WPS tools to support geological and geomorphological mapping

Authors

- **Ivan Marchesini**, CNR IRPI, Perugia, *Italy*
- **Mauro Rossi**, CNR IRPI, Perugia, *Italy*
- **Massimiliano Alvioli**, CNR IRPI, Perugia, *Italy*
- **Michele Santangelo**, CNR IRPI, Perugia, *Italy*
- **Mauro Cardinali**, CNR IRPI, Perugia, *Italy*
- **Paola Reichenbach**, CNR IRPI, Perugia, *Italy*
- **Francesca Ardizzone**, CNR IRPI, Perugia, *Italy*
- **Federica Fiorucci**, CNR IRPI, Perugia, *Italy*
- **Vinicio Balducci**, CNR IRPI, Perugia, *Italy*
- **Alessandro Cesare Mondini**, CNR IRPI, Perugia, *Italy*
- **Fausto Guzzetti**, CNR IRPI, Perugia, *Italy*

KEYWORDS : WPS, geology, geomorphology, open source, SDI

The Open Geospatial Consortium (OGC) Web Service (WS) standards are technical documents developed for World Wide Web applications designed to share information, and facilitate the inter-operability of geospatial data. In particular, Web Coverage Service (WCS), Web Mapping Service (WMS), Web Feature Service (WFS), and Catalogue Service for the Web (CSW) are part of the Information Management Web Services Tier [17] to share metadata, and raster and vector thematic maps. An increasing number of Spatial Data Infrastructures (SDIs) is being developed and implemented to provide effective access to geospatial data exploiting OGC services.

Examples are available for disaster research and risk management [12] [15] [20], monitoring of glaciers [18], marine administration [25], e-Government [10], and the management of groundwater resources [11], coal mines [23], and generic environmental data [29].

The Web Processing Service (WPS) is a specific OGC standard for the design of interfaces to facilitate the publication of geospatial processes [13]. Implementation of WPSs remains less common than the implementation of WMS, WFS, and WCS, and is practiced chiefly by the Open Source (OS) community [27]. Multiple software can be used to deploy a WPS, including Deegree (http://www.deegree.org), 52°North (http://52north.org/), GeoServer (http://geoserver.org/), and the Zoo Project (http://zoo-project.org/) [5]. For uDig (http://udig.refractions.net/) and QGIS (http://www.qgis.org/) client GIS software, specific WPS plugins are available. GRASS GIS 7 offers a method to create a WPS, and can be integrated in a WPS server through the "wps-grass-bridge" framework (http://code.google.com/p/wps-grass-bridge/). Multiple WPS processes can be linked in a single processing chain [4], and can be run on a cloud or a grid infrastructure, for improved performance [6]. WPS implementations can provide "standard" GIS processing capabilities (e.g., [2]), or can deploy complex modelling tools [7] [14].

