Software fires detection and extinction for forest

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Resume - This article shows the most usual fire detection and forest extinction application technologies at present. We will see all different methods used by these applications that can be found in the Market and some examples. Also, some basic questions about the most influent parameters when a fire must be extinct are shown. Finally, after having shown all the technologies, we will build a model about an intelligent system which not only detects, but also extinguish wildfires.

I.INTRODUCTION

Nowadays, Wildfires are one of the most important environmental problems in Mediterranean countries. Yearly, thousand of yards are affected by this problem. In the last few years many projects related to wildfires have been carried out with the same goal: reduce the effects that a forest fire causes. And the trend continues, these projects are becoming more sophisticated and are integrating the latest technology that exists in the market.

Most of the projects are dedicated to wildfire detection through image processing and neural nets systems so it allows that forest fires can be monitored, with several predictive models of fire behaviour.

Secondly we will show different methods which are the most used to detect forest fires actually and also examples of projects that use these methods.

Thirdly, how main factors can determinate the extinction of a forest fire and how those data can be treated automatically to integrate them in a software.

Finally we describe the prototype that we want to develop, trying to give details of the technology used and answering why it has been chosen.

II.WILDFIRE DETECTION

It is important to monitor mountains and forest using an efficient, quick and precise system of detection at the beginning of a forest fire and its location. An expensive system to extinct a forest fire depends on how quickly detects the fire and set up the initial action or soon-attack. In this way we can be surprised if before they grow out of control, if it is not so, it is very difficult and dangerous to extinct it.

They spend lot of time determining the exact point, so that the system can provide any information necessary for the operation of automatic choice, in order to get an immediate action or soon-attack

The objective is to detect a possible outbreak of fire and to determine its extension as quickly as possible, as well as determining the exact location thereof.

Currently there are different types of technologies being used for this purpose. They include the use of infrared cameras and satellite imagery and the use of a geographic information system (GIS).

III.A. Detection using infrared and optical cameras:

[12] The objective is to monitorize the forest area and the automatic detection of fires as well as the exact location of the fire, using infrared and optical cameras. These systems usually consist of a central oversight monitor, a unit for images processing and surveillance towers distributed by the ground. Each surveillance tower usually has the vision of the infrared camera and another television located on a device capable of moving horizontally and vertically, so that it provides the cameras a 360 degrees vision over the monitored area.

The cameras send recorded images to the image processing unit and from this one; a possible fire can be detected using the images that had been sent.

When a fire alarm is detected, automatically the camera detects the fire and stops in its position. Then the alarm will appear on the screen, warning the people that manage the control point. When the person in charge of the central alarm verify that it is a real wildfire, we will launch the established action protocols.

System Forest 99:

[9] The software that uses this type of cameras is the "System Forest 99" developed by the local company Baeza and implemented in Andalucia. It became operational in the “Infocid 2000” campaign.

This system is based in the use of infrared cameras to detect forest fires and it is activated when an alarm is set in motion a plan of attack. In order to get a quick detection and to obtain the maximum effectiveness of the system, this system consists in a complex monitoring stations network and a good communication network, from which are controlled the high potential risk fire areas. Those are the ones with more trees and that ensure both a correct vision of a large area, as an optimum link of communications.

To sum Forrest System 99 provides the following improvements:

-- Exact location of the source of heat.

-- Avoid false alarms.

-- Improve night vision compared with that made by a person.

-- Produce a deterrent effect.

-- Contribute to decision-making in extinction.

System for early detection of forest fires:

[11] Developed by the company INVAP for the Prevention System and combat forest fires in Mexico.

This is another example of a forest fire detection system based on optical and infrared cameras. It would allow the immediate detection of fires outbreaks, because the scheme will be implemented in a systematic sweep with the possibility of halting the movement and amplifying the image so it can locate any potential fire hazard.

This system provides interesting developments because it has installed a system that collects meteorological data (atmospheric pressure, relative humidity, temperature, wind speed and direction, rainfall and dew point) that is very important to determinate a good plan of attack against the detected fire.

In addition, another technology developed is a safety device against vandalism. Its function is to detect the presence of people in an area near the remote station. Because of this, it is equipped with motion sensors and fixed black and white cameras. The signs and pictures of the device will be forwarded to the board of command and control.

