GEOSPATIAL INFORMATION ON LANDSLIDES AND FLOODS IN ITALY

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ABSTRACT:

We describe a system for the dissemination of geographical and thematic information on landslides and floods in Italy. In the framework of the Integrated Management of the Environmental Data project – GIIDA – of the Italian National Research Council (CNR), the research Institute for Geo-Hydrological Hazard Assessment (IRPI) has designed and implemented a new Spatial Data Infrastructure (SDI). The SDI is compliant to Open Geospatial Consortium (OGC) specifications for the publication, access, and discovery of dedicated services, including WMS, WFS, WCS and CSW services. The CNR IRPI spatial data infrastructure (SDI) fully exploits Open Source Software (OSS). Adoption of an OSS approach for the design and the implementation of the new SDI proved valid, and economically convenient. As part of the GIIDA project, the national landslide warning system for the possible occurrence of rainfall-induced landslides in Italy was integrated in the new SDI. The integration proved successful, and was facilitated by the fact that the warning system operates on data and geographical information stored in a PostgreSQL + PostGIS database.

1. INTRODUCTION

In 2007, the European Parliament established the Infrastructure for Spatial Information in the European Community (INSPIRE). The INSPIRE Directive 2007/2/EC entered into force 15 May 2007, with the goal of establishing a common Spatial Information Infrastructure (SII) for the European Union and the Member States. Through specific implementation rules, the Directive establishes how individual Member States shall implement national Spatial Information Infrastructures. According to Yi Shan-zhen et al. (2000), a Spatial Information Infrastructure, also referred to as Spatial Data Infrastructure (SDI), shall facilitate the sharing, interoperability and integration of geographical information among different components (i.e., offices, agencies, bodies) of a Region or a Country, and should guarantee the efficient flow of information from the authors to the users.

A driving force for the standardization of geographical information and services is the Open Geospatial Consortium (OGC). The Consortium promotes the interoperability and sharing of spatial (geographical and thematic) data and resources through the production of technical specifications, most of which were accepted by the International Organization for Standardization (ISO) in the ISO 19100 series. OGC specifications relevant to geospatial data sharing in a distributed network include specifications for: (i) the design of Web Mapping Services (WMS), for the visualization of geographical data as images, (ii) Web Feature Services (WFS) and Web Coverage Services (WCS), for the delivery of geographical information in vector (feature) and raster (coverage) format, (iii) Catalogue Services for the Web (CSW), for the design and implementation of digital catalogues of metadata for geospatial data and services (Sonnet, 2005).

In 2009, the Earth and Environment Department (http://dta.cnr.it) of the Italian National Research Council (CNR) launched the GIIDA project. The scope of GIIDA, an Italian acronym for Integrated and Interoperable Management of Environmental Data, is to establish a multi-disciplinary e-infrastructure for the efficient management, processing, and dissemination of Earth and Environmental information resources, including data, services, models and sensors. In the framework of the INSPIRE Directive, GIIDA intends to design and implement the CNR Spatial Information Infrastructure for Earth and Environment resources (Nativi, 2009) (Figure 1).

The GIIDA project is conducted by 17 CNR research Institutes, the Corpo Forestale dello Stato (Corps of forest rangers), the EV-K2 institute and 18 non-CNR Institutions (3 Regional administrations, 4 research centers, 5 universities, 5 SMEs - Small and Medium Enterprises), grouped into seven thematic areas: (i) biodiversity, (ii) climate change, (iii) air quality, (iv) soil and water quality, (v) natural and man made hazards and risk, (vi) infrastructure for research and public administrations, and (vii) ocean and marine resources.

Figure 1. Framework for the Integrated and Interoperable Management of Environmental Data (GIIDA) project structure (Nativi, 2009). See text for explanation.

For the GIIDA project, the CNR research Institute for Geo-Hydrological Hazard Assessment (IRPI) coordinates the thematic area on natural and man-made hazards and risk. More specifically, IRPI focuses on the dissemination of geographical and thematic data on landslides and floods, including (i)

landslide inventory maps at different scales and covering different geographical areas, (ii) landslide susceptibility, hazard and risk maps, and (iii) information on historical landslide and flood events in Italy.

2. CNR IRPI SPATIAL DATA INFRASTRUCTURE

2.1 Spatial Data Infrastructure

Since the publication of the WMS specification by the OGC, in 1999, there has been an increasing interest of users and software developers for this standard, which has resulted in improved software implementations.

