GUIDANCE: A New Situation for Near-Real-Time Monitoring of Surface Displacements in Landslides Hazard Overview

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ABSTRACT

We are presenting method for near-real-time monitoring of surface displacements due to landslide phenomena, namely Advance displacement monitoring system for Early warning (guidance). The procedure includes: (i) data acquisitions and transfer protocol; (ii) data collections, filtering, and validations; (iii) data analysis and restitution through a set of dedicated software; (iv) recognition of displacement/velocity threshold, early warning messages via SMS and emails; (v) automatic publication of the results on a dedicated webpage. We show how the system evolved and the results obtained by applying guidance over three years into a real early warning scenario relevant to a large earthflow located in southern Italy. guidance has speed-ups and facilitated the understanding of the landslide phenomenon, the communications of the monitoring results to the partners, and consequently the decision-making process in a critical overviews. Our work might have applications for landslide monitoring and in other contexts, as monitoring of other geographic hazards and of critical infrastructures, as open-pit mines, buildings, dams, etc.

Keywords*: landslidings; surface distortion; monitoring; early warning system .*

1. INTRODUCTION

Landslide processes causes every year bigger damage, as well as a large number of deaths worldwide. The identifications and analysis of surface deformation playing an important role for understanding the growth of landslide phenomena, and is vital in monitoring activities aimed at ensuring safety of people and/or infrastructures. Furthermore, the analysis of the surface growth of an instable slope allows obtaining information that can be used for the correct design and the implementation of effective stabilization measures.

Nowadays, a wide spectrum of instruments is available to monitor topographic changes due to slope movements, allowing us to recover displacements with sub-centi-metric accuracies at high earthly frequencies. These monitoring systems are often based on a quantitative analyses of accurate measurements obtain by means of different sensors, including: Synthetically Aperture Radar Differential Interferometry , Global Position Systems (GPS) Robotize Total Stations and extensometer networks .In some cases, Early Warning Systems (EWS) working in landslide overviews are based on surface distortion measurements .Warnings and alarm thresholds are set on measured displacements and velocities, and critical values are defined by experts taking into the account the landslide typology, the kind of monitoring instruments used, and the value uncover at threat.

2. OPERATIONAL PRINCIPLES

The belief behind the near-real-time monitoring situation proposed in this work is outlined in figure 1.The latter shows the key elements of guidance, while a more detail flow-chart describing the procedure step-by-step is presented in figure 2. The here in the presented methods, applications, and results of guidance are refer to a monitoring network base on a Robotizing Total Station (RTS) and a set of optical prisms (targets) installed in an installing slope area. However the concept, as well as the key elements of the system plan, can be applied also to different sensors and monitoring overview.

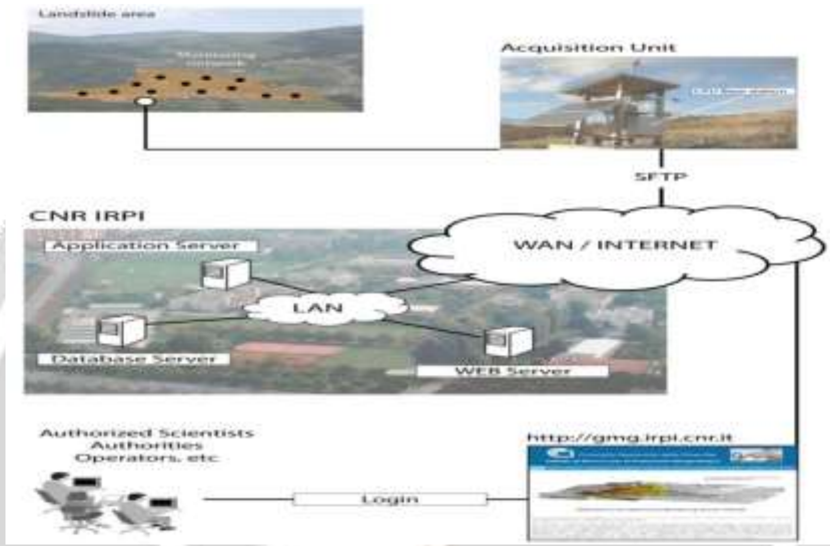

Fig. 1. System applied for displacement monitoring via RTS in a landslide.

