PERGAMON

Expert Systems with Applications 25 (2003) 545–554

Expert Systems with Applications

www.elsevier.com/locate/eswa

An intelligent system for forest fire risk prediction and fire fighting management in Galicia

Amparo Alonso-Betanzos[a,*], Oscar Fontenla-Romero[a], Bertha Guijarro-Berdiñas[a], Elena Hernández-Pereira[a], María Inmaculada Paz Andrade[b], Eulogio Jiménez[c], Jose Luis Legido Soto[d], Tarsy Carballas[e]

[a]Department of Computer Science, Faculty of Informatics, University of A Coruña, Campus de Elviña s/n, 15071 A Coruña, Spain
[b]Department of Applied Physics, University of Santiago, Spain
[c]Department of Physics, University of A Coruña, Spain
[d]Department of Applied Physics, University of Vigo, Spain
[e]Department of Biochemistry, IIAG, CSIC, Santiago, Spain

Abstract

Over the last two decades in southern Europe, more than 10 million hectares of forest have been damaged by fire. Due to the costs and complications of fire-fighting a number of technical developments in the field have been appeared in recent years. This paper describes a system developed for the region of Galicia in NW Spain, one of the regions of Europe most affected by fires. This system fulfills three main aims: it acts as a preventive tool by predicting forest fire risks, it backs up the forest fire monitoring and extinction phase, and it assists in planning the recuperation of the burned areas. The forest fire prediction model is based on a neural network whose output is classified into four symbolic risk categories, obtaining an accuracy of 0.789. The other two main tasks are carried out by a knowledge-based system developed following the CommonKADS methodology. Currently we are working on the trail of the system in a controlled real environment. This will provide results on real behaviour that can be used to fine-tune the system to the point where it is considered suitable for installation in a real application environment.

Keywords: Neural Networks; Knowledge intensive systems; CommonKads; Forest fires; Fire risk prediction; Resources management

1. Introduction

Over the last two decades in southern Europe, more than 10 million hectares of forest have been damaged by fire. Each annual fire-fighting season incurs significant costs, measurable principally in terms of loss of human life, investment in fire-fighting resources, damage to the environment and the cost of recuperating the affected areas. However, the costs and complications of fire-fighting make it impractical to simultaneously maintain active fire-fighting units in various parts of a country. Recent years, therefore, have seen a number of technical developments in the field, aimed at improving communications networks, detection systems and fire prediction systems design. However, due to differing conditioning factors (vegetation type, climate, soil composition, orography, etc), it is not feasible to adopt general solutions or to adapt solutions developed for specific regions or countries.

This paper describes a system developed for the region of Galicia in NW Spain (Fig. 1), one of the regions of Europe most affected by fires. During the 1990s, for example, although it represents a mere 5.8% of the surface area of Spain, Galicia alone accounted for around 50% of all forest fires in that country. Moreover, in the same period the number of forest fires continued to grow despite an increase in the human and financial resources allocated to fire-fighting (Merida, 2002).

The system developed in this work fulfills three main aims, as follows:

1. It predicts forest fire risks and therefore acts as a crucial preventive tool by permitting fire-fighting units to focus on areas with the highest fire risk.

* Corresponding author. Tel.: +34-981-167150x1250; fax: +34-981-167160.

E-mail addresses: ciamparo@udc.es (A. Alonso-Betanzos), cibertha@udc.es (B. Guijarro-Berdiñas).

0957-4174/03/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/S0957-4174(03)00095-2

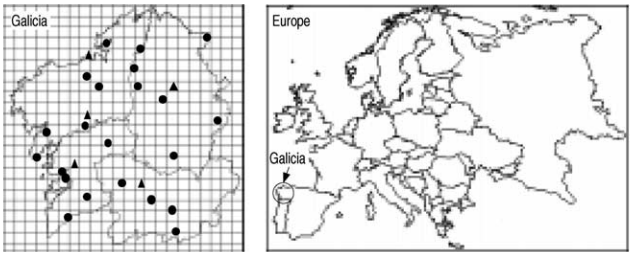

Fig. 1. Location of automatic (●) and non-automatic (▲) meteorological stations in Galicia.

