Wi-GIM Life

Wireless Sensor Network for landslide monitoring and early warning

LIFE12/ENV/IT001033

Layman's report

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General information on the project

Duration:

01/01/2014 – 31/03/2017

Test sites:

Roncovetro (RE, Italy)

Sallent (Catalonia, Spain)

Beneficiaries:

- International Consortium on Advanced Design
- Department of Earth Sciences (University of Florence)
- Cartographic and Geologic Institute of Catalonia
- National Institute of Geophysics and Volcanology
- Emilia-Romagna Region

Web site:

www.life-wigim.eu

Facebook:

@wigimlifeproject

YouTube:

Wi-GIM Channel

Total cost:

1.043.090 €

EU contribution:

49%

Introduction

Landslides represent one of the most serious and common geological hazards in the world. Their **impact on human life**, already high, is increasing due to climate changes and growing urbanization, which leads to the realization of houses and infrastructures also close to unstable slopes.
A less dangerous hazard for human lives but with severe economic consequences is represented by subsidence, that is the slow sinking of the ground level, which, after some years, can **destroy buildings also on large areas**.
Landslides are caused by rainfall, earthquakes or humans (leaks in the water ducts, mining activities, earthmoving).
Also subsidence can either have a **natural or man-made origin**, as it is fostered by significant water and oil pumping or constructions overloading the ground.
Wi-GIM project aims at facing such issues by developing an innovative monitoring system to measure real-time the deformations of the ground caused by these phenomena. This permits to provide alarms for the people living in a risky area in case of impending danger.
Wi-GIM is financed by the Life+ program, the financial instrument of the European Community supporting environmental, nature conservation and climate action projects.

32.322: deaths caused worldwide by 2620 landslides (not counting those triggered by earthquakes) between 2004 and 2010

26.500: victims of the landslides activated by the earthquake occurred on 08/10/05 in Pakistan

60 millions €: damages estimated in Sallent (Spain) due to subsidence

300 millions: people exposed to landslide risk worldwide

499.000: landslides mapped in Italy

3.500: landslides mapped in Spain

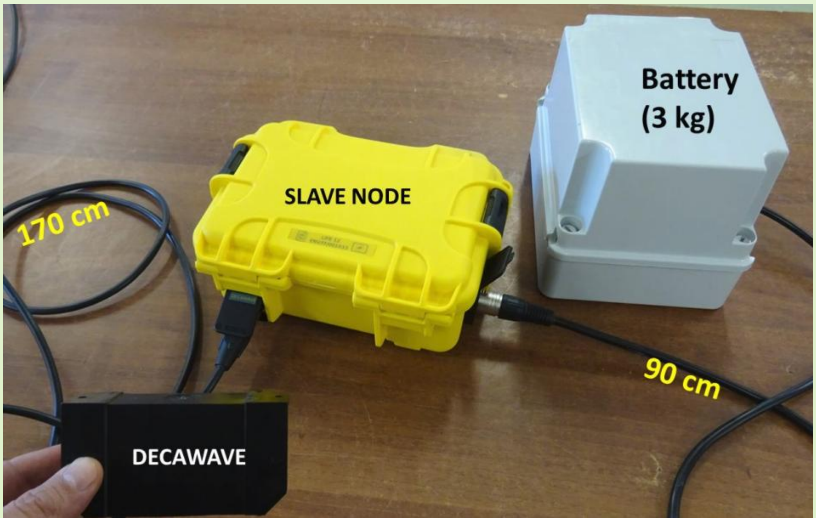
Sources: Petley (2012); Petley et al. (2006); Chigira (2010)

The importance of monitoring

Both landslides and subsidence are phenomena that change with time. They can cause deformations of few cm per year, therefore representing a danger for the stability of structures but not for human life, and then they can accelerate catastrophically.
In order to understand the risk of a phenomenon and its evolution with time it is fundamental to study it continuously through advanced monitoring systems. Regularly checking the movements of the ground is an important tool for local authorities as it helps to assess the risk for people and structures.
In such cases the monitoring activities are aimed at **alerting the population about an impending risk**, like a fast moving landslide, so that people threatened by a hazard are able to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.
Although there are many monitoring systems, none of them is specialized in working during emergency conditions, which require low-cost and fast-deploying instruments able to continuously acquire a complete set of ground displacement data.