Service fire detection Orange:

[6] Orange is developing a system to detect fires using the mobile phone network. This is again the same idea, detection based in infrared detecting outbreaks heat, but transmitting in the mobile networks.

They have developed some specific devices for natural environments for this project. They have temperature, infrared and ultraviolet sensor, which are interconnected by Wi-Fi or GPRS. These devices will be placed some distance and transmit data over the GSM / GPRS network to a server. The information can be viewed on a website that generates alerts, reports and graphs.

IV.B. Detection from satellite images:

[10] Forest fires are clearly seen from the heights of Earth orbit. In addition to the columns of smoke, sensors installed on satellites, which are used for this kind of projects, can "see" the infrared heat emitted by themselves.

The detection systems of wildfires through images collected by satellites are the most novel. Both NASA and the European Space Agency are using this technology in their detection projects.

Figure 1. -- Envisat satellite –

Figure 1 taken by Envisat satellite. The image corresponds to a forest fire occurred in California.

Figure 2.-- Envisat satellite –

Figure 2 captured by the satellite Envisat, corresponds to the fires in Galicia and Portugal in 2006.

The satellites measure the infrared radiation emitted by the Earth to detect the temperature at the earth's surface and produce maps with "hot spots". When the satellite detects a temperature above the 38'85 º C interprets that there is a fire. In Spain remote sensing is used for fire prevention for several years

Firerisk Project:

[2] [4] This project is developed by the Alcalá de Henares University (Madrid, Spain).

The project aims is to develop an operational methodology to evaluate the risk of wildfire as well as its integration into valid documents for the work of forest management. To get this, along with more traditional methods of spatial analysis, is suggested the use of new technologies such as remote sensing and GIS. It uses the information that different space observation satellites give, but it needs other sources of information that will be mixed within a GIS.

V.C. Detection from other methods:

[14] A company of Vila-real (Castellon, Spain) has created a detection system based on laser methods assets. This system has two fundamental characteristics: the response time that elapses from when the fire is originated until the system is able to detect it (it is "very fast") and the ability to indicate the "real location of the fire along with its intensity or virulence". The main difference with infrared-based systems is that this system detects smoke columns, what makes a faster detection, while what the infrared detect is the heat.

VI.D. GIS:

A geographic information system is an assembly of hardware, software, geographic data and people, which is designed to collect and manage geographically referenced information in order to solve complex problems.

The functionalities are:

-- *Location:* ask about the characteristics of a particular place.

-- *Status:* compliance or not conditions imposed on the system.

-- *Change:* comparison between temporal or spatial situations other than some feature.

-- *Routes:* calculate best routes between two or more points.

-- *Guidelines:* detection of spatial patterns.

-- *Models:* generation of models from simulated events or actions.

In the field of forest fires are often working with satellites. Experiences show that this way of working has great potential in terms of prevention, monitoring, assessment and restoration.

VII. Extinction of wildfires:

When it is necessary to make decisions during the design of the plan, must be also beared in mind a large amount of information about the characteristics of fire (weather conditions, topography of the land, fuel types), the available to the media, the coordination and communication with others units and centers, etc.

When designing the plan attack it should be taken into account factors affecting the spread of fire, and also the available ways to carry out its extinction, and with the entire information act in accordance with the needs of each case.

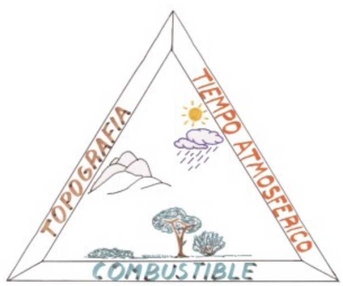


Figure 3 - Triangle of fire –

In Figure 3 are shown the factors that determinate the development of a forest fire, which are topography, fuels and weather. Each exerts influence over the other. For example, in the upper parts of ridges have more precipitation than lower and temperatures go down as it rises along the slopes.

Getting the environmental characteristics at the time of the fire, the fuel that is in the area and the terrain features that is affected by soil can help to "predict" the behavior of the fire and thereby maintain a more effective attack.