Although the implementation of an OGC client in the framework of an existing GIS is a relatively simple task, the development of a complex geo-spatial data infrastructure (SDI), which requires the interplay of multiple software and hardware components, remains difficult. A simple (basic) infrastructure includes at least the following elements (Nogueras-Iso et al., 2005): a database system, metadata, a network infrastructure, and dedicated technologies for the collection, management, retrieval, and representation of the geographical information.

More specifically, to implement an SDI the following minimum hardware and software components are necessary: (i) a network server, (ii) a relational database management system (RDBMS) with dedicated spatial (geographical) extensions, (iii) software for the design and the implementation of specific OGC services (e.g., WMS, WFS, WCS), and (iv) an application for metadata production, management and publication. The infrastructure can also include a Web-GIS interface, to facilitate browsing of the geographical information. Figure 2 shows the structure of a simple (basic) SDI.
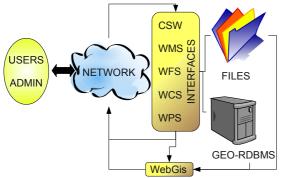

Figure 2. Sketch of a simple spatial data infrastructure, SDI.

The OGC services are used to publish geographical data stored in the spatial RDBMS, also exploiting a Web-GIS application. Users can access the data through GIS, individual browsers, and metadata clients. System administrators configure and manage the system using simple, dedicated interfaces. The SDI must be accessible from the Internet. For the purpose, specific Web Server software is required. Typically, in a SDI a larger number of software and hardware components results in larger implementation and management costs.

2.2 An Open Source Software approach

Most frequently, Open Source Software (OSS) ensures a good cost/quality ratio, enhanced interoperability, and improved adoption of existing standards. For geospatial software, the Open Source GEOspatial (OSGEO) Foundation supports, builds, and distributes open source geospatial software of high quality. The Foundation has a record of accomplishments of open and collaborative projects, with a clear investment program oversight, and consistent adoption and implementation of OSGEO principles. Further, the International Conference for Free and Open Source Software for Geospatial (FOSS4G) is an annual meeting for software developers and users interested in constructing, managing and disseminating geo-spatial information. The FOSS4G software is widely adopted by regional, national, and international organizations (see e.g. Ticheler, 2009). In Italy, a relevant user of FOSS4G software is the Italian national Department for Civil Protection (DPC) that has adopted an OSS approach for the design and the implementation of the SDI (Dello Buono, 2009).

When designing and implementing an SDI in a research and development environment – such as for CNR IRPI –, Open Source Software is more flexible (has less limitations) than proprietary software. OSS allows for copying, modifying, and distributing the software – including the source code – with no licence restrictions. This is of particular interest to CNR IRPI, since software, procedures, and specific applications can be re-distributed to other users freely, at no additional cost.

2.3 Software

Software used to implement the CNR IRPI Spatial Data Infrastructure for storing, managing, and publishing landslide and flood data includes: (i) PostgreSQL 8.2.11 + PostGIS 1.3.5, a powerful RDBMS with spatial extension, (ii) Geoserver 1.7.4, a Java server that allows users to share and edit geospatial data using a graphical frontend, (iii) Geonetwork OS 2.4, a catalogue application to manage spatially referenced resources, (iv) ExtJS 3.0 + GeoExt 0.6 + OpenLayers 2.8, a set of JavaScript libraries for building rich Web mapping applications, (v) UNM MapServer 5.0.2, a platform for publishing spatial data and interactive mapping applications on the Web, and (vi) GeoSDI ERA 0.1, a Web application designed by GeoSDI (www.geosdi.org) for the Italian national Department of Civil Protection (Dello Buono, 2009). The SDI is hosted on servers running RedHat Fedora Core 8. Figure 3 illustrates the logical framework for the CNR IRPI Spatial Data Infrastructure.

PostgreSQL, with the geospatial extension PostGIS, is used to store the geographical and thematic information, allowing for an efficient management of features and attributes, and access to standard functionalities of a RDBMS (e.g., independence of data from application, security, physical and semantic data integrity). With PostGIS, the geographical information can be managed and updated easily, including through automatic scheduled procedures. The latter is important when dealing with rapidly changing phenomena, and related data (e.g., weather data). The software implementation guarantees immediate availability of new maps on the Web, after each database update process. Moreover, since PostgreSQL controls the concurrent access to table data, it allows for the simultaneous editing of the same map by multiple users from different locations (e.g. the compilation of a landslide

inventory map by multiple investigators, each working in a different area).