2.1 Acquisition Unit

The first step is the data acquisitions. In general, the basic feature (acquisition parameter, time scheduling, power management, *etc.*) of different acquisition unit (RTS, extensimeter, or other monitoring instruments) are manage via ad-hoc proprietary software usually deployed in a base station installed directly at the monitored site. After the measurements sessions,given data is then periodically uploaded and analyzed. However, when Internet connection is available (GSM, GPRS, dial-up or dedicated back phones), the local controls station may be queried directly from a remote server, usually located at the monitoring division site, and transmitted through secure file transfer protocol .

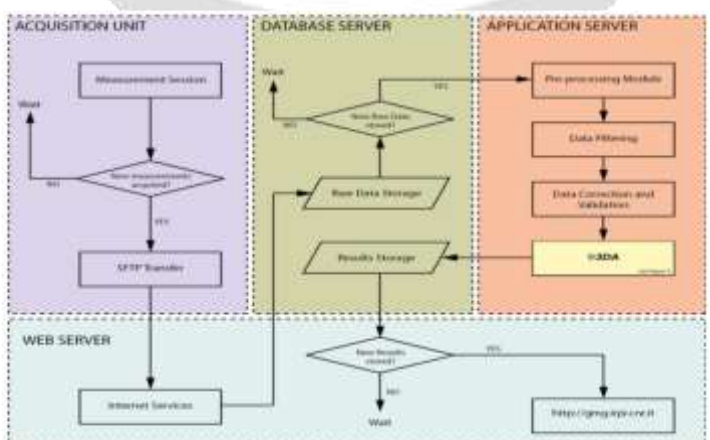

Fig. 2. Detailed Flow Chart of the key elements.

2.2 Database and Applications Server

After file transfer process, data is uploaded and stored in a dedicated Database server, and are ready for the processing steps. The database structure (whose description is omiitted for broevity), is built around three main entities: the observed phenomenon, the monitoring instrument, and the measurements. The Database server and the Application server are managed via a software (ADMIiN) implemented in Visual Basic, which consists of several modules, including: (i) a data acquisition module, which manages the connection with the base stations through the Internet (for a raw data transfer); (ii) a database interface modules, which reads the raw data and writes processed data into the database; (iii) a pre-processing modules.

At begining data pre-processing module converts raw data into the accurate metric-scale and operates system. Taking into account the example of RTS, the instruments record both angular values (in rads) & distance (in m) in a local reference system, thus data want to be converted to the physical parameter of interest (displacement components, in m) defined in a geographic coordinate system. Then, the database is checked, by removing inappropriate data, noisy measurements, spikes, and handling missing values. After that, the data is corrected and valeidated by considering a set of predefined algorithms

2.3 Three-Dimensional Displacement Analysis

Surfaces displacement data are haabitually presenting either as a tables containing numeric values reelevant to a time intervals, or in the form of bi-dimensional charts, where the measured quantity (baselines change, line-of-sight change, easting, northing, vertical motion, or some combination of the observed deformation components) is plotted *vs* time. By comparing the actual representations of the displacement data to the result of pioneeristic monitoring activities in landslide overviews, it is evident that differences are minimal.The bi-dimensional charts may be straightforward to experienced people, who are used to deal with monitoring data; however, in real operative scenarios multidisciplinary teams work for civil protection purposes, and a rapi ed and accurate understanding of the deformation measurements as well as a clear and unambiguous representation of the data is vital to efficiently supports decision maker.

