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A web based DSS for the management of floods and wildfires (FLIRE) in urban and periurban areas

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A R T I C L E I N F O

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A B S T R A C T

The FLIRE DSS is a web-based Decision Support System for the combined forest and flood risk management and planning. State of the art tools and models have been used in order to enable Civil Protection agencies and local stakeholders to take advantage of web based DSS with no need of local complex infrastructure and maintenance. Civil protection agencies can predict the behavior of a fire event using real time data and in that way to plan its efficient elimination. Also, they can implement "*what-if*" scenarios for areas prone to fire and thus develop plans for forest fire management. Flood services include flood maps and flood-related warnings; these become available to relevant authorities for visualization and further analysis on a daily basis. Real time weather data from ground stations provide the necessary inputs for the calculation of the fire model in real time and a high resolution weather forecast grid support flood modeling and "*what-if*" scenarios for the fire modeling. The innovations of the FLIRE DSS are the use of common Earth Observation (EO) data as the backbone of the system to produce data for the support of fire and flood models, the common use of weather related information, the distributed architecture of the system and the web-based access of it with no need for installation of dedicated software. All these can be accessed by all means of computer sources like PC, laptop, Smartphone and tablet either by normal network connection or by using 3G and 4G cellular network. The latter is important for the accessibility of the FLIRE DSS during firefighting or rescue operations during flood events. FLIRE DSS can be easily transferred to other areas with similar characteristics due to its robust architecture and its flexibility.

1. Introduction

Decision Support System (DSS) is a computer-based information system which has the efficiency to support business or organizational decision-making activities. Such systems can provide services for the planning, operation and management of an organization in order to support make decisions. DSS introduce multiple interdisciplinary aspects into the planning process in complex decision environments by adding the geospatial domain (Chrysoulakis et al., 2010). DSS are popular in several fields like water resources management (Koutsoyiannis et al., 2003), environmental management (McIntosh et al., 2011), fire management (Kalabokidis et al., 2013; Noonan-Wright et al., 2011) and flood management (Honghai and Altinakar, 2011).

The application of a DSS is considered vital in the areas of fire and flood management where the early detection of the ignition of the fire or the early warning on the flood event are crucial for the protection of human lives, properties and assets.

Forest fires and flash floods are among the most destructive

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natural disasters, the occurrence of which is related with severe socioeconomic impacts, including loss of human lives, health and quality of life degradation, loss of private and public property and destruction of economic activities. The occurrence and the extent of both natural disasters strongly depend not only on the existing weather conditions in an area, but also on human intervention, which is particularly pronounced in peri-urban areas and can increase the environmental impact. These phenomena have typically been investigated separately, with different systems collecting information and modeling the resulting risk.

This approach overlooks two significant facts:

- The input data (field and remote sensing) required in both cases are essentially the same, and hence a "*collect once – use for many purposes*" paradigm can be adopted resulting in increased accuracy and economies and,
- The phenomena are tightly interrelated, with forest fires exacerbating the risk of flooding and preceding floods drastically reducing the risk of fires.

A combined approach to manage flood and fire risk would achieve better, more realistic results at a decreased cost and thus have considerable added value beyond current practice. The fact that end-users, in the form of emergency services (civil protection) are more often the recipients of both warnings only strengthens the case for a combined risk assessment and management.

The aim of the FLIRE DSS is to change the paradigm for the coupled, effectual and strong risk assessment and management of both flash floods and forest fires. This has been achieved by using state of art tools, technologies and methods and taking into account prevention, adjustments and interaction issues.

The innovations of the FLIRE DSS are: (a) The use of Earth Observation data, in a periodical basis (hypertemporal Earth Observation data analysis), mainly from Copernicus Sentinel missions in order to parametrize the models of the fire behavior (fuel map design) and the flood assessment (landcover map – curved number analysis), (b) The use of same weather information data (in situ and forecasts) for the models; both the collected and analyzed data are collected once (reducing the required recourse) and used for many purposes (same Earth Observation data for both models, same weather information data for both models) and (c) FLIRE DSS has a distributed architecture, and in case of failures, the system will continue to work as backup systems exits in geographical isolated areas.

