Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation

Report

D4.2 *Guiding tool for deployment of joint rapid response networks*

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Participants:	*INGV, ETHZ, CNRS, GFZ*
Author:	*A. Govoni, L. Margheriti, M.Pignone, Moretti M., S. Hainzl, T. Boxberger S,. Husen, B. Delouis and A. Paul*

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1. Summary

The development of a guiding tool for the deployment of joint rapid response seismic networks will help during the emergencies to achieve a more effective station geometry that could improve the earthquake locations avoiding common inefficiencies that usually can happen when several teams rush to the epicentral area. Most of the problems arise usually from the lack of knowledge about the epicentral area and the lack of coordination and information exchange among the teams involved in the field activities. This tool has been designed to be available from the European Rapid Response Networks (ERRN) portal (http://nera-ern.gfz-potsdam.de) as a web service accessible even from portable devices and to be compatible with GIS open standards to be easily used an information layer in more complex GIS processing. With this design it will also help to share the information between all the partner institutes participating to the field activities and will allow the other partners to follow the improvements of the seismic network deployment.

In this deliverable we describe the design of the tool and we show its potential in tests performed on the Italian territory. Thanks to the open structure of the tool, all the information relative to existing seismic stations, current seismicity, etc. can be easily added for different areas in Europe and in the world. Furthermore we report about a real case in October 2012 at the Calabria-Basilicata border Ml=5.0 earthquake occurred during a seismic sequence started at the end on 2011 that produced and is producing thousands of small earthquakes. The tool was used for the deployment of a joined temporary seismic network.

2. Introduction

Rapid response networks are an important element of the response to seismic crises. In areas where permanent networks have poor detection capabilities, temporary networks are very important to improve the seismic monitoring. Rapid response missions require a high degree of flexibility and preparedness. A typical mission as a response to a magnitude 6+ event, with aftershocks interesting crustal volumes of some tens of kilometers, may involve the deployment of 30-50 stations belonging to 4-5 different network operators spread over several hundred square kilometers, all to be accomplished within hours to days in the middle of a disaster area. The commonly daunting logistics of such missions, the specific demand on the instrumentation in terms of robustness and power consumption, the financial and human resources needed to maintain a rapid response team, the need of ensuring data quality and integration into existing data acquisition systems, make rapid response missions a very challenging task.

Currently within Europe, temporary deployments are primarily a national task, organized by some of the major networks, institutions or research institutes. The Mw 6.3 L'Aquila earthquake of April 2009 was a success story of collaborative rapid response networks

(Margheriti et al 2011); Italian, French and German groups coordinated the deployment of their stations to form a joint network. The experience gained in this mission emphasized the necessity to optimize collaboration, facilitate rapid data exchange and structure data processing procedures among the rapid response network community. During the Po Plain emergency, May-June 2012 (Moretti et al., 2012), we could benefit of the first results of the work performed by the NERA partners involved the activity of NA4 "*Networking European Rapid Response Networks".* Our goal is to build an open and expanding, sustainable partnership of rapid response teams across Europe. The participating institutions, representing some of the major players in this domain in Europe, form the core of this network, which is expected to incorporate other rapid response teams.

In this report we will address the need of a tool to guide the deployment of joint rapid response networks to select sites for seismic stations that are effective in improving the hypocentral locations of the current seismicity and in improving the permanent networks detection capability in the seismic sequence area. the improvements of all the institutes involved in the networking of rapid response seismic networks, INGV, ETHZ, CNRS, GFZ, will participate and contribute to the further improvement of the developed tool.

3. Optimizing the seismic network for earthquake location purposes

Procedures for rapid deployment of temporary networks depend on the seismological problems that are to be tackled, which is basically a scientific problem of experimental design. A lot of constrains are to be considered in real cases for this design to be not only effective but also cost-effective. This is a typical problem that can be addressed by GIS systems once all relevant information layers are available. Here are the main layers to be considered:

1. network geometry : it must be designed to improve hypocentral location accuracy and the network detection capability using a reasonable number of sites.
2. site sensitivity : soil conditions, anthropic noise, population density, infrastructures,
3. road conditions : with emphasis on closed roads/bridges that can greatly affect site installation/maintenance times.
4. site connectivity : when real time data transmission is needed, depending on the data carrier used, also satellite visibility (VSAT), line of sight (UHF, WiFi, HyperLan, WiMax) among sites/repeaters, UMTS signal coverage must be considered.
5. seismicity : both historical and instrumental, permanent network stations (site, realtime data, state of health).

