Study and development of a GIS for fire-fighting activities based on INSPIRE directive

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by Andrea Maria Lingua, Marco Piras, Maria Angela Musci, Francesca Noardo, Nives Grasso, Vittorio Verda

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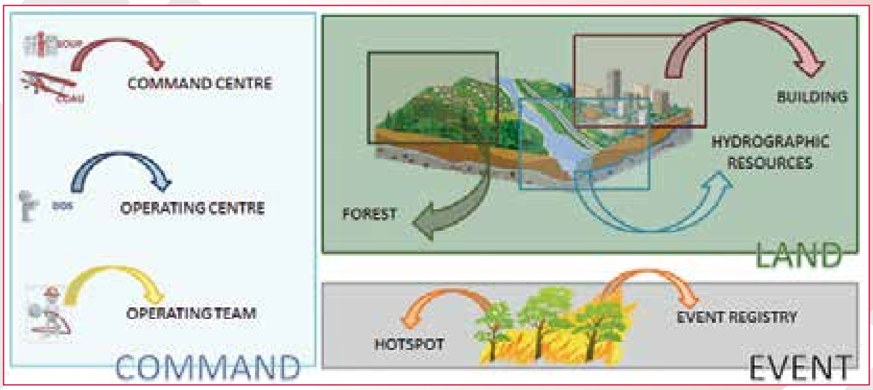

Fig. 1 – External model definition.

The activities connected to the forest-fire fighting could be essentially divided in three parts: before, during and after the fire.
In these activities, the most complex are the monitoring and management of at-risk fire zones and fire-fighting procedures especially for large fires (> 40ha). In the case of "big fire", which are fires with a very large extension, the main problem is the coordination between the human resources (ground, marine and air) which work to fight the fires. This aspect is more critical when the fire is across the boundary, because there is not a European protocol for interventions and each country has different procedures and CONOPS (concept of operations). Thus becomes clear the complex reality that competent authorities must handle in such emergencies (Andrews and Rothermel 1982; Bovio 1993; Teie 2005).
The AF3 project (Advanced Forest Fire Fighting) is part of the 7th Framework Program and it is focused on the prevention and the management of big forest-fires through the development of innovative techniques. The AF3 purpose is to improve the efficiency of fire-fighting operations in progress and the protection of human lives and heritage by developing innovative technologies to ensure the integration between existing and new systems. Furthermore, the AF3 project aims to increase interoperability among firefighting supports (Chuvieco et al 2010).
The project defines a unique control center devoted to coordinate all activities, from monitoring to the intervention on field. Among the technological aspects, the project provides the design of an SDI platform (Spatial Data Infrastructure) which is essentially based on a GIS (Geographic Information System). In the following sections, GIS model proposed for a part of the system will be described. This GIS is structured according to INSPIRE (Infrastructure for Spatial Information in Europe) Directive.

