LANDSLIDE MONITORING

Introduction

Monitoring of terrain movements (unstable slopes, landslides, glaciers, …) is an increasingly important task for today's geotechnical people asked to prevent or forecast natural disaster that could affect human lives.

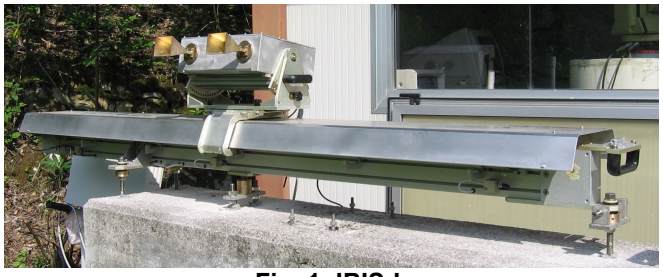

Fig. 1: IBIS-L

IBIS-L introduces a totally new solution in this field of application, providing many advantages over traditional instruments:

- Remote sensing of up to 4 km.
- Displacement accuracy up to 1/10 mm.
- Real-time two-dimensional mapping of simultaneous displacements over large areas (several km^2)
- Sampling of movements every 5 minutes
- Autonomous operation
- • Day-night, all weather operation

Hereinafter the results of a survey performed on a landslide in Tessina, Belluno province, Italy are given as an example of landslide monitoring. The experimental results consist of:

- visualisation of the two dimensional radar image of the landslide;
- visualisation of a two dimensional displacement map of the entire landslide;
- visualisation of a single pixel displacements towards time.

Measure description

One of the advantages of IBIS-L is that it simultaneously measures the displacements of all the scenario illuminated by the antenna beam providing a continuous mapping of displacements of the entire area.

In order to exploit this key feature for landslide monitoring, the best position to install the sensor is in front of the moving area so that IBIS-L antenna beam can cover the entire landslide, as illustrated in **Fig. 2**. From the installation point IBIS-L illuminated the entire landslide area of 400m x 1000 m (width x length).

The system was configured with the following operational parameters:

- maximum range: 2000m
- range resolution: 50cm;
- angle resolution: 4.5mrad;
- sampling interval: continuous.

The measure has lasted entire three days (night and day continuous operation) sampling the scenario every 10minutes.

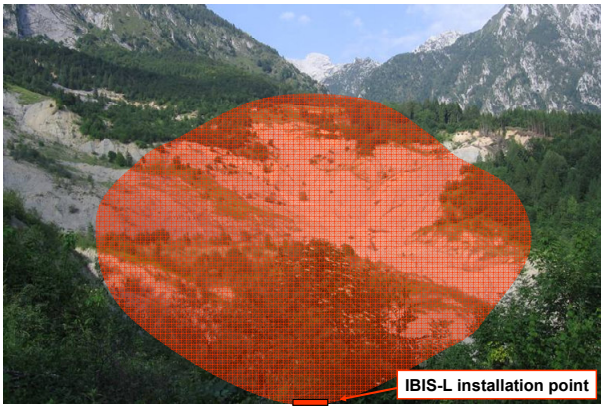

Fig. 2: IBIS-L area coverage

Fig. 3: installation site

Results – Landslide Radar Image

Fig. 4 shows the focalisation map of the landslide produced by IBIS-L (IBIS-L position is in (0,0) coordinates): the map provides the operator the information on the intensity of the backscattered signal received by IBIS-L and so provides a qualitative estimation of the quality of the measure for each pixel belonging to the image.

Higher the backscattered signal for the pixel, higher is the accuracy of the displacement measure.

The power image can be projected over a Digital Elevation Model (DEM) to get a three dimensional representation of the scenario (Fig. 5).