Most of these information layers (mainly layers 2,3,4,5) are already available to GIS systems from a variety of geographic data source/services and are in some cases also updated in

real time (i.e. road conditions, seismicity). Several factors described in these layers can affect the performance of the final seismic network.
We will address specifically layer 1. For optimizing the design of mobile networks, we use a software simulation package to model a virtual network installation, simulating the anticipated capability of this network geometry by assigning typical signal to noise ratios and detection matrixes to virtual stations, combining them with the (known) locations and capabilities of existing stations (tapping into existing databases). With respect to the other important layer M.Pignone has developed an inter visibility layer in ArcGis that will be more flexible in the future.

The tool can include available mapping information and other information on the permanent seismic and geodetic networks on the current and historical earthquakes and on the observed shaking collected in the ERRN communication platform. We are creating a comprehensive planning tool that will be installed in the Earthquake data portal (http://www.seismicportal.eu/jetspeed/portal/) and linked to the ERRN Communication Platform.

3.1 Experimental design applet for a seismic network

To build layer 1 the tool is based on the experimental design algorithm for seismic network developed by Curtis et al. (2004). This algorithm has been coded by Anthony Lomax (co-author of Curtis) in a java applet available at http://alomax.free.fr/projects/expdesign/.
Given a velocity model, an (optional) attenuation relation, a set of target source regions to monitor, and an (optional) set of existing receivers, the Experimental Design Applet selects an optimal set of potential new receivers based on the relative importance of each potential receiver to the monitoring problem. The importance of each receiver is given by a relative quality factor (varying from 0 for poor quality to 1 for high quality).

The quality factor for a receiver will be higher if it provides information and constraint on event locations that is not provided by other existing or potential receivers. This constraint is determined from the vectors of partial derivatives of travel-time at the receiver with respect to perturbations in the positions and origin times of events in the target source regions. These are the partial derivatives for the event location problem; they depend on the velocity model and the distance and azimuth of the receiver from the sources. The quality factor for a receiver will be lower if it provides information on the event locations that duplicates that of other receivers, or if it is far from the source regions (depending on the attenuation relation).

Anthony Lomax was available to turn the java applet into a command line java application that can be run on any web-server platform. For our purpose, we
developed a PHP job able to gather real time seismic information on the area of interest (active stations and current seismicity); run the java application with proper parameters and convert all outputs in a XML format retrievable by clients as a standard web-service.

3.2 Test

In October 2012 at the Calabria Basilicata border, Pollino region, a Ml=5.0 earthquake occurred during a long seismic sequence started at the end of 2011 that is producing thousands of small earthquakes. The epicentral area was already monitored by 8 stations of the Italian seismic network and by two temporary real time stations T0701 and T0702 which were installed at the end of May 2012 after the occurrence of a Ml=4.3 event. We tested the PHP application that gathered the real time seismic information on the area of interest (active stations and current seismicity) from INGV EIDA web services, executed the Experimental Design Application, produced a KML output file with the design results (plus some debug output) suitable for GoogleEarth. This output was also tested on different mobile devices (iOS and Android smartphones and tablets). Figure 1 shows the results in GoogleEarth. The permanent stations operating in the epicentral area are the green triangles, the stations relevant and used in the simulation are light blue, the earthquake hypocenters whose location has to be optimized are the white stars with labels S00, …, S05. The application searches over a regular grid represented by the gray small diamond and compute a quality factor for each point. The best 15 (this number is user selectable) sites are selected (green square). Using the results on the grid we computed also a contour map that can be useful for the operator on the field to identify the areas with the highest quality factor.

