Tools for Remote Sensing, Early Warning and Data Acquisition for an Advanced Computer-Supported, Efficient Fire Fighting Management System

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Abstract

Since ever, lookouts are the most common early warning system for wildland fires. Other methods like aircraft, satellite surveillance are applicable. During the last years, video based detection systems are tested by different organisations and already installed for commercial operation. Today, technology is available to perform automated smoke detection to report Wildland fires. As the initial attack is one of the most important facts for fighting forest fires, it is from same importance, to detect a fire already in an earliest stage. Smoke is one of the first visible sign of starting fires and it must be the main target, to detect the raising smoke plume. The automated precise detection of a wildfire exceeds by far the use of a simple video camera combined with an image processing software. The many disturbing factors appearing in the natural environment, like clouds or moving objects, must be eliminated to reduce the number of alerts to the dispatcher at the fire management centre and on the other hand, provide as much utilizable data as possible. Factors, not correlated to a fire, have to be eliminated. Basically, typical smoke parameters must be used for image processing to get a reliable detection. A Software, developed by the German Aerospace Center (DLR) provides this functionality. Once, a fire is detected, all data, related to the event has to be communicated to a Management Centre, for the further processing and handling in the fire management procedures. It is desirable to achieve additional information´s and data's and provide this to the Fire Management Centre. AWFS mainly provide data like images of the alerts, digital coordinates for identification of the incident location with a GIS, smoke classification information and all relevant meteorological information from the sensor area. Once, the achieved data's are supplied into the database, they are available and useful for expert systems like data base, fire propagation modelling as well as for simulation models in 3D geo information systems. Based on an open communication platform, the gathered information's can be processed and made available to all resources involved. So, an AWFS is one device to create an intelligent fire management tool. Turn key solutions will consider the correlated system devices like communication and autonomous power supply in the independent environmental and geographical conditions.

Introduction

Fire Lookout Towers where installed in the early 1900 in most regions of the world. This was the start of an organized and structured method for wildfire detection. The fire watchers observe the forests for up to 12 hours a day in the most difficult circumstances (extreme temperatures, poor hygienic conditions, isolation, only short breaks of concentration) and report on any smoke formation. Additionally, the authorities have to spend large sums on the construction of observation towers, which also need to be maintained and operated in accordance with relevant legislation and regulations. Since then, many research programs and studies are performed to

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optimize the detection and fighting of wildland fires. During the last years, technology improved and several companies and organizations invested in the research for remote sensing systems. Based on different platforms like satellite (MODIS, Bird), aircraft or unmanned aircrafts, different sensor technologies are in use. Infrared, near infrared, spectrometric systems and video systems are installed in different platforms for the described application. But even with the whole spectrum of different sensors and detection methods available by now, all of them show limitations in fire detection capabilities. The big advantage of human lookouts is the combination of experience, matched with the visible conditions in the surveyed area. No technical solution is able to provide this feature. although, the human factor “concentration” gives a big advantage to technical solutions used for remote sensing. Mostly, environmental conditions like fog, clouds or reflections caused by sun or moving objects are setting the restrictions in the capability for an automated detection. None of the today available methods is the perfect, reliable solution for the modern requirements for an Initial Attack Success. This article concentrates on terrestrial, video sensor based sensors and the possibility to identify smoke plumes caused by forest fires by analyzing the images with an image processing Software to provide a real automated smoke- and forest-fire detection and the correlated alarming. Video sensors with implemented image processing software where developed into quite effective systems during the last years since processing power of today available computers supporting fast and powerful image processing software. But for an automated detection it needs more than just an image processing software. So many different factors are appearing in the environment, which look similar to fire signs, limit standard video systems. There is no really fully automated smoke detection system available on the market. For a proper automated detection, it is a prerequisite, to eliminate all the effects and influences, not related to a smoke plume or a fire to generate only the real true fire alarm. In case that there is an automated system used for fire detection, there should be quite more than a simple alert message reported to a Fire Management Center. An modern detection system should be able to gain many direct fire related data’s like visible fire information, exact geographical position, type and actual status of the fire as well as other relevant data’s, important for the fire suppression activities like Weather data, life monitoring of the incident and last but not least, open communication interface with other fire management systems like 3D Geographical Information Systems (GIS), Fire propagation modeling systems and attached alarm handling systems to the involved resources. The gained data should be provided on an Internet platform to make them available for evaluation, training or analysis measures. To be ready for further improvements, a detection system should consider the integration of future available satellite sensor data’s.

