Intelligent Forest Fire Monitoring System – from idea to realization

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Abstract

Wildfires, including forest fires, are natural phenomena that cause significant economic damage and have quite devastating effect to the environment all over the world. Early fire detection on one side and quick and appropriate intervention on the other one, are of vital importance for wildfire damage minimization. The fire season 2003 was quite severe one, particularly in Split and Dalmatia County. Provoked by great damages caused by 2003 wildfires in autumn 2003 a project was initiated at University of Split Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture Department for Modeling and Intelligent Systems, having the main goal to find a way how advanced information – communication technologies (ICT) could be used to improve wildfire prevention and protection. After three years of research and testing in 2006 the Intelligent Forest Fire Monitoring System called iForestFire was presented. iForestFire belongs to the last generation of wildfire monitoring and surveillance systems, having a lot of innovative and advanced features. Since 2006 it has been applied in various Croatian national and nature parks, but also the whole Istria region is covered by iForestFire network having 29 monitoring stations and 7 operational centers. The paper describes main features of iForestFire system with emphasize on its development and implementation.

Key words: wildfire, wildfire detection, smoke detection, intelligent system

1 Introduction

Wildfire or wildland fire is any uncontrolled burning of natural vegetation (grass, shrub, forest timber, litter and slash) in the wilderness area. When the vegetation layer is more precisely known, the more specific names could be used like forest fire, grass fire or bushfire. Wildfires represent a constant threat to ecological systems, infrastructure and human lives. According to prognoses, wildfires, including fire clearing in tropical rain forest, will halve the world forest stand by the year 2030. In Europe, up to 10,000 km2 of vegetation is destroyed by fires every year, and up to 100,000 km2 in North America and Russia. Wildfires are responsible for approximately 20% of CO2 emission into the atmosphere (Kührt et al, 2001).

Croatia belongs to countries with high wildfire risk. In summer season, seven coastal counties in Croatia, including in particular the Adriatic islands, are permanently exposed from high to very high fire risks. This is due to meteorological conditions, densely spaced conifer forests and a lot of tourists. According to Croatian Forests data (Žaja, 2008) from

1992 to 2007 there were 4.851 wildfires in Croatia and the burning area was 251.910 ha. Fire seasons 2000 and 2003 were particularly severe with 706 and 532 wildfires and the total damage caused by wildfires was huge. For example in 2003 only in Split and Dalmatia County there were 130 wildfires, the total burned area was 9.700 ha, the direct damage caused by wildfires (firefighters interventions and post-fire terrain recovery) was 16 mil.€, and the indirect damage, taking into account energetic equivalent of lost woody biomass, was assessed to 66 mil.€ (Stipaničev et al., 2004, Stipaničev et al. 2007). Wildfires in 2003 were particularly catastrophic on Split and Dalmatia County islands. For example, on islands Hvar and Brač the burning area was between 1/4 and 1/3 of total islands area and the small island Biševo near Vis has been totally burnt. Figure 1 shows photos of few 2003 fires on Split and Dalmatia County islands photographed by the author of this paper.

Figure 1 – Wildfires on Dalmatian islands in 2003

Provoked by great damages caused by 2003 wildfires in autumn 2003, a project was initiated at Department for Modeling and Intelligent Systems University of Split Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, having the main goal to find a way how advanced information – communication technologies (ICT) could be used to improve wildfire prevention and protection. After detailed survey of research topics and implementation of ICT systems in wildfire prevention task in other countries subjected to wildfires, we have focused ourselves primarily on these three topics:

- Automatic early wildfire detection,
- Calculation of micro location wildfire risk index, and
- Wildfire behavior and propagation simulation.

The first topic is the most important one, because the only effective way to minimize damage caused by wildfires is wildfire early detection and fast and appropriate reaction, apart from preventive measures. Great efforts are therefore made to achieve early wildfire detection, which is traditionally based on human wildfire surveillance, realized by 24 hours observation by human observers located on selected monitoring spots. In Croatia the human wildfires surveillance is mainly organized by Croatian Forests – the governmental organization responsible for protection and exploitation of forests in state ownership. 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 wildfire surveillance is video cameras based human wildfire surveillance and monitoring when remotely controlled video cameras are installed on monitoring spots, and the human observer is located in the observation center. Such system could be used not only for early fire detection, but also for distant video presence on fire remote location.