With the obtained data we must decide, which are the basic actions that need to be made first and the most appropriate method of extinguishing the fire, so it will be extinguished as quickly as possible.

VIII.A. Fuel:

It is necessary to characterize the combustibility of a zone, because the greater the accumulation of fuel in an area, the more heat may release and the more intense the fire could be.

Fuels should be classified depending on the type of fuel, the horizontal provision of fuel and depending on the vertical provision of fuel.

IX.B. Weather atmospheric:

The meteorological variables that influence forest fires can be classified into two groups: those affecting the start of the fire and those that affect the spread.

At the time of the fire extinction we must look the variables that affect the spread of fire. The wind is the decisive factor. Wind is a crucial element in the behavior of fire, often being responsible of the fire that overcomes the barriers of defense and the formation of crown fires that are manifested in virulent form.

X.C. Topographic factors:

Topography is the most consistent of the three factors and has great influence on the other two. There are three factors that affect in a very important way to the behaviour of fire:

-- *Setup:* it has a great influence on the wind, and it will affect at the direction and speed of the spread of fire.

-- *Exhibition or hillside position:* it has an important effect on temperature and relative humidity, in the development of vegetation that covers and in the humidity state of vegetables fuels.

-- *Pending:* topographic is the most important factor in the behaviour of fire. It influences the modes of transmission of energy doing that upstream, phenomena convention of radiation are more efficient. The more inclined the slopes are, the greater speed the fire spreads.

XI.D. Extinction Methods:

Direct Method:

If the fire is at its initial stage or has some features that allow act in the proximity of the flames, or water is available and ways to launch it, the fire can be attacked directly on to quell the blaze. With this method we can act mainly on two elements of the triangle of fire, heat and oxygen.

Indirect method:

It consists in isolating fuel the flames, establishing lines of defence in a right distance from the front lines, in order to circumscribe one or more perimeters to complete the stage of control.

This method acts primarily over fuel, removing it by strips or pouring chemicals that permeate the fuel and prevent or retard burning.

XII.E. Software:

SIDAEX:

[1] [15] It is a system developed by the Granada University (Granada, Spain).

They have created a computer model that reproduces the extinction of forest fires. It is capable of generate independently plans for extinguishing forest fires from existing data on land (the place where the fire was generated, environment, resources, etc.).

This system comprises a series of computer programs, including two: BACAREX, a data base which reflects the experience of the Plan INFOCA, and SIADEX, a program capable of use data from previous plans to establish performance.

The extinction technician may access the system via Internet, using a desktop computer, a laptop or a PDA (a small digital device).

XIII. Prototype to develop:

We want to develop a prototype of an intelligent system which is able to detect quickly a potential wildfire, and suggest the more effective attacks for its extinction.

This application must detect early a forest fire, activate the alarm, show an attack plan, and present the basic characteristics of the affected area.

For the early detection of a fire, the system will use webcams that will be located in the watchtowers. These images are transmitted to a server through an image recognition algorithm that will detect the smoke caused by a possible fire. So it should differentiate between smoke from a fire and smoke of an engine, dust, etc.

When a fire is detected, it can be known where it has led since each image comes from a camera that is uniquely identified. This is essential in order to set the exactly location with no errors.

To detect wildfires after exposing the most common methods that are used, we have opted for the web and infrared cameras, and not by satellite images. The first outbreak can detect fires in real time, while satellite images spend more time until is possible to detect a fire. We think that the use of satellite images is more appropriate for tasks of monitoring and tracking of a forest fire than for detection.

Also in each watchtower there will be installed anemometers (which will measure wind speed), electronic weathervanes (which will detect the wind direction) and thermometers (which will measure the outside temperature). When it detects a possible fire, the computer will require data from speed and direction of wind, and the outside temperature from the sensors. Those sensors will only transmit the information collected when the computer required the information.

The first-attack plan will be based on the application of bayesian networks to this problem, forest fires.

We need to know exactly all the circumstances of the land where the fire has been detected, such as topographical features of the terrain or weather conditions, or the fuel of the area where the outbreak has been detected.