In some cases, normally in areas without population, fires are useful for the alteration of an ecosystem; there is no need for a suppression of those fires. These natural fires still should be monitored in case, that the spread of the fire may cause threats to human assets.

This article will not evaluate the different available remote sensing systems. Mainly, the author will identify some of the major requirements, a reliable video based detection system should provide to an Fire Management Center and the implementation into the modern concept for fire fighting as a basic tool for the global strategy. In the second Part, a solution is evaluated, which is successfully implemented into the French SDIS13 Fire Management center and which seems to cover already today a wide spectrum of the needs for a future oriented fire management concept.

Surveilance requirements

Several analyses made all over the world, result, that a fire should be detected maximum 15minutes after ignition. This is documented also in the requirements of the fire suppression community (INSA, 2000). This analysis showed also, that the value of the information on fire detection decreases according to a negative exponential curve. This means, that a fire can be easily extinguished in an early stage. If a fire exceeds a certain size, the probability to develop into a disaster fire is increasing rapidly. The measure to be taken by the fire fighting management becomes much more complicated and complex. Today's used fire detection systems should consider real incident factors and data's out of the fire line to set the basic requirements for such systems. Figure 1 shows a growing fire in south of France with a time difference of 6 Minutes and the diagram with the relevance of time. The local Fire Fighting Groups report fire expansion speeds of up to 5 km per hour, when there are the well-known mistral winds involved. This can result in large burned areas even before any detection can be reported with an extended size of the fire, which makes it already difficult to fight. The same effect is given in California, USA, when the Santa Anna Winds are blowing. Additional, the Santa Anna Winds, blowing from the dessert to the see, carrying a lot of sand with them, so that the range of visibility is strongly limited and a location of the fire position will be nearly impossible. Another factor, known from the real fire fighting operation is the approach of the resources to the fire location. Due to poor information delivered with the alarm to the fire management centre, forces are often directed to wrong roads and therefore loose a lot of time before they reach the real position of the fire. In addition to the detection time there are another 15 to 60, or more minutes, before the fire fighters can start fire suppression work. This was also one of the major problems at the Alto Tajo Fire at Guadalajara in July 2005 reported by Parker Snyder in the "Wildland Firefighter" Report. According to an issued statement, the fire was declared at 2:45pm and the first ground team arrived at 6:00pm. The earlier available airborne fighters could not operate effective, due to the extended smoke all over the valley and the unknown fire position. Under these aspects, a detection time of 15 minute is becoming a very critical factor. Today's detection systems should be able to detect a fire within less than 5 minutes and in addition, it must deliver all relevant and reliable data's and information which are achievable for a modern and effective fire suppression management.