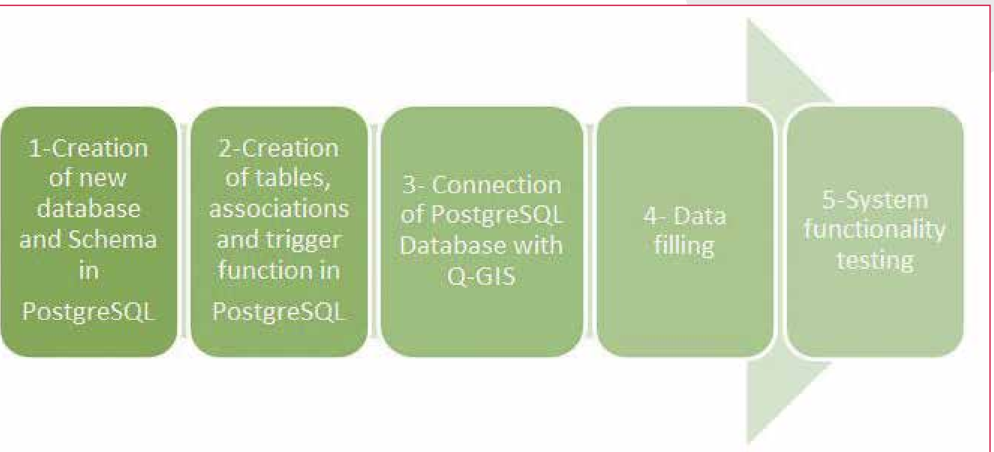

Fig. 2 Steps to create AF3 Database in PostgreSQL and Q-GIS.

GIS and fire-fighting: a brief description of the European scenario

Currently, in Europe there are already several GIS useful for decision support at different stages of fire management. However, the opportunity to have both updated or real-time data, and a complete and consistent information, is often missing. Especially it is difficult to have an actual data interoperability with the existing available technologies. In most cases, the information collected in the GIS are incomplete and they concern only one phase of the overall management process. There are, indeed, systems used, exclusively, for prediction or for planning or emergency control. In this way, a lot of information is lost. However, this historical information could be helpful to make more comprehensive the tool for decision support. Furthermore, it lacks a central system to register distribution and availability of resources in risk periods, standardized systems for fires registry and systematic registration systems of firefighting operations. Finally, the metadata of the observed maps are not always available and the data validity is impossible to be determined.

For example, in Europe, WebGIS known as EFFIS (European Forest Fire Information System http://forest.jrc.ec.europa.eu/effis/) was developed by the JRC (Joint Research Centre). This GeoDB, still under construction, records only the data related to fire risk analysis and the occurred fires in Europe.

Description of the GIS in AF3

In order to propose an innovative GIS platform devoted to support the big forest fires management, the following activities must be considered: forecasting, monitoring, planning, active fight and post-fire practices. Nowadays, the modern system is not designed for a specific end-user and it stands out for its versatility. However, it is possible to establish different authorization for different users and method of use.

In order to realize the dedicated GIS for AF3, the traditional modelling process was followed. As well known, needs to pass from the complexity of the reality to a formal schema describing entities and tools used in fire-fighting operations.

External Model

The first step was the development of an external model. In this model, the useful information could be gathered in three categories of objects: the competent authorities (command), the objects to be protected (territory), the event and the ignition point (fire and hotspot) (Figure 1). In the case of AF3, there is only one control center that handles local operations centers, the terrestrial and aerial troops. The command center (*command center*) is the national control center. Local operations centers (*operating center*) are in charge to monitor and to fill register of the fire cadaster and the mission report. Instead, the teams (*operating team*) take care of active fight on the field.

Conceptual and Logical Model (INSPIRE oriented)

Next steps are the definition of conceptual and logical models. Therefore, these stages consist in identification of entities, attributes, definition of relationships between the entities and the data formats. The INSPIRE directive, thus, provides fundamentals for completely defining the information layers closely related to the land description (e.g. digital terrain model and digital surface model), the event progression (e.g. time) and meteorological data (e.g. wind direction and speed, temperature, humidity). This European specification has a general nature, which needs to be suitably extended for adapting to the specific application. Some "*ad hoc*" entities are added in order to consider the data related to the command chain, fuel model and forest types definition (Burgan et al, 1998; Baskets 1999 Baskets 2002; Han Shuting et al 1987).

Currently, it is necessary to highlight that in Italy, as in Europe, a systematic survey and monitoring of the forests are missing. Moreover, standardized methodology for the preparation of suitable fuel models does not exist.