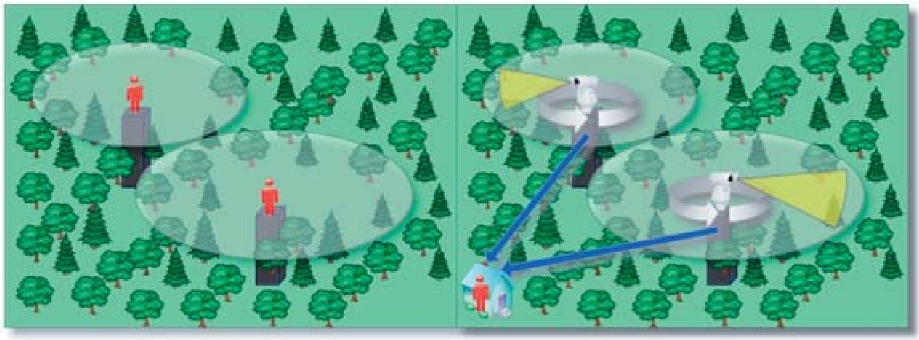

Figure 2 – The difference between human wildfire surveillance (left) and video camera based human wildfire surveillance (right)

The video cameras based human wildfires surveillance has many advantages in comparison to direct human observation from monitoring spots. Few of them are:

- A wider area could be covered, because one human observer could monitor few video monitoring field units.
- Cameras are usually equipped with power zoom (optical zoom with 22 x magnification) so the observer could easily inspect suspected areas.
- System usually has video storing capabilities, at least for the last couple of days, and that is quite useful for post-fire analysis.

The main limitation of video cameras based human surveillance is that fire detection depends entirely on the human observation. The observer is located in more comfortable environment, the observation center, but he (or she) has to carefully watch multiple computer monitors at the same time, so problems like fatigue, boredom and loss of concentration could be encountered. That was the main reason for introduction of various forms of automatic and advanced automatic wildfire surveillance and monitoring systems and networks. The system described in this paper, named iForestFire® – Intelligent Forest Fire Monitoring System (Croatian name is IPNAS® – Inteligentni Protupožarni NAdzorni Sustav) (iForestFire, 2011), belongs to the last generation of advanced automatic wildfire surveillance and monitoring systems, having a lot of innovative and advance features. It was entirely developed at University of Split Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, so iForestFire is a good example of university – industry cooperation, because today it is a successful commercial product installed in various Croatian national and nature parks and Istria County, but also a product that have significant export opportunities.

In the rest of this paper, a short introduction to automatic wildfire monitoring and surveillance systems will be given, main features of iForestFire system will be described with emphasis to its advanced and innovative aspects and finally a short discussion about iForestFire development, implementation and commercialization will be added.

2 Automatic wildfire surveillance and monitoring system

The research and system development in the area of automatic wildfire surveillance system was extended in the last couple of years. There are two main types of automatic wildfire surveillance systems: satellite systems based on satellite wildfire monitoring and terrestrial systems based on wildfire monitoring from ground monitoring stations. In this moment terrestrial systems are more useful because early fire detection is not the only one task that contemporary automatic wildfire surveillance and monitoring system has to fulfill. Beside the automatic detection of wildfires, the distance video presence on fire remote location is almost of equal importance and today's satellite systems could not fulfill that task. Satellite systems could be used only for wildfire detection with limited spatial and time resolution. Therefore the automatic wildfire surveillance and monitoring ground-based or terrestrial system used as an enhancement of human based wildfire surveillance are dominant today.

In ground-based or terrestrial systems different kinds of fire detection sensors could be used:

- Video cameras sensitive in visible spectra where wildfire detection is based on smoke recognition during the day and fire flames recognition during the night.
- Infrared (IR) thermal imaging cameras where wildfire detection is based on detection of heat flux from the fire (Arrue et al, 2000).
- Optical spectrometry that identifies the spectral characteristics of smoke (Forest Fire Finder, 2010).
- Light detection and ranging (LIDAR) systems that measure laser light backscattered by the smoke particles (Utkin et al, 2003)
- Radio-Acoustic Sounding System (RASS) for remote temperature measurements and thermal sensing of a particular forest region (Sahin et al, 2009).
- Acoustic Volumetric Scanner (VAS) that recognizes the fire acoustic emission spectrum as a results of acoustic fire sensing (Viegas et al., 2008).
- Sensor network based system, where a number of sensor nodes (in most cases wireless sensors) are deployed in forest, measuring different environmental variables used for fire detection. There are lot of different approaches, from more or less standard wireless sensor network (Byungrak et al, 2006), application of so called Fiber Optic Sensor Network (FOSN) developed within the EU-FIRE project (Viegas et al, 2008) to exotic proposals where animals have to be used as mobile biological sensors equipped with sensor devices (Sahin, 2008).