2. FLIRE DSS structure

FLIRE DSS is the web based decision support system for integrated weather information management, forest fire management and floods information management. It uses service-orientation architecture (SOA) and is based on IT sources (Information Technology) and Geoinformation (GI). Innovative components of the DSS, acting as backbones, is the extensive use of EO data for modeling support, the shared weather information as input to the models as well as the web-based technology; this allows the end user to have unrestricted access by any computer means with no need of installation of software application.

Fire propagation modeling and floods case scenarios based on weather forecasts are used as web services. The components of the system are used as web services via a Graphical User Interface (GUI). The FLIRE DSS is consists of three different modules and several components (Fig. 1) under the FLIRE Server. The server uses *ftp* and *http* communication protocols as well as web service technologies. The GUI has been designed and developed based on the user's requirements consulted in a Community of Practice approach. The FLIRE DSS consists of the following components:

1) Weather Information Management Tool (**WIMT**): It handles, manages and provides the available weather information data.
2) Storms Early Warning System: It serves information about storms in the study area. Is part of the WIMT tool.
3) Early Fire Warning System (**EFiWS**): It provides control of the Fire Management System and the Fire Index.
4) Flood Risk Assessment System (**FLORAS**): It provides the user with flood maps based on weather forecasts and flood maps for different rainfall scenarios. Also include smart alerts and scenarios for future planning.
5) **FLIRE server**: Unify the aforementioned modules.
6) **GUI** – Web browser: The user interface.

3. Software availability

FLIRE DSS is accessible from the web (www.flire-dss.eu) with no prior installation of any add on software for support on the browser. It is a password protected system, in which only authorized users can have access for security reasons. The user's manual is available from here: http://goo.gl/lkWUgM. A free version (http://goo.gl/kWW8nK) is available for any user want to understand the functionalities and the innovations of the system. It has demo data for fire and flood models but provide live access to the weather data (stations and forecast). In Table 1, the technical characteristics of the application are provided.

4. Discussion

4.1. DSS innovation

The innovation of the FLIRE DSS are: (a) the use of hypertemporal Earth Observation from Copernicus Sentinels in order to parametrize the models of the fire behavior and the flood assessment, (b) the use of same weather information data (in situ and forecast) for the models; both the collected and analyzed data are collected once (reducing the required recourse) and used for many purposes (same Earth Observation data for both models, same weather information data for both models) and (c) FLIRE DSS has a distributed architecture, thus in case of failure of a component, the system will continue to work as backup systems exits. JavaScript web application is used for the frontend while the support data are organized in *xml*, *kml* and raster data files. The developed web services provide the web application with both real and non-real time data and data dictionaries.

4.2. User involvement, acceptance and use

During the design phase, Community of Practice (CoP) has been implemented in order to have the user's needs and requirements on such a system. The FLIRE DSS has been demonstrated to the Civil Protection, the Fire Brigade agencies and the Local stakeholders in order to have an interplay for improvements on the design and the presented tools. FLIRE DSS is a promising tool for these key components of the local administration. It provides the natural disaster management departments with the advantages of the GIS abilities without the challenge of the installation of complicated and expensive software. The DSS provides the users with real time information on the current weather conditions in the area as well as high resolution imageries which support the identification of the shortest paths to reach the areas of fire or flood and other important information for the surrounding terrain. An Important component of the FLIRE DSS is the potential of the users to use