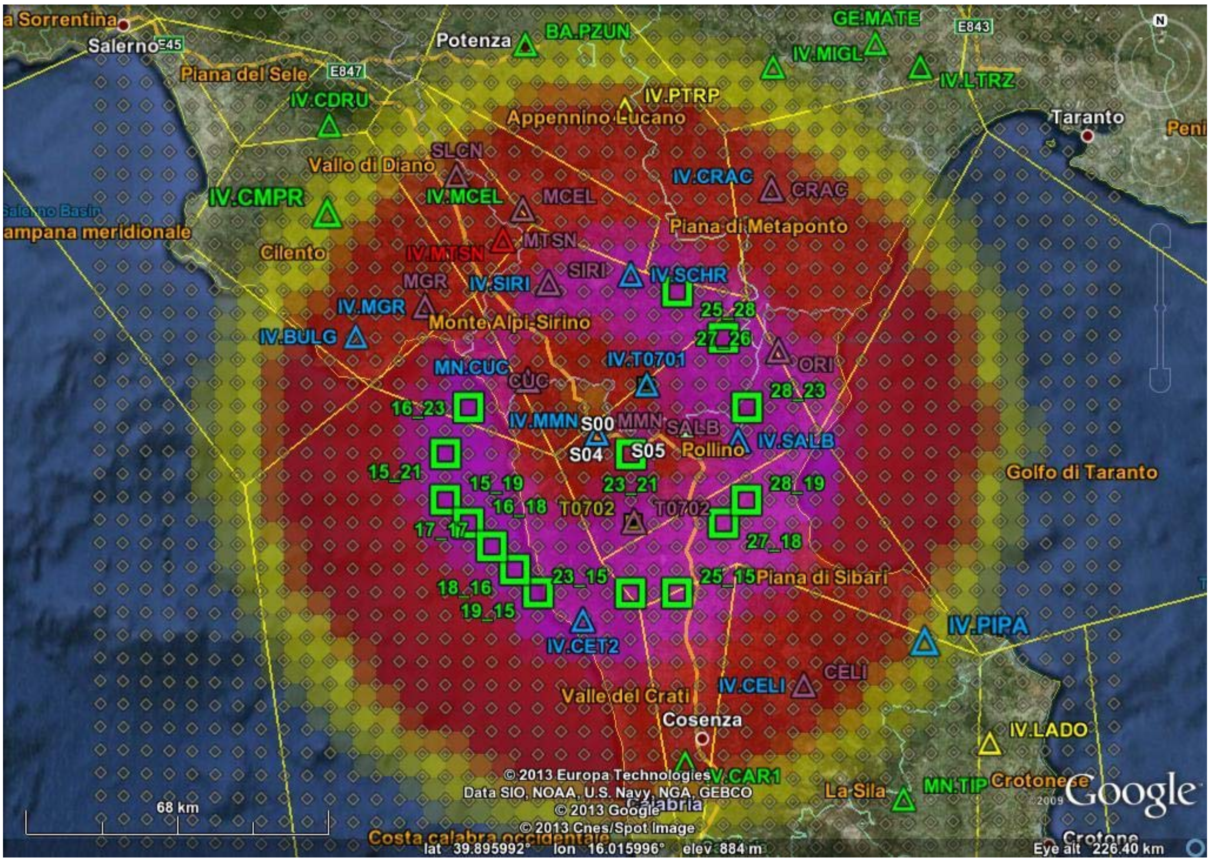

Figure 1: Example run of the tool in the Pollino area. The triangles are the active stations in the area (green are the active stations, blue are those used by the Experimental Design). White stars are the sources used. Green squares are the best sites selected in the simulation. Grey diamonds are the sites on a regular grid tested during the simulation, for each point a quality factor is computed. We turned this information in a contour map useful for guiding field operator (color goes from yellow: low quality to purple: high quality).

This example run has been very useful for tuning the several parameters needed for computing the whole simulation and to obtain reasonable results. The same output casted in one of the GIS supported formats (and KML is one of the possible) can be fed to a more refined GIS application capable to apply several other constraints on the area identifying the best installation areas. The layer of figure 1 is essentially geometric but knows nothing of real world exept sources, recievers, wave velocity and attenuation. Real world constrains like 'stations must be on land' and 'inter visibility' will be applied by a GIS application that will select best 'physical' sites considering all other sources of information.