The exact location of the focus is clear from the location of the camera that has detected a possible fire. Each camera has an IP address associated. In addition to the exact location of each camera, it has certain parameters associated that characterize the terrain and vegetation that monitors. This way, when the server recognize a possible fire from an image sent by a camera, it gets the IP address of the camera that has commanded it, and we will know the location, topographical features and fuel is in the area.

We get the environmental characteristics from the sensors placed on the outside.

All this information feeds the Bayesian network, which must be able to decide the best attack based on the data provided.

Bayesian networks or probabilities are a graphical representation of units for probabilistic reasoning in expert systems.

When we talk about showing an attack, we mean that the application must show the available resources more adequate to quell the fire, such as water pumps, seaplanes, and so on. It should also suggest the best technique that can be used against that fire, and the exact location of where the fire must be attacked.

It should also show the characteristics of the terrain, such as the type of fuel, land topography, and meteorological factors as much detail as possible to minimize the time of recognition, and to organize the team as quickly as possible.

We think that it is need a smart system that detects the fire very quickly, but also can determine quickly which are the possible attacks to quell it. Thus immediately after detecting a

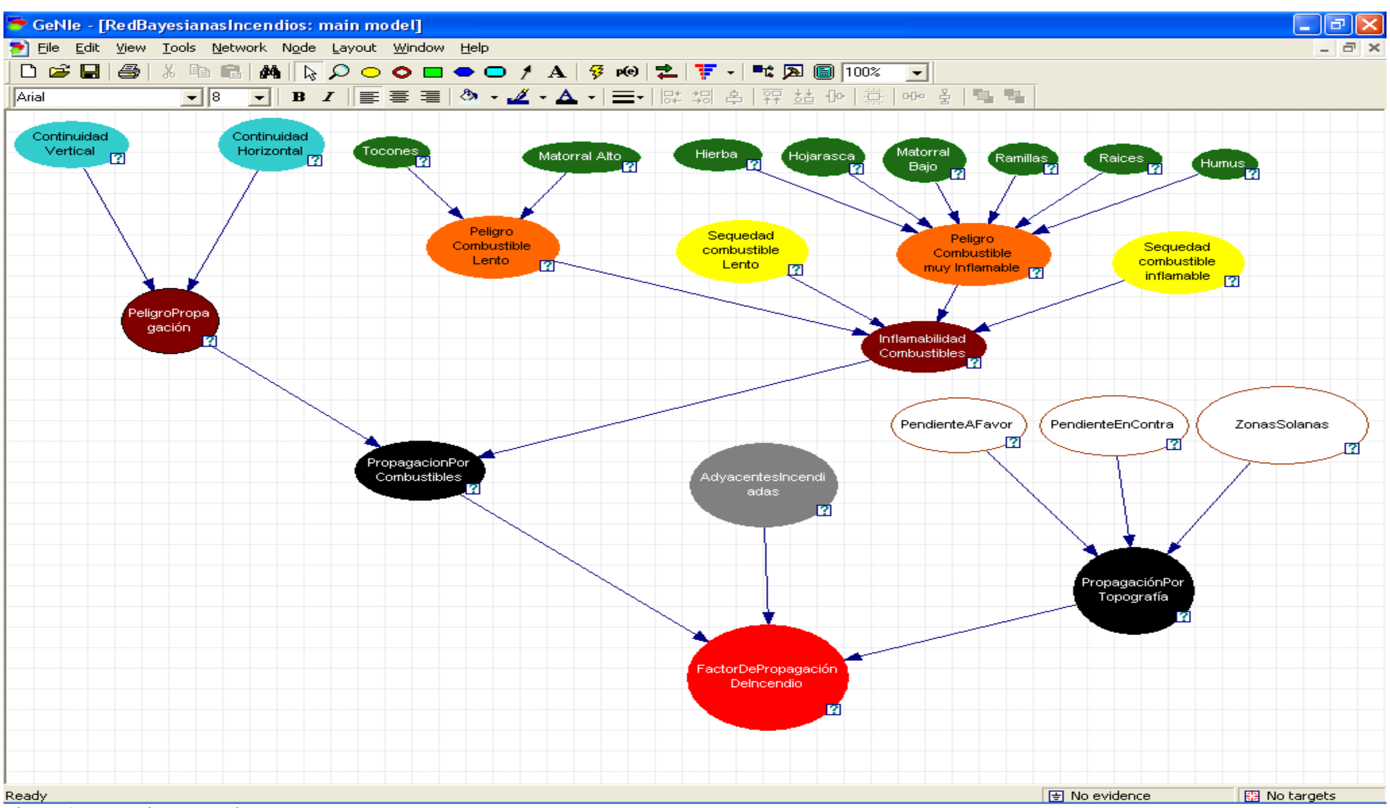


Figure 4 – Bayesian network

fire provide to forest officials all the features and facilities and the best plans suited to it extinction.