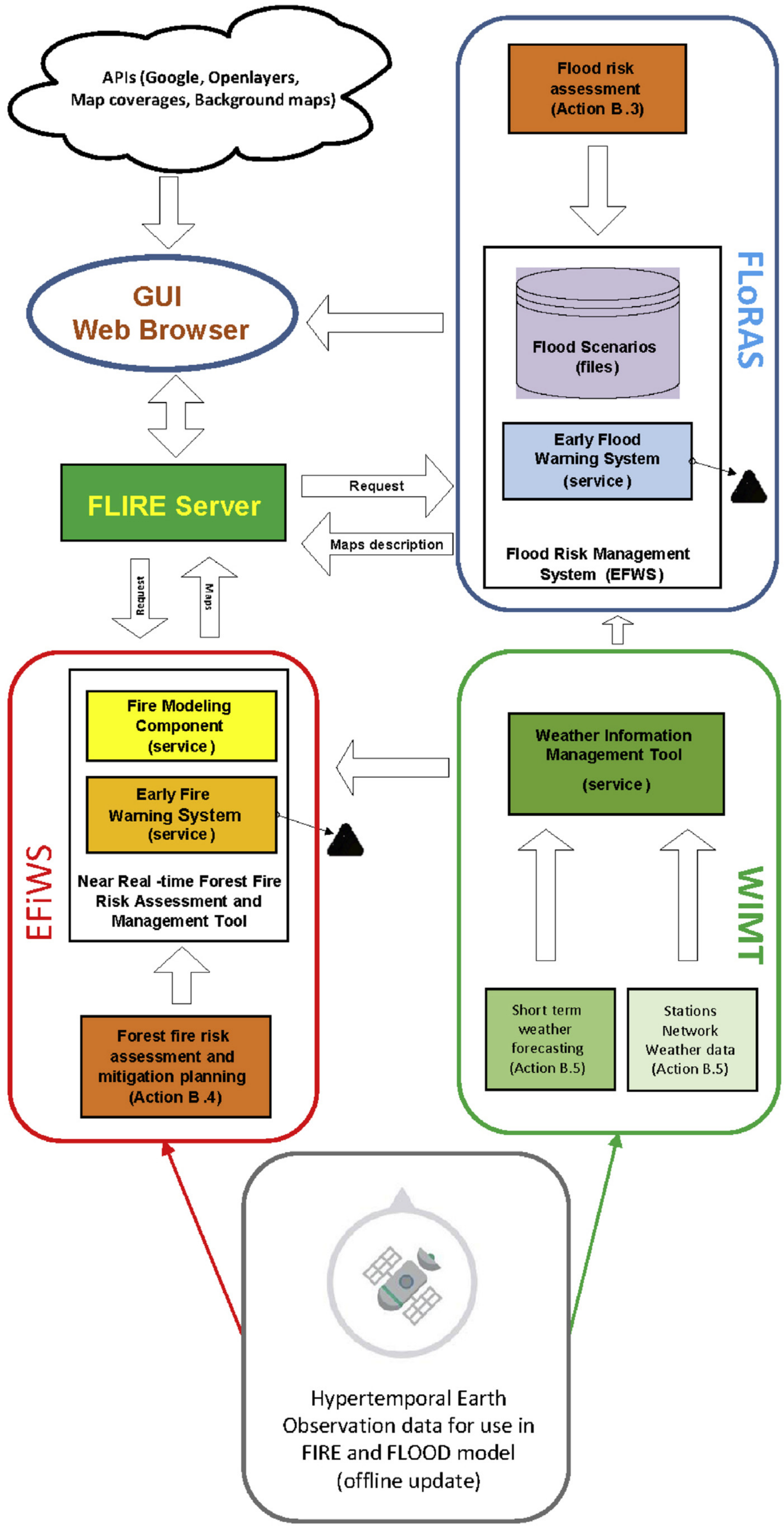

Fig. 1. FLIRE DSS flowchart.

Table 1
The technical characteristics of the FLIRE DSS.

