Forest Fire Protection by Advanced Video Detection System - Croatian Experiences

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Abstract – *Forest fires represent a constant threat to ecological systems, infrastructure and human lives. The only effective way to minimize damage caused by forest fires is their early detection and fast reaction, apart from preventive measures. Great efforts are therefore made to achieve early forest fire detection, which is traditionally based on human surveillance. There are two types of human surveillance – direct human observation by observers located on monitoring spots and distant human observation based on video surveillance systems. More advanced approach is automatic surveillance and automatic early forest fire detection. Today there are several different approaches but the most feasible is the system based on video cameras sensible in visible spectra. In almost every country which encounters high risk of forest fires at least one such system was developed and proposed. Some of them are on the market under various commercial names. Croatia also has its own system called **Integral Forest Fire Monitoring System** (in Croatian **IPNAS**) developed at the Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture University of Split. The system was experimentally tested during 2005 and 2006 fire seasons on three locations in Split and Dalmatia County (Marjan Split Vidova gora Brač and faculty building Split) but it is also in everyday use in National Park Paklenica from June 2006. This paper describes the main idea behind the Croatian system IPNAS and discusses our experiences during its field tests period in 2005 and 2006.*

1. INTRODUCTION

Forest fires represent a constant threat to ecological systems, infrastructure and human lives. According to prognoses, forest fires, including fire clearing in tropical rain forest, will halve the world forest stand by the year 2030. In Europe, up to 10,000 km^2 of vegetation are destroyed by fire every year, and up to 100,000 km^2 in North America and Russia. Approximately 20% of CO_2 emission into the atmosphere is caused by forest fires [1] .

Croatia belongs to countries with high forest fire risk. In summer seasons seven coastal counties in Croatia and in particular the Adriatic islands are permanently exposed from high to very high fire risks, due to densely-spaced conifer forests. Only in Split and Dalmatian County In the year of 2003, wildfire occurred as many as 130 times. The total burned area in the year 2003 was 9.700 ha. The direct and indirect damage of the lost woody biomass in 2003. in Split and Dalmatian County was assessed at the level of 16 and 60 mil.€, respectively [2].

The only effective way to minimize damage caused by forest fires is their early detection and fast reaction, apart from preventive measures. Great efforts are therefore made to achieve early forest fire detection, which is traditionally based on human surveillance. Usually the human surveillance is realized by 24 hours observation by human observers located on monitoring spots. In Croatia the human forest fires surveillance is mainly organized by Croatian Forests (Hrvatske šume) – the governmental organization responsible for protection and exploitation of forests in state ownership. Human surveillance is usually organized only during summer months. For example in Split and Dalmatia County there are 16 forest fire surveillance stations of Croatian Forests in operation from June 1st to September 15th and there are also few other observation stations organized by other authorities and organizations. Human observers are usually equipped only with standard binoculars and communication equipment and their observation area is only the area covered by their sight of view.

A rather new, technically more advanced approach to human forest fire surveillance is installation of remotely controlled video cameras on monitoring spots. Now the human observer is not located on the monitoring spot anymore. His observation station is the monitoring centre equipped with adequate video presentation and video storing devices connected with wires or wireless to distant video cameras located on monitoring spots. The video cameras based human forest fires surveillance has many advantages in comparison to direct human observation on monitoring spots. Let us mention the most important of them:

a) Using video cameras the human observer is capable of monitoring a wider area covered by few video monitoring field units.

b) Cameras are usually equipped with power zoom (optical zoom with 22 x magnification) so the observer could easily inspect suspected areas.

c) System usually has video storing capabilities, at least for the last couple of days, and that is quite useful for post-fire analysis.