A. Bayesian Network:

A Bayesian network is a directed acyclic graph representing the cause-effect relationships between nodes.

Because of this, it is a good response to our demands. We can introduce as much nodes as we need, because the field characteristics and the effect will show us the danger degree that exists to spread a particular area of the watched land. To create our network we have used the Decision Systems Laboratory program from Pittsburg´ s University, which provides a better intuitive interface than other programs with the same technology.

As mentioned previously, our fire behavior model is as real as possible and there should be taken into account many terrain factors. Therefore in our network can be seen that we have included not changing the factors (topology and fuel) and how much detail as possible.

As it is shown in the figure 4, we have created a large network in which is introduced information about the amount of fuel, their dryness level and other topographical features of the terrain. Also it has been taken into account whether there was any area adjacent to submit fire on it, since this affects a very crucial at a more rapid spread of fire.

A green node are input nodes, and corresponds with one of the three factors of the triangle of fire we have seen previously (Figure 3). They enter the grade of fuel, quantity of the kind referred to in terrno there. The fuels introduced into the network are:

--“Matorral Alto” (scrublands high)
--“Matorral Bajo” (Under scrublands)
--“Tocones” (Stumps)
--“Hojarasca” (Fallen Leaves)
--“Hierba” (Herb)
--“Ramillas“ (Little Branches)
--“Raíces” (roots)
--Humus

The values that can take these nodes are:
“MuyPocos” (Very few)
“Pocos” (Few)
“Medios” (Means)
“Bastantes” (Enough)
“Muchos” (Many)

Blue nodes represents the continuous fuel degree in two different aspects, one represents the continuous horizontal degree and the other continuous vertical one. They can take null, low, medium and high as input values.

Yellow nodes symbolize the dryness degree that exist both in slow fuel type as highly flammable ones. They are entry nodes, and their values can be little means or much. Gray nodes corresponds to other node cause, and indicates whether there are adjacent burned areas or not, and their input values can be yes or no.

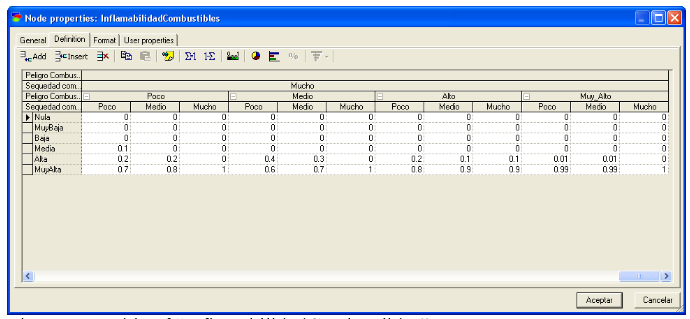
White nodes correspond to topographic characteristics of the area. These nodes can be:

-- Favourable slope: in the direction of fire.
-- Against slope: against the direction of fire.
-- Sunny Area.

They can take null, very little, little, medium, high and very high values as input.

Orange nodes symbolize dangerousness fuel degree depending on the type of fuel in question. We have differentiated on the one hand the slow rate of fuel (which takes longer to begin to burn), and in the other hand the highly flammable fuel (with little amount of heat turned very easily). These nodes are nodes effects of green nodes, as output can take very little, little, medium, high and very high.

Brown nodes represent the spreading fuel danger, one effect of continuous and the other by dryness degree and quantity of fuel. These ones are effect nodes of blue and green ones respectively. Depending on the impact of each node can take effect on them as output values: very low, low, medium, and quite a lot. As an example of the effect it has on the nodes we see that figure 5 shows the table of values to be based on the input values. Discuss such that when the fuel danger, highly flammable fuels danger are very high and dry slow fuels and very much flammable, has a 100% chance the danger is very high for fuel.



