Expert Systems with Applications 38 (2011) 9225–9236

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

A data fusion framework with novel hybrid algorithm for multi-agent Decision Support System for Forest Fire

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ARTICLE INFO

Keywords:
Detection and prediction of forest fire
Artificial Neural Network
Naive Bayes Classifier
Fuzzy Switching
Decision Support System

ABSTRACT

In this study Forest Fire Decision Support System (FOFDESS) which is a multi-agent Decision Support System for Forest Fire has been presented. Depending on the existing meteorological state and environmental observations, FOFDESS does the fire danger rating by predicting the forest fire and it can also approximate fire spread speed and quickly detect a started fire. Some data fusion algorithms such as Artificial Neural Network (ANN), Naive Bayes Classifier (NBC), Fuzzy Switching (FS) and image processing have been used for these operations in FOFDESS. These algorithms have been brought together by a designed data fusion framework and a novel hybrid algorithm called NABNEF (Naive Bayes Aided Neural-Fuzzy Algorithm) has been improved for fire danger rating in FOFDESS. In this state, FOFDESS is an integrated system which includes the dimensions of prediction, detection and management. As a result of the experiments, it was found out that FOFDESS helped determining the most accurate strategy for fire fighting by producing effective results.

1. Introduction

In the globalizing world, forest fires are the leading natural disasters which concern all the countries in respect of their effects and results. The fires are significant threads which cause the combustion of millions of hectares of forest area worldwide every year, significant amount of fire fighting costs, reactional value and even life-property losses. The most effective way of reducing the damages caused by forest fires is quick fire detection and response together with all the protective measures. Therefore, today various studies have been made in order to improve early fire prediction and detection systems even together with the ones which helps to develop response strategies during the fire (Alonso-Betanzos et al., 2003; Bernabeu, Vergara, Bosh, & Igual, 2004; Satoh, Weiguo, & Yang, 2004). Each developed system is successfully in use on their dimensions (prediction, detection or management). But, the greatest disadvantage of these systems is their independent development from each other. This situation has given a birth to a need for development of Decision Support Systems which include prediction, detection and management dimensions together. Furthermore, forest fire prediction and detection operations are dependent to many factors such as meteorological measurements (temperature, humidity, rainfall, etc.), ambient measurements and coefficient calculations. In order to reach effective results in the mentioned procedures, all the factors must be considered and brought together.

Data fusion which brings many sensors together and receives the related data from the connected databases is a more sensitive and accurate technique in comparison with one sensor usage (Elmas & Sönmez, 2008; Hall, 1992; Llinas & Waltz, 1999) In recent years data fusion techniques have been successfully used in complex systems which require many calculations and parameters in military, medicine, industry, etc., fields to obtain high degree decision fusion (Ataeia et al., 2005; Jouseau & Dorizzi, 1999; Yuan, Dong, & Wang, 2009). In this study a Decision Support System for Forest Fire (FOFDESS) has been developed by means of data fusion techniques. FOFDESS includes prediction, detection and management dimensions for forest fires. Each of these dimensions is a part of Decision Support System and brought together within the data fusion framework. Every dimension has its own sensors and high degree decision fusion has been carried out by gathering data received from multi-sensors with algorithms. During data fusion process, Artificial Neural Network and Naive Bayes Classifier algorithms which produce successful results and are widely used for pattern recognition, estimation and classification procedures have been used. In the study, the activity of FOFDESS during a controlled fire started in forest area has been tested. The test run has been performed in Antalya which is the most sensitive region of Turkey with respect to forest fires. The results have showed that FOFDESS have effective and powerful inferences in every step of the fire.

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doi:10.1016/j.eswa.2011.01.125

2. Decision Support Systems and FOFDESS

Decision Support Systems constitute a class of computer-based information systems including knowledge-based systems that support decision-making activities (http://en.wikipedia.org/wiki/Decision_support_system). Building computer-based expert systems requires eliciting, analyzing, structuring, validating and interpreting the information when researchers deal with a particular problem (Liebowitz, 1997). In recent years many applications have been emerged relative to agent-based Decision Support Systems. New approaches of researching intelligent Decision Support System (DSS) appear following the rapid progress of agent systems and network technology. The main point of using Decision Support Systems (DSS) is to provide a user with the possibility to consult with an automated system while making decisions. The DSS, as a rule, includes a set of procedures, starting from data determination and processing, and finishing by generation and evaluation of alternatives. Thus, a typical DSS can be logically divided and represented by three main calculation modules or levels: the first one, responsible for data fusion and pre-processing, the second, dedicated to necessary calculations (modeling, data mining, etc.) and the third, which executes simulation and manages human–computer interaction (Sokolova & Fernandez-Cabellero, 2009). DSS for forest fire applied in this study contains these levels and they will be explained in caption of Data Fusion Framework.

