Advanced automatic wildfire surveillance and monitoring network

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Abstract
Wildfires cause significant economic damage and have quite devastating effect on environment all over the world. Early fire detection and quick and appropriate intervention are of vital importance for wildfire damage minimization. In both cases, video-monitoring system could be quite useful. In this paper, after a short survey of various approaches to the wildfire monitoring, particularly to terrestrial automatic wildfire video monitoring system, an example of advanced automatic wildfire surveillance and monitoring system, designed as a practical realization of observer network theory, is described. The wildfire observer network called Istria iForestFire Net is illustrated from its theoretical background based on formal theory of perception to its features and capabilities.
Keywords: wildfire, forest fire, smoke and flame detection, distant virtual presence, augmented reality, fire fighting

1. Introduction

Wildfires represent a constant threat to ecological systems, infrastructure and human lives. In Mediterranean area the threat of wildfire has always been high, but in the last couple of years it has increased significantly, particularly due to the climate changes. Croatia is not an exception; it also belongs to countries with high wildfire risk. In summer seasons several coastal counties of Croatia are permanently exposed from high to very high wildfire risks.

Apart from preventive measures, **early fire detection** on one side and **quick and appropriate intervention** on the other, are measures of vital importance for wildfire damage minimization.

Early fire detection is traditionally based on **human wildfire surveillance**, realized by 24 hours observation of human observers located on selected monitoring spots. Traditional human surveillance is useful for early fire detection, but it does not provide sufficient additional information about fire. According to Croatian firefighters commandants experience human observers description of fire intensity and development are in most cases useless for fire fighting decision-making and fire-fighting strategies development. If the fire was spotted and reported by citizens using mobile phones, the situation with fire description is even worse and according to fire reporting statistics that is the most usual case of fire reporting in Croatia. To consider the real wildfire threat and develop appropriate fire-fighting strategy, the firefighter commander or another trained firefighter appointed by him, has to visit and inspect the fire location. Such action takes time, and in wildfire fire fighting every minute is important.

Modern Information-Communication Technology (ICT) could solve this problem. Technically and functionally better wildfire monitoring system could be implemented as **video cameras based human wildfire surveillance and monitoring**. In this case remotely controlled video cameras are installed on various monitoring spot and the human observers are located in the observation center. Such a system could be used not only for **early fire detection**, but also for **distant video presence**. Now firefighter commander or coordinator located in observation center could see with his (or her) own eyes the situation on fire location in real time. If the wildfire-monitoring network conceived of multiple cameras covering the whole region is established, the distant video presence is even more important, particularly if the monitored location could be seen from more then one monitoring spots.

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 watch carefully multiple computer monitors all the time, so problems like fatigue, boredom and lost 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**.

In this paper an example of **advanced automatic wildfire surveillance and monitoring network** developed at University of Split and implemented in Istria County, shortly called **Istria iForestFire Net** is described. Istria iForestFire Net is not just another application of well known video monitoring technology, it is innovative for its theoretical foundations based on observer network theory and formal theory of perception and its architecture and implementation, having a lot of new features not found in conventional wildfire video monitoring systems.

2. Automatic wildfire surveillance and monitoring systems

The research and system development in the area of automatic wildfire surveillance was extended in the last couple of years. There are two main types of automatic wildfire surveillance systems: satellite systems based on satellite fire monitoring and terrestrial systems based on fire monitoring from ground monitoring stations. Contemporary automatic wildfire surveillance and monitoring system has to fulfill two main tasks:

- Automatic (early) detection of wildfire and
- Distance video presence on fire remote location.

The meeting of the second task is the reason why the terrestrial systems are better solution than satellite-based wildfire monitoring. **Satellite systems** are suitable for monitoring wide forest areas. Examples are Canadian Fire M3 - Monitoring, Mapping, and Modeling System (Fire M3, 2009), European EUMETSAT Active Fire Monitoring (FIR, 2010) or NASA MODIS Rapid Response fire locations system (MODIS, 2010). They could be quite useful for early fire detections in wide unsettled areas, but they are not appropriate for fire monitoring in areas like the Adriatic coast and islands. For fire monitoring in regions like those, the terrestrial or ground-based systems are more suitable. Two main reasons for that are spatial and time resolution and distant video presence. Spatial and time resolution in wildfire monitoring regions like Adriatic coast and islands has to measured in minutes and meters, and that is not the case with satellite based systems. Also satellite systems are capable only to detect fires, but for firefighters distant video presence is almost of equal importance.

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

- Video cameras sensitive in visible spectra. Their detection is based on smoke recognition during the day and fire flame recognition during the night.
- Infrared (IR) thermal imaging cameras. Their 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 & Vilar, 2003)
- Radio-Acoustic Sounding System (RASS) for remote temperature measurements and thermal sensing of a particular forest region (Sahin & Ince, 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 nodes (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 its 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.