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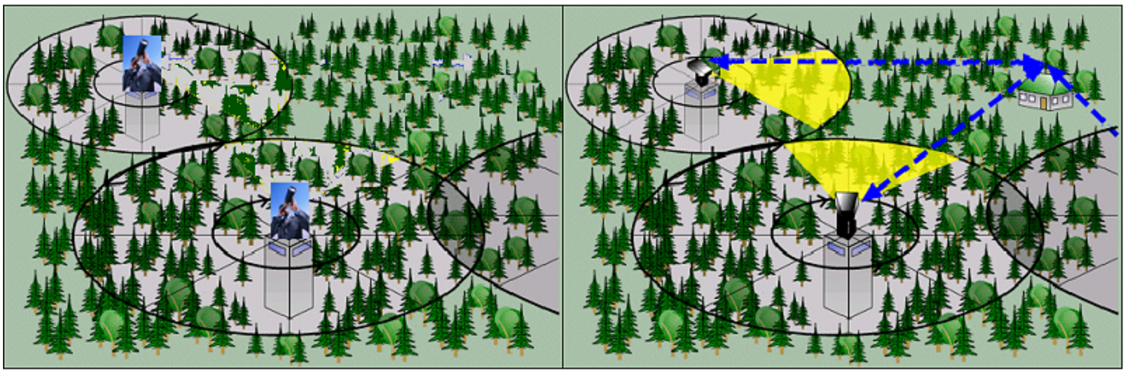

Figure 1. *The difference between human forest fires observation based on direct monitoring and distant monitoring using video cameras. In direct monitoring one observer has to be located on each monitoring spot, and in video based monitoring system the observer, located in monitoring centre, could monitor wider area covered by few monitoring units*

In Croatia only one area is completely covered by such a system. That is the Istria region where the video surveillance system today consists of 22 video monitoring units, and in 2005. of 14 monitoring units [3].

The next more advanced step in forest fire monitoring is automatic surveillance and automatic early forest fire detection system and that is the main topic of this paper and our next section.

2. AUTOMATIC SURVEILLANCE AND AUTOMATIC FOREST FIRE DETECTION SYSTEM

The research and system development in the area of automatic forest fire surveillance was extended in the last couple of years. There are two main types of automatic forest fire surveillance:

a) terrestrial systems based on monitoring from ground monitoring stations, and
b) satellite systems based on monitoring from satellites.

Satellite systems are suitable for monitoring wide forest areas like Canada or Siberia Sometimes airplane-based systems are used to monitor such areas, but today wide area monitoring is usually only satellite-based. As an example, let us mention Canadian Fire Monitoring, Mapping, and Modelling (Fire M3) System [3], or European FUEGO program [5]. For monitoring areas like the Adriatic coast and islands terrestrial or ground-based systems are more suitable.

In terrestrial systems different kinds of fire detection sensors could be used:

- video cameras sensitive in visible spectra based on smoke recognition during the day and fire flame recognition during the night,
- infrared (IR) thermal imaging cameras based on detection of heat flux from the fire,
- IR spectrometers which identify the spectral characteristics of smoke gases, and
- light detection and ranging (LIDAR) systems which measure laser light backscattered by the smoke particles.

Infrared and laser-based systems are more sensitive and they generate less false alarms, but their price is quite heigh in comparison to video (CCD) cameras sensitive in visible spectra. For example the price of one typical high quality outdoor pan/tilt CCD camera is 3.000 EUR, and the price of one typical IR thermal imaging camera is 25.000 EUR. Additional feature of CCD video cameras which are today on the market is their dual sensitivity. They are color cameras sensitive in visible spectra during the day , and black and white cameras sensitive in near IR spectra during the night.

The terrestrial systems based on CCD video cameras sensitive in visible and near IR spectra are today the best and the most effective solution for realizing automatic surveillance and automatic forest fire detection systems. In almost every country which encounters high risk of forest fires at least one such systems was developed and proposed. Some of them are on the market under various commercial names like FireWatch (Germany), FireHawk (South Africa), ForestWatch (Canada), FireVu (England), UraFire (France) etc. In all those systems automatic forest fire detection is based on smoke recognition during the day and flame recognition during the night.

The main disadvantage of those optical based systems is high rate of false alarms due to atmospheric conditions (clouds, shadows, dust particles), light reflections and human activities. Because of that, systems are usually supervised by a human operator and his decision is the final one. After the fire alarm is generated and suspicious part of the image is marked, the human operator confirms or discards the alarm. So the task of a human operator is not to monitor camera displays all the time, like in direct human surveillance based on video monitoring mentioned in Introduction, but only to confirm or discard possible fire alarms. If the human operator is not sure about a fire alarm he could switch the system to manual operation and make additional inspections using camera pan, tilt and zoom features. Using such automatic surveillance system, human operator efficiency is highly improved. He can control more cameras but also his fatigue is greatly reduced.