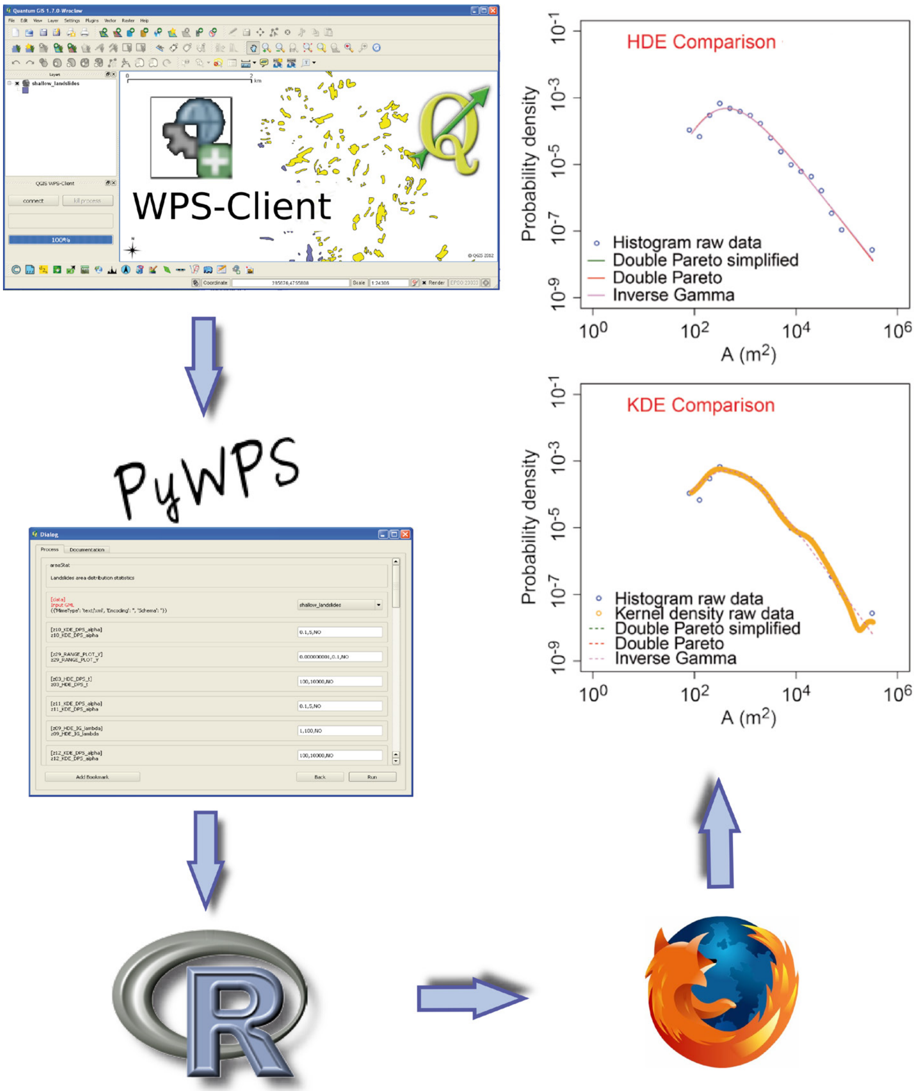
The Geo-Hydrological Hazard Protection Research Institute (IRPI), of the Italian National Research Council (CNR), has implemented an SDI dedicated to disseminating geospatial data and information on geo-hydrological hazards, in Italy. The SDI exploits Open Source Software [24] and in particular: (i) PostgreSQL 9.0 + PostGIS 1.5 (http://www.postgresql.org/, http://postgis.refractions.net/), (ii) GeoServer 2.0.2 (http://geoserver.org) (iii) GeoNetwork OS 2.6 (http://geonetwork-opensource.org/), (vi) ExtJS 3.4 + GeoExt 1.0 + OpenLayers 2.11 (http://www.sencha.com/products/extjs, http://geoext.org/, http://openlayers.org/). The system is implemented using more than 20 virtual machines hosted on four phisical servers. Moreover, to deliver map services to different types of users, the CNR IRPI SDI exploit a specific thematic Web portal (http://geomorphology.irpi.cnr.it/map-services) that portal gives access to geographical and thematic data and information on landslides and floods, including: (i) landslide inventory

maps at different scales and covering different geographical areas, (ii) landslide susceptibility, hazard, and risk maps, (iii) information on historical landslide and flood events in Italy, and (iv) a prototype system to forecast the possible occurrence of rainfall-induced landslides in Italy [9] [21] [20].
SDIs provide chiefly data discovery, retrieval and visualization capabilities, i.e. cataloguing and data sharing services [6]. The published thematic maps are most commonly obtained through complex procedures implemented using different programming languages and software. The software is not always available to scientists, students, public administrators, or the general public. The adopted procedures are occasionally described in scientific articles, or technical reports, but rarely the software code is available. When the code is available, it may be difficult (or impossible) to use because of incompatibility/portability problems, or dependence on additional external libraries. Limited or incomplete understanding of software, procedures, or programming languages, further restricts widespread use of the resources.

To overcome some of these problems, we have developed and deployed software tools, and associated processing procedures, to support geological and geomorphological mapping. Based on GRASS GIS 7 (grass.osgeo.org/grass70/), R (www.r-project.org/), and Python Web Processing Service (PyWPS), the tools are implemented as standard WPS, and allow for: (i) statistical modelling of the distribution of landslide areas, (ii) estimation of the attitude of bedding planes from the corresponding bedding traces, (iii) production of maps showing the geometrical relationship between bedding planes and terrain slopes, and the (iv) automatic delineation of hydrological slope units.

The first tool estimates the probability density and the frequency density of landslide areas shown on landslide inventory maps. The tool implements parametric and non-parametric statistical approaches, including Histogram Density Estimation (HDE), Kernel Density Estimation (KDE), and Maximum Likelihood Estimation (MLE), and produces a document listing statistics of the original data, parameters of the estimated distribution functions, and charts showing the estimated distribution functions [19] (see Figure 1).

FIGURE 1


WPS-Client
PyWPS
HDE Comparison
Probability density
A (m2)
Histogram raw data
Double Pareto simplified
Double Pareto
Inverse Gamma
KDE Comparison
Probability density
A (m2)
Histogram raw data
Kernel density raw data
Double Pareto simplified
Double Pareto
Inverse Gamma

The second tool can be used to determine the attitude (dip direction and angle) of single of multiple bedding planes in area, using a digital representation of the terrain (Digital Elevation Model, DEM) and a map showing "bedding traces" i.e., lines representing the geometrical intersection between bedding planes and terrain, obtained chiefly through the visual interpretation of aerial photographs, or through field mapping. The tool outputs a geographical vector layer of points and associated information on the dip direction, the dip angle, and the related uncertainty, for each point [16]. The output can be used to prepare structural maps.