Forest fire prevent and management systems that will be developed at places with high forest fire risk must be safe, stable and with strong implication quality. An effective fire preventing and management system should contain these three periods mentioned below (Elmas & Sönmaz, 2009):

- Before the fire period (estimation dimension). This period purposes to prevent a possible fire.
- The starting moment of the fire (detection dimension). The purpose is early detection of an existing fire.
- During the fire (management dimension). The purpose is to estimate about the behavior of the fire.

FOFDESS applied in this study contains these three periods counted above. These dimensions of FOFDESS will be explained below. But first of all, it will be better to talk briefly about the general structure of FOFDESS for a clear understanding of the issue. Fig. 1 shows the general structure of it.

As seen in Fig. 1, there are three different sensing units in the system such as meteorological station, camera and sensor nodes in order to realize the three dimensions (estimation, detection, management) of the designed system. These sensor units have been shown in Fig. 2. There is a tower at the center of the observed region in FOFDESS. CCD camera, meteorological station and WIMAX (Worldwide Interoperability for Microwave Access) transmitter antenna have been located on the top of this tower. Around the tower there are sensor nodes that are spread over the observed area. All of the sensor nodes transfer their data into the base station at the tower. The communication between the sensor nodes and the base station is supplied by Radio Frequency (RF) Transmitters. There is a computer for data collection and fusion at the central observation unit. The connection between the central computer and the sensors has been supplied by WIMAX network with IEEE 802.16 standards.

The fire danger rating is carried out at estimation dimension by receiving the immediate data obtained from temperature, humidity, wind, rainfall, pressure and insolation sensors located in the meteorological station. A forest fire that has just started is automatically detected at detection dimension. In this process, CCD camera and sensory network units have been used for enabling the co-decision. CCD cameras are located to the tower in the forest area that will be observed. By passing the camera views through the image processing algorithm, it is detected whether there is a fire in the monitored area or not. There are temperature, humidity and smoke detectors in the sensory nodes located in the observed area. According to the data changes received from the detectors, it is detected that whether there is a fire in the area or not. The spread speed of an existing fire can be estimated at the management dimension. The data fusion process and algorithms that will perform these procedures of the system dimensions are explained below.

3. Data fusion framework of FOFDESS

Many models can be used for the data fusion process representation. A functional data fusion model can show the functions, databases and connections. But an architectural model is suitable for displaying software/hardware configuration, data flow and external/internal interfaces. Mathematical models should be used in order to indentify the algorithms and the logical processes. By the reason that variously characterized data is formed in a data fusion

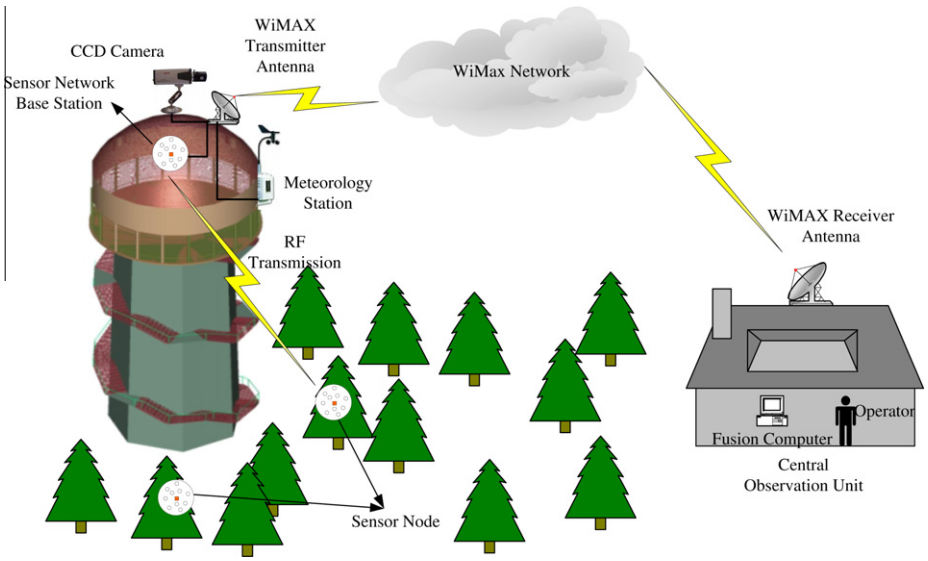

Fig. 1. The general structure of FOFDESS.