Croatia belongs to countries with enhanced summer forest fire risk. The catastrophic fire season in the year of 2003. motivated researchers at the Department for Modelling and Control at Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture University of Split to initiate research connected to early detection of forest fires based on images captured by video cameras in the visible spectra. After two years of research, advance and innovative forest fire video detection and early warning system was developed and experimentally tested during 2005 and 2006 fire seasons. The system was named **Integral Forest Fire Monitoring System** (in Croatian **IPNAS – I**ntegralni **P**rotupožarni **NA**dzorni **S**ustav) and developed by partial support of Ministry of science, education and sport of Republic Croatia and Split and Dalmatia County authorities.

3. CROATIAN INTEGRAL FOREST FIRE MONITORING SYSTEM - IPNAS

Initial research was started in 2003. by collecting images of fires in typical landscape characteristic for Croatian coast and islands. In cooperation with Jelsa Voluntary Fire Brigade on island Hvar. Controlled fires were burned and lot of video material collected. Fig.2 shows typical images.

Figure 2. *Images of initial fires in typical landscape characteristic for Croatian coast and islands (island Hvar)*

Several algorithms were tested but in parallel we have worked on the whole system for automatic surveillance with automatic forest fire detection development. Finally, in the year of 2005. the prototype version of our system called **Integral Forest Fire Monitoring System** was finished under support of Ministry of science, education and sport of Republic Croatia through a technological project [6] and Split and Dalmatia County authorities through a study [7]. The system development team consists of four main researchers (**D. Stipaničev, D. Krstinić, M. Štula, Lj. Bodrožić**) and a lot of consultants and developers.

IPNAS structure is shown in Fig.3. The system is based on field units and a central processing unit. The field unit is conceived of pan/tilt/zoom controlled video cameras and a mini meteorological station connected by Wireless LAN to a central processing unit where all analysis, calculation, presentation, image and data archiving is done. The system is Web based because the user interface is displayed in a standard Web browser, and the user can reach any system module through tunnelled SSL (Secure Socket Layer) VPN (Virtual Private Network). Multiple level of authentication stop the potential intruders.

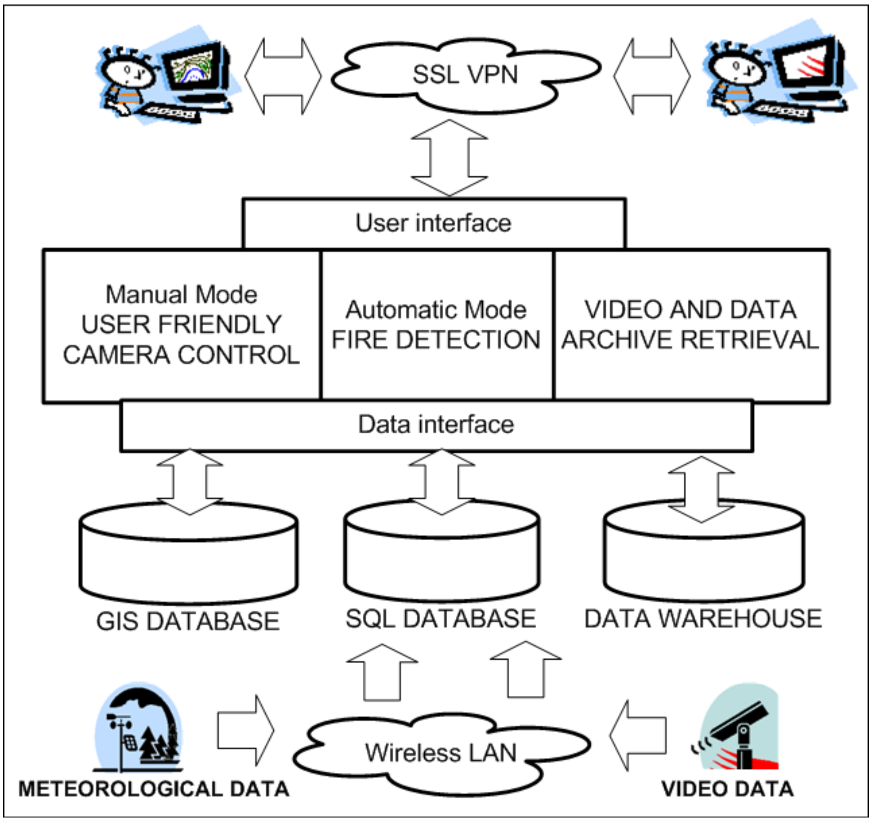

Figure 3. *Structure of Croatian Integral Forest Fire Monitoring System (IPNAS)*

IPNAS is based on three types of data:

a) Real-time video data – Digital video signal is used both in automatic and manual mode. In automatic mode it is a source of images for automatic forest fire detection and in manual mode it is used for distant video presence and distant monitoring using pan/tilt control and powerful zoom.

b) Real time metrological data –The meteorological data is today used in a post-processing unit for false alarm reduction, and tomorrow will be useful for local fire risk index calculation in prevention phase and fire spread estimation in fire fighting phase.

c) GIS (Geographical Information System) database – stores information on pure geographical data (elevations, road locations, water resources etc.), and all other relevant information related to a geographic position, like fire history, rain-water resource locations, land cover – land use, soil characteristics, local forest corridor map, tourist routes and similar. This data tomorrow will be quite useful for fire management activities and today it is used for user friendly camera pan/tilt control.

The user interface is a dynamic and interactive Web page where real time video and meteorological data is shown together with GIS data and user friendly interface for camera pan/tilt/zoom control in manual mode. Fig.4 shows the main user interface page for experimental monitoring unit on Marjan hill in Split.

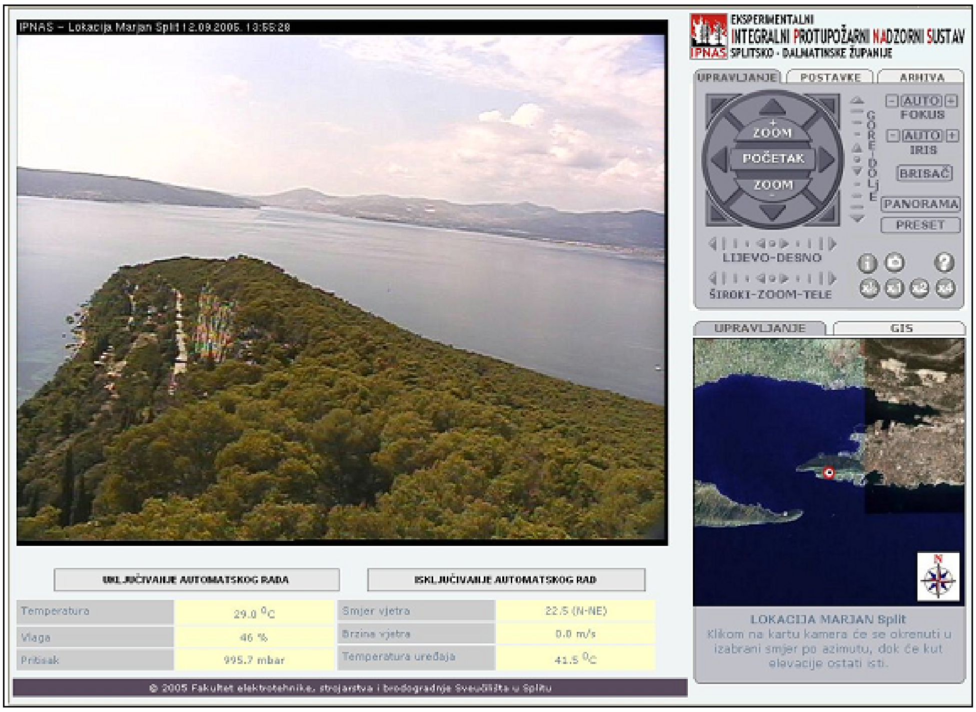

Figure 4. *IPNAS user interface is a dynamic and interactive Web page with the all real-time data and a user friendly interface for camera control in manual mode*