The third tool implements a method for the interpolation of bedding planes to obtain spatially distributed information on the geometrical relationship between bedding planes and local terrain slope [22]. The tool outputs a geographical vector layer of polygons classified on five morpho-structural domains, including: (i) "anaclinal", (ii) "orthoclinal", (iii) "cataclinal under-dip", (iv) "pure cataclinal", and (v) "cataclinal over-dip" slopes. The output aids geological field mapping [1], and can be used as an input terrain variable to determine landslide susceptibility [3].

The last tool partitions a territory into slope-units, hydrological terrain subdivision bounded by drainage and divide lines [3], exploiting a digital representation of the terrain (DEM). The size and geometrical characteristics of the slope-units are controlled by user-defined modelling parameters, including the minimum half-basin surface area, and the maximum aspect standard deviation. The terrain subdivision obtained by the tool can be used to model landslide susceptibility [3] or hazard [8].

[1] BARCHI, M., GUZZETTI, F., FEDERICO, C. Reconstructing thrust geometry by map analysis techniques: three examples from the Central Apennines (Italy). *Bollettino Società Geologica Italiana* (1991) 110, 833-841.

[2] BÉJAR, R., LATRE, M.A., LOPEZ-PELLICER, F.J., NOGUERAS-ISO, J., ZARAZAGA-SORIA, F.J., MURO-MEDRANO, P. R. SDI-Based Business Processes: A Territorial Analysis Web Information System in Spain. *Computers & Geosciences* (2012). http://dx.doi.org/10.1016/j.cageo.2012.04.010.

[3] CARRARA, A., CARDINALI, M., DETTI, R., GUZZETTI, F., PASQUI, V., REICHENBACH, P. GIS Techniques and statistical models in evaluating landslide hazard. *Earth Surface Processes and Landform* (1991) 16, 427-445.

[4] DE JESUS, J., WALKER, P., GRANT, M., GROOM, S. WPS orchestration using the Taverna workbench: The eScience approach. *Computers & Geosciences* (2011) doi:10.1016/j.cageo.2011.11.011.

[5] FENOY, G., BOZON, N., RAGHAVAN, V. ZOO-Project: the open WPS platform. *Applied Geomatics* (2012) doi: http://dx.doi.org/10.1007/s12518-011-0070-0.

[6] GIULIANI, G., NATIVI, S., LEHMANN, A., RAY, N. WPS mediation: An approach to process geospatial data on different computing backends. *Computers & Geosciences* (2011) doi:10.1016/j.cageo.2011.10.009.

[7] GRANELL, C., DIAZ, L., GOULD, M. Service-oriented applications for environmental models: Reusable geospatial services. *Environmental Modelling & Software* (2010) 25, 182-198.

[8] GUZZETTI, F., REICHENBACH, P., CARDINALI, M., GALLI, M., ARDIZZONE, F. Probabilistic landslide hazard assessment at the basin scale. *Geomorphology* (2005) 72, 272-299, doi:10.1016/j.geomorph.2005.06.002.

[9] GUZZETTI, F., ROSSI, M., PERUCCACCI, S., BRUNETTI, M.T., MARCHESINI, I., ARDIZZONE, F., BALDUCCI, V., BIANCHI, C., CARDINALI, M., FIORUCCI, F., MONDINI, A., REICHENBACH, P., SALVATI, P., TONELLI, G., DELLO BUONO, D., IZZI, F., AMATO, L., LA SCALEIA, G., MAIO, D., PAGLIARA, P., DE BERNARDINIS, B. A national early warning system for rainfall-induced landslides in Italy. *American Geophysical Union, Fall Meeting 2010*, abstract #NH31C-02. 2010

[10] HANSEN, H.S., SCHRØDER, L., HVINGEL, L.T., CHRISTIANSEN, J.S. Towards Spatially Enabled e-Governance: A Case Study on SDI implementation. *International Journal of Spatial Data Infrastructures Research* (2011), 6, 73-96.

[11] JARAR, O.H., LOWNER, R., BENAABIDATE, L., WACHTER, J. HydrIS: An open source GIS decision support system for groundwater management (Morocco). *Geo-Spatial Information Science* (2009) 12(3), 212-216.

[12] KÖHLER, P. WÄCHTER, J. Towards on Open Information Infrastructure for Disaster Research and Management: Data Management and Information Systems Inside DFNK. *Natural Hazards* (2006) 38,1-2, 141-157.