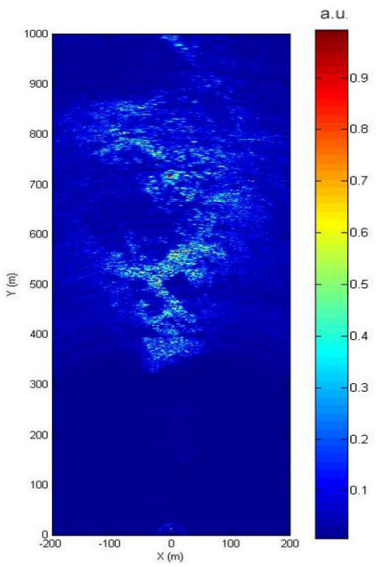

Fig. 4: landslide power image

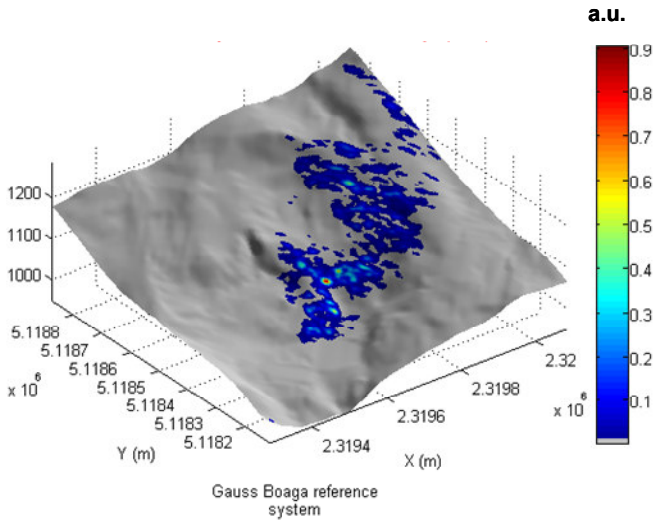

Fig. 5: landslide power image projected over DEM

Results – Landslide Displacement Map

One of the most important advantages of IBIS-L is that it provides real-time two-dimensional mapping of simultaneous displacements of the illuminated area, as shown in next figure that represents a screen shot of the PC screen on which the management software of the system was running during the measurement.

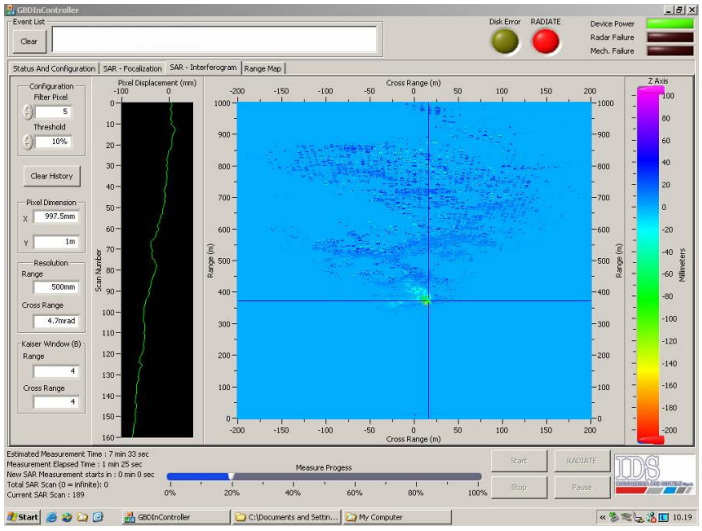

Fig. 6: real time displacement map

This screen shot has been acquired after 189 scans that correspond to about 31 hours of acquisition time.

Fig. 6 shows:

- the displacement map of the entire illuminated area: the colour of each pixel corresponds to the measured displacement and can be retrieved using the colour bar on the right side of the panel;
- the displacement towards the scan number of a selected pixel on the displacement map. It can be seen that the selected pixel has moved about 8.5mm in the direction towards IBIS-L.

The possibility of performing remote monitoring with real time displacement results can be exploited in security or hazard risk management applications to generate alarms or trigger human actions.

Displacement maps of the landslide and single pixel movements towards time can be also obtained by a post elaboration of the data acquired by the system and saved on the PC hard disk.

The figures below show the displacement maps obtained from processing the data from three different observation periods reported in the following table:

Period	Start	End	Duration
1	12:52 day1	22:33 day1	09:41
2	22:33 day1	08:05 day2	09:08
3	09:21 day2	19:18 day2	09:32