The innovative Wi-GIM system

Recent progresses in wireless technology and electronics allow us to develop new low cost applications to the field of landslide and subsidence monitoring.
In particular we developed a monitoring system for detecting ground movements called **Wi-GIM** (Wireless sensor network for Ground Instability Monitoring).
The most innovative feature of this system is that it integrates two different technologies in order to reach a good accuracy and, at the same time, keeping low cost and complexity.
Wi-GIM system is based on two types of nodes: 1) a coordinator node (master), that manages the whole system, aggregates and stores data locally and transfers them to a remote server; 2) peripheral nodes (slaves), scattered on the portion of territory to be monitored and provided with sensors and a wireless module.
The localization of each node occurs integrating ultrawide band (UWB) and continuous wave radar (CWR) technologies, in order to achieve cm accuracy. In this way it is possible to build **a network where the position of every node is known**.
If a movement of the ground occurs, the nodes installed in the locations that experience movement are able to measure it.
With respect to the monitoring systems usually employed, Wi-GIM can provide 3D information on the displacement by keeping a low cost and permitting a rapid installation.
To validate the prototype of Wi-GIM it has been coupled with a series of prisms mounted on poles whose movements have been measured with a topographic station.



Wi-GIM features:

- cm precision
- Duration of batteries: around 1 month
- Maximum distance between two nodes: 140 m
- Cost (industrialized): 50-70 € per node
- Fast installation and configuration
- Low vulnerability (completely wireless)

Wi-GIM at work

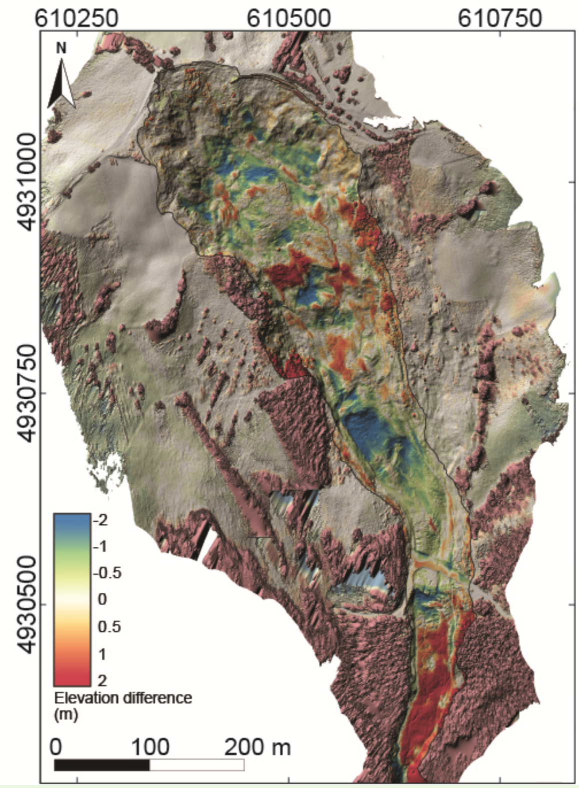
Wi-GIM system has been installed on the landslide of Roncovetro (Emilia Romagna Region, Italy) and in the village of Sallent (Catalonia, Spain) affected by a severe subsidence.

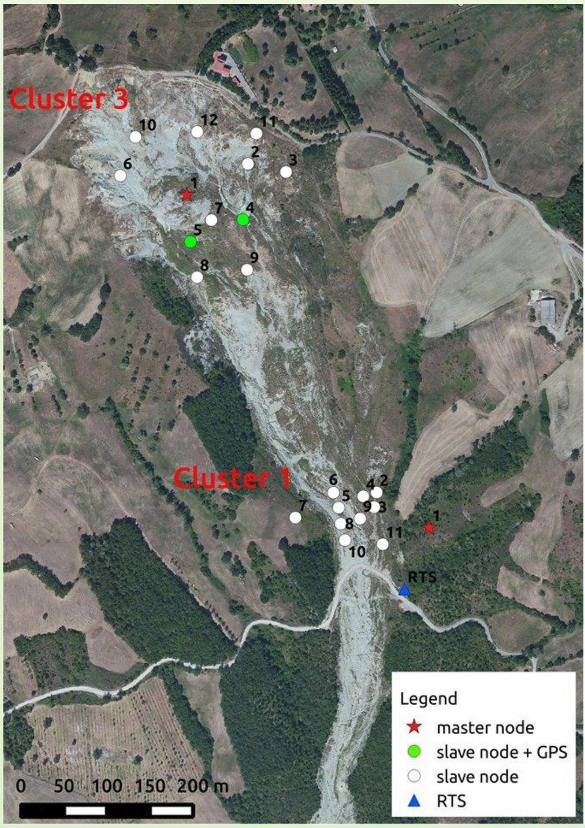
Sallent is located at the centre of the Catalan evaporitic basin above an abandoned **underground salt mine**. Some areas of this mine are unstable due to tunnel collapses and saline dissolution caused by water infiltrations. The most damaged zone is Estació neighbourhood where, in January 2009, around 120 residents of 43 homes were permanently evacuated, and a plan to the evacuation of the whole neighborhood (405 properties) was implemented due an acceleration of subsidence. After the **evacuation**, the most affected section of the neighborhood was closed to public access and its buildings demolished.