Each technology has its advantages and disadvantages. Most of them are promising, but they are still in experimental stage, particularly sensor networks, VAS, RASS and LIDAR systems. For example LIDAR - light detection and ranging system is used to carry out chemical detection from great distances and has the potential to be an efficient system for wildfire detection. However, it requires the lighting of the horizon with a laser beam that causes public health risks, besides not being very feasible from the economic point of view. Because of that, today in commercial use are mostly video based system equipped with cameras sensitive in visible spectra and/or infrared spectra and systems based on optical spectrometry. Optical spectrometry is rather new technology. It is based on a chemical analysis of the atmosphere by an optical spectrometry system. A telescope is coupled with optical sensor connected to a spectrometer unit with optical cable. The system analyzes the way the sunlight is absorbed by the atmosphere. It is quite efficient having the smallest number of false alarms, but of course it has a lot of disadvantages too. The main one is that it scans the space above the tree crowns on horizon, so the smoke has to be higher than the horizon. The second one is dubious night detection when standard video camera is used first to detect light and then optical spectrometry is used to detect fire flames. Because of that in commercial optical spectrometry based systems, the video cameras in visible spectra are also included. Infrared systems are good choice for wildfire detection, but their price is still quite high in comparison to video cameras sensitive in visible spectra, they have limited space resolution and they could not be used for distant video presence. Therefore, contemporary systems for wildfire detection based on infrared cameras are usually also equipped with cameras sensitive in visible spectra.

The conclusion is that almost in all commercially available systems, the camera sensitive in visible spectra is also present. As an old adage said: “The best hunting solution is to kill two rabbits with one shot.” we think that today the most suitable solution for terrestrial automatic wildfire detection and monitoring systems is to use cameras sensitive in visible spectra, particularly from the price/quality point of view. If you want to build a network, you need a lot of monitoring devices and the price of various advanced fire detection systems are much higher than today’s high quality video cameras. Additional feature of today’s video cameras is their dual sensitivity. They are usually color cameras sensitive in visible spectra during the day, and black and white cameras sensitive in near IR spectra during the night, so the detection capabilities, particularly in sunrise/sunset parts of the day are greatly improved. The second reason why visible spectra video cameras based system are the best choice is because their way of detecting wildfires is the most close to human based wildfire detection. Human wildfire observers primarily use his (or her) vision sensor (eyes) to detect wildfire. Sometimes humans use additional visual enhancement devices like binocular to check suspicious areas, but humans never use other sensors for early wildfire detection. During our research and development phase we have spoken with a lot various human wildfire observers and no one of them said that he (or she) is using for example hearing (ears) to detect wildfires. That was the reason why our efforts from the beginning were to develop ground-based wildfire monitoring system based on visible cameras sensitive in visible spectra.

Off course we were not the only ones who have thought of that way. In various countries that encounter high risk of wildfires, various terrestrial systems based on cameras sensitive in visible spectra were developed and proposed. In all of them automatic wildfire detection was based on smoke recognition during the day and flame recognition during the night. The main disadvantage of those systems is rather high false alarms rate, due to atmospheric conditions (clouds, shadows, dust particles), light reflections and human activities. Therefore, systems are usually designed as semi-automatic systems, which means that a human operator supervises the automatic wildfire detection and his (or her) 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. The task of a human operator is not to monitor camera displays all the time, like in video cameras based human wildfire surveillance mentioned in previous section, but only to confirm or discard possible fire alarms. If the human operator is not sure about a fire alarm, he (or she) could switch the system to manual operation and make additional inspections using camera pan, tilt and zoom features. Using such semi-automatic surveillance system, human operator efficiency is highly improved. One operator can manage more video monitoring units but also his (or her) fatigue is greatly reduced.

iForestFire - Intelligent Forest Fire Monitoring System belongs to this category. It is an innovative, cloud computing based, semi-automatic wildfire detection system with quite advance distant video presence capabilities.

3 Main features of iForestFire - Intelligent Forest Fire Monitoring Systems

iForestFire is integrated and intelligent video based wildfire surveillance and monitoring system. Wildfires are detected in incipient stage using advanced image processing and image analyses methods. Intelligent fire recognition algorithms analyze images automatically, trying to find visual signs of wildfires, particularly wildfire smoke during the day and wildfire flames during the night. If something suspicious is found, pre-alarm is generated and appropriate image parts are visibly marked. The operator inspects suspicious image parts and decides is it really the wildfire or not. The system is capable to work with both types of cameras: video cameras sensitive in visible and near IR spectra and real IR thermal imaging cameras, but video cameras sensitive in visible spectra are preferred.

Theoretical background of iForestFire is innovative and newly introduced wildfire observer network theory based on three-layer sensor network architecture, formal theory of perception and notation of observer (Stipaničev et al, 2007a; Šerić et al, 2009). Wildfire observer, illustrated in Figure 3, is the core element of iForestFire system. It has three horizontal layers: data or sensor layer, information or service layer and knowledge or application layer, vertically interconnected by low-level or data observer working as proprioception unit (syntactic and semantic validation of sensors and sensors data) and two high-level observers, the image fire observer and the decision fire observer, working as exteroception units (making conclusions based on sensory data).

