Integrated surveying system for landslide monitoring, Valoria Landslide (Appennines of Modena, Italy)

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Summary

prediction and prevention of landslide risk through the utilization of integrated surveying systems

Boschi di Valoria landslide, located on Appennines of Modena in the Northern Italy, which relatively large size, about 1.6 square km

Integrated Instruments:
Automatic Total Station looking at 45 reflectors
GPS master station, reference for three rovers on the landslide.
a bi-dimensional clinometer to monitor "local" disturbing effects
gеotechnical sensors (inclinometers and piezometers)
alert system
GIS for landslide risk management

Test in progress
- interferometric survey (IBIS system)
-New Automatic total station Leica TM30
Boschi di Valoria Landslide is an ancient large-scale active earth landslide - multiple reactivation phases in the last 60 years; high potential for further development, both in the upper landslide zone and in the toe area.

The surface monitoring of the landslide needs both GPS and robotic station systems because of its relatively large size (about 1.6 km²: 3.5 km long and 0.7 km wide (points not in view) to create a prevention model.

Risk for:
- damaged roads and endangered houses during a sequence of reactivations
- Dolo river: it is located at the toe of the slide and in case of event, the overflow of water could isolate entire small villages.
- In addition to that, the possible retrogression of the rear scarps could cause relevant damage to infrastructure.
• robotic station (TCA2003 Leica) and of a double frequency GPS receiver (GMX902 Leica) with an antenna AX1202 Leica.

• bi-dimensional clinometer (Nivel 220 Leica)

• remote control at university and Authority for hydrological risk monitoring.

Example of GPS benchmark – periodic survey
fixed in the soil for 1.5-2 m

Reflectors with special mount

GPS rover
Localization of topographic and geotechnical instruments on Valoria Landslide. Continuous system architecture. Movement vectors of prisms and GPS on the landslide: blue arrows – displacements of lost prisms and red arrows – displacements of active reflectors. Rif1, Rif2, Rif3, Rif4, Rif5, Rif6 are reference reflectors. GPS_A, GPS_B, GPS_C are rovers GPS. Extensometers are indicated with an orange circle and borehole instruments (piezometers and inclinometers) with a green triangle.

**Periodic surveys**

three periodic GPS campaigns from November 2007 until January 2008

Fast static surveys a logging rate of 1 second

seven periodic surveys with the automatic total station TCA2003 from December 2007 to February 2008 every two weeks.

The robotic station measured about 45 precision:

repeatability of 5 mm per day in movement detection
Continuous measurements

The robotic station measures about 45 reflectors every three hours (complete cycle - three layers).

GPS network is composed by the master GPS, located at Aree Vecchie, which is the reference station, and three single frequency GPS rovers, located in the landslide.

- Precision: 
  - Repeatability 3 mm per day in three coordinate movement detection.

- Landslide movements by automatic TS during continuous measurements. Monitoring of coordinates N (left), E (right) of the most interesting reflectors.
Localization of topographic and geotechnical instruments on Valoria Landslide. Continuous system architecture. Movement vectors of prisms and GPS on the landslide: blue arrows – displacements of lost prisms and red arrows – displacements of active reflectors. Rif1, Rif2, Rif3, Rif4, Rif5, Rif6 are reference reflectors. GPS_A, GPS_B, GPS_C are rovers GPS. Extensometers are indicated with a orange circle and borehole instruments (piezometers and inclinometers) with a green triangle.

GPS rover (left) and its displacements in N,E coordinates (right)
Stability of master station

Tilt of robotic station (up) and measurements of bi-dimensional clinometer (bottom)

Variation in time of the distance from the robotic station and reference reflectors Testo

The cyclic movement of master station seems to be perfectly elastic, so it should not disturb data analysis and results interpretation.

GPS master station in ITRF

- absolute coordinate - accuracy
- local stability

GPS data of the master permanent station, VALO, were archived and then processed in daily sessions (Gamit/Globk software) with respect to the EUREF permanent station, MOPS, located about at 50 km far away. GPS data archive computed was only 1.5 months long. VALO coordinates were computed and adjusted in the IGS05 reference frame with respect to the nearest EUREF permanent stations and by means of their published coordinates (MOPS, MEDI, PRAT, IENG, MESL). In the near future, GPS data are going to be deeply studied and analysed so that it could be possible to find out an explanation to the area movement and compute the displacement velocity.
IBIS - Image by Interferometric Survey

MONITORAGGIO DELLA FRANA DI BOSCHI DI VALORIA (MO)

23-25 Febbraio 2009

### CONFIGURAZIONE E POSIZIONAMENTO

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<th>Value</th>
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<td>RISOLUZIONE IN CROSS-RANGE</td>
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<tr>
<td>DURATA SESSIONE</td>
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</table>

**Site of Installation**

![IBIS-L](image)
From the quality map, it is evident that there are about 40,000 good measurement points, with an internal parameter greater than 0.7 due to electromagnetic response.
CONFIGURAZIONE E POSIZIONAMENTO

Parametri di Configurazione e Posizionamento

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<th>Parametro</th>
<th>Valore</th>
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Sito di installazione

GeoRadar

Quality Map

Mappa di Qualità

Vista di IBIS-L sul versante
Dalla mappa di qualità si evidenziano circa 40000 buoni punti di misura.

New TM30 Leica Automatic Station
very long range EDM

Conclusion

integrated system applied to Valoria landslide it has been possible to observe a big landslide in each part of it, even part of the landslide that are not accessible at all.

study and prediction

Most significant displacements, measured by periodic surveys, took place during autumn 2007: from few cm to meter per day at the toe.

During 2008 movement entity was less important than that of 2007, especially during spring and summer time, it should be related to drier climate in last year.

The stability of station pilaster used for Robotic instrument was controlled.

precision: monitoring and prevention till to 3 mm per day repeatability

completely automatic remote system: task the evaluation of the risk and to put in state of the alert authorities and then the Civil protection

promising test with interferometry terrestrial radar

Leica TM30 - accurate and very quick (three times rather than Leica TCA2003)