provide primary information for environmental monitoring and infrastructures maintenance.
Application Areas:

- real time alarm on active avalanche and rockfall slopes;
- active landslide monitoring (e.g. safety check for roads and cities);
- geological surveillance (e.g. open-pit mines);
- stability check for civil infrastructures (bridges, dams, buildings, etc.);
- deformation analysis of industrial structures (oil tanks, hydropower 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 by the fall of a single big boulder or by the continuous fall images of debris of minor volume. Alarms include high resolution videos of the interested area, cropped from the whole Server at full resolution. The device archives very detailed images at a predefined frequency, for instance once a minute, in order to realize all the a-posteriori analysis, typically related to events with a long time evolution (e.g. detection of small structural modifications).

GEO-Surveyor application installed on the central server analyses all the archived images and generates different maps (motion, oscillation, vibration) showing in false colors the most critical areas. For instance, maps of small landslide displacements or small structural deformations 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 time-lapse videos of the interested area 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

Collecting images from different locations (drone, helicopter or manual survey) it is possible to build a 3D surface of the target. Special optical markers placed in a fixed way over the target surface and efficient IR lights installed within the device allow the processing algorithms to increase the spatial resolution up to 1mm. The survey can be repeated with a suitable frequency, for instance after significant modifications of the target surface. The optical markers shall be placed near to the most important points of the target surface and they allow the main control function even in absence of ambient or artificial lighting.

Architecture and available versions

The system is composed by the monitoring device, the external survey camera, the local server and the central server.

Versions and positioning

GEO-Surveyor should be installed within 100 mt to 1.600 mt range from the monitored area. The area size and its spatial resolution depends on the device camera model combined to the angle between the camera lens axis and the angle of inclination of the target surface.

The optimal position is with an orthogonal direction look (90° degrees) to the target surface, however GEO-Surveyor can effectively monitor the area from angled perspectives (e.g. 15°-20° degrees) providing very good results.

CASE STUDY/MOUNTAIN LANDSLIDE

The first **GEO-Surveyor** prototype has been successfully realized 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 analysed by the staff in charge of the control, the Geologic Area Structure of the Aosta Valley Region Authority. Due to the extreme dangerousness of the landslide, the device was installed using existing infrastructures in a position quite far from the optimal one, because the looking direction is nearly parallel to the target surface.
GEO-Surveyor proved itself to be a very useful novel technology for integrating traditional field surveys in mapping geo-morphological

features, especially in hazardous and inaccessible landslide sectors. Accurate mapping of the rockfall distribution provides important information for decision makers, allowing them to prepare landslide susceptibility and hazard models.
Even though the positioning was not ideal, the system has been able to provide reliable and accurate pieces of information. At the Aosta Control Room the system keeps on collecting three types of information:

- an historical archive of the landslide front, about 150 mt, with 4 cm spatial resolution;
- real-time alarms of rocks falling and debris;
- dense displacement maps of the whole landslide.

Control Room GEO-Surveyor Server

At the control room a user friendly interface supports experts and operators during their event validation and model evaluation procedures.

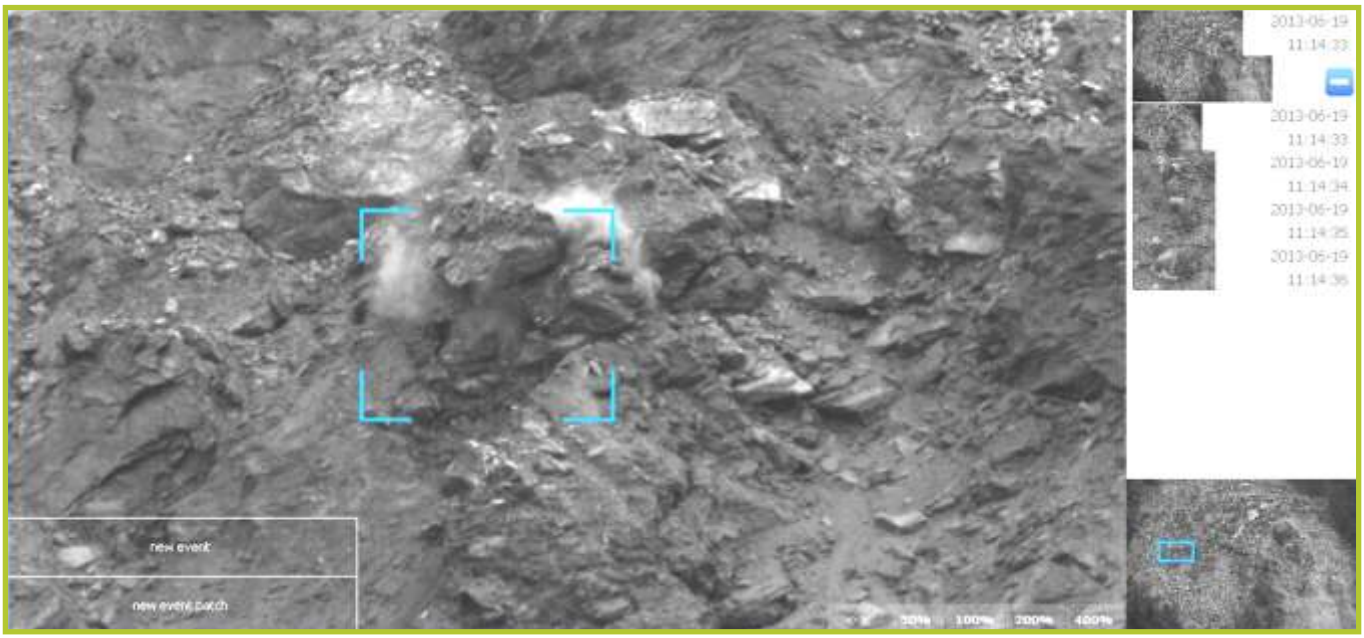
Long term historical events are stored on the central database. Past events as well as real time events can be visualized and processed.