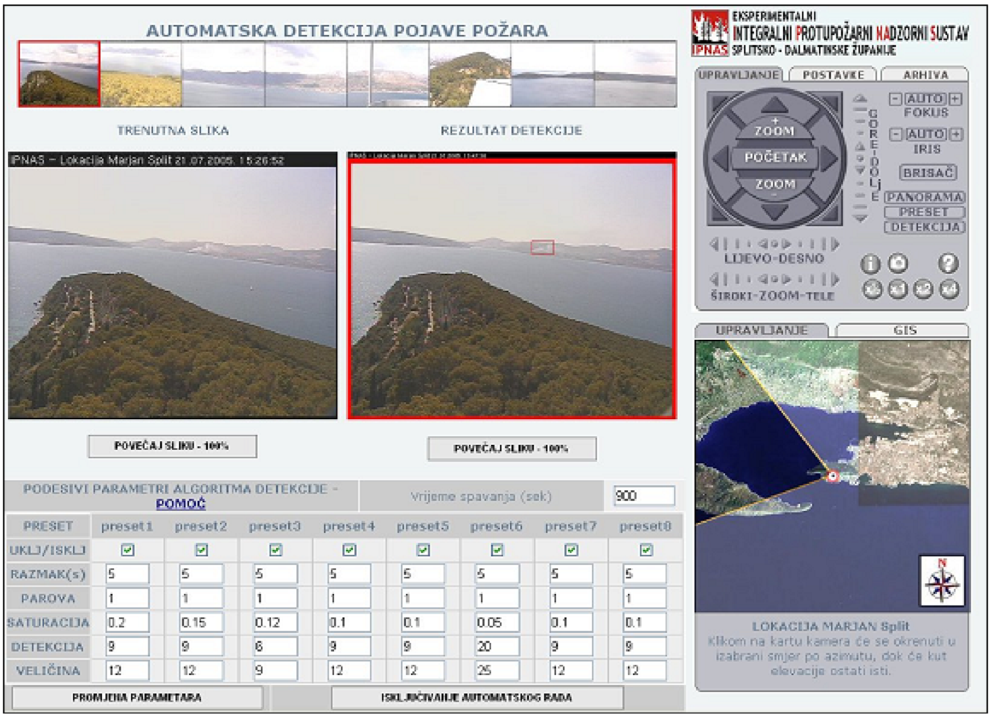

Figure 4. *IPNAS user screen in automatic mode. Detection algorithms has few parameters which could be adjusted in real time to decrease the false alarm rate*

In manual mode the camera could be moved using keyboard, virtual joystick or by simply clicking on a geo reference map, panorama image or preset position images. In automatic mode there are several parameters which could be adjusted in real time in order to decrease the false alarm rate. Fig.5 shows the user screen in the case of automatic mode.

During the fire season 2005. three experimental monitoring units were tested, one on the Marjan hill in Split, the second one on the Vidova gora mountain on island Brac and the third one on our faculty building in Split.

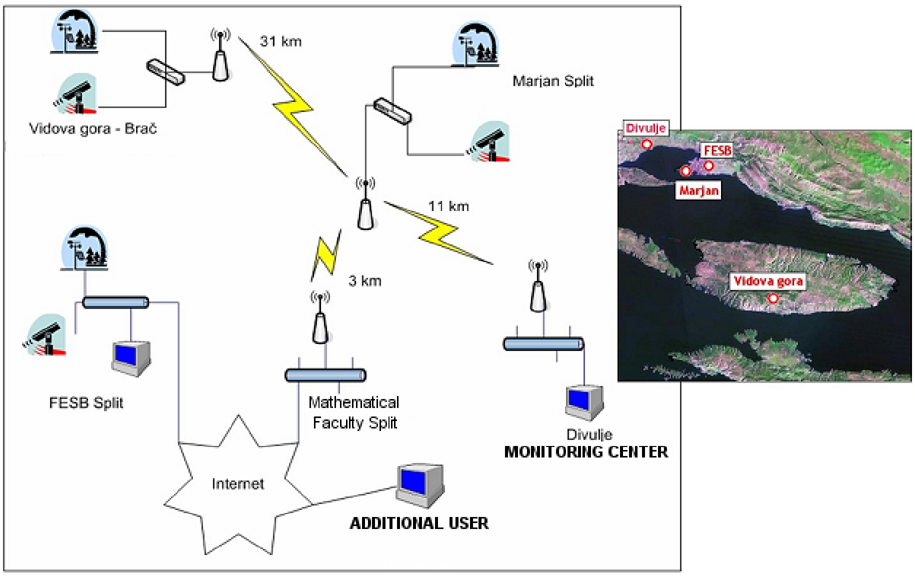

Figure 5. *The structure of the experimental system that was in function during 2005 summer fire season*

These field tests were performed in cooperation with Fire Brigade Administration for the Coast, Protection and Rescue Operations Administration, Ministry of Interiors in Divulje so the main monitoring centre was located in Divulje. The system was experimental and its main task was testing software, monitoring units and the communication network. The communication was realized by wireless point to point communication based on IEEE 802.11 equipment. Three wireless links were established. Two of them (Divulje – Marjan and Marjan – Mathematical faculty) were inside the European standards, but the distance of the third one (Marjan – Vidova gora) was too big (31 km) so it was necessary to increase the equivalent isotropically radiated power (EIRP) and that link was not inside the European standards. The system was experimental and after 2005. testing period the monitoring unit at Vidova gora was removed. In real realization such links have to be realized using legal, licensed equipment. Figure 6. shows monitoring units on Marjan Split and Vidova gora Brač (left and center).

During this experimental period we have acquired a big collection of false alarms that help us to improve the fire detection algorithm and functionality of the whole system. As a result in the year of 2006. the new improved version of Integral Forest Fire Monitoring System was released. In June 2006. the new system was installed in National Park Paklenica. The system installation was quite demanding because the monitoring spot was Crni Vrh at 1730 m in the middle of NP Paklenica reachable only by foot and helicopter. The monitoring tower and monitoring unit of NP Paklenica system is shown on Fig.6 (right photo). Also during 2006. summer season the monitoring unit on Marjan was also in function.

Experiences with those systems were quite satisfactory. The false alarm rate was satisfactory during the day and during the night. The only problematic periods were sunrise and sunset, because day and night fire detection algorithms are quite different. For operator is was inconvenient to manually adjust the transition time between day and night, and that was the reason for increased fire alarm rates. In our new software version an automatic system for day /night transition will be included.

Figure 6. *Experimental monitoring stations mounted on fire observation towers on hill Marjan in Split (left), mountain Vidova gora on island Brač (center) and mountain Crni Vrh in National Park Paklenica Velebit.*

During 2006. tests no fire alarms were detected by the NP Paklenica system, but the system on Marjan hill has detected several fires. Figure 7. shows one of them (Kozjak July 26, 15:11:49).

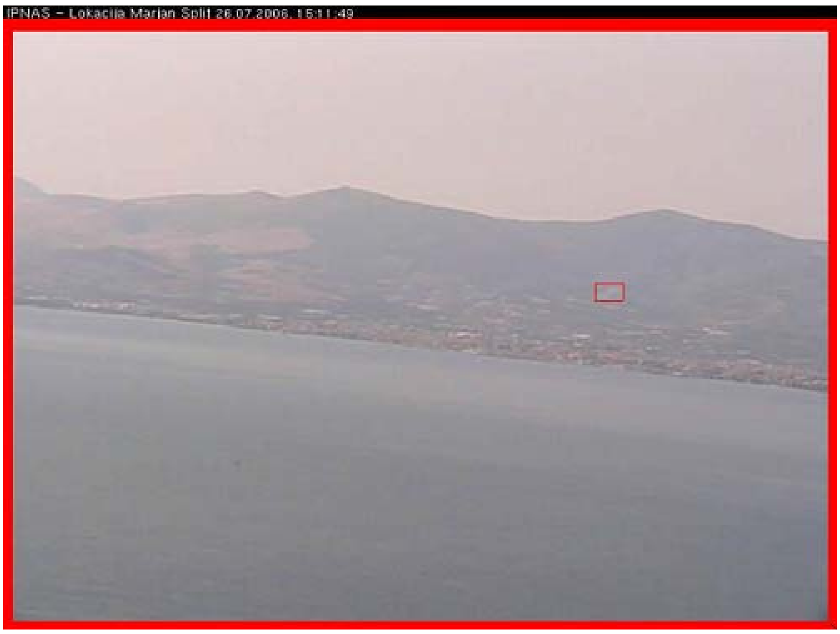

Figure 7. *Fire detected by the Marjan system on Kozjak mountain on July 26, 2006. 15:11:49*

Fig. 8. shows one typical false alarm which could not be easily recognized as a false alarm. The image-based detection system recognized these situation as smoke, but the post processing false alarm filter rejected it, because it was a rainy day (the smoke like part was a rain drop on the camera objective).

Figure 8. *False alarm which looks like a real smoke (rain drop on camera objective)*

4. CONCLUSION AND FUTURE WORK

The only effective way to minimize damage caused by forest fires is their early detection and fast reaction, apart from preventive measures. Great efforts are therefore made to achieve early forest fire detection, which is traditionally based on human surveillance. Technically more advanced forest fire surveillance systems is based on video camera monitoring units mounted on monitoring spots and distant monitoring from operation centre. The next step is automatic surveillance and the automatic forest fire detection system. In almost every country which encounters high risk of forest fires at least one such system was developed and proposed. Some of them are on the market under various commercial names. In 2005. after two years of research and development the first Croatian experimental system called **Integral Forest Fire Monitoring System** was ready for the testing phase. Three experimental monitoring stations were installed. Experiences gained from the first testing year yield system improvement, so for 2006. the new improved system was ready, not only for testing, but also for everyday work. The first installation was in NP Paklenica. Experiences were quite satisfactory and today the system is mature for further implementation. Parallel with those activities we have worked on a project of integral forest fire monitoring system for Split and Dalmatia County [7]. This project is now in the final phase. The whole system consists of 56 monitoring stations and 10 operating centres. Fig. 9. shows the monitoring stations layout. It is planed to be realized in several phases and we hope that until the year 2010. the whole Split and Dalmatia County will be covered by an advanced forest fire video monitoring system. Estimated cost of the whole system is approximately **2.1 mil.€** and that is only **2.5 %** of the official estimation of damages caused by forest fires during 2003. in Split and Dalmatia County.

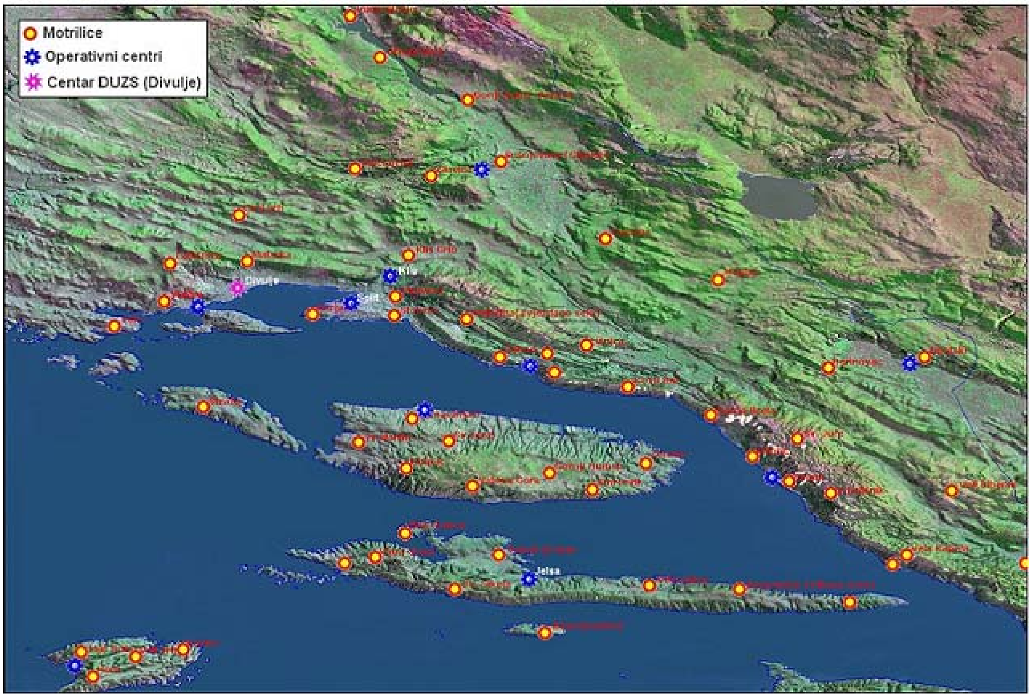

Figure 9. *Monitoring units of the Integral forest fire monitoring system of Split and Dalmatia County.*

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