Development of operational forest fires propagators: methodological approach and implementation

Desarrollo de propagadores operativos en incendios forestales: acercamiento metodológico e implementación

Joaquín Ramírez[1], Luis Ferragut[2], Santiago Monedero[1]

Abstract

At present, there exists a wide range of fire behaviour models and studies aiming to simulate fire behaviour, but there is still an important gap between the scientific research in this field and its practical use in real fire fighting activities [1]. In this work, we intend to narrow this gap by the introduction of a complete fire behaviour service and models all integrated within an easy to use GIS environment intended to give real and practical solutions for fire fighting agencies.

The main elements of this tool are the following:
Physical, scientific approach

1) Implementation of a finite element toolbox.
2) Implementation of Rothermels model [2]
3) Reaction diffusion (theoretical) models solved by the finite element Method [3]
4) Daily high definition Windfield analysis based on meteorological wind, topography and fire itself [4]

Information available

5) High definition fuel analysis
6) Daily moisture analysis

Friendly end user environment

7) Easy inputs and outputs in all standard formats.
8) Integrated satellite images.
9) 3D mapping.

This job is a part of PREVIEW, an European VI Framework Programme Integrated Project intending to setup the next generation of services for disaster management support, within the GMES initiative. A cluster of experienced organisations within Europe is preparing the basis of this new generation of services, compiled in a single portfolio covering all scales at pan-European level, built from final user needs and taking into account all previous efforts in the area. All the information services are developed, tested and validated at European scale with operational users on pilot test sites distributed over 9 countries. The project duration is between 2005 to 2009.

---

1 Tecnosylva, SL. Parque Tecnológico de León, 24009 - León. España
Fax: +34 987 849539, email: jramirez@tecnosylva.com
2 Departamento de Matemática Aplicada, Universidad de Salamanca y IUFFyM Instituto Universitario de Física Fundamental y Matemáticas.

The Preview Project Fire Services

At present, there exists a wide range of fire behaviour models, tools and studies aiming to help in fire fighting activities. Nevertheless these systems are usually difficult to be used for non experts and are operationally difficult to manage. Here we propose a complete operational forest fire support system which tries to solve many existing problems in this field.

The Fire Services proposed in the Project are aimed to support the four phases involving the fire events: prevention, early warning, crisis and post-crisis.

Prevention phase:

- **Fuel Parameters**: it is focused on providing long-term changing data suitable for end users (fuel type, fuel load and canopy cover). This is a long–term changing information, and will have two different updating rates. An initial layer, with very high resolution imagery as base for the long term geographic definition, and a medium term review, made with medium resolution imagery and FIRE DAMAGE products focused on high risk areas.

Early warning phase:

- **Fire Risk Indices**: risk anticipation service is intended to daily predict and monitor fire risk in time and space merging new variables and improving spatial resolution.

Crisis phase :

- **Fire Monitoring**: the objective of this service is the continuous near-real-time prevision of fire parameters such as hot spot location, fire temperature, fire power evolution, etc benefiting from the synergy among new systems (MSG SEVIRI with 15 minutes temporal resolution) and already well known ones (MODIS and NOAA)
- **Fire Propagator**: The aim of the service is the development of a high performance propagator with an easy to feed model engine and a powerful display interface to be used during extinction activities

Post-crisis phase :

- **Fire Damage Assessment**: this service is focused on the seasonal provision of fire severity (level of damage on vegetation) and the preliminary burnt area for certain fires occurred during the fire campaign.

Fire propagator

The aim of the service from and end users point of view is the development of a high performance propagator with these objectives:

- Easy to feed model engine, as transparent to the user as possible.
- Direct integration of the products developed in this work (Fuel type, Fuel load, Canopy Cover) and other GIS meteorological and EO data
- Results showed over VHR imagery in 3D, and with the forest fire fighting resources and any other information to result a really operational FFDSS.
- Become a useful platform to support training for FF technicians without high level GIS skills

- No need of understanding fire propagation models nor time consuming format conversions

The mathematical models to be used in the fire propagator are both Rothermel’s model and a physically based fire spread model developed in [2]. It is commonly accepted that among them, the physically based models are the most promising option in order to obtain reliable rates of spread of fire even though Rothermel’s model is still the most widely used tool for fire propagation. For this reason, an important synergy is obtained by implementing both models within the same final service.