In the CNR IRPI spatial data infrastructure, WMS, WFS, and WCS services are implemented using Geoserver. Styling of the individual data layers is obtained exploiting the GeoExt Styler extension, which creates OGC Styled Layer Descriptor (SLD) files, i.e. a profile of the OGC WMS specification that extends the WMS standard allowing enhanced symbolization and colouring of geographical data. Power users can take advantage of the service using GIS tools, integrating proprietary data with the data made available by CNR IRPI.
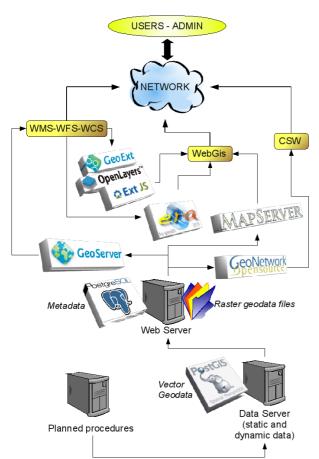

Figure 3. Framework for the CNR IRPI Spatial Data Infrastructure (SDI) used to disseminate information on landslides and floods in Italy.

Geonetwork is used to compile and manage metadata, and to provide a specific service (CSW) for discovering maps and documents. In general, compilation of reliable and sufficiently complete metadata is time consuming, and requires efforts from all the individual parties that have contributed to the production of the geographical information. For the purpose, Geonetwork proves particularly useful. It allows management of different users and authorization levels for the compilation of metadata, facilitating cooperation among the users. Users registered as *editors* can compile and edit metadata, whereas *reviewers* and *administrators* can compile, edit, review, and publish the metadata. The CNR IRPI catalogue produced by Geonetwork contains metadata compiled manually according to ISO19115/39 standards, and metadata harvested automatically from the Geoserver services.

ExtJS and GeoExt/OpenLayers are used to design the Web-GIS interface adopted to disseminate the geospatial information. The software suite is flexible, and allows for the design of efficient, user-friendly interfaces. The rationale behind the GeoExt library is the creation of objects from OpenLayers maps, which can be managed using ExtJS for the implementation of the Web interfaces. Since OpenLayers maps can be created from the same OGC services provided by Geoserver, the implementation of the WebGIS is the results chiefly of the underlying geospatial infrastructure.

Finally, GeoSDI ERA, through a simple WebGIS interface, permits the efficient integration of geographical and thematic data with data and information provided by other WMS services.

In the designed SDI (Figure 3), the Data Server stores *static* and *dynamic* geographical and thematic data. Static layers include, e.g., administrative, hydrological, and geographical boundaries, geological and geomorphological maps, landslide inventory maps, landslide susceptibility and hazard maps, and landslide risk maps, for different areas in Italy and at different scales. Dynamic layers are produced by specific automatic procedures that update the maps daily (see § 2.4). Static layers include raster and vector data, whereas dynamic layers include vector data only. The Web server provides OGC services and specific WebGIS applications. Raster data are stored as Geotiff files, and metadata are stored in the PostgreSQL database.

WMS services are provided using commonly adopted reference systems in Italy, including WGS84 (EPSG: 4326), UTM-ED50 (EPSG: 23032, EPSG: 23033), UTM-WGS84 (EPSG: 32632, EPSG: 32633), Gauss-Boaga Roma40 (EPSG: 3003, EPSG: 3004), and Google Spherical Mercator (EPSG: 900913). The Molodensky three geodetic datum transformation parameters (-87, -98, -121) are used for the European Datum 1950, and the Helmert seven parameters estimated for the Italian Peninsula (-104.1, -49.1, -9.9, 0.971, -2.917, 0.714, -11.68) are used for the Roma 1940 Datum (GRASS Development Team, 2009).
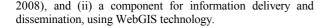
Table 1 lists the types and links of the services currently provided by the CNR IRPI SDI.

Type	URL
Metadata	http://geonetwork.irpi.cnr.it/geonetwork/
WMS	http://geoserver.irpi.cnr.it/geoserver/wms
WFS	http://geoserver.irpi.cnr.it/geoserver/wfs
WCS	http://geoserver.irpi.cnr.it/geoserver/wcs

Table 1. Services and URLs provided by the CNR IRPI Spatial Data Infrastructure.