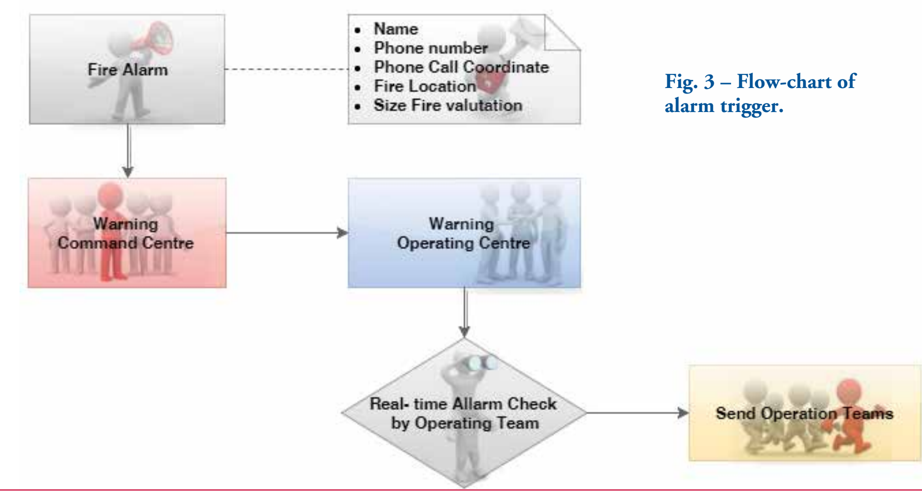

Fig. 3 – Flow-chart of alarm trigger.

Considering these aspects, an approximation on the fuel models has been done. In particular, in Italy, the only achieved result is a regional classification of forest types, but it cannot be considered equally valid for the calculation of the danger indexes. The development of this issue would improve our capacity of fire forecasting and, consequently, in the fire-fighting management.

Internal Model

Open source platforms were chosen to implement the database. Specifically, PgAdmin III were used to manage the database PosgreSQL with its spatial extension PostGIS and the graphical interface. This software allows the creation of tables and relationships, the implementation of triggers and queries, the realization of views for users and different uses and finally the semi-automatic input of data. This system is not equipped with a graphical interface to visualize the spatial data, therefore a connection with Q-GIS was realized.Thus, the procedure of GeoDB implementation follows the steps shown in Figure 2.
A peculiarity of the internal model was the trigger, which is an *"ad hoc"* procedure for the automatic manipulation (insertion, modification and deletion) of information related to a triggering event (Perry 1990). To complete the automatic management of the entire system, a large number of triggers must be implemented. Below as example, it has been described the "trigger" that starts when fire alarm is activated.
In this specific case, when the alarm is recorded in the system, the program executes the procedure schematically shown in the flow-chart in Figure 3.

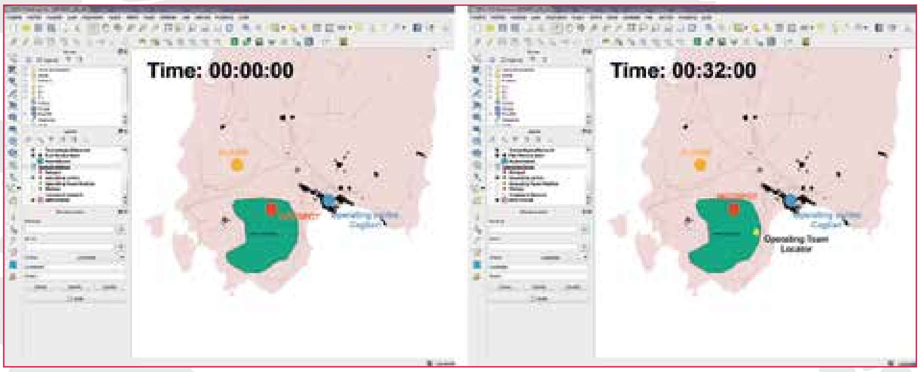

Fig. 4 – Example of query: hotspot and operating centre localization (left) and operating team localization (right).