2. It backs up the forest fire monitoring and extinction phase.
3. It assists in planning the recuperation of the burned areas.

The above aims are achieved, from a technical point of view, using artificial neural networks and expert systems.

Our article is organised as follows: Section 2 provides a brief background analysis; Sections 3 and 4 describe, respectively, the fire prediction module and the subsystem for fire management and recuperation of the affected areas; Section 5 describes the overall architecture and additional features of the system; finally, Sections 6 and 7 discuss, respectively, the results obtained and our conclusions.

2. Background

Developed countries currently avail of well structured organisations, programmes and protocols for fighting forest fires, a fact that undoubtedly facilitates the application of new technologies in the domain.

The forest fire domain is an ideal one in which to apply intelligent systems. A large part of the domain knowledge is to be found in procedural models and written material; the remaining knowledge resides in practical accumulated experience that can be captured using knowledge engineering techniques. Nonetheless, in the fire fighting field, intelligent systems are still in the research or prototype phase and are just beginning to be tested in real environments.

A variety of computerised systems have already been developed for the tasks described above, i.e. fire prediction, fire management and recuperation of affected areas. We will discuss these in turn below.

Regarding the *fire risk prediction* task, the FOMFIS (Forest Fire Management and Fire Prevention System) system (Caballero et al., 1999) is an international project partly funded by the European Union. On the basis of weather conditions it provides a measure of probable fire risk for a given area, together with a list of the possible causes of a fire. Another system currently being developed by the Joint Research Centre of the European Commission under its Natural Hazards Project (San-Miguel-Ayanz, Barbosa, Schmuck, Schulte, & Barisisch, 2001) is a fire risk evaluation system based on linear regression models to predict fire hazard for an entire province (Sebastian Lopez et al., 2001). Although other forest fire hazard indices have been developed and applied (Chandler, Cheney, Thomas, Trabaud, & Williams, 1983), their capacity for prevention is greatly reduced outside the area for which they have been designed, as demonstrated in Espinosa, Galinanes, Paz-Andrade, Legido, & Melikhova (1998).

A second set of applications is geared specifically to optimising the fight against forest fires and the management of the resources used for fire extinction. Worthy of particular note in this area are the CHARADE, CARICA, PIROMACOS and FOMFIS systems. The CHARADE project, originated as a software platform, is designed to supervise environmental emergencies using case-based reasoning. A demonstrator has been developed which, by analysing past cases, constructs preliminary intervention plans adapted to each situation (Avesani, Perini, & Ricci, 1993; Ricci, Mam, Marti, Normand, & Olmo, 1994), subsequently evaluated in terms of a fire simulation, resources and geographic information. Experimentation with this project has led to the development of the CARICA system, which includes additional features such as a database of genuine emergency cases and a forestry agent training model (CARICA, 2000). Finally, the PIROMACOS (PIROMACOS, 2002) project optimises fire-fighting using a variety of geographical databases as well as controlling the overall extinction process. It combines information on the fire's advance with information on resources, and indicates any changes necessary in fire-fighting strategies. The optimal strategy is obtained using Bayesian global optimisation methods, updated for changes in the fire profile and in the fire extinction process. All this information is contained in a Geographical Information System (GIS), which manages the databases and the outputs of a program that simulates the progression of the fire. More recently, tailor-made systems have been developed for specific regions of Europe, such as the above-mentioned FOMFIS, a prototype of which has been tested in three areas of southern Europe, namely, Galicia, Aquitaine (France) and Evia Island (Greece). It estimates the most cost effective strategy for both fire prevention and fire-fighting. Operating offline, it provides information on the likely outcome in terms of fire-fighting costs and environmental damage.

The final set of applications concerns *recuperation of burned areas*. The impact of fire on the environment can be reduced through the acquisition of knowledge on the area (in terms of meteorology, topography and vegetation), an evaluation of the consequences of fire and the application of recuperation measures. An example of a system that automates these tasks is the PROMETEUS (U.F. Service, 2002) project, a knowledge-based system that uses a GIS as interface. It acts as a Decision Support System (DSS) that responds to the expected consequences of a fire on the environment. As part of its development, experiments