From a mathematical point of view, the difference among these two fire simulation approaches is especially relevant. Physically based models are the most promising but have the important draw back of being computationally expensive in time and complex in their final implementation. These models are based on partial differential equations and thus to be solved a Finite Element tool is required.

It is well known that wind profiles over the fire are one of the main mechanisms of fire spread. More over, some studies reveal how a correct high definition wind profile can significantly improve fire behaviour simulations. In many cases, the wind profile used for simulations is based on a crude interpolation of some experimental punctual wind profiles, and thus, these approaches do not take into account the surface of the terrain nor the presence of fire itself which modifies the wind profiles around the fire. In this work, we take advantage of the Finite Element Toolbox developed for the fire to obtain a high definition wind profile taking into account surface and fire temperature. The model is based on [3], and may be used for both, the Rothermel’s model and the physically based model.

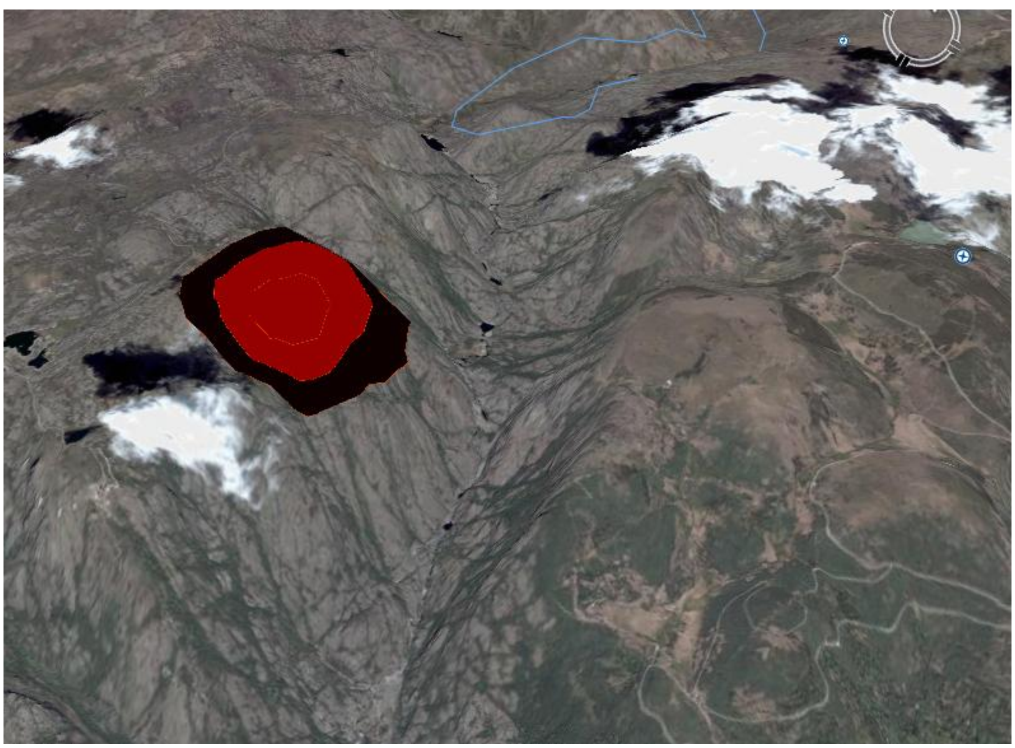

Figure 2: ***Actual view of an ongoing fire over the free software Google-earth.***

Methodology, algorithms, models used

Operational use of propagators

There has been a very important effort in the scientific side to build robust models, but to become operational it is necessary to focus on users requirements to operational tools. A propagator is a tool with three main parts:

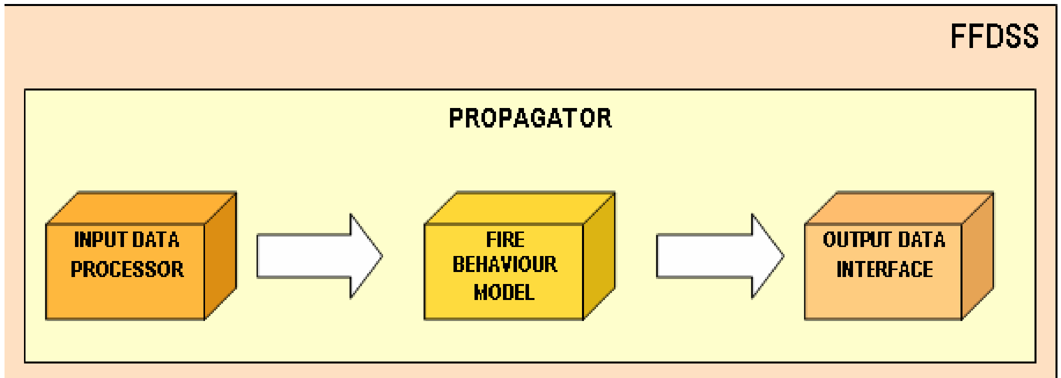

Figure 1: Structure of a forest fire propagator

- Input data: easy to get data to feed the model. If the model parameters are not in common use for the users, tool will not run. Tipical data required
    - Terrain: DTM, slope, aspect (no change in operational scale of time)
    - Fuel: model type (NFFL), biomass, canopy cover, (seasonal change)
    - Weather: speed and direction of wind, temperature, humidity (daily change)
- Data processor: nearly no intervention form the user needed. It should be capable to convert from any forta of vector and imagery data to raster layers to feede the model
- Fire behaviour model: strong enough to give accurate results without huge hardware requirements
- Output data: easy to interpret results. Due to heterogeneus technical level of the users in decission centers, the results should be easy to understand by most possible user in the center. The outputs will be focused in the capability of fight against the fire that the users have: length of flames and spread rate. The third basical output will be the surface burnt for the simulation period.

Fire Behaviour Models

There are a lot of different ways to predict wild fire behaviour over landscape, divided into physical, semi-empirical and empirical models [5]. The level of maturity of fire behaviour models is high (more than 30 years), but the use is very low [1].

In this project, two models will be implemented in the propagator. The Rothermel model, as a common standard well known and accepted for users, used to validate result, an a physical model [4] to integrate new approach of fire behaviour in operational enviroments.

Scenarios of use of the propagators

The operational phase has two different scenarios:

- the fire fight command centres (FFCC), usually at NUTS 3 level (provincial, department, etc.)
- the fight against fires in the field

Fire propagators use in Euromediterranean area should be short-range models, because of the number and size or fire events. The use of propagator should be focused after the detection phase, at the FFCC, where the cycle of work is detailed below. At the initial evaluation phase, every alarm should be analyzed with the help of the propagator, and in several cases it should be done more than 40 times per day.
Only big fires, with a duration of more than 36 hours, will get the fire behaviour analysis equipment in the field to help the fight with this capabilities. And only after this tool is well accepted in the FFCC, it will be the time to begin using it in the field, where portable capabilities and easiness to run for the operational use are the main characteristics required. The final objective is that any fire alarm that an FF operational center has a propagator run over it to support first time decisions. Yearly, a center like Zamora has more than 1500 fires. All of them should have the support of a technical evaluation of danger done by a propagator, which needs no intervention to give results; it should run automatically once the alarm is located. In any other case, it will not be used, as it happens now.

References

[1] Xanthopoulos G., Varela V., Fernandes P., Ribeiro L. and Guarnieri, F., 2005. Eufirelab deliverable D-06-02. Decision Support Systems And Tools: A State Of The Art. Avalaible at www.eufirelab.org

[2] R.C. Rothermel. A mathematical model for predicting fire spread in wildland fuels. General Technical Report INT-115, USDA Forest Service, Intermountain Forest and Range Experiment Station, 1972.

[3] L. Ferragut, M.I. Asensio, S. Monedero. Modelling radiation and moisture content in fire spread. Commun. Numer. Meth. Engng 2000; 00:1 6

[4] M.I. Asensio, L. Ferragut, J. Simons. A convective model forest fire spread simulation. Applied Mathematical Letters 18, pp. 673-677, 2005.

[5] Morvan D., Larini M., Dupuy J.L., Fernandes P., Miranda A.I., Andre J., Sero-Guillaume O., Calogine D. and Cuiñas P., 2005. Eufirelab deliverable D-03-01Behaviour Modelling of Wildland Fires: a State of the Art. Avalaible at www.eufirelab.org