GeomonWeb: a Web-Based Monitoring System for Landslide Phenomena

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GEOMONWEB: A WEB-BASED MONITORING SYSTEM FOR LANDSLIDE PHENOMENA

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Abstract: *We present GeomonWeb, a web-based system developed to improve landslide's monitoring activities potential. The system allows going from the data acquisition, to the data transfer and processing, as well as the diffusion of the results in near-real-time via web. The monitored parameters are presented in a clear and self-explaining manner, so that rapid assessments of a hazard potential can be facilitated to people with different backgrounds and roles during emergency contexts.*

1. Introduction

Landslides are one of the most frequent natural hazards, causing every year severe economic losses as well as fatalities all around the World [2]. Monitoring landslides is an essential activity to recognize sudden evolutions of phenomena that might cause a potential risk for people and/or infrastructures. Nowadays, several technology solutions are available to monitor the evolution of important physical parameters in near-real-time, intrinsically allowing a multiparametric approach to describe the kinematics of landslides [3-5]. Such approach is crucial for recognizing a hazard potential and to define risk scenarios. However, in several cases there is a large delay between the acquisition and processing of the whole data and the diffusion of the results used for a multiparametric assessment. Moreover, in several cases the people involved in the monitoring activities have different backgrounds, especially during emergency contexts (scientists, decision makers, civil protection operators, etc.). Thus, the divulgation of the results has to be rapid, clear and possibly self-explaining, in order to avoid further delays and misunderstandings during the emergency operations [4].

In this work, we present GeomonWeb, a web-based system developed to improve the potential of landslide's monitoring activities. The system includes several procedures and subroutines that allow going from the data acquisition, to the data transfer and processing, as well as the diffusion of the results in near-real-time via web. The monitored parameters (rain precipitations, surface displacements, inclinometric data, etc.) are presented in a clear and self-explaining manner, so that the rapid assessments of a hazard potential can be facilitated to people with different backgrounds and roles during an emergency context.

We describe examples of application, considering realistic monitoring scenarios; moreover, the use of GeomonWeb in emergency circumstances received positive feedbacks from the Italian Civil Protection.

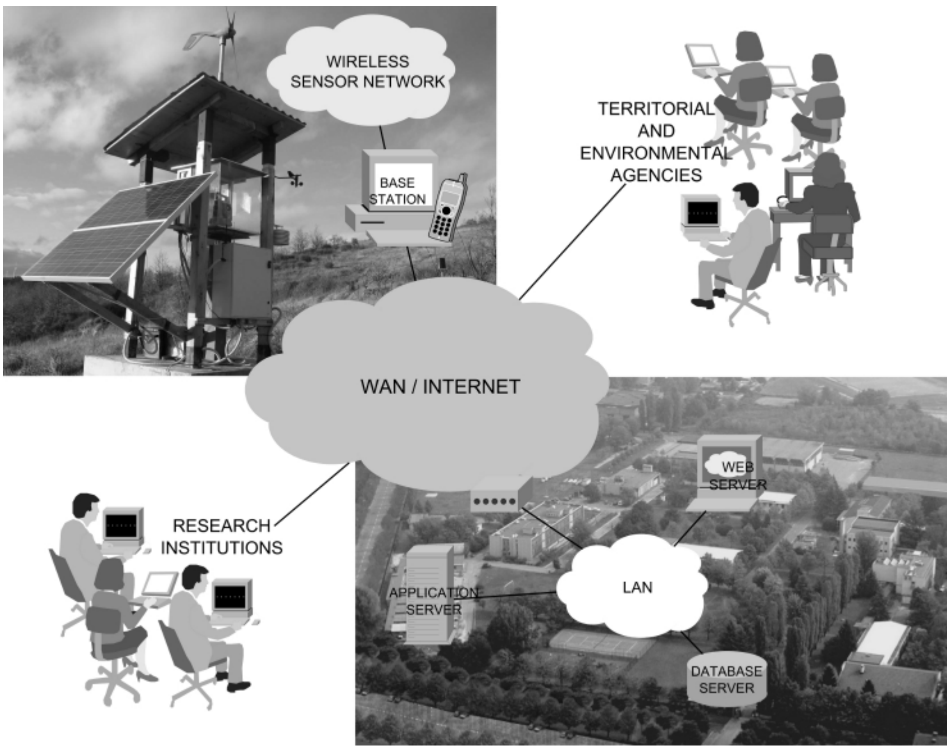

Figure 1. A typical monitoring network

2. Background monitoring network

Monitoring of landslide phenomena is a well-studied problem. Researchers, together with national environment and territorial protection agencies, agree with the common idea that wireless sensor network [1] are well suited for providing a timely and up-to-date monitoring data at low infrastructure and workforce costs. Typical wireless sensor networks for monitoring landslide phenomena involve a set of autonomous sensors and related instruments and equipment (e.g., weather stations, robotized total stations, strain gauge indicators, extensimeter). Some of these instruments are independently connected to the Internet and may be queried autonomously. However, in the most common situation, sensor data are centralized by an ad-hoc software (one for each type of sensor) and stored in a local base station (see Figure 1). In some – still common – cases, data should be downloaded in loco periodically and physically transferred to calculus centers. However, when Internet connection is possible (through GSM, GPRS, UMTS, dial-up or dedicated backbones) the base station may be queried directly from a remote server, usually located in the monitoring division site.