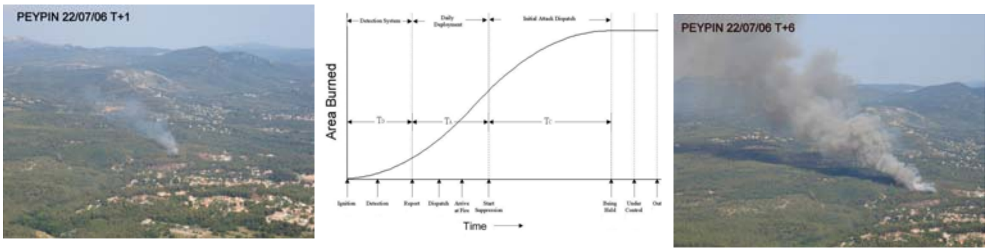

Figure 1— Fire spread in response to time

Detection performance

Figures and statistics about the reporting and alarming are vitiating strongly. According to an analysis made in the European FUEGO project, the organized detection was documented with 60 percent tower based, 30 percent mobile observers, which are organized detection, 1 percent aerial and 9 percent by random citizen detection. Annual issued analysis reports from USA and Canada show figures, where more than 50 percent are random detection. Still, the quality and the information of the detection reports are not valuable. Especially reports, arriving by random detection, might be containing poor or even wrong information's about location, size and type of the fire. According to the SDIS13 fire Brigade at Marseille, sometimes imprecise information about the fire position is reported and the fire brigade trucks are driving wrong access roads to the fire. This can happen under difficult visibility conditions, which are quiet common in coastal areas with misty and foggy weather, as well as from random reported fires by people with poor geographical knowledge. Considering the huge costs for organized detection, compared with the reliable quality of the detection result, there are several substantial arguments to employ remote sensing detection systems.

Surveillance requirements

In addition to the quality and reliability aspects for an Automated Detection System, the arguments for a surveillance requirement must be evaluated, if an wildland area shall be surveyed. The Wildland Fire Operation Research Group (FERIC) at Saskatchewan, Canada, breaks down this Surveillance requirement into three factors:

Value- represents the asset value that might be lost in case of a fire

Risk- stands for the likelihood of loss of an event (weather, lightning)

Hazard- suggests the significance of a loss event (fuel in the area)

Each factor is based on a scaled value range. Calculated with the formula

SR (Surveillance requirement) = V*R*H,

The result is a level of surveillance requirement, which gives an suggested classification of the surveillance level.

With a high level of surveillance requirement as well as the intention to use a reliable early detection method, the indication clearly recommends a remote sensing system. In principle, different kinds of sensors are suitable for the detection of fires. CCD-cameras find the smoke, infrared (IR) radiometers detect the heat flux from the fire, IR spectrometers identify the spectral characteristics of the smoke gases, and light detection and ranging (LIDAR) systems measure the laser light backscattered by the smoke particles.

Basically, looking over a forest area, smoke is the first visible sign over the tree tops of a starting fire at the ground. Various technical systems have thus been developed to give autonomous alert in the event of fire. Most of these use CCD cameras or IR detectors. Although numerous technical methods have been tested, reliability standards have never been sufficient to develop a product that is suitable for the global market. IR sensor systems tested in Spain can only detect the fire itself. This might be very late in dense forest areas where not a direct view is possible to the fire ignition point. An infrared sensor shows some advantages used for aerial detection, fire mapping or satellite observation. Looking from the top, it can be possible to detect hotspots on the ground area in the forest. As non of the mentioned systems might be an ideal solution, each systems should be capable to operate as a stand alone solution as well as combined in any configuration to interchange and process the gained data's. However, smoke is the relevant feature for the early recognition of fires in densely wooded areas. Optical systems are scanning in the complete visible spectrum range, from 380 nanometer to 780 nanometer, a wide spectrum as shown in Figure 2, while smoke gases appear in different values in a grey scale. This large bandwidth is one of the factors that explain why video systems imply a high rate of false alarms due to clouds, light reflection, agricultural activities, any moving objects and industrial plants. Working with the commonly known image processing standards it will be nearly impossible to eliminate all disturbing factors in the observed area, which are not correlated to smoke.

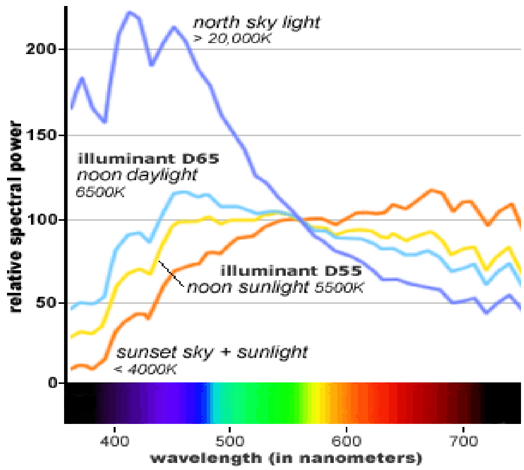

Figure 2—Spectrum of visible wavelengths influencing detection

Sensors, which are scanning and operating in this large visible spectral range, have to handle disturbance factors like:

Moving objects - like cars, animals, people, aircraft, clouds, shadows, air turbulences,

Fixed objects - with changing interferences like trees moving in the wind, sun reflections on various objects.