[13] KRESSE, W., DANKO, D. M., FADAIE, K. STANDARDIZATION. In Kresse and Danko (Eds.): *Springer Handbook of Geographic Information*. Springer-Verlag Berlin Heidelberg. 2012

[14] LECCA, G., PETITDIDIER, M., HLUCHY, L., IVANOVIC, M., KUSSUL, N., RAY, N., THIERON, V. Grid computing technology for hydrological applications. *Journal of Hydrology*, (2011) 403 (2011) 186-199.

[15] MANSOURIAN, A., RAJABIFARD, A., VALADAN ZOEJ, M.J., WILLIAMSON, I.P. Using SDI and Web-Based System to Facilitate Disaster Management, *Computers & Geosciences* (2006) 32, 303-315, Canada.

[16] MARCHESINI, I., SANTANGELO, M., FIORUCCI, F., CARDINALI, M., ROSSI, M., GUZZETTI, F. A GIS method for obtaining geologic bedding attitude. *Proceedings of the Second World Landslide Forum - Putting Science into Practice*, Rome, 3-9 October 2011. In press.

[17] PERCIVALL G. Progress in OGC Web Services Interoperability Development. In Di, Liping & Ramapriyan H.K (Eds.): Standard-Based Data and Information Systems for Earth Observation. *Lecture Notes in Geoinformation and Cartography* (2010) 37-61. Springer Berlin Heidelberg, http://dx.doi.org/10.1007/978-3-540-88264-0_4.

[18] RAUP, B., RACOVITEANU, A., KHALSA, S.J.S., HELM, C., ARMSTRONG, R., ARNAUD, Y. The GLIMS Geospatial Glacier Database: a New Tool for Studying Glacier Change. *Global and Planetary Change* (2007) 56, 101-110.

[19] ROSSI, M., CARDINALI, M., FIORUCCI, F., MARCHESINI, I., MONDINI, A. C., SANTANGELO, M., GHOSH, S., RIGUER, D.E.L., LAHOUSSE, T., CHANG, K.T., GUZZETTI F. A tool for the estimation of the distribution of landslide area in R. *Geophysical Research Abstracts Vol. 14*, EGU2012-9438-1, 2012 EGU General Assembly 2012

[20] ROSSI, M., PERUCCACCI, S., BRUNETTI, M.T., MARCHESINI, I., LUCIANI, S., ARDIZZONE, F., BALDUCCI, V., BIANCHI, C., CARDINALI, M., FIORUCCI, F., MONDINI, A.C., REICHENBACH, P., SALVATI, P., SANTANGELO, M., BARTOLINI, D., GARIANO, S.L., PALLADINO, M., VESSIA, G., VIERO, A., ANTRONICO, L., BORSELLI, L., DEGANUTTI, A.M., IOVINE, G., LUINO, F., PARISE, M., POLEMIO, M., GUZZETTI, F., TONELLI, G. SANF: a national warning system for rainfall-induced landslides in Italy. *Proceeding of the 11th International Symposium on Landslides (ISL) and the 2nd North American Symposium on Landslides (NASL)* 2012. Banff, Alberta, Canada, 2-8 June 2012. In press.

[21] SALVATI, P., MARCHESINI, I., BALDUCCI, V., BIANCHI, C., GUZZETTI F. Management and publication of a continuously updated catalogue of geo-hydrological events with consequences to the population in Italy. P*roceedings of the Second World Landslide Forum - Putting Science into Practice*, Rome, 3-9 October 2011. In press.

[22] SANTANGELO, M., BUCCI, F., CARDINALI, M., MARCHESINI, I., ROSSI, M., GUZZETTI F. Morpho-structural influences on landslide pattern and distribution: Grass GIS tool application. *Geophysical Research Abstracts Vol. 14*, EGU2012-12457, 2012 EGU General Assembly 2012.

[23] SONG, X., RUI, X., HOU, W., TAN, H. An OGC standard-oriented architecture for distributed coal mine map services. *Journal of China University of Mining and Technology* (2008) 18(3) 381-385.

[24] STEINIGER, S., HUNTER, A.J.S. Free and Open Source GIS Software for Building a Spatial Data Infrastructure. In: *Geospatial Free and Open Source Software in the 21st Century* (2012). Bocher E. & Neteler M. (Eds.), Part 5, 247-261.

[25] STRAIN, L., RAJABIFARD, A., WILLIAMSON, I. P. Marine Administration and Spatial Data Infrastructure. *Marine Policy Journal* (2006) 30 (4), 431-441.

[26] TUCHYNA, M. Establishment of spatial data infrastructure within the environmental sector in Slovak Republic. *Environmental Modelling & Software* (2006) 21, 1572-1578.

[27] ZHAO, P., FOERSTER, T., YUE, P. The Geoprocessing Web. *Computers & Geosciences* (2012) http://dx.doi.org/10.1016/j.cageo.2012.04.021.