In our work, we consider a substantially complex scenario where data may be accessed and analyzed by different actors. For a schematic view of our network, the reader may refer to Figure 1. In the scenario we consider here, actors may be, for instance, researchers interested in analyzing monitoring data for multiple purposes: model definition, time series analysis, alarm threshold triggering, geomorphological study, and so on. These actors are not necessarily interested in up-to-date data: usually they download a snapshot of the data once for all, or at low periodicity, and perform their analysis offline.

Other typical actors of this network are people working for territorial and environmental agencies, such as the National Civil Protection Agency, local and national administrations and so on. These institutions need a prompt response from the system, and they should be able to access monitoring data in near real-time. Moreover, data should be presented clearly, without ambiguities, in a user-friendly interface to allow actors involved in civil defense to provide a timely response in case of probable dangerous events.

All these actors are, of course, located in different buildings, city zones, and even in different regions or countries. Hence, the fastest, easiest and more efficient way to make data accessible is to publish them in the Internet through a dedicated webserver.

Given this scenario, we can identify a set of critical issues that need to be addressed, which might be summarized as follows:

1. **Integration**: data are captured at different sampling frequencies, using different coordinate systems, different metric scales and usually different data formats;
2. **Conversion**: raw data provided by the instruments are not immediately exploitable. For instance, wire extensometer encoders record values in millivolts and they need to be converted to units representative of the physical parameter of interest (in this case an extension, thus in meters);
3. **Filtering**: measurements are often subjects to external factors that may influence their values, and should then be promptly corrected;
4. **Storage**: data need to be stored in a coherent database structure in order to simplify data query, report and analysis;
5. **Presentation**: depending on the actor role, data may be presented as tables, curves, histograms, charts, ad-hoc graphic representations and so on;
6. **Protection**: each actor may access only part of the data (both in terms of time and number of monitored parameters), depending on its role and privacy policies.

3. A web-based integrated monitoring system

In order to address all the critical issues presented in the previous section, we provide a user-friendly web-based interface that simplify the search and retrieval of monitoring parameters as well as their temporal analysis. GeomonWeb[1] consists in two main modules (see Figure 2): a *data processing module* and a *Web-application module*. The data processing module performs all the automated and necessary operations for transforming raw monitoring parameters. This part of the software is implemented in Visual Basic and consists in a *data acquisition unit*, which manages the connection with the base station via the Internet (for raw data downloading), a *database interface unit* that writes processed data into the GeomonWeb database, and a set of *data preprocessing units*.

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1 Available at: http://dbirpi.to.cnr.it/geomonweb/geoweb2/home.php

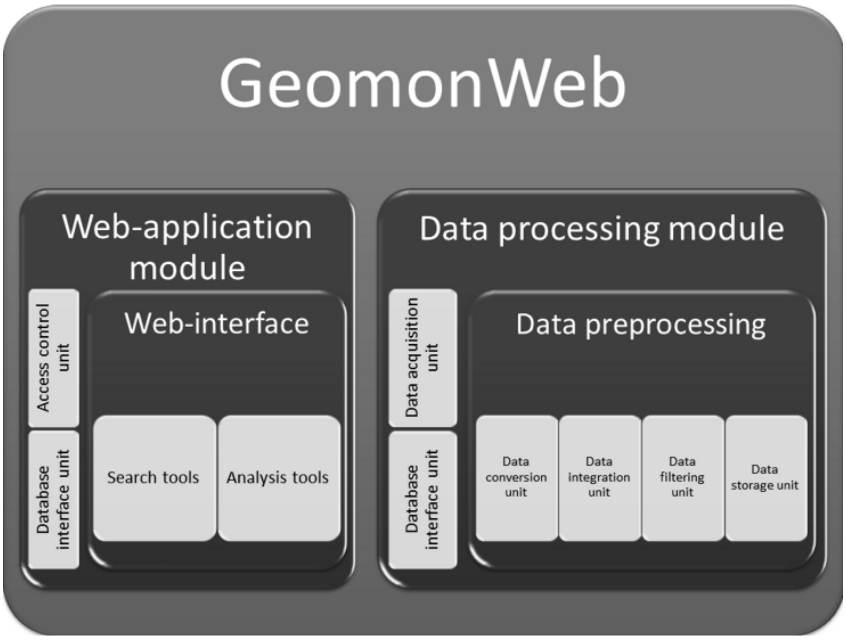

Figure 2. GeomonWeb software architecture

The data structure (whose description is omitted for brevity), is built around three main entities: the observed *phenomenon*, the *instruments*, and the *measure*. In summary, the database stores periodic measures from a set of instruments monitoring some landslide phenomena.