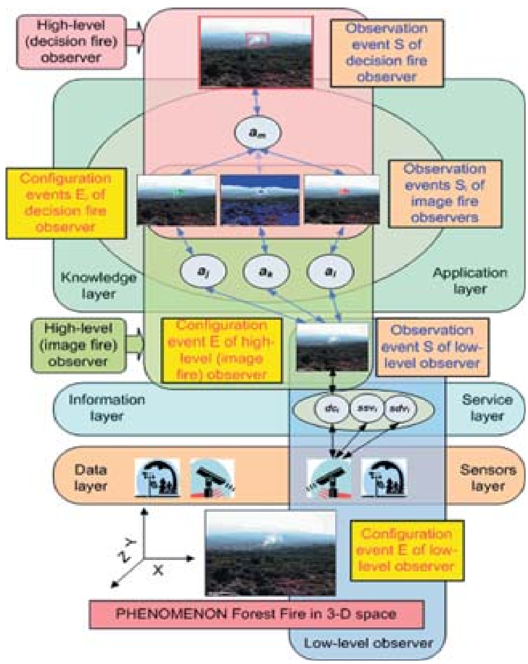

Figure 3 – Wildfire observer is organized as three-layer observer network

iForestFire is a cloud computing or Web Information System (WIS) which means that the operator could be located on any location with broadband Internet connection and his (or her) user interface is standard Web browser. The system is based on field units and a central processing unit. The field unit includes the day & night, pan/tilt/zoom controlled IP based video camera and IP based mini meteorological stations connected by wired or wireless LAN to a central processing unit where all analysis, calculation, presentation, image and data archiving are done. The system is also an example of Future Generation Communication Environment (FGCA) where all applications and services are focused on users, and "user" in our case is the natural environment, having the main task its own wildfire protection. For such environment behavior the term environmental intelligence (EI) was introduced (Stipaničev et al, 2007a; Šerić et al, 2009).

iForestFire is both integral and intelligent user friendly system. Its organizational structure is shown in Figure 4.

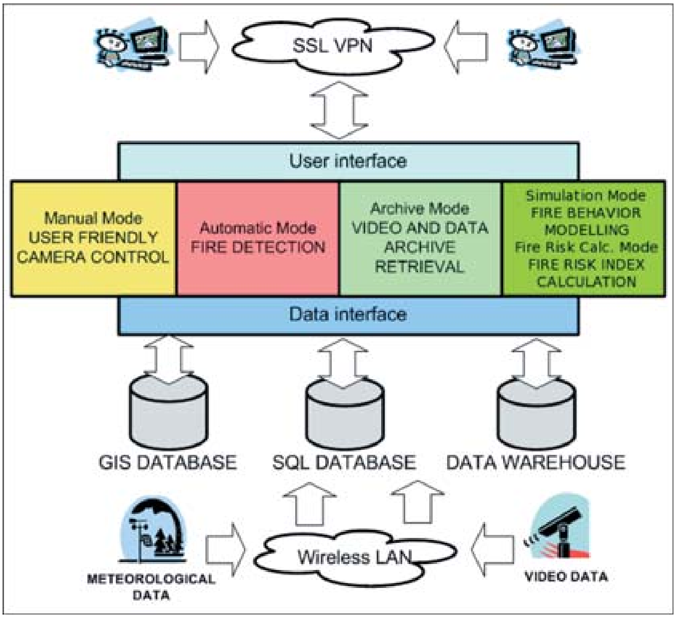

Figure 4 – The structure of iForestFire system

It has three data bases: data warehouse with input images and alarm images, SQL database with meteorological data and temporal information of alarm images and GIS database with all relevant GIS data. iForestFire has five working modes:

- Manual Mode – user-friendly camera manual control by pan, tilt and zoom.
- Automatic Mode – automatic fire detection based on images captured by video cameras in the visible and near infrared spectra.
- Archive Mode – video and meteorological data archive retrieval using various user-friendly procedures.
- Simulation Mode – fire behavior modeling and fire-spread simulation using meteorological data and various GIS layers.
- Fire Risk Calculation Mode - micro location fire risk index calculation using, not only meteorological data, but sociological parameters connected with forest fires too.

iForestFire is integral because it is based on three different types of data:

- Real time video data. Digital video stream is used in both, automatic and manual system modes. In automatic mode the video stream is a source of images for automatic wildfire detection and in manual mode the video stream is used for distant video presence and distant video inspection.
- Real time meteorological data. The meteorological data is used in the post-processing unit for false alarm reduction, but it is important for wildfire risk calculation during the monitoring phase and wildfire spread behavior modeling during the fire-fighting phase. Main meteorological parameters are measured using high tech IP based ultra sound mini meteorological station (iMeteo, 2011), also developed during iForestFire project.
- GIS (Geographical Information System) database. GIS system stores not only informa-

tion on pure geographical data (elevations, road locations, water resources etc.), but also all other relevant forest fire information related to a geographic position, like fire history, land cover – land use, roads and forest corridors and similar. These data are used for user-friendly camera pan/tilt control but also they are quite useful for firefighting management activities. GIS data is essential for Simulation Mode and Fire Risk Calculation Mode.

iForestFire is intelligent because it is based on artificial intelligence (AI), computational intelligence (CI) and distributed intelligence (DI) technologies like:

- Multi - agent based architecture. The system software organization is based on agent architecture. Intelligent software agents are responsible for sensors integrity testing, image and meteorological data collecting, syntactic and semantic image and data validation, image and data storing, image pre-processing processing and post-processing and pre-alarms and alarms generation. All agents share the same ontology and speak the same agent communication language (ACL) (Šerić et al, 2009). To demonstrate the system complexity, let us mention that on one server having 5 monitoring locations with 16 preset positions on each video unit, more then 300 agents are working in parallel.
- Advanced image processing and analyses algorithms. In its automatic mode, the wildfire detection is based on various advanced image processing, image analyzing and image understanding algorithms. Various algorithms work in parallel based on advanced motion detection, advanced image segmentation, fires smoke dynamic pattern analysis, color-space analysis and texture analysis (Krstinić et al,2009; Krstinić et al, 2011). Typical detection result for monitoring station located in Buzet region (Istria) is shown in Figure 5.
- Advanced procedures for false alarms reduction. In post-processing analysis, various methods derived from intelligent technologies field are used to reduce the number of false alarms, as for example advanced image processing techniques (Jakovčević et al, 2009), rule-based expert system, data fusion algorithms (Stipaničev et al, 2007b) and integration of fire risk index calculation with automatic adjustment of detection sensitivity (Bugarić et al, 2009). Algorithms have a number of tuning parameters, but our experience was that users adjust them rarely. The poorly adjusted parameters sometimes cause overly false alarm generation. That was the reason why we have introduced the possibility of automatic parameter adjustment based on meteorological data fusion and augmented reality features. Results of fire risk index calculation are used to automatically increase or decrease system detection sensitivity on various image regions. Also a powerful QoS (Quality of service) was developed, particularly related to wildfire observer detection quality evaluation (Jakovčević et al, 2010). QoS is used particularly as a tool for further improvements of detection quality.
- Augmented reality. The system is geo-referenced, so for every image pixel the corresponding geo-coordinate could be known and vice versa. The augmented reality features, now in experimental phase, based on fusion and integration of GIS information and real time video images are used in both, automatic and manual mode. Two examples of augmented reality use in automatic mode are automatic adjustment of detection sensitivity and determination of smoke location geo-coordinates. In manual mode important GIS information could be shown on video screen like toponyms, coordinates, altitudes, but GIS data are also used in advanced cameras manual control.

In system design phase particular attention was given to create a user-friendly system. All iForestFire modules and components could be reached and administrated through dynamic and interactive Web pages, where real time video and meteorological data are shown together with GIS data and user friendly interface for camera pan/tilt/zoom camera control. From the beginning, the firefighters were involved in experiments with iForestFire system prototype, so the final user interface was designed taking into account their advices. Figure 5 shows a typical camera control screen, and a typical fire alarm screen.

Figure 5 - iForestFire camera control screen with various manual control modes and typical fire alarm screen at location Buzet in Istria. The user can accept or discard the generated alarm.

For right decision about firefighting intervention, both the early fire detection and appropriate judgment about the potential fire danger are important. That is the reason why from the firefighters' point of view, both automatic detection of wildfires and manual camera control modes are of equal importance. Because of that, we have implemented in iForestFire various user-friendly procedures for cameras manual control like:

- Geo-referenced camera map control. The user can control camera pan movement by simple clicking on geo-referenced map. The camera control system is integrated with GIS, so it automatically detects and informs the user is the chosen point visible from the camera location or not.
- Geo-referenced one-click multiple cameras map control. In regions where the monitoring cameras network is established (like Istria County) the so-called one-click multiple cameras control was implemented. The user simply click on geo-referenced map and in background visibility of that location is calculated for all cameras in neighborhood, appropriate azimuth and elevation angles are calculated and all cameras are automatically pan and tilt moved to show chosen location (Stipaničev et al, 2009).
- Camera control using panorama image. In left upper corner of Figure 5 the 360o panorama image is shown. By simply clicking on panoramic image camera moves to chosen position by both pan and tilt.
- Camera control using preset positions. Camera could by simple click on preset thumbs, moved to preset positions, pre-defined by pan, tilt and zoom.
- Virtual pan-tilt-zoom commands and joystick emulation. Virtual commands are shown in upper right part of Figure 5. Simple, self-explaining virtual commands for pan tilt and zoom camera control were implemented, together with joystick software emulation.

iForestFire has a powerful archive retrieval methods for input images, generated alarm images and meteorological data. All of them could be easily reached and analyzed using various image and image data retrieval procedures based on advanced Internet technologies.
Each monitoring station is equipped with advanced IP based ultra sound mini meteorological station used for measuring the most important meteorological parameters: air temperature, relative humidity, air pressure, wind speed, wind direction and wind gust. Additionally it is possible to measure other meteorological parameters important for wild-

fire behavior and system performances, as for example isolation, precipitation, moisture, ground temperature or lighting activity. Meteorological data are used in Automatic Mode for false alarms reductions in post-processing procedures, but also in our experimental Fire Risk Calculation Mode and Simulation Mode. Figure 6 shows the system interfaces for micro-location wildfire risk calculation and simulation of wildfire propagation.