A sequence of images at adaptive scale is shown below. In order to show the best details, the full image is cropped when the GEO-Surveyor detects a movement on the monitored slope.

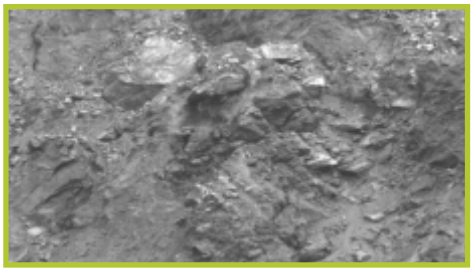
Complete image 6573 x 4384 pixel

Cropped image for video FULL HD 1920 x 1080 pixel

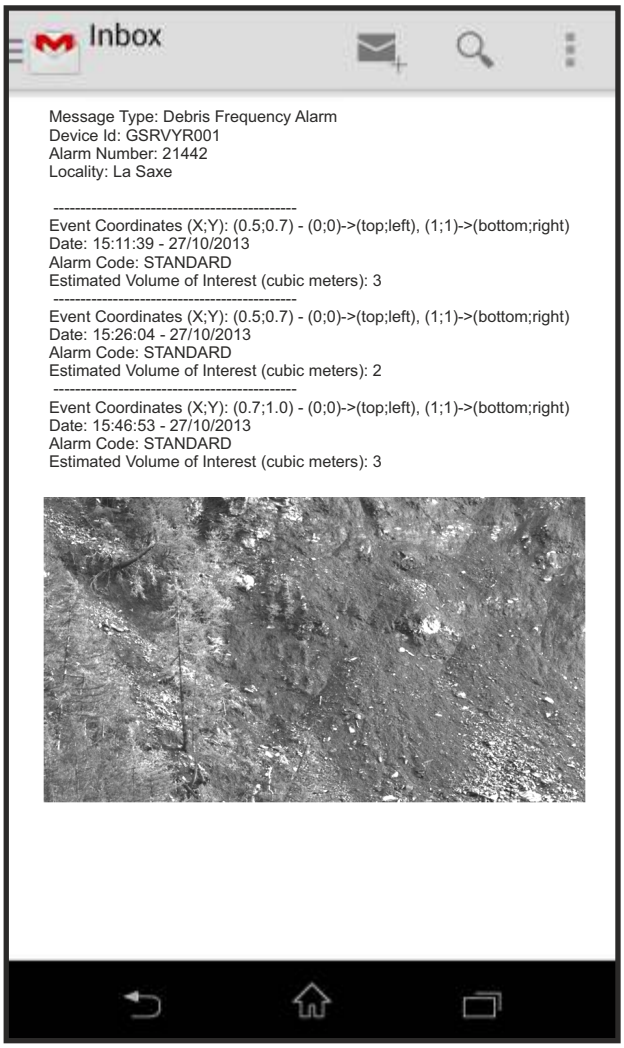
Alarms are provided in real-time on the AU, on the Central Server and sent to smartphones whenever the operators are not at the Control Room. Messages are formatted accordingly to the reception device and they carry both textual and visual information related to the spatial location of the event.and its dangerousness.