Peligro Combus..												
Sequedad com..	Mucho											
Peligro Combus..	Poco			Medio			Alto			Muy_Alto		
Sequedad com..	Poco	Medio	Mucho	Poco	Medio	Mucho	Poco	Medio	Mucho	Poco	Medio	Mucho
Nula	0	0	0	0	0	0	0	0	0	0	0	0
MuyBaja	0	0	0	0	0	0	0	0	0	0	0	0
Baja	0	0	0	0	0	0	0	0	0	0	0	0
Media	0.1	0	0	0	0	0	0	0	0	0	0	0
Alta	0.2	0.2	0	0.4	0.3	0	0.2	0.1	0.1	0.01	0.01	0
MuyAlta	0.7	0.8	1	0.6	0.7	1	0.8	0.9	0.9	0.99	0.99	1

Figure 5 – Table of “InflamabilidadCombustibles”

Black nodes symbolize the two types of dangers that exist, on the one hand the fuel danger and other danger by continuity. The “PropagaciónPorCombustibles” node is the cause of the nodes effect "PeligroPropagacion" and "InflamabilidadCombustibles". “PropagaciónPorTopografía” node is the cause of "PendienteAFavor", "PendienteEnContra" and "ZonasSolana" effect nodes. Depending on the influence they may have their nodes effects on them; it may take as output null, low, medium, high and very high.

The last node remains to be taking is the red one. Red node represents the ultimate factor for the spread on the area that we are calculating the prediction. This node will determine the degree of danger of spreading to the area, whose output values may be invalid, very little, little, medium, high and very high. This node is the one that takes us back the final answer, which determines the degree of danger of spreading plowed this area and its probability.

B. Process simulation of fire behavior:

We divided the ground to monitor different areas that will form our territory on which we are simulating. To start the fire behavior simulation process you need to indicate the area where the fire began (in the final design would be given this post by the fire detection system, which would provide the exact location of the fire) and indicate wind direction and speed (and collect the same data from a weather station located on the outside).

Once the fire has started, we begin the simulation process. The first thing we have done for each area of field is estimating its spread factor, and we transform the information for each area into understandable data for our Bayesian network. Once we have done this, we input the values into the net and it gives us the back spread factor of each area. When we finished making this process, we determine the areas that will be affected by the fire.

When we know the spread factor of each area, we must determine if the air is going to fire or not. At the moment influences the outcome of the Bayesian network, and the information captured from weather station.

For each area, the system checks the wind direction regarding the origin node, and it also checks the spread factor obtained as a result of the process that has generated the bayesian network. Depending on the type of spreading factor we must consult the speed wind, because when the spreading factor is medium, low or null and the wind speed is very high, it makes that this area sooner or later catch fire (we have reached this conclusion after conducting an investigation on the matter). On the other hand, depending on the length of the field and the wind speed, the system decides how long it will take to reach the fire to some or other areas.

When the process finishes and the system has obtained as simulation conclusion that this area is going to burn, the system adds the area to a list of areas on fire.

This process is repeated as many times as necessary, so that in the first pass, there is only one area origin of a fire, but as it repeats the process and are added to the list of AREAS burned areas, these are origin in the following areas past.

XIV.Conclusions:

With the above, we think that new applications that will be developed in the future in the wildfires area, not only should focus on early detection of fires, as well as they should add features such as the design of an automatic attack plan.

Furthermore we believe that with the diverse technology that we are provided of, it could be developed a very good application for early fire detection using different types of technology, and relying on each other. In order not having to decide if the application must be based on satellite images or based on web and infrared cameras, we think that it can be based on both, giving each its benefits.

We also consider important to study the possibility of providing a strategy to attack the fire so effective that will be unique to each fire detection, and to provide just in the moment when the fire is detected.

With an implementation of these characteristics combined with an effective prevention plan by the competent authorities, it could pose a significant improvement in combating forest fires trying to reduce the consequences thereof.

But we must not ever forget that there is no better strategy for fire fighting than prevention, and that is something in our hands.

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