FOMFIS: FOREST FIRE MANAGEMENT AND FIRE PREVENTION SYSTEM

D. Caballero[1], G. Xanthopoulos[2], D. Kallidromitou[3], G. Lyrintzis[2],
M. Bonazountas[3], P. Papachristou[3], O. Pacios[4]

Introduction

FOMFIS is an acronym (**FO**rest Fire **M**anagement and **FI**re Prevention **S**ystem) for an international forest fires research project. The project had a two-year duration and was completed early in 1999. It was partially funded by the European Commission DG XII within the IV Research and Technical Development Framework Programme (Environment and Climate Programme, ENV4-CT96-0335), in the area of Natural Hazards (Caballero 1998). Nine partners participated in the project. They were IBERINSA (Co-ordinator), SEMA GROUP, IBERSAT, SESFOR, and the Conselleria de Agricultura de Galicia from Spain, EPSILON and the Institute of Mediterranean Forest Ecosystems and Wood Products Technology of the National Agricultural Research Foundation from Greece, the Centre de Productivite et d'Action Forestiere d'Aquitaine from France, and Software AG Italy (SAGI) from Italy.

The project aimed at the definition, design and implementation of a computer based system giving support to the planning process of the activities and resources distribution for the preventive operations belonging to the forest fire defence services. The main goal of the FOMFIS project was to integrate, within a single computer application frame (the FOMFIS system), a set of technological solutions using the same information system platform, thus allowing forest fire service personnel to accomplish timely, accurately and cost effectively their off-line planning

[1] IBERINSA SA, Madrid, Spain
[2] National Agricultural Research Foundation, Athens, Greece
[3] EPSILON INTERNATIONAL SA, Athens, Greece
[4] SEMA GROUP SA, Madrid, Spain

duties. More specifically, the FOMFIS system was conceived and built as a modular system running under the same user interface integrating remote sensing, statistical analysis, stochastic generation, knowledge-based simulation systems, simulation models and spatial analysis tools. It operates on personal computers with an Intel Pentium processor. It runs under the Windows NT Server operating system, and is strongly based on the commercially available Geographic Information System Arc/View 3.0.

Elements and concepts of the FOMFIS system

The most important concept of the FOMFIS system is the *Probabilistic generation of scenarios.* Scenarios of changing weather conditions and risk are generated while keeping fuel distribution and topography constant. More specifically, in the generation of forest fire scenarios three stages are considered:

- *Generation of meteorological conditions evolution* through the study of meteorological historical data and/or following user specified patterns.
- *Generation of wind conditions evolution* through probabilistic generation of wind patterns that is based on a statistical analysis of historical data.
- *Generation of fire outbreaks.* The system uses historical data of forest fires to characterize the distribution of fire appearance in time. Besides, and coupled with the above, the system makes use of a fire appearance risk map to spatially distribute fire outbreaks. Also, users are allowed to define a particular fire distribution of interest over time and space.

The next important element of FOMFIS is *integral risk estimation.* Integral risk maps are generated from forest fuel distribution, weather and wind patterns. Integral risk takes into account the fire potential due to the fuel and the conditions together with the intrinsic value of the terrain where a fire could occur. Derivation of the map, as a raster layer, is based on the assumption of uniform conditions (forest fuel, slope, aspect, wind and weather) in each cell of the raster map.

This allows the system to determine local spread conditions and hence to characterize the fire destruction potential. Actually, three risk indexes are calculated for every cell. The first is *the instantaneous destruction rate* expressed in surface units per time for every cell. The second is the *loss rate in monetary units per time unit* which is calculated by combining the first index with land value per surface unit. The latter is estimated from economic, social and ecological components. Finally, taking into account the predictions of number of fires that is expected to happen in each cell, and provided that all the fire outbreaks will propagate the same way within the same raster cell, an *integral value loss rate* is estimated by simply multiplying the loss rate by the number of expected fires. The resulting raster maps synthesize the destruction potential and value loss for the whole area and are extremely useful to planners to understand where attention should be paid according to the duality fire potential and terrain value.

Within the FOMFIS project the possibility to semi-automatically obtain valid *fuel maps from satellite remote sensing* (LANDSAT and SPOT satellite images) was researched. In order to obtain the geographical distributions of forest fuels (in the form of standard fuel models) it was required to establish a relationship table between vegetation classes and such fuel models. Then, image classification had to identify vegetation patches, grouped by classes. Two classification approaches were evaluated:

- A divergent approach which establishes sequential disaggregation of initial coarse vegetation classes, easily distinguishable from the satellite images, into finer ones using other easily measurable variables, such as vegetation average height. This leads to precise equivalence tables between models and the identified vegetation units.
- A convergent approach, which starts with very fine division (large number of classes and sub-classes) of fuel types and all available image bands. Using a multispectral maximum likelihood classifier a thematic map is produced with a large number of classes but a large degree of confusion between them. Subsequently these classes are aggregated until errors are reduced and meaningful fuel classes are produced.