Visual effects - like fog or smog, which camouflage the smoke plume in long distances.

These factors demonstrate, that an automated smoke detection requires more than a commonly used video system and image processing software to guarantee a save analyzing and a minimum of false alerts. Under these aspects, the limitation of video systems became obvious.

Smoke, caused by forest fires, appears in a small range of the light spectrum as smoke is visible almost in grey tints. Therefore, the detection of smoke may be better performed with a black and white sensor. Additional, irrelevant space frequencies can be eliminated by band-pass filtering the standard difference image. As the special red filter reduces the green colour of the forest significantly, smoke of wood fire can be silhouetted against the surrounding forest. This fact supports additional suppression of interfering signals (as an example, smoke is easy to distinct from cloud shadow therefore. Still a moving cloud itself appears difficult to be distinguished from a smoke plume. Finally, adaptable threshold values prompt the decision, whether fire alarm is to be released or not.

Definitely, the detection must be possible during daylight as well as during the night. These factors confirm clearly, that scanning and analyzing in the black and white spectral range is superior for smoke detection. Figure 3 shows clearly the difference in contrast as a result of a filtered spectrum range for surveillance.

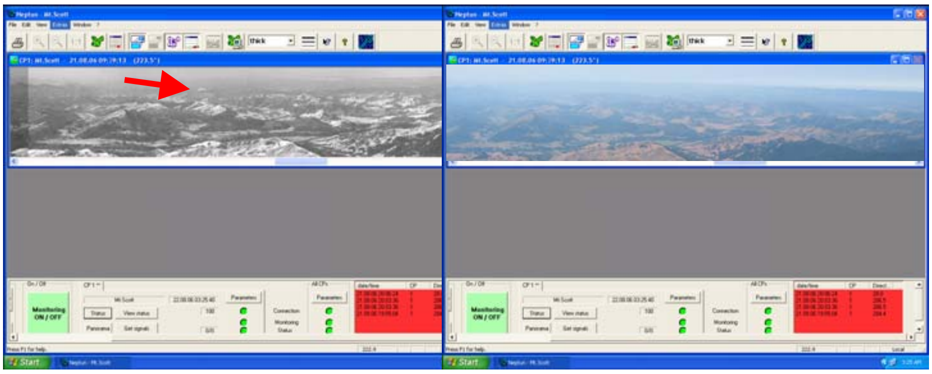

Figure 3— Filtered B/W detection versus Colour sensor

The detection results with the b/w sensor are much higher and clearer and so, the scanned area can be much larger. The black and white screen in figure 3 shows an alert in a distance of 35 miles while nothing is visible in the colour screen at all.

As described before, a modern remote sensing system cannot be limited to a simple detection tool. A fire management centre requires quite more information than a simple alarm report. Many additional data should be achieved by a sensor.

Once a fire is reported, the Management Centre should be able to monitor the spread or the fighting of the fire. During this monitoring, the basic surveillance and smoke detection should continue. Furthermore, the monitoring of a fire must contain colour information. By visual analyzing of the smoke plume, the structure and the different colour of the smoke, the operator gets excellent information about the situation of the incident. The operator will be able to perform a kind of smoke classification and generate a decision on the fighting requirements at the different locations of the fire line. Depending on this gathered information, the decisions for dispatching of air- or ground based fire fighting resources can be supported.

Beside this visible fire information, a remote sensing system shall supply strategic data such as distance and geographical position of the fire. This information can be generated with a geo referenced sensor. If one sensor is covering the surveyed area, the distance must be calculated with a trigonometric function. Depending on the topography, the accuracy will become worse in mountainous landscape. For flat areas this procedure is quite suitable. The better solution might be a double coverage by multiple sensors, configured as a network. This provides on one side fail save redundancy for the observation and a measurement function by using the cross bearing method on the other side. Then it will be possible to pin point the coordinates of a fire line very precisely. The identified position of a fire can be displayed at the control office on a digital map of the area. Together with the azimuth and elevation data from the pan tilt unit, the information can be processed with a 3-dimensional Geographic Information System (GIS). Together with the adequate Software module, the fire position as well as the size can be simulated almost independently of the topographical situation. Figure 4 shows a typical fire simulation in a GIS software.