Tab. 1: observation periods

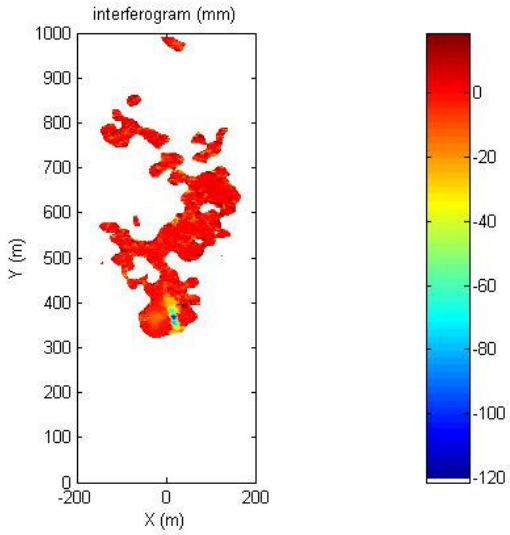

Fig. 7: IBIS-L displacement map – period 1

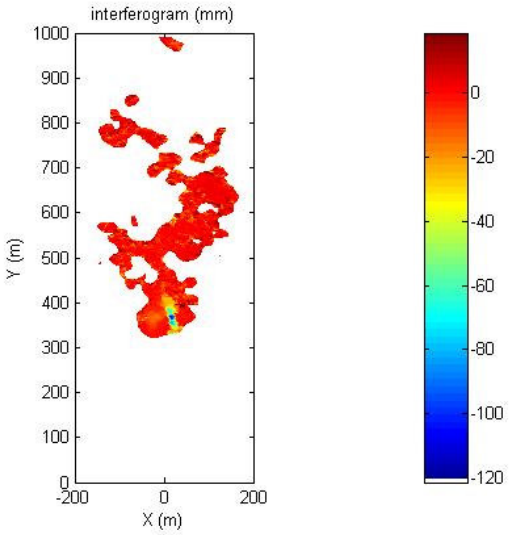

Fig. 8: IBIS-L displacement map – period 2

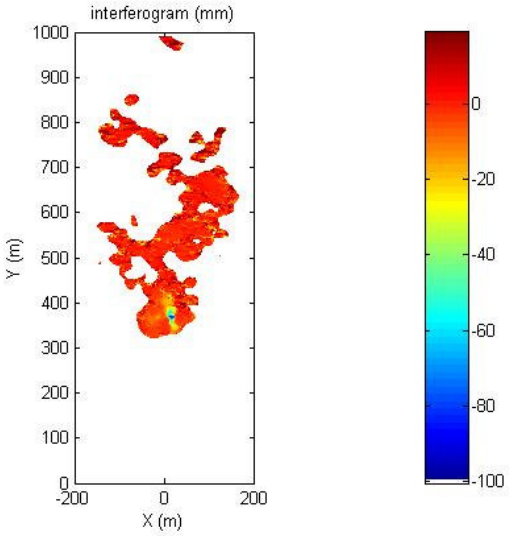

Fig. 9: IBIS-L displacement map – period 3

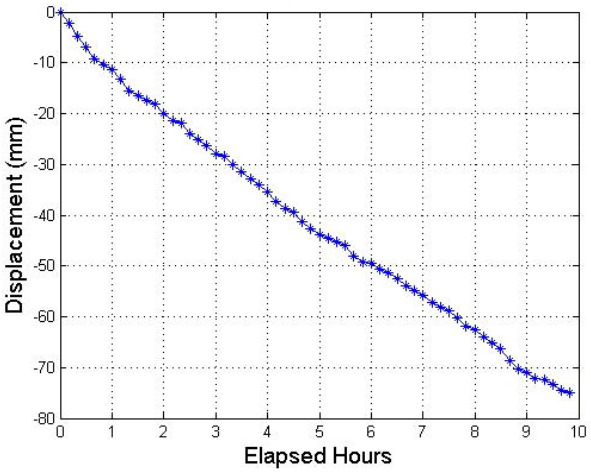

Fig. 10: IBIS-L single pixel displacement – period 1

By the observation of the previous figures it is possible to infer that:

- IBIS-L provides global displacement information for the entire illuminated area within the observed time period; the maps have been spatially filtered in order to display only the displacement of high coherent pixels;
- Besides the two dimensional displacement maps, from IBIS-L data it is possible to extract even single pixel displacement information in order to focus the attention on specific pixels of interest. Fig. 10 shows an example of single pixel displacement: the pixel belongs to the most moving part of the landslide at about 400m far from IBIS-L.

Conclusions

This case study highlights the possibility to use IBIS-L as instrument to monitor the movement of a landslide with an accuracy of tenth of millimetre.

The use of IBIS-S allows to:

- Monitor the landslide from a remote site at some tenth or hundred of meters far from the unstable area;
- Monitor the area without the need to access the landslide because there is no the need install sensors or reflectors on the unstable area;
- Monitor at the same time the entire area of the landslide;
- Monitor the landslide in any weather condition;
- Monitor the landslide without the presence of an operator, because it is possible to leave the system working autonomously.

IDS Ingegneria Dei Sistemi S.p.A.

Branch Office

GeoRadar Division

Via Sterpulino 20

56121 PISA - ITALY

Switchboard:

Phone: +39.050.9671.11

Fax - +39.050.9671.21

Sales and Marketing Department:

Phone: +39.050.9671.23/24/43/45

✉ **E-mail:** sales.gpr@ids-spa.it