The success of the resulting fuel maps was variable. The best results were obtained by combining a texture band from SPOT to the six Landsat TM spectral bands. Verification of the classified images in Galicia, Spain gave a classification accuracy ranging from 76% to 86%.

Another part of the FOMFIS project was devoted to the design and implementation of *Socio-Economic Risk Models (SER)* which yield the expected number of fires by unit area in a given time, according to relationships between socio-economic factors and forest fire starts. This work is necessarily area-specific. Separate models were derived for the two test sites of the FOMFIS system, Galicia in Spain and Greece. A spatial and a temporal model were derived for Galicia, and a spatial model was derived for Greece. Furthermore, two predictive micro-scale models were developed for the Comarca of Noia (Galicia) and the area of the Forest Service Office (Dasarheio) of Limni, on the island of Evia in Greece. These models predict the number of fires per unit area per unit time.

Efficiency-oriented fire presuppression planning is another important element of the FOMFIS system. This task can be conceptually simplified as the minimization of time involved in the operations, such as fire detection, communication to base, forces preparation and start-up, air and ground transport, deployment of resources in the fire area and fire extinction and control. In FOMFIS the calculation of access time of ground vehicles is based on raster maps: roads are converted to raster cells into which a transport-resistance value is stored, depending on the type and state of road and terrain slope. This is interpreted as time values, those invested by vehicles in crossing each cell. For cross-country access the type of vegetation and the slope are also considered in the calculation. From this ground *'Impedance Map'* an accumulated time access map is derived, calculated by iterative automata following the minimum-time path. The resulting map stores the time invested in traveling from a given point to every cell. Aerial coverage is estimated by directly considering distances to air-bases and average speed of aircraft. The resulting map is combined with ground access to estimate real coverage of fire fighting resources. Efficiency of fire vehicles in their water re-charging cycles to the nearest water point is also estimated. Lookout efficiency, is calculated through viewshed analysis. Planners are allowed to play with different distributions of bases, water points, lookouts and roads and see the effect in terms of efficiency of their new locations. The costs associated with this planning are also calculated.

The next element of the FOMFIS system is *fire theater simulation.* After obtaining the fire scenarios evolution and fire defense resources and infrastructures planning, their interaction over time can be simulated, estimating costs of operations and losses due to wildfire destruction. Simulations count on a very efficient forest fire spread engine which calculates fire propagation and fire characteristics for every cell (Caballero et al. 1994). Flame length, heat per unit area and fireline intensity are also estimated and used to dimension the required forces to achieve successful containment and extinction. Many factors that affect firefighting productivity of ground and aerial resources are taken into consideration in the simulation of fire fighting operations (Xanthopoulos 1994). The latter are finally reduced to a set of operations: direct attack over flames, indirect attack and aircraft water discharges. All the calculations are based on real data and observations which give average values of productivity.

The system simulates the fire theater during a user-specified time period that can range from one day to several months. As fire scenario components, such as weather and wind, are obtained from probabilistic calculations they could differ from real world in a single simulation. Thus, the user may automatically run the same simulation several times while slight, stochastic variations are added every time. The system computes, in the end, average tendencies of fire theater evolution to give just orders of magnitude, instead of deterministic predictions. Results of simulations are presented in the form of tables and graphics. They include weather and wind pattern evolution, fire outbreaks distribution, fire growth average values such as size, fire line intensities, fire importance etc.. Several reports are obtained regarding resources usage, dispatching and efficiency. Simulations also produce results in terms of monetary values. The cost of firefighting operations during the simulation period and infrastructure maintenance cost are also computed and then compared with monetary losses estimation due to fire destruction. The final evaluation allows planners to identify which strategies could have deeper impact on the final results, comparing costs, efficiencies and losses.

Conclusions

The FOMFIS system combines risk forecasting, efficiency and costs estimation, allowing users to make complex “what-if” type analyses and obtain realistic results that include both average conditions and worse case scenarios. The combination of these three elements is a real added value for a decision support system and has received positive responses from users in the first trials. Several innovations included in FOMFIS could be easily transferred to on-line fire management systems. Furthermore, the strategy could be transposed to other systems regarding natural catastrophes which demand emergency forces planning and deployment.

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