Name of software or data set	FLIRE DSS
Developer	FORTH - Giorgos Kochilakis
Contact address, telephone, fax and email numbers	+302810391774, dpoursanidis@iacm.forth.gr, zedd2@iacm.forth.gr, kogxylak@iacm.forth.gr.
Year first available	2015
Hardware required - software required	A web-browser by using normal PC, laptop, tablet of smartphone (network connection required)
Availability	http://www.flire-dss.eu
Program language	Javascript, ASP
Program size	22 Mb
Form of repository (database, files, spreadsheet)	XML databases, KML databases
Size of archive	1.26 Gb per month
Access form	Through web-browser

weather data in order to analyze and plan "*what-if*" scenarios during dry seasons for the fire services or during wet seasons for flood services. The scenario model outputs can be used for an efficient planning in the areas that are prone to these natural hazards.

FLIRE DSS provides easy access to the system's components via a website that host the platform instead of a classic desktop application. Moreover, all the components of the system are geographically isolated, providing the system the desired distributed architecture. The fire model has been designed as a web service and has as a backbone, the well-known BEHAVE model which is widely used in the era of wildfire management. The well-established models HEC-HMS, HEC-RAS and SWMM have been selected for flood modeling. The hydrological model HEC-HMS and the catchment hydraulic model HEC-RAS have already been successfully applied several times in the study area in event-based mode (e.g. Papathanasiou et al., 2012; Papathanasiou et al., 2009). Efficient calibration of both models was achieved through the cross-validation of simulated results with observed datasets, when available.

4.3. Model use and verification

FLIRE DSS has been intensively checked for its performance and reliability by accessing it from different technological sources. It has been accessed and tested by office computers and laptops with wired and wireless network connections and different operation systems (Microsoft Windows, Linux, Apple Mac OS), tablets and smartphones with 2G/3G/4G network and various operation systems (Apple iOS 8, Android) from remote areas. The performance of the FLIRE DSS as it concerns the meteorological model skill to quantitatively forecast rainfall has been evaluated. The verification covered the period from March 2013 up to December 2014, a period that comprises 37 rain episodes, with at least one station recording more than 20 mm of rain within 24 h. For the verification period, 44 rain gauges were selected, operated by the National Observatory of Athens and the National Technical University of Athens. A contingency table was built for the totality of the 37 episodes and several statistical scores were calculated. The calculation of the statistical scores revealed a decreasing trend of the Probability of Detection (POD) with increasing rain threshold, with a POD of 0.42 for the highest precipitation amounts, a score that is close to that referenced in the literature for similar activities of high-resolution rain forecasts in the Mediterranean area. On the other hand, the calculated False Alarm Ratio (FAR) was very low (lower than 0.17) for all rain thresholds, providing an indication that the model has no tendency to provide false alarms.

Verification of the quantity of forecasted rain against observations (calculation of mean error and mean absolute errors) showed scores that are close or even better than scores reported in the literature for the Mediterranean region (Mazarakis et al., 2009; Oberto et al., 2012). The performance of the FLIRE DSS related to the response time (WIMT, G-FMIS and Fire Danger Index) has been also evaluated. A series of 250 ignition point scenarios using weather data have been evaluated. The fastest the response the more close to real time system could be voted. The fire model has a response in about 27 s (mean value) after a cold start with a maximum at 61 s and a minimum at 23 s. In some cases the system needs more that 35 s. Similar behavior has been noted by using the weather forecast data. Flood data are transferred to the DSS when they are available (daily basis) and there is no time lag for the visualization.

5. Outlook

The ultimate goal of the FLIRE DSS is the migration to a mobile platform, in order to become available to the firefighters, to the civil protection and to the stakeholders on the field. By using, it will the opportunity to exploit the fire behavior potential in order to plan the efficient elimination, satellite images for navigation and spatial information related to the flooded areas. FLIRE DSS is applied in East Attika, but due to its architecture and flexibility, can be transferred to other areas or to a broader area (region, country). The only requirements are the creation of a fuel map and a Landover map by using accurate and update Earth Observation data and information from a network of ground weather stations for it. Weather forecast data can be calculated by using the same technique. A minor hardware upgrade will be necessary for the storage of bigger datasets and the control of the traffic due to the accessibility of more users in cases of its transfer in a region level or country level.

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