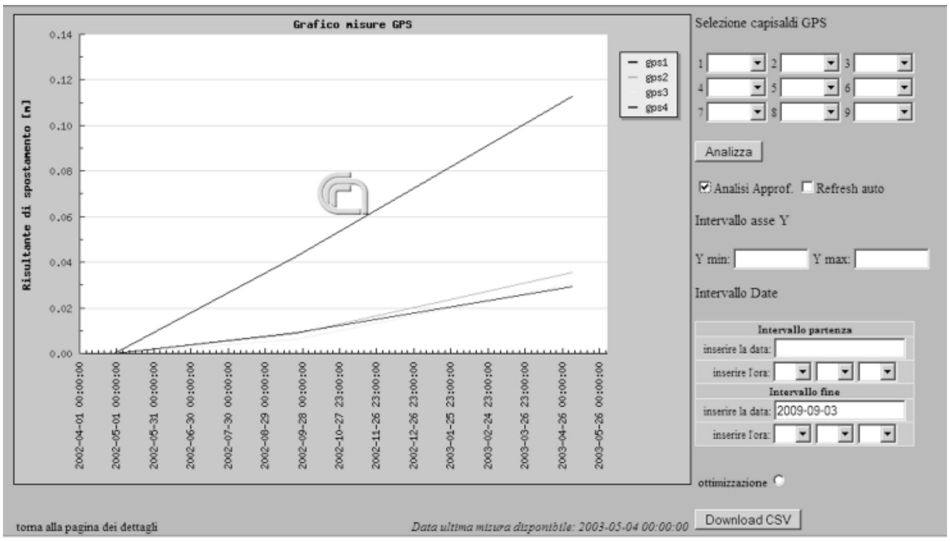

Figure 3. A screenshot of the GeomonWeb web-interface

The data preprocessing sub-module consists of four basic units that: 1) convert raw data into the correct metric-scale and coordinates system, 2) integrate data coming from different sources, often sampled at different frequencies, 3) filter the database by removing inconsistent data, noisy measures, picks, spikes, and handling missing values, 4) format the resulting processed data and store them into the database.

The Web-application module implements all necessary functions for handling and searching data, as well as a set of basic tools for enhanced temporal data analysis, and make them accessible through a user-friendly web-based interface. The application is implemented in PHP[2] + MySQL[3] under the HTTP server Apache[4]. It consists of an *access control unit*, a *database interface unit* and a *web-interface* sub-module. The first unit controls that each user (e.g., maintainer, analyst, National Civil Protection agent, researcher,

2 http://www.php.net/

3 http://www.mysql.com/

4 http://httpd.apache.org/

and so on) is granted the correct data and tool access privileges. The database interface unit provides the database connection and the query functions for handling and searching data preprocessed by the data processing module. The web-interface provides user-friendly utilities for searching and browsing the data, as well as many graphical tools to analyze the temporal evolution of any stored physical parameter measure. Figure 3 shows an example of the application front-end. We recall that the user access level determines the availability/hiding of a certain amount of information, both in terms of time-period (last month week, last month, and so on) and temporal resolution of the data (daily samples, hourly samples), but also in terms of number of physical parameters (GPS measures only, weather station parameters only, precise combinations of physical measures).

4. Discussion and conclusions

To better explain the above-mentioned crucial point, we make two examples of application. In the first one, we are in an emergency status, while in the second one, we are in a typical scientific research situation:

1. The National Civil Protection Agency needs to monitor a critical active landslide phenomenon and to provide timely rescue intervention for the population. In this case, the critical physical parameters should be presented as soon as possible, even if they are roughly preprocessed. Moreover, they should be presented in a simple form (presenting only the necessary information), without ambiguities and using color codes for underlining possible alert situations or anomalies. Response of the system is the strongest requirement in this case.
2. A research group is studying the dynamic behavior of landslides following different physical parameters. It will not need to access recently stored measures, but it requires that the analyzed data are reliable, trustable and validated by the monitoring division. In this case, high sampling frequency is not a strong requirement, and missing values may be replaced using interpolation when possible. Hence, quality and reliability of the data are the two strongest requirements in this scenario.

In a nutshell, GeomonWeb serves both as active monitoring utility and monitoring data repository (with some enhanced analysis tools). It has been already tested in real emergency situation, such as the recent Montaguto landslide phenomenon, and has attracted the interest of the Italian Civil Protection Agency. As future work, an English version will be released together with some new automated functionality for enhanced multivariate time series analysis and for common maintenance operations.

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