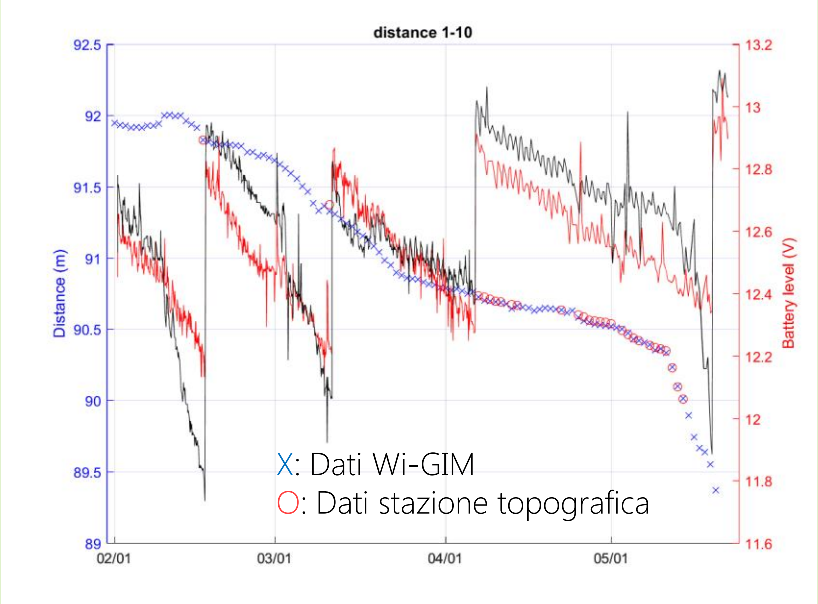
Here two Wi-GIM networks are installed, SAL1 and SAL2, constituted respectively by 7 and 3 nodes, located both inside and outside of the subsidence area. Measurements are automatically carried out 3 times a day.

A CWR has been installed to increase the precision of measurements, that are confronted with those obtained from a topographic station used to validate the prototype.

The **Roncovetro landslide** is a 2.5 km long earth flow, with a volume of 3 millions m³. It starts from Mount Staffola and reaches Tassobbio stream, where it causes the generation of a small lake. The upper part of the landslide has reached a velocity of 10 m/day.
The landslide reactivated in autimn 1993 and since then it never came to a stop, even though it slows down during dry season. The maximum velocity was recorded on the upper part and it was more than 100 m/year.
Also in this case two Wi-GIM networks have been installed, one on the upper part and the other on the central part of the landslide. Data validation has been carried out through a robotic total station and also by comparing 3D models acquired in different times by a drone.
The latter data showed the presence of lowering areas in the upper part that represent the erosion of the material operated by gravity. This material accumulates at different levels, in particular where the landslide is narrower, thus producing a raising in of the ground.
Validation measurements are in good agreement with data acquired by Wi-GIM. Furthermore the latter have been associated to a threshold system. This means that, whenever a node exceeds a certain displacement velocity, **an automatic alarm is generated** and sent to the operators of the system. They have the task of filtering possible false alarms and communicate the alarm to the competent administrations.