Real-time alarms on the server unit



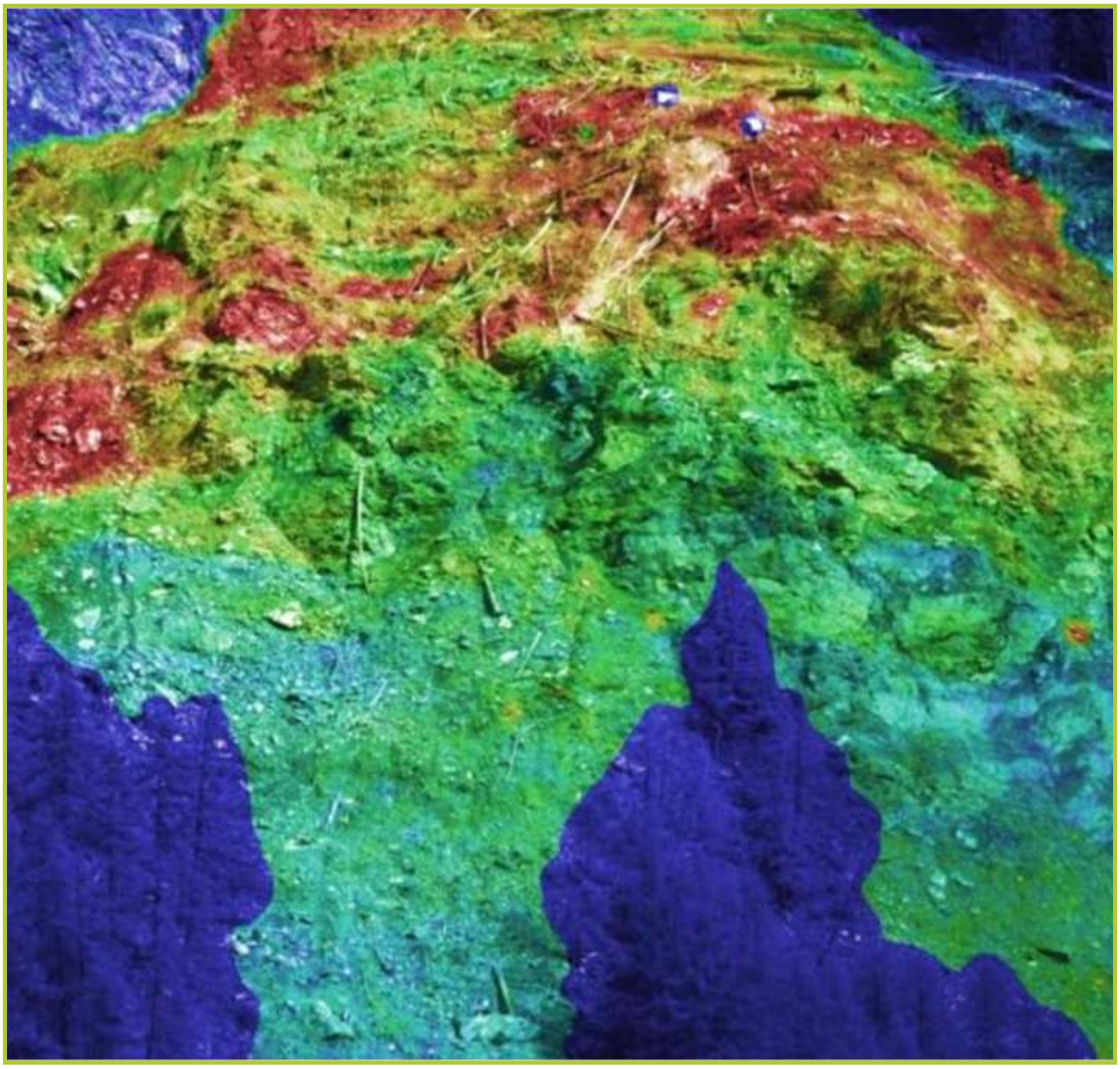
An automatically detected event



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 identified images were as much similar as possible with lighting conditions so the comparison should be effective. Using image processing algorithms (optical flow), the displacement map is computed and converted in metric unit (e.g. mm/month). The processing 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 grey-level image in order to allow the immediate reading by the experts: the most interesting areas of the landslide are highlighted by the false-color map for the intensity view of the observed displacement. It is possible to activate time-lapse recording mode. In this mode the software generates high res video at different sampling rate in order to replay in few seconds the events occurred in a very longer time interval. Such video provides an immediate evidence of 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.

Open-pit Mine Applications

One of the GEO-Surveyor most suitable application is at Open-Pit Mines.
Thanks to the free running real-time detection of rockfalls and landslides, the alarms are generated within a few seconds and the operational areas can be promptly evacuated.
Typically open-pit mines are large and deep open spaces and the absence of any visual obstacle or vegetation inside the area allows very effective and accurate landslide monitoring.
Due to the normal circular symmetry conformation of the mines, the standard configuration consists of an array of devices installed on the mine edge on the opposite side of the monitored benches. A 360° degrees configuration monitor the whole open-pit mine.
Each device is wi-fi, wired or wireless connected to the central system.
Every single device generates rockfall alarms while every couple of following devices of the array measures in 3D the landslide with 1 mm to 5 mm accuracy.
Optical landmarks can be simply installed on the opposite side of the mine edge as well as on the mine bench faces and on the berm intervals in order to improve the measurement accuracy.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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