Case of study (Sardinia)

Data

In order to test the GIS functionalities, a specific test site has been selected. In particular, a database related to South part of the Sardinia (close to Cagliari) has been considered.
Therefore, defined a specific area, all fundamental data have been collected, where the most important information are the state of the forests, fuel models, water resource localization, roads and technological networks, command center, operational centers, teams, meteorological data, hotspots, alarm have been inserted.
Using these information layers, which are suitably designed and compiled, using QGIS, it was possible to realize an example of a query on the system. Since the alarm is activated (Figure 4 - left), the trigger is able to automatically calculate the competent command center, the nearest operating center, with the adapted number of men and assets. Finally, in real- time, data of the team and its location can be displayed (Figure 4 - right).
On the field, the team will be monitored and managed by the command center, by means of the automatic registration of their coordinates (Figure 5), measuring in real time the team position.

Conclusion

The developed GIS model describes only a part of the "fire prevention and management system" provided by the AF3 project, but its complexity is

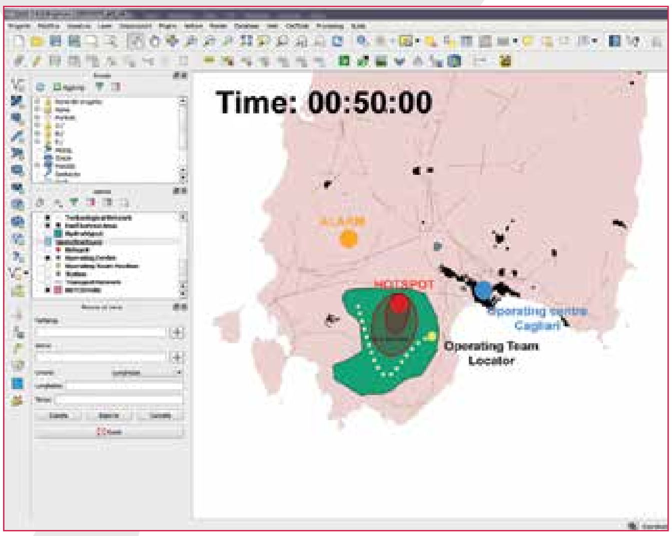

Fig. 5 – Example of query and trigger visualization. Real time team positioning on the field.

quite evident. Especially, it underlines that it is difficult (in some case almost impossible), to define exactly some entities (e.g. Fuel model or fuel moisture). Moreover, an unique European procedure does not exist, therefore it is very complicated to define the CONOPS and a system with a single command center.

The proposed model shows that also the open source platforms allow to realize a complex SDI structure. The triggering system for the automatic procedures allows to add value to SDI, because it makes the system real-time responsive.

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KEYWORDS

INSPIRE directive; fire fighting; GIS

ABSTRACT

According to the Annual Fire Report 2013 (European Commission-Joint Research Centre, 2014), there have been 873 forest fires in Europe, in 2013, for a total of 340559 ha of territory. A comparison of this data to that of the previous years, highlights that, when the intended goal is that of preserving the environment and saving human lives, the importance of the correct management of forest fires can not be underestimated. In the past years, the European Union has invested in the development of the INSPIRE Directive (Infrastructure for Spatial Information in Europe) to support environmental policies. Furthermore, the EU is currently working on developing "ad hoc" infrastructures for the safe management of forests and fires.

The AF3 EU project (Advanced Forest Fire Fighting), financed by the FP7, addresses the issue of developing innovative tools to handle all stages of forest fires. The project develops a single control center for the coordination of monitoring, manoeuvring, and post-fire operations. The SDI platform (Spatial Data Infrastructure) represents another component which was designed in the context of this project. It is based on a GIS (Geographic Information System) which is able to efficiently integrate multi-modal data.

Following an analysis of the state of the art of information systems for forest fire-fighting, and in light of the end-user requirements analyzed within the AF3 project, we propose a geo-topographic database based on the INSPIRE Directive and developed on open-source platforms, which provides interoperability of the data and allows forecasting and monitoring of high-risk areas, decision making, damage estimation, and post-fire management.

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