Thus, important limitations of the bi-dimensional charts are: (i) a specific background-knowledge of the data and of the phenomena is usually required in order to reading, understanding and interpreting the displacement results; (ii) the informative contents of the data is usually distributed within a large number of outputs documents; (iii) this presentation is unsuitable for rapid and effective presentation of the updated situation, especially to people not having basic knowledge of monitoring systems, but should act and react promptly (e.g., authorities, worker, population). For these reasons, we implemented a set of procedures to achieve about 3DA algorithm, as implemented in matlab high levels program.

About 3DA allowing for a numbers of interpolation algorithms (e.g. nearest neighbor, bilinear, triangular, *etc.*) and has several built-in features that controls the data import as well as the final represented output. After the measurements sessions and the data processing steps, the results are automatically sent to a Web server. A dedicated webpage (“LiveData”, hosted at the address has been set up in order present the results of the procedure.

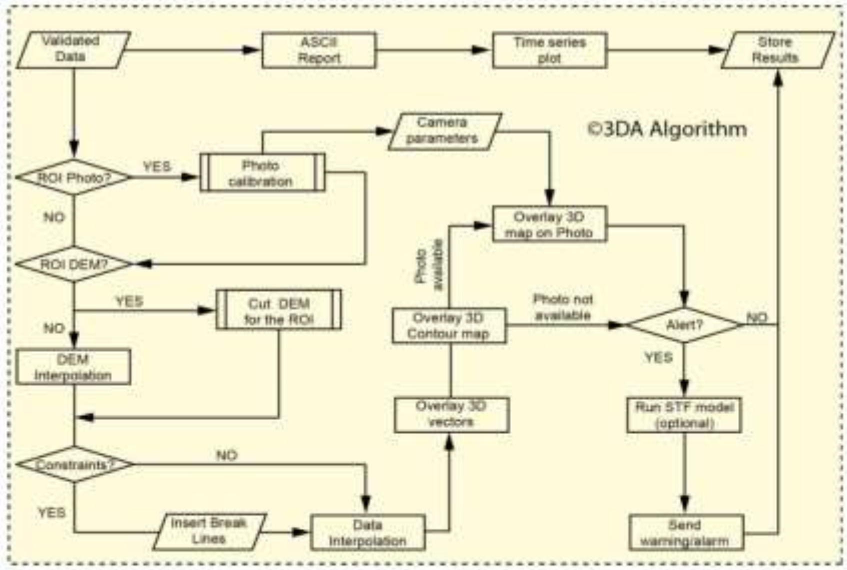

Fig. 3. Detailed flow chart as implemented in Matlab.

At this page, accredited users may promptly consult the monitoring data few minutes after the end of the measurement sessions. For each monitored site, the web page is organized in different sections. The first page, called "Synthesis", shows the last available update of the monitoring systems present in the area. In this page, selected plots and about three dimensional algorithm representations are shown in order to provide rapidly to the end user about the current status. After, users may explore other web-pages, each dedicated to the different instruments installed in the site with some representation that show the recorded history. In some case, the web platform is also used to share additional information, such as reports, files with details on the monitoring network, last monitoring bulletin, etc.

3. CONCLUSIONS

We presented method, an innovative procedure to manage and share near-real-time displacement monitoring data. The methodology in general, and more specifically its final step, it is useful to disseminate the information about the current situation of the landslide. However, we remind that false alarms due to inaccuracies in the data because of instrument malfunctions, physical changes at the measurement site, and/or very local/shallow reactivations may always occur. Thus, critical decisions in emergency landslide scenarios, as starting an evacuation and/or closing the traffic on a road/railway, cannot be based only on the results of topographic monitoring and carried out automatically. The added value of method is to provide a straightforward and common platform to share information between the involved operators/experts about the monitoring results in near-real-time. In emergency situations, alerts are automatically sent only to the experts, which have to revise and validate the monitoring results, and then carefully evaluate following actions in cooperation with authorities and decision makers.

4. REFERENCES

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