2.4 National Landslide Warning System

CNR IRPI is developing a national landslide warning system for the Italian Department for Civil Protection, DPC (Rossi et al., 2009). The system is intended to provide spatially distributed daily (and potentially 3-hour) forecasts for the possible occurrence of rainfall-induced landslides in Italy. It consists of two main components (Figure 4): (i) a component for rainfall data analysis and processing, and comparison with existing empirical rainfall thresholds (Guzzetti et al., 2007,

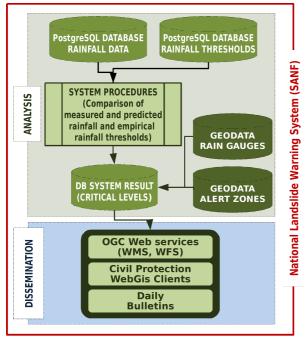2008), and (ii) a component for information delivery and dissemination, using WebGIS technology.

Figure 4. Logical scheme for the National Landslide Warning System for the possible occurrence of rainfall-induced landslides in Italy. The system is designed and implemented by CNR IRPI for the Italian national Department for Civil Protection (DPC).

Rainfall data analysis is based on the comparison of rainfall measurements and empirical rainfall threshold for the possible initiation of landslides (Guzzetti et al., 2007, 2008). For the purpose, the system uses: (i) rainfall measurements obtained from a national network of 1945 rain gauges, (ii) quantitative rainfall forecasts obtained through numerical meteorological modelling, (iii) empirical rainfall thresholds for the possible initiation of landslides constructed exploiting literature and archive data, (iv) geographical information on the location of the 1945 rain gauges, and (v) a geographical subdivision of the Italian territory in 126 alert zones, adopted by the DPC to manage geo-hydrological hazards. The information is stored in a PostgreSQL database equipped with the PostGIS extension.

The main output of the system consists of critical rainfall levels, in five classes, for each rain gauge and for each alert zone. Critical rainfall levels are determined from rainfall measurements and 24-hour quantitative rainfall forecasts. For the alert zones, two types of critical levels are determined aggregating the levels of the individual rain gauges in each alert zone. The first critical level is established determining the maximum critical level reached by a rain gauge in each alert zone (worst case scenario), and the second critical level is established considering the mode of the critical levels attributed to all the rain gauges in the alert zone.

The requirement of the DPC to access the landslide forecasts in quasi real-time, easily, and from different locations, conditioned the design of the dissemination infrastructure, including the adoption of specific WebGIS technology.

Critical rainfall levels, calculated daily by the system, are stored in specific PostgreSQL database objects (i.e., tables and views). These objects, together with the available geographical information on the location of the rain gauges,

and the location and extent of the alert zones, are exploited to generate maps showing the critical rainfall levels, which are distributed as WMS and WFS services. The PostegreSQL objects and the corresponding WMS and WFS services are updated daily. Exploiting the WebGIS infrastructure designed and implemented in the framework of the GIIDA project, three WebGIS clients were prepared for the dissemination of the critical rainfall levels. For any given day, two clients show critical rainfall levels obtained using the rainfall measurements, and the quantitative rainfall forecasts. A third client is used to show the historical forecasts (last four days). The three clients integrate basic tools for the manipulation of critical rainfall levels, mainly selection and filtering of the information (Figure 5).

Figure 5. Map portraying the daily forecast for the possible occurrence of rainfall induced landslides in Italy. The map shows critical rainfall levels, in five classes, for 1945 individual rain gauges (dots) and for 126 alert zones.

Further, the system produces a bulletin listing maps showing critical rainfall levels generated automatically using standard OGC calls and alphanumeric data on critical rainfall levels, for each rain gauge and for each alert zone. The bulletin is prepared and delivered daily to the DPC.

3. CONCLUSIONS

In the framework of the GIIDA project, of the Italian National Research Council (CNR), a new Spatial Data Infrastructure (SDI) was established for the effective management, processing, and dissemination of Earth and Environmental information in Italy. The SDI fully exploits Open Source Software (OSS), including PostgreSQL + PostGIS, Geoserver, Geonetwork, ExtJS + GeoExt + OpenLayers, UNM MapServer, and GeoSDI ERA. The new SDI delivers information to different users adopting a combination of Web Mapping Services (WMS), Web Feature Services (WFS), and

Web Coverage Services (WCS). Catalogue Services for the Web (CSW) are used for metadata.

As part of the GIIDA project, the national landslide warning system for the possible occurrence of rainfall-induced landslides in Italy was integrated in the new SDI. Integration was facilitated by the fact that the warning system operates on data and geographical information stored in a PostgreSQL + PostGIS database.

Design and implementation of the infrastructure required four months of two people. Most of the time was dedicated to the development of the WebGIS interface. Adoption of an Open Source Software (OSS) approach for the design and the implementation of the new SDI proved valid, and economically convenient.

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