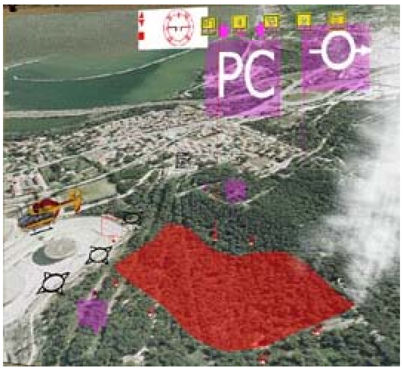

Figure 4— Fire and fighting simulation with 3D GIS

Further strategic aspects for a fire expansion are the local weather conditions. Metrological sensors, installed at the sensor location can deliver important meteorological data, relevant for the fire suppression. Temperature, wind speed, wind direction, air pressure and humidity information can be provided to the Fire Management Centre as well as to be used with a fire propagation software to calculate the development of the fire as shown in Figure 5.

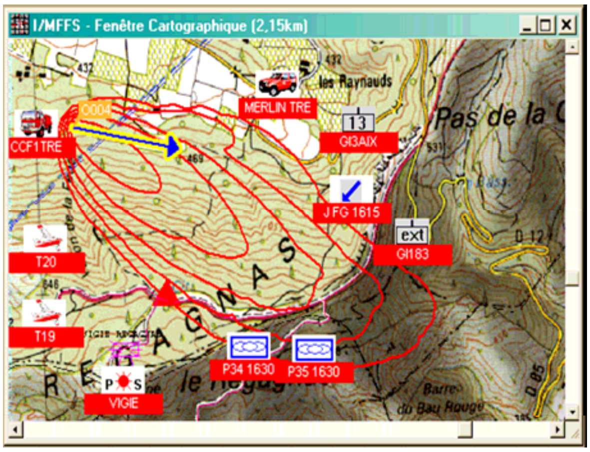

Figure 5— Fire propagation Software

These tools are today commonly used in fire management all over the world. Employed as stand alone equipment, for sure an improvement in the fire fighting strategy. Combined and operated in an intelligent computerized network, they become a powerful tool for remote sensing, early warning system for an computer aided, efficient Fire Fighting Management.

Automated Wildland Fire detection system (AWFS)

All the generic factors, evaluated before, being prerequisites for an efficient Automated Early Detection System, are pointing to many advantages of the black & white AWFS system. So, it may be interesting to focus on the main functionalities of AWFS.

AWFS is a terrestrial digital remote observation system, which is capable to supervise large wooded regions in order to analyse, to evaluate, to link and to store obtained data. In good weather conditions, the surveyed area can be up to 5000km2 per sensor.

The system operates with a CCD sensor, used for space mission applications and on software algorithms based on an EU/UN research program for forest fire prevention and were developed by the DLR Scientists. The method involves an optical detector, a rotating platform, an image processing unit and a Control Office. The system searches for smoke in the light spectrum around 620 nm thereby using a filter with a narrow bandwidth in order to increase contrast ratios and to cut off other colours not related to smoke. Furthermore, to exclude the disturbing parameters the software analyses and evaluates the following 5 smoke characteristics by a series of independent features:

Color, Brightness, Dynamics, Expansion and Texture

The camera carries out a revolution of 360° in 36 steps of 10° each. The tilt angle of the camera can be programmed for each 10° segment in order to follow the horizontal line and to cover the observed forest area for an optimized surveillance. For each 10° sector, the system captures three images with a two second delay between each picture as shown in figure 6.