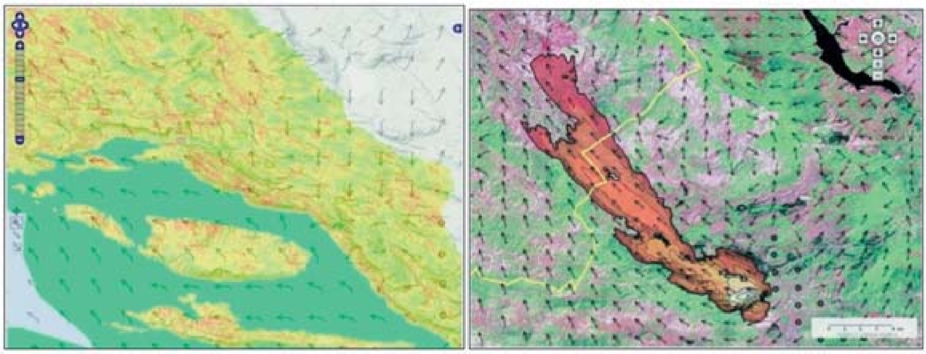

Figure 6 – Experimental system for micro-location wildfire risk calculation (left) and simulation of wildfire propagation (right)

In Fire Risk Calculation and Simulation Mode external meteorological services are also used, for example the results of meteorological simulations performed by simulation model ALADIN-HR. These data are automatically collected from the servers of Meteorological and Hydrological Service of Croatia twice a day. Figure 6 shows ALADIN-HR wind data superimposed on fire risk and simulation of fire propagation maps.
iForestFire is also award wining ICT project. In 2008 iForestFire won first price (Tesla Golden Egg) on VIDI e-novation award, competition founded by VIDI publication and Rudjer Boskovic institute. It was elected as the most prominent and innovative ICT project in Croatia in 2008.

4 Development and commercialization of iForestFire system

Development of Intelligent Forest Fire Monitoring System started in autumn 2003 as a seminar on the postgraduate (Mr.Sc.) study at Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, provoked by great damages caused by 2003 wildfires. The student Damir Krstinić (who was also the voluntary firefighter at island Hvar) enrolled the course Digital Image Processing and Analyses. The results of his seminar entitled “Wildfire smoke segmentation” were more than promising, so we have decided to apply for technology project, and in 2003 we have received a grant TP-03/0023-09 "System for early forest fire detection based on cameras in visible spectra" supported by the Ministry of Science, Education and Sport of Republic Croatia. The grant funds were enough to start more intensive research, but not enough to finished it, so a part of our research were also funded by ordinary project 023-0232005-2003 "AgISEco Agent-based intelligent environmental monitoring and protection systems", by support of Split and Dalmatia County authorities through a study "Holistic approach to forest fire protection in Split and Dalmatia County" and by our own resources.
In initial system development four researchers were involved - Darko Stipaničev as a team leader, Maja Štula as a designer of overall Web based information system, Damir Krstinić

as a designer of wildfire detection algorithms and Ljiljana Šerić as a designer of wildfire observer agent architecture. From the beginning the main firefighters adviser was Tomislav Vuko, the vice commander of Croatian firefighters for Adriatic Coast and Islands.

Research started in 2003 with wildfires video materials collecting necessary for detection algorithm development. Controlled fires were burned at island Hvar in cooperation with voluntary firefighters. Lot of video material was recorded and soon the first version of off-line detection algorithm was developed. Figure 7 shows examples of first algorithm detections in the typical landscape of island Hvar.

Recording and collecting wildfire images and video sequences is quite important for detection algorithm development and testing so this activity was carried out all the time. Today our database has more than 2.500 images selected and segmented by reference (ground truth) human observer. Figure 8 shows one typical example. On manually segmented image all regions were distinguished, because in the latest version of our detection algorithm region context based wildfire alarm reduction has been applied so it was important to have manually segmented, not only wildfire smoke – no smoke regions, but also other regions like sky, water, vegetation, man-made objects etc.

Figure 7 – Examples of detection images in the typical landscape for Croatian coasts and islands (island Hvar 2003)

Figure 8 – Input image and corresponding manually segmented image regions represented by various gray tonalities

After successful laboratory implementation, the real life field-testing was performed during fire seasons 2004 and 2005. Three experimental monitoring stations were installed on Marjan Hill near Split, Vidova gora on island Brač and FESB faculty building in Split. 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 centers were in Divulje and the second one in our laboratory. Figure 9 shows the experimental system layout and Figure 10 the experimental station on Marjan hill.