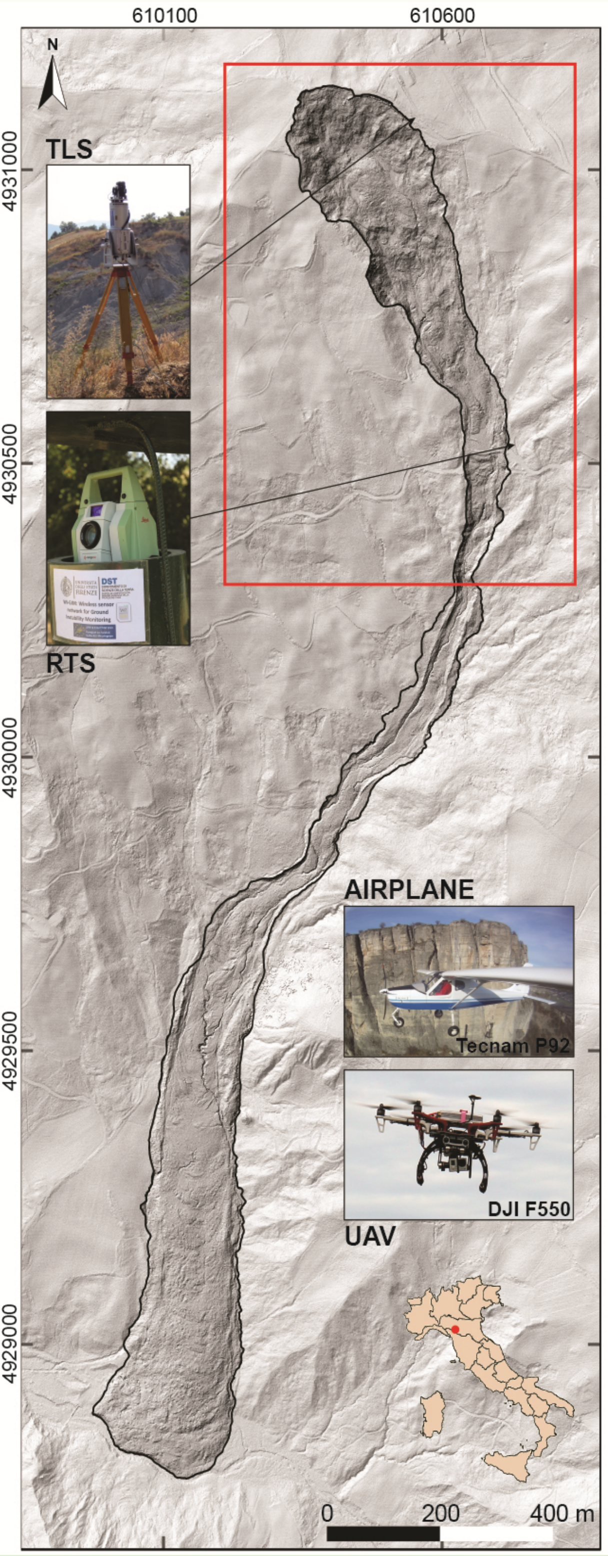






Wi-GIM: results

In order to obtain a **low-cost monitoring system** for measuring ground movements in emergency conditions, **Wi-GIM** system has been developed.
Currently, based on the tests performed in laboratory and at the test sites of Sallent and Roncovetro, the system is able to measure relative distances between nodes installed on the ground, exploiting a precision of around 8 cm.
Every node must be in line of sight with at least other 3 nodes (or 4 if a 3D information is needed) but, since the distance between them can be up to 140 m, it is possible to cover relatively large areas keeping low cost.
Furthermore the installation of the nodes has been designed to be **fast and simple** since it only consists in their positioning on the ground and in the possible acquisition of their coordinates through a GPS.
The duration of the battery varies depending on the climate conditions and on the acquisition frequency of measurements (customizable according to needs).
On average, keeping 1 measurement every 2 hours, batteries have shown a duration of 35 days.



Repercussions and future developments

The results of the project have been divulged through a series of **dissemination activities** thanks to web tools, the organization and participation to workshops and seminars, scientific publications and the formation of students and common citizens.

Specific education on the theme of hydrogeological risk prevention also through the development and application of a monitoring system, represents one of the effects of the project on society.

The industrialization and prosecution of research may lead to further improving Wi-GIM, also thanks to continuous **technological innovations** that, in few years, permit to enhance performances (for example by employing renewable energies to extend the duration of the batteries) and also to reduce costs.

Further developments can result from the application of **Wi-GIM to completely new contexts**, exploiting its high adaptability obtainable thanks to appropriate variations in the acquisition parameters.

Eventually, the use of new software and algorithm for data elaboration can produce interesting improvements concerning data interpretation and the precision and accuracy of measurements.

ICAD

Istituto Nazionale di Geofisica e Vulcanologia

UNIVERSITÀ DEGLI STUDI FIRENZE
DST Dipartimento di Scienze della Terra

Regione Emilia-Romagna

ICGC Institut Cartogràfic i Geològic de Catalunya

UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO Dipartimento di Ingegneria dell'Informazione