In various countries, which encounter high risk of wildfires, various terrestrial systems based on cameras sensitive in visible spectra were developed and proposed. In all of them automatic forest fire detection is 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 **semi-automatic**, which means that a human operator supervises the systems 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.

3. Advanced automatic wildfire surveillance and monitoring systems and network

By integrating automatic wildfire surveillance and monitoring system with real time meteorological data, geographic information system (GIS), meteorological simulations, fire risk index calculation and fire spread simulation, a lot of new features could be added. The result of such integration is the **advanced automatic wildfire surveillance and monitoring system**. These systems could be used not only for early fire detection and distant video presence at fire location, but also for various activities connected with pre fire, fire and post fire stages. In the last decade various integrations have been proposed, from Canadian real-time forest fire monitoring and management system (Trevis & El-Shimy, 2004), to E-FIE (Caballero *et al*., 2001) and forest fire perception in SPREAD project (Martinez-de Dios *et al.*, 2007). This paper describes one such advanced automatic wildfire surveillance and monitoring system called iForestFire® developed at University of Split and widely applied in various National and Nature Parks of Republic Croatia as stand-alone units, but also as an advanced automatic wildfire surveillance and monitoring network in Istria region.

Advanced automatic wildfire surveillance and monitoring network has to be established when the whole region has to be protected. Advantages of network architecture have been emphasized in the past, for example in DICES project (Martinez-de Dios *et al.*, 1999) or PRODALIS project in Landes region, France (PRODALIS, 2007). In this paper an example of advanced automatic wildfire surveillance and monitoring network called **Istra iForestFire Net** is described, from its theoretical foundations, based on observer network theory and formal theory of perception to overall system architecture and functionality. The system has a lot of new features based on recent developments in information – communication technologies and software engineering.

4. Theoretical background - the formal theory of perception and observer network theory

A lot of different automatic wildfire detection systems have been proposed, based on various detection algorithms, but systematic and uniform theory of automatic wildfire detection was missing. During iForestFire system development we have tried to establish a uniform **wildfire observer network theory** based on the three-layer sensor network architecture, formal theory of perception and notation of observer (Stipaničev *et al.*, 2007a; Šerić *et al.*, 2009). Our starting point were formal theories of human perception and human observation. The reason for that was because traditional wildfire detection is based on human observation and in designing automatic systems we only try to mimic this process.

In psychology and the cognitive science the human perception is defined as the process of acquiring, interpreting, selecting and organizing sensory information (Lindsay & Norman, 1977). The formal theory of perception (Benett *et al.*, 1989; Benett *et al.*, 1996) tries to mathematically formalize this process, primarily by assigning probability to a certain percept (scenario) based on sensory inputs. The essential part of this theory is the notation of **observer** as a six-touple:

$$O = (X, Y, E, S, \pi, \eta) \qquad (1)$$

where X and Y are two measurable spaces, E and S are subsets of X and Y respectively, π is a measurable surjective function and η is a conclusion kernel. Let us define a **wildfire observer** (either human or automatic) as the same six-touple and explain the meaning of all its elements.

The task of the wildfire observer is wildfire detection in incipient stage based on data collected from various sensors. In the case of the **human wildfire observer** detection is primary based on vision sensor (eye), but humans often use other sensors like sound sensor (ear) or smell sensor (nose). In the case of the **automatic wildfire observer** various primary sensors, mentioned in Section 2, could be used, but we will focus our attention on artificial vision sensor (video camera) as a primary sensor and various meteorological sensors as additional sensors.

Space X is a **configuration space** of the observer and E is a **configuration event** in that space. For wildfire observer the configuration space X is the set of all possible phenomena (scenarios) that could happened in environment, like storm, lighting, fog, rain, snow and of course wildfire which is the subset of X called the configuration event E of the space X. Wildfire observer sensors map the configuration space X to the **observation space** Y. The mapping function, which includes functions of all sensors used in observation, is the perspective map π. The observation space Y holds images of scenarios in X with respect to the perspective map π (π : X Y). This is illustrated in Figure 1. For artificial vision sensor (video camera) the perspective map π includes the transformation of the 3D environment space to 2D image plane where the phenomenon (fire) detection has to be performed. The space Y is the set of all processed images. On some of them the wildfire will be detected and the set of all those images with positively detected wildfires is the **observation event** S, the subset of the space Y. For real observers the perspective map has to be injection, but not necessary surjection, so the set Y usually holds fewer elements then the set X, but when mapping is done, all elements of X are mapped into elements of Y.

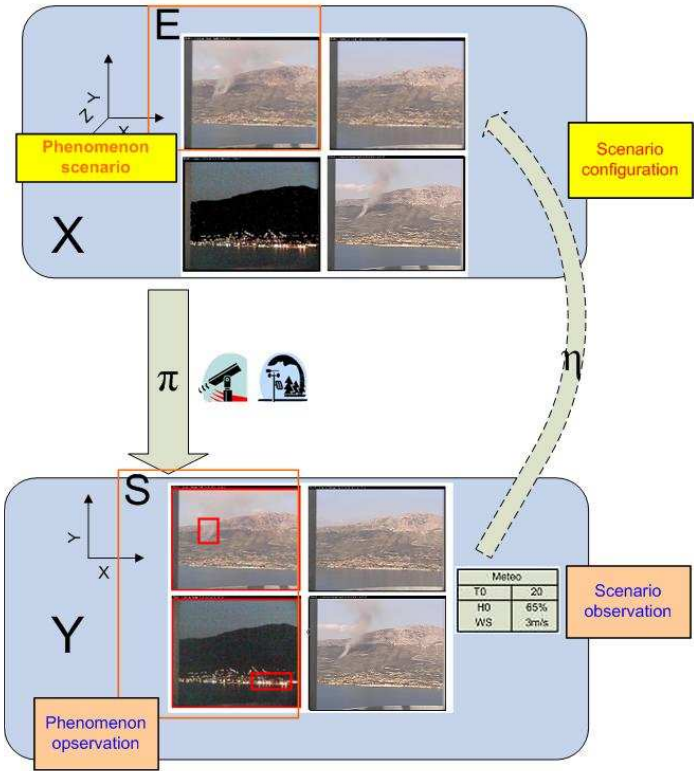

Figure 1. Illustration of automatic wildfire observer (correct detection – upper left, false alarm – lower left, correct reject – upper right, missed detection – lower right)

As the perspective map is not surjection, sometimes happens that a scenario from E (fire) and a scenario from ¬E (not fire) could have the same image inside the set S. So if former scenario (not fire) happens, the observer can falsely conclude that phenomenon had happen. This situation is called the false alarm. The probability of the false alarm is given by the conclusion kernel η. The kernel η gives for each element of S the probability distribution supported on E, thus the conclusion kernel gives the final result of our observer – the probability that different scenarios from E really happen and belong to S. There are 4 possible situations illustrated on Figure 1: **correct detection** - the phenomenon (fire) marked by x_i takes place in environment ($x_i \in E$) and observer conclude that its corresponding $y_i = \pi (x_i)$ is the observed phenomenon ($y_i \in S$), **false alarm** - $x_i \notin E$ and $y_i \in S$, **missed detection** - $x_i \in E$ and $y_i \notin S$ and **correct reject** - $x_i \notin E$ and $y_i \notin S$.

In developing wildfire detection system we have applied the theory of perception and notation of observer to the three-layer sensor network architecture (EYES, 2005). The final result was **three-layer observer network architecture** shown for wildfire observer in Figure 2.

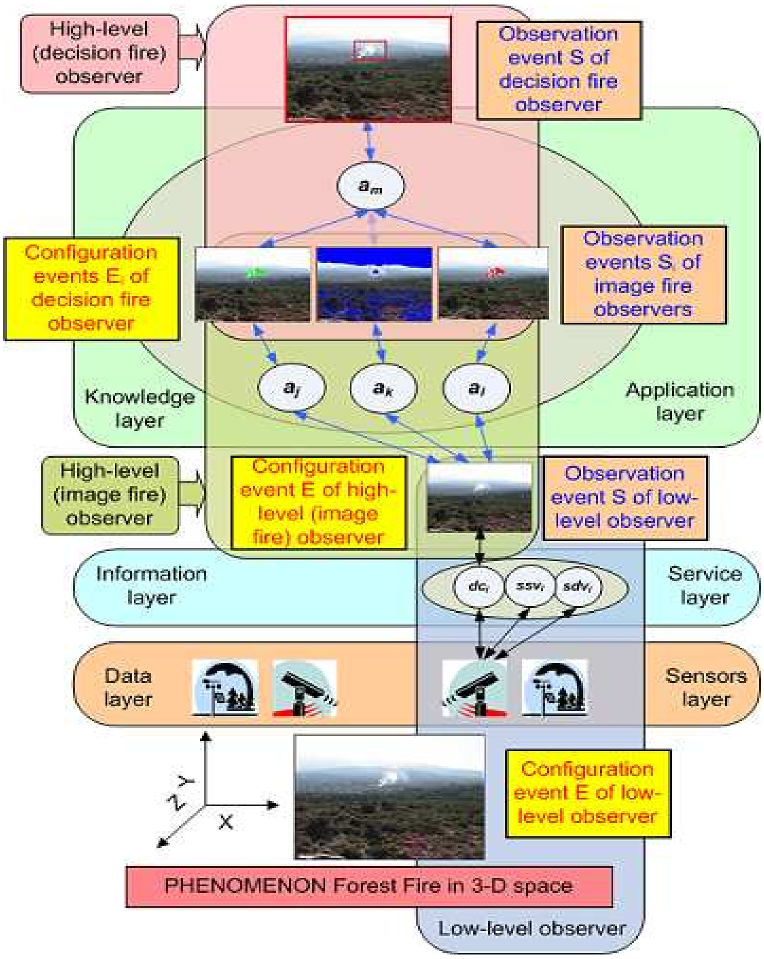

Figure 2. Forest fire detection system seen as an three-layer observer

Three layers are arranged horizontally: sensors or data layer, service or information layer and application or knowledge layer, vertically interconnected with two observer types - the low-level observer and the high-level observer. Sensor nodes (video cameras and mini meteorological stations) are located on **sensors or data layer**. **Service or information layer** contains all services important for supporting sensors and other devices on sensors layer, and **application or knowledge layer** includes all advanced applications for processing, interpretation and presentation of sensors data. The ***low-level observer*** or ***data observer (DO)*** is responsible for image acquisition and image preparation for high-level observers. Its configuration space is the real world, configuration event the real phenomenon – wildfire in 3-D space, observation space the 2-D space of images and the observation event is the set of appropriate digital images showing the phenomenon of interest. The theory of perception distinguishes proprioception (validation of sensors and sensors data) and exteroception (making conclusions based on sensors data) (Lindsay & Norman, 1977). According to that the main task of the low-level observer is proprioception. On information layer low-level observer has three services: dc_i, ssv_i and sdv_i illustrated in

Figure 2. Service $\boldsymbol{dc_i}$ is responsible for data collection, service $\boldsymbol{ssv_i}$ for syntactic failure detection and service $\boldsymbol{sdv_i}$ for semantic failure detection. An example of a typical syntactic failure is video camera breakdown when there are no video signals at all, and an example of a typical semantic failure is camera offset from predefined preset positions.

Task of the ***high-level observer*** is exteroception, making conclusions based on sensor data. The high-level observer includes several types of internal observers arranged in groups. In one group two observers are the most important: observer for wildfire detection and observer for wildfire location determination. Each group of internal observers is connected with one low–level observer, in reality with one monitoring station. The high-level observer is also structured in layers. For example for wildfire detection task on the first layer there are various ***image fire observers (IFO)*** and on the second, higher layer there is one ***decision fire observer (DFO)***. All image fire observers correspond to one low-level observer. This means that all of them have the same configuration event E and that is the digital image created by the low-level observer corresponding to one video camera. Image fire observers represent various forest fire detection algorithms and procedures, so they have different observation events representing results of various detection algorithms and procedures. Outputs of the image fire observers are inputs to decision fire observer, so decision fire observer configuration events are results of detection algorithms. The observation event of the decision fire observer is the final decision about forest fire detection.

iForestFire system is a practical implementation of the wildfire observer network theory. The multi-agent architecture was our final choice for system realization after testing various architectures suitable to fulfill all requests connected with observer network theory realization and additional requests as for example system capability to work in distributive environment, modularity and controllability through a number of users parameters. Finaly the wildfire observer was realized as a **multi-agent system** configurable using database, knowledge base and properties files. All low-level and high-level observers' services were realized as software agents sharing the same ontology and having the same agent communication language (ACL). More details about wildfire observer and its multi-agent realization based on observer network theory could be found in (Stipaničev *et al.*, 2007a; Stipaničev *et al.*, 2007b; Šerić & al., 2009). In this paper only the main features and capabilities of the most complex system implementation as a network covering the whole region are described.

5. Istria iForestFire Net

Istria is a region located on a peninsula at the north side of Croatian Adriatic coast. It has 2.820 km^2, 206.344 inhabitants and a long coastline of 539 km. It is one of the most developed Croatian counties, and the firefighting organization is not exception. In Istria there are 7 firefighting sub-regions, 7 professional brigades and 29 voluntary organizations, all of them very well equipped with modern firefighting vehicles and other equipment. Istra firefighters have started with implementation of standard video cameras based human wildfire monitoring system in 2005, but in 2008 the major upgrade to advanced automatic wildfire surveillance and monitoring system has been initiated. Today the system called Istria iForestFire Net is in everyday operation. It is composed of 29 video monitoring stations, 18 mini meteorological stations and 7 processing and operational centers, forming a network covering the whole Istria peninsula as Figure 3 shows.