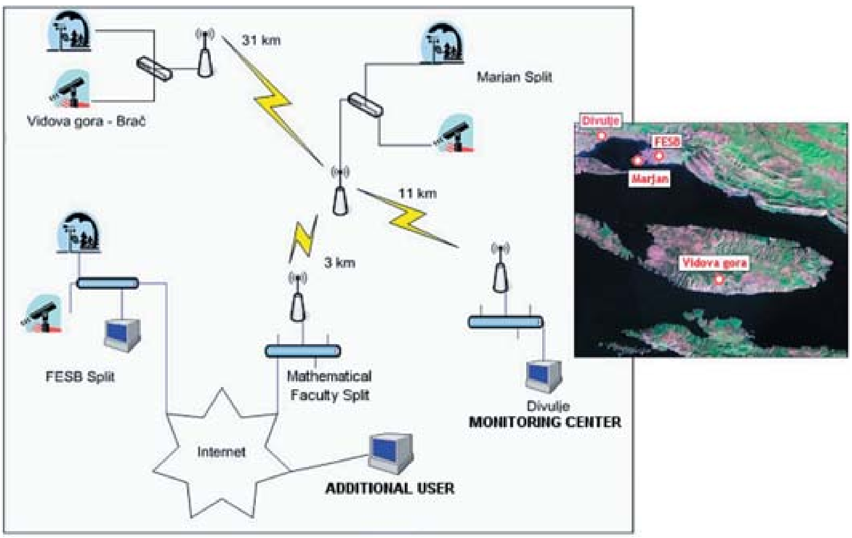

Figure 9 – The experimental system layout used for iForestFire prototype testing in 2004 and 2005

After the testing period a lot of improvements in both, hardware and software design were implemented and in 2006 the commercialization phase has started and the first real life monitoring system was installed in National Park Paklenica supported by Ministry of Culture of Republic Croatia. The system was partially developed as a technological project supported by Ministry of Science, Education and Sport of Republic Croatia and in contract signed with them our obligations were also the system commercialization. Two models were possible – to establish a new spin-off company or to find a strategic partner. In that moment, the second option was more convenient for us, so we found the strategic partner in company Lama d.o.o. from Split (iForesFire, 2011). Lama was responsible for system promotion, selling, installation and maintenance, but further system improvements, development and research were and remain until today our obligations.

The development of system like iForetFire is a never-ending story. The system version is now 2.7 (October 2010) and beside the initial researchers involved in system development from the begineeng, in today's version significant contributions were given also by Toni Jakovčević (advanced IP based meteorological station, detection algorithm), Marin Bugarić (Web GIS based system features), Josip Maras (component based system architecture), Petar Jerčić (software developement) and Kaja Radić (electronic components design and realization).

Figure 10 – The experimental station on Marjan hill

Since 2006 the system was successfully applied in various Croatian national and nature parks (7 monitoring stations and 5 operational centers), but the most advanced is network application in Istria County. Istria system called Istria iForestFire Net (Stipaničev et al, 2010) has 29 monitoring stations and 7 operational centers, mutually interconnected using encrypted VPN and hardware firewalls developed by our strategic partner – the company Lama. Figure 11 shows system layout and few screen prints of that system. iForestFire also has a quite promising export potentials. In March 2011 two demo units are in installation phase, one in Greece and the other in Portugal.

Last but not least it is important to emphasize that iForestFire has initiated a lot of scientific research, too. As a result of research connected with system development three PhD theses were written and defended (D.Krstinić, Lj.Šerić and T.Jakovcevic), two PhD theses are in preparation phase and lot of scientific papers were published in journals, books and conference proceedings. A specialized Web portal dedicated to wildfire observers and smoke recognition has been created and maintained (http://wildfire.fesb.hr), but also our interest in more general scientific wildfire research has resulted in establishment of Center for Wildfire Research (http://cipop.fesb.hr).

Figure 11 – Istria iForestFire Net – advanced wildfire monitoring network in Istria County

5 Conclusion

The only effective way to minimize damages caused by wildfires is wildfire early detection and fast and appropriate reaction, apart from preventive measures. Great efforts are therefore made to achieve early forest fire detection, which is traditionally based on human surveillance. This paper shows how modern ICT technologies could be used for automatic wildfire detection and monitoring. It describes the advanced wildfire surveillance and monitoring system named iForestFire and entirely developed at University of Split Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture.

iForestFire is a practical realization of the observer network theory. Observer network was defined as an advanced sensor network described using formal theory of perception and a notation of the observer. iForestFire is both integral and intelligent system. Integral because it is based on various data types (images, meteorological data, GIS data) and intelligent because it has a lot of features derived from various intelligent technologies (multiagent architecture, advanced image analysis and image recognition algorithms, advanced procedures for false alarm reduction, augmented reality).

The system was developed as a technological and scientific research project, but today it is commercial system widely used for advanced wildfire surveillance and monitoring in various Croatian national and nature parks and Istria region, so it is a good example of successful university – industry cooperation, particularly because its development has provoked a lot of scientific research activities resulting in a number of PhD thesis and published papers in journals, books and conference proceedings.