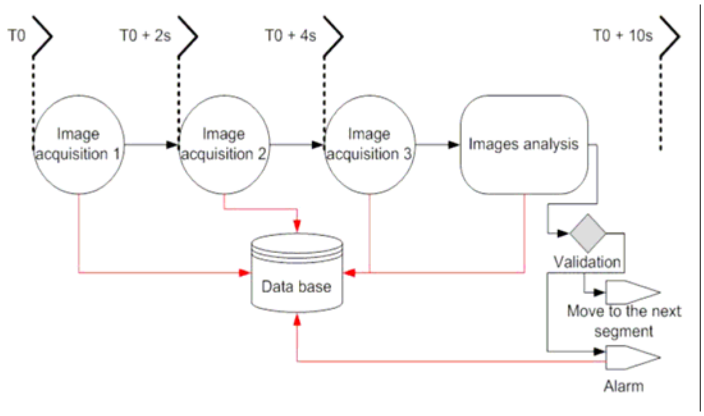

Figure 6— Image analyzing

In a first step, typical features of smoke are looked for by analyzing standard differences in the images. Wind and thermal convection of hot smoke gases change the grey scale value of smoke areas in the subsequent images. However, other environmental effects like clouds, wind, dust formations, reflections, bird flights, cars can cause similar effects for short periods of time. Moving objects can be eliminated by an additional evaluation of the third image, because smoke is quite stationary within the time between first and last image (several seconds). Irrelevant space frequencies are eliminated using band-pass filtering for the standard difference image. A special red filter reduces the green colour of the forest significantly to reduce basically the bandwidth of the visible spectrum. Finally, adaptable threshold values prompt the decision, whether fire alarm is to be released or not.

In a second step, the texture of the smoke plume is evaluated. The respective method is based on the structural analysis of the texture of smoke, which can be clearly discerned from the surrounding structures. From the mathematical view, the structures are described as stochastic effects superimposed to the average grey scale value. Therefore, it is first necessary to calculate the estimated average grey scale value, so that the stochastic arises from the difference between the original and the estimated image. The mathematical basis is explained by Hetzheim (1999). Typical smoke structures are separated then by means of various procedures. A second image, which is prerequisite to the first step described above, will be used to verify the results. In accordance with the observed features both methods proceed classing the identified possible smoke areas with probabilities. These are subsequently condensed to one probability. As an example, the total probability is low, if the identified areas do not overlap and clearly differ in size.

Each of the two methods described above works sufficiently enough to detect smoke on its own, but their simultaneous employment increases the reliability of smoke detection considerably (Kührt et al., 2001).

If the system construes it as smoke emanating from a fire, it sends an alarm signal to the Control Office.

The Control Office is the Control Centre as well as the interface to all other attached Fire Management Systems. The Control Centre is equipped with a computer and appropriate software. It deals with the following tasks:

Control of several camera locations

Receive alarm images and data

Visualize alarm images in a suitable way and in correlation with digital maps

Display a low-resolution panorama view of all towers administrated by the centre

Manual area definition in order to permanently mask smoke of irrelevant origin (chimneys, villages, etc.)

Provide the operator with tools for adequate evaluation of images (zoom, image sequences, filters, facilities to change contrast and brightness)

Display the bearing lines of alarm messages on digital maps

Fade-in additional information and databases in accordance with the user's requirements and the attached systems

Provide Meteo data from the sensor site to the attached Fire Management Systems

Store all data and system conditions in a database for remote access and external users

Conclusion and Discussion on the AWFS Remote Sensing System as a basic tool for the Global Strategy

AWFS systems have reached a very high level of competence in detecting smoke of a starting forest fire at a very early stage, day and night. When integrated in the network of a computerized Fire Management System it becomes the tactical instrument of an Early Warning System with a collection of valuable supplementary information that finally allows a precise localization of the disaster zone and a very fast deployment of the rescue operation and arrival at the site, thus it supplies the accurate specification of the infrastructure for an efficient fire fighting operation.

AWFS represent a cost efficient investment into the prevention of forest fires.

As opposed to video systems the AWFS collect data in black and white that enables the sensor to operate up to a depth of 40 km in radius, a capability not match by any other system today.

The complex data collected by a cluster of sensors installed in a vast area of forest are processed at the Control Centre where alarms are evaluated and finally supplied into the Fire Management System.

Fire Watch offers the assurance to meet the analyzed technical and strategically requirements and specifications of an efficient Early Detection System. This infrastructure turns out to be a basic tool for the Global Strategy. The present and future requirements of a modern Fire Management Concept are not met by standard video systems at present and also in the future.

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