

Automated Fire and Flood Hazard Protection System

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ABSTRACT: *AUTO-HAZARD PRO*, a European Union-funded research project, integrates real-time and on-line fire and flood hazard management schemes into a GIS-type platform. The system runs on an operational mode in Disasters Management Centers and in connection with local resource management agencies across hazard-prone EU areas. Specific results include: (i) a geographical data base, with electronic information (i.e., fire occurrence, topography, soils, weather, vegetation, land use, administrative and technical resources) and digital mapping capabilities for natural hazards, fire protection and effects mitigation; (ii) a Decision Support System dealing with proactive planning and emergency management of real-time fire episodes, including weather data management, geographical data viewer, a priori risk forecasting, automatic fire detection, optimal resource dispatching, and post-fire effects in the format of a flood warning module. Collection, input, storage, management and analysis of the information depend on advanced and automated methodologies using remote sensing, GPS, digital mapping and GIS. The system is supported by an operational weather forecasting model that supplies regular weather forecasts and down-scaled forecasts in the areas of interest. Field sensors of autonomous fire detection are linked to the Operations Center within *AUTO-HAZARD PRO*, where the alarm signal is evaluated to stimulate proper responses. Short-term dynamic fire and flood danger indices are developed for better and realistic prevention and pre-suppression planning. Proactive development of such information infrastructure, with the use of computers and the integration of ground and satellite technologies, assists not only in fire prevention and post-fire rehabilitation planning, but also during fire outbreaks using growth simulation models for prompt (human and technical) resource dispatching, initial attack and effective damage mitigation. In addition, the incorporated flood analysis and management module may offer considerable services particularly after a devastating flood event. All in all, such efforts point out that there must be a fundamental shift from a prevailing crisis management approach (short-range preoccupation and technological fixes) to a more anticipatory risk management that allows concentrating on contingency planning and reasonably foreseeable futures.

1 INTRODUCTION

The Automated Fire and Flood Hazard Protection System (*AUTO-HAZARD PRO*) is a European Union-funded research project that has been designed to improve the level of technological development on wildfire and flood risk management in Europe, and therefore, to help authorities on taking the appropriate actions to protect the environment and humans (www.autohazard.org). Improvement of the scientific knowledge about technological and biophysical fire processes should minimize environmental degradation and optimize ecosystem management strategies, contribute to the design of emergency response procedures, and help to assess wildfire's role on vegetation damage, wildlife changes and air pollution in various scales. Since fires have regional and local detrimental effects (on the environment, human life and property in rural and urban areas), improvement of the technological knowledge on this subject yields important economic and social benefits.

The main objective of the *AUTO-HAZARD PRO* project was to integrate real-time and on-line wildfire hazard and post-fire (i.e., floods) management schemes into a GIS-type platform. The project aimed on the development of: (i) an environmental and technological Data Base Management System, with electronic information (i.e., fire occurrence, topography, soils, weather, vegetation, land use, administrative and technical resources) and digital mapping capabilities for natural hazards/ fire protection and effects mitigation; (ii) a Decision Support System (DSS) dealing with proactive planning and emergency management of real-time fire episodes including operational weather modeling, a priori risk assessment, automatic fire detection, optimal resource dispatching, and post-fire flood forecasting.

2 APPLIED METHODOLOGY, SCIENTIFIC ACHIEVEMENTS & MAIN DELIVERABLES

Collection, input, storage, management and analysis of the information were based on advanced and automated methodologies using remote sensing, GPS, digital mapping and Geographic Information Systems (GIS). Development of the prototype system was accomplished on 3 study areas in Greece and Spain, with the potential to later encompass whole regions of EU countries on operational basis (Kalabokidis *et al.* 2002).

Activities of this 3-year project focused on the proper implementation, calibration and validation of data sets, algorithms and software. Validation carried out by selecting adequate references of existing, proven models, data sets and algorithms for comparison; testing of new algorithms and meteorological operational activities; and systematic data gathering of real data about different elements in *AUTO-HAZARD PRO* throughout the celebration of field campaigns, including:

- field sampling for digital maps acquired through remote sensing;
- actual atmospheric and weather data gathering (historical records);
- actual data of forest fire detection (experimentation); and
- actual data of forest fires (historical, real and experimental burnings).

2.1 Satellite and GIS Cartography

Natural hazard protection requires the use of large volumes of data that change continuously over time and space, creating both the need and the opportunity to automate the tasks. Within the project, integrated satellite and ground technologies were being applied using advanced geo-informatics tools and models for the inventory, mapping and monitoring of geomorphology, land cover and uses, atmospheric and physical processes, and anthropogenic influences (Kalabokidis 2004).

Multi-spectral QuickBird satellite images (2.5-m resolution) for the whole island of Lesvos, Greece, and for the forest area within the Province of Madrid, Spain, and IKONOS 1-m panchromatic and 4-m multi-spectral data for Samos Island, Greece, were used to extract useful geographical information (Figure 1) to study and monitor the wildfires and floods (e.g., cover types, fuel models, road networks, land-use boundaries, watersheds and stream networks, etc.). The appropriate database was developed and integrated into the DSS; the database was also used as input to various simulation models and for mapping purposes.

2.2 Atmospheric Modeling and Operational Weather Forecasting

Within the project, 5-day high resolution weather forecasts are provided by the SKIRON/Eta weather modeling system at approximately 10-km horizontal grid increments for *AUTO-HAZARD PRO*'s study areas (<http://forecast.uoa.gr/forecastnew.html>). The forecasts were validated with Remote Automatic Weather Stations (RAWS) observations, and further improvement of the forecasts was carried out by developing and using a Kalman filtering technique to SKIRON/Eta outputs. Figure 2 shows an example of the 72nd-hr SKIRON/Eta forecasted wind field over Greece, together with the meteograms for locations in Lesvos Island (Molyvos), Greece; the model has predicted high wind speed over the Aegean Sea reaching 12 m/s and 16 m/s in Lesvos and Samos islands, respectively. Such wind conditions are often related to forest fire spreading.

2.3 Innovative Wildfire Risk Forecasting

An innovative large scale Wildfire Danger Rating System (WDRS) was developed. The main output of WDRS is the Fire Danger Index that is based on Fire Weather Index, Fire Hazard Index, Fire Risk Index and Fire Behavior Index (Figure 3). These indices are not just a relative probability for fire occurrence but a quantitative rate for fire danger appraisal in a systematic manner. The function mapping of the indices is accomplished with Artificial Neural Networks (NN), and the training of NN is based on historical fire data (Kalabokidis *et al.* 2004). The whole wildfire risk forecasting scheme was tested and validated during the fire season of 2004 by the project's end-users in Spain and Greece. More specifically, the dynamic Fire Danger Index is composed of four individual ones as follows (for determining preparedness levels and also as a critical element of the decision-making process for resources dispatching to a wildfire):

- Fire Weather Index; which is based on data received by RAWS and the weather forecasting system. Atmospheric temperature, relative humidity, precipitation and wind fields are the main variables in this index.

Figure 3. The AUTO-HAZARD fire danger rating module.

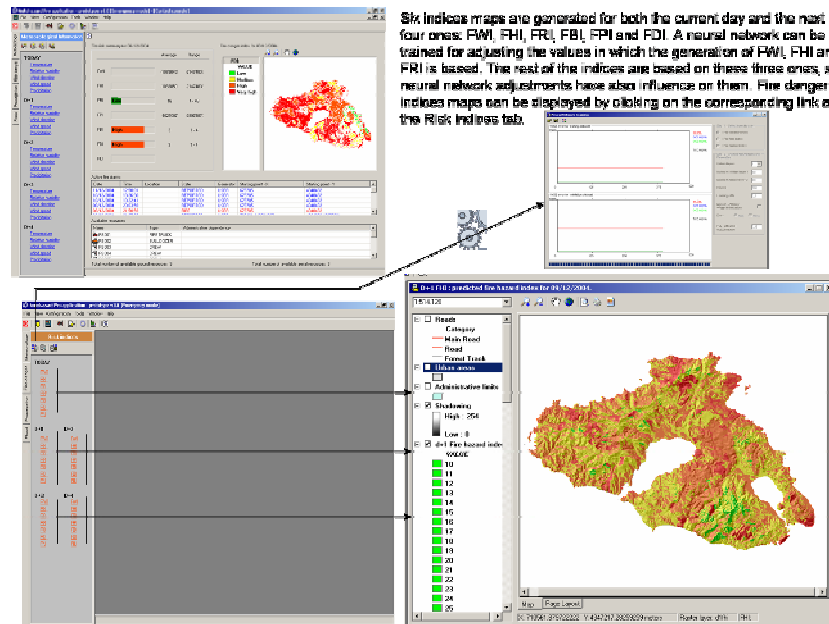


Figure 4. The AUTO-HAZARD fire propagation simulation module.

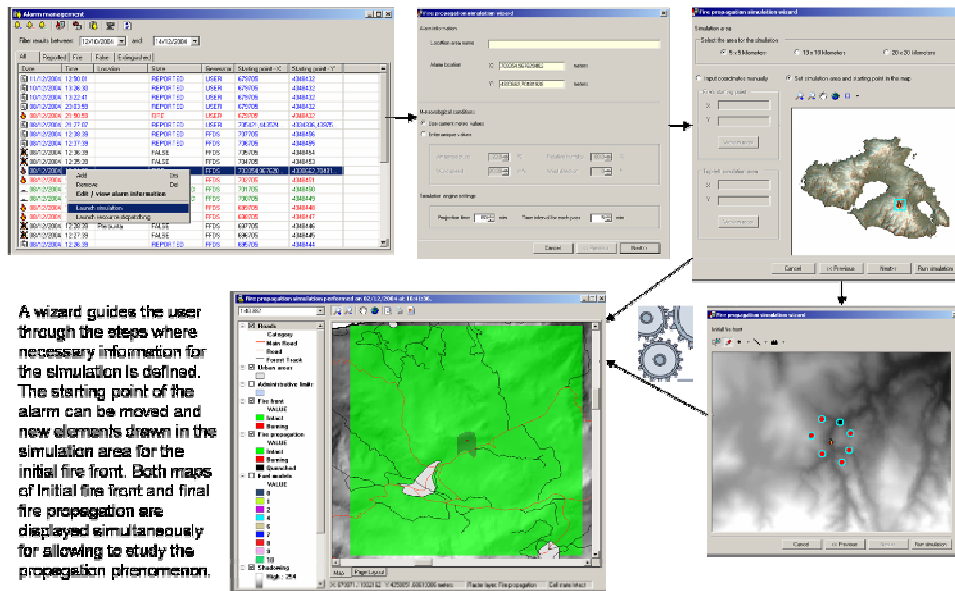
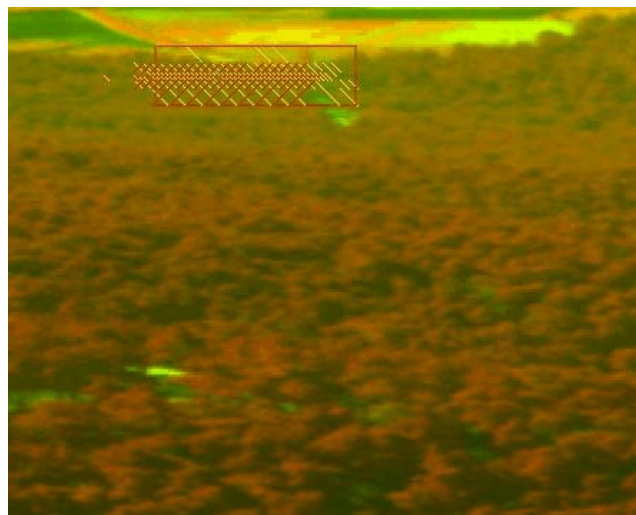


Figure 5. False color image with detections (crosses) and raised alarm (red border around detections).



2.5 Post-Fire Flood Forecasting and Erosion Hazard

The *AUTO-HAZARD PRO* has investigated the flood phenomena as post-fire incidents on the island of Samos, after the devastating fires and floods of the year 2000. The estimation of flood risk in real-time and the long term estimation of soil erosion risk independent of real-time were the two basic aspects of the Flood Module of the *AUTO-HAZARD PRO* DSS. The Flood Module is based on two separate procedures, namely the pre-processing and the on-site analysis procedure. Two modeling methodologies proposed and developed to evaluate the flood risk of a catchment and estimate the soil erosion in burned catchments using a GIS platform for Samos Island, Greece (Kalabokidis *et al.* 2004).

2.6 Software Application and Network Infrastructure

The *AUTO-HAZARD PRO* Decision Support System (DSS) is the outcome of the program that integrates and automates the methodologies and the scientific results of the work done along the project, by using a user-friendly graphical interface (Figure 6). It is an integrated system, that when installed in a operational management center can provide to decision makers important information in regard to proactive planning and the level of readiness with the help of danger forecast, the fire detection by using a multi-spectral camera, and the fire simulation. It can also propose to the manager the load of air and ground forces that should be dispatched. Furthermore, it includes functions regarding flood forecast and estimation of soil erosion as a post fire effect.

The DSS philosophy was to create a system that supports effectively its end-users along the whole fire risk management process (and externally flood hazard) by means of a fast and easy to use interface, which allows taking advantage of the capabilities of the diverse technologies, models and systems it integrates (i.e., GIS, communication software, automatic fire detection, fire risk index generation and flood risk generation models). Thus, the user-friendly and efficiently designed application allows the user viewing the meteorological conditions, checking the fire risk in different time horizons, simulating the propagation of a fire or sending messages to fire-fighting resources (Figure 7) through different communication technologies (SMS, e-mail and Net sending). The final application provides capabilities of simultaneous visualization of different information (fire danger indices, available resources and active fires), fire alarm information management and resource information management (e.g., Figures 3 and 4).

3 CONCLUSIONS & POLICY IMPLICATIONS

The developed *AUTO-HAZARD PRO* system is expected to complete and integrate the qualitative approach of wildfire danger estimation being used by some EU countries nowadays (Kalabokidis *et al.* 2002). The Wildfire Danger Rating System has the ability of short-term forecasting of wildfire risk in order to help in better and realistic prevention and pre-suppression planning. The forecasting scheme is based on multiple layers of information that are coming from the quantitative and systematic analysis of fire occurrence and growth factors; parameters taken into consideration include vegetation, topography, weather conditions and human geography of the pertinent areas. The system has incorporated the operational weather forecast model SKIRON that provided detailed forecasts of weather conditions. RAWs are utilized for the continuous recording and transmission of weather data in real time to any selected Operational Center via cellular phone and/or VHF broadcasting.

Major component of the *AUTO-HAZARD PRO* project is an autonomous fire detection system. To improve the fire detection range, the NDVI (Normalized Difference Vegetation Index) was used as it gives the best contrast between vegetation and the smoke. Position accuracy of the camera was sufficient to create a good overlap between consecutive images and also seemed to cause very few false alarms. During trial tests performed in Lesvos Island in 2003 and Madrid in 2004, smoke detection was very accurate in distances up to 12 km.

The *AUTO-HAZARD PRO* DSS is an environmental risk management system for real-time and on-line operation, that once installed in an Operational Management Center can provide for prompt decision making with important information in regard to proactive planning and levels of readiness with the help of risk forecast, fire detection and fire simulation. The DSS includes the following functionalities in order to: download weather data and create today's and predicted meteorological maps; calculate Fire Danger Index and create corresponding maps; receive automatic alarm messages and images from a detection camera; simulate fire propagation; provide advice on dispatching and dispersion of resources to forest fires; and send information regarding a fire in a selected group of users via mobile SMS or e-mail.

New technologies of Geo-informatics (Geographic Information Systems, Decision Support Systems, Digital Technology, Remote Sensing, etc.) and Electronics (Remote Automatic Weather Stations, detection sensors, etc.) contribute to more effective organization for environmental protection with prompt de-

tection and risk assessment, systematic observation of bio-physical and socioeconomic parameters and decision support management (Kalabokidis 2004).

4. REFERENCES

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Figure 6. A snapshot of the AUTO-HAZARD PRO DSS.

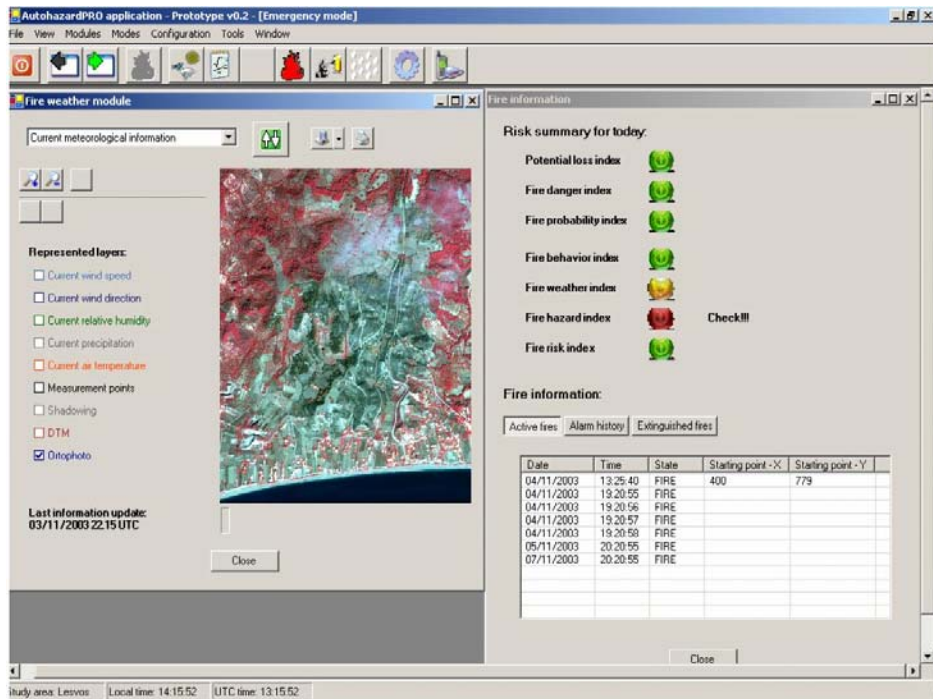


Figure 7. Event message sending.