References

1. Arrue B C, Ollero A, Martinez de Dios J R (2000) An intelligent system for false alarm reduction in infrared forest-fire detection. IEEE Int. Systems, May/June 2000, 64-72.
2. Bugarić M, Jakovčević T, Stipaničev D (2009) Automatic adjustement of detection parameters in forest fire video monitoring system, MIPRO, May 2009, Opatija, pp. 270-275
3. Byungrak S, Yong-Sork H, and Jung-Gyu K, (2006) A Design and Implementation of Forest-Fires Surveillance System based on Wireless Sensor Networks for South Korea Mountains, IJCSNS Int. Journal of Computer Science and Network Security, V.6 No.9B, pp.124-130
4. Forest Fire Finder NGNS IS, http://www.ngns-is.com/html/florestas/fff_intro_eng.html (Accessed March, 1 2011)
5. iForestFire (2011) Itelligent Forest Fire Monitorig System, http://iforestfire.fesb.hr (Accessed March, 1 2011)
6. iMeteo (2011) Advance Ultrasound IP based Mini Meteorological Station, http://imeteo.fesb.hr (Accessed March, 1 2011)
7. Jakovčević T, Stipaničev D, Krstinić D, (2009) False alarm reduction in forest fire video monitoring system, MIPRO 2009, May 25-29, Opatija, 264-269
8. Jakovčević T, Šerić Lj, Stipaničev D, Krstinić D, (2010) Wildfire smoke detection algorithms evaluation, VI Int. Conf. on Forest Fire Research, Coimbra, Nov 15-18 2010.
9. Krstinić D, Jakovčević T, Stipaničev D, (2009) Histogram-Based Smoke Segmentation in Forest Fire Detection System, Information Technology and Control, Vol.38, No.3, 2009. 237-244
10. Krstinić D, Kuzmanić Skelin A, Slapničar I (2011) Fast Two-Step Histogram-Based Image Segmentation, IET image processing. 5 (2011), 1; 63-72
11. Kührt E, Knollenberg J, Mertens V (2001) An automatic early warning system for forest fires, Annals of Burns and Fire Disasters, vol. XIV, n. 3, Sept. 2001
12. Sahin Y, Animals as Mobile Biological Sensors for Forest Fire Detection, Sensors 2007, 7, 3084-3099
13. Sahin Y G, Turker Ince S, Early Forest Fire Detection Using Radio-Acoustic Sounding System, Sensors 2009, 9, 1485-1498
14. Stipaničev D, Hrasnik B (2004) Integral, holistic model of wildfire prevention in Split and Dalmatia County, Expert Study for Split and Dalmatia County, FESB Split, 2004. (231 pages) (in Croatian)
15. Stipaničev D, Hrastnik B, Vujčić R (2007) Holistic Approach to Forest Fire Protection in Split and Dalmatia County of Croatia, Wildfire 2007 Int.Conference, Sevilla, Spain, May 2007.
16. Stipaničev D, Bodrožić Lj, Štula M (2007a) Environmental Intelligence based on Advanced Sensor Networks, Proc.of 14th Int.Conference on Systems, Signals and Image Processing, Maribor, Slovenija, 27-30.6.2007
17. Stipaničev D, Bodrožić Lj, Štula M (2007b) Data Fusion in Observer Networks, Proc. of Second (IEEE) International Workshop on Information Fusion and Dissemination in Wireless Sensor Networks. Pisa, Italia, 08.10.2007, 1-6
18. Stipaničev D, Bugarić M, Bodrožić Lj (2009) Integration of Forest Fire Video Monitoring System and Geographic Information System, Proc. of 51st Int.Symp ELMAR 2009, Zadar, Sept 2009, pp.49-52
19. Stipaničev D, Štula M, Krstinić D, Šerić Lj, Jakovčević T, Bugarić M (2010) Advanced automatic wildfire surveillance and monitoring network, VI International Conference on Forest Fire Research, Coimbra, Porugal, Nov. 15 – 18, 2010, 053, 15 pages

20. Šerić Lj, Stipaničev D, Štula M (2009) Observer network and forest fire detection, Information Fusion, DOI: 10.1016/j.inffus.2009.12.003, on-line from Dec 28, 2009.
21. Utkin A, Vilar R, Feasibility of forest-fire smoke detection using lidar, International Journal of Wildland Fire 2003, 12(2) 159 – 166
22. Viegas X, Pita L P, Nielsen F, Haddad K, Calisti Tassini C, D'Altrui G, Quaranta V, Dimino I, Acoustic and thermal characterization of a forest fire event, Proceedings of SPIE, Remote sensing of fire, San Diego CA , 2008, vol. 7089, pp. 708904.1-708904.12
23. Žaja D (2008) The role of Croatian Forests d.o.o. in fightings again wildfires, International Workshop – new Methodes and Approaches to Wildfires Prevention and Protection, Dec, 8-11 2008., Makarska (in Croatian)