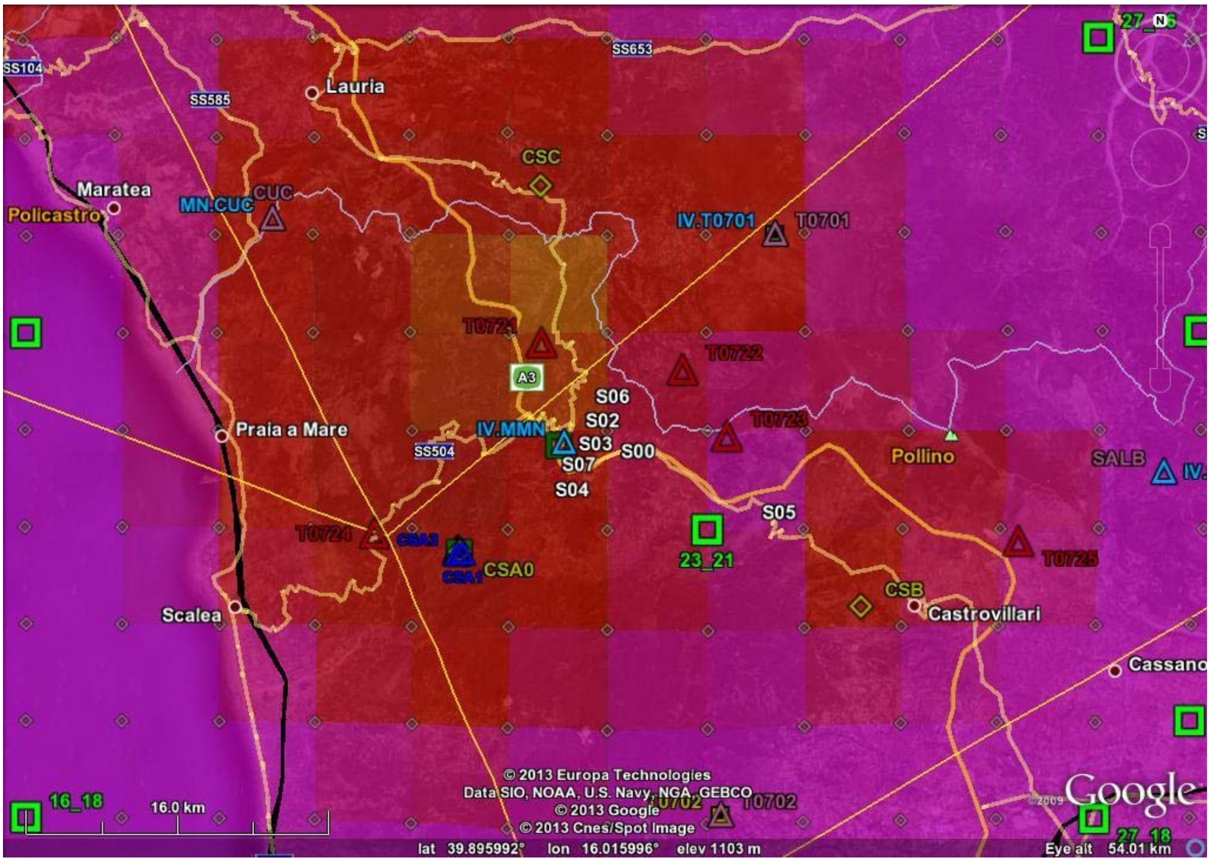

Figure 2: deployment of temporary stations: red triangle INGV stations yellow diamonds GFZ broadband. The background color is the output of the guiding toll: it defines areas to deploy seismic temporary stations with increasing importance for selected sources locations

In the two days following the Ml=5 earthquake occurred on October 25th an INGV team installed 5 stand-alone stations T0721 - T0725, all equipped with a Lennartz LE-3D1s velocimeter and an episensor accelerometer. The some of the data are already available on EIDA. The station T0724 on November the 15th was equipped with a UMTS router started to be transmitted in real time to the monitoring room in Rome (UMTS transmission). In the meanwhile GFZ decided to install seismic stations in the Pollino area. A joint GFZ-Potsdam-INGV mission to the Pollino area was realized in collaboration with Uni-Hamburg and Potsdam. In the first days of November 2012 we installed 10 stand alone stations in the Pollino area: 3 Broadband stations (Reftek 130 + STS 2.5 sensors) deployed SW (CSA0 - Contrada Scorpari, near Orsomarso), SE (CSB - San Basile) and N (CSC - Casteluccio), with respect to the epicentral area; and 5 short-period stations (Earth Data Logger + Mark L43c) deployed around the Orsomarso BB-sensor (CSA0) as an array (CSA1/2/3/4/5); and finally 2 accelerometers (Kinemetrics Altus, CSAA installed at the array site and CSMA installed near the INGV station MMN). In Figure 2 is shown the complete deployment of temporary stations after the Ml=5 earthquake in the Pollino area (the deployment history starting from the end of 2011 is described in Margheriti et al. 2013, *in Italian*) . The background color is the output of the guiding toll to optimize the location of the seismic sources identified by the white label S0*. We mainly selected sites in the red-purple region but could not match the green squares suggested by the tool.

4. Planned activities

The developed command line java application and the PHP job are the first step to create a comprehensive planning tool which will be installed in the Earthquake data portal http://www.seismicportal.eu/jetspeed/portal/ and linked to the ERRN Communication Platform http://nera-ern.gfz-potsdam.de/. The current version will be made available as an INGV web service by June 2013 after a final debugging, the extension of the output format to the OGC WMS/OSGeo TMS GIS open standards, a generalization to EMSC data services in order to retrieve seismic network information and seismicity of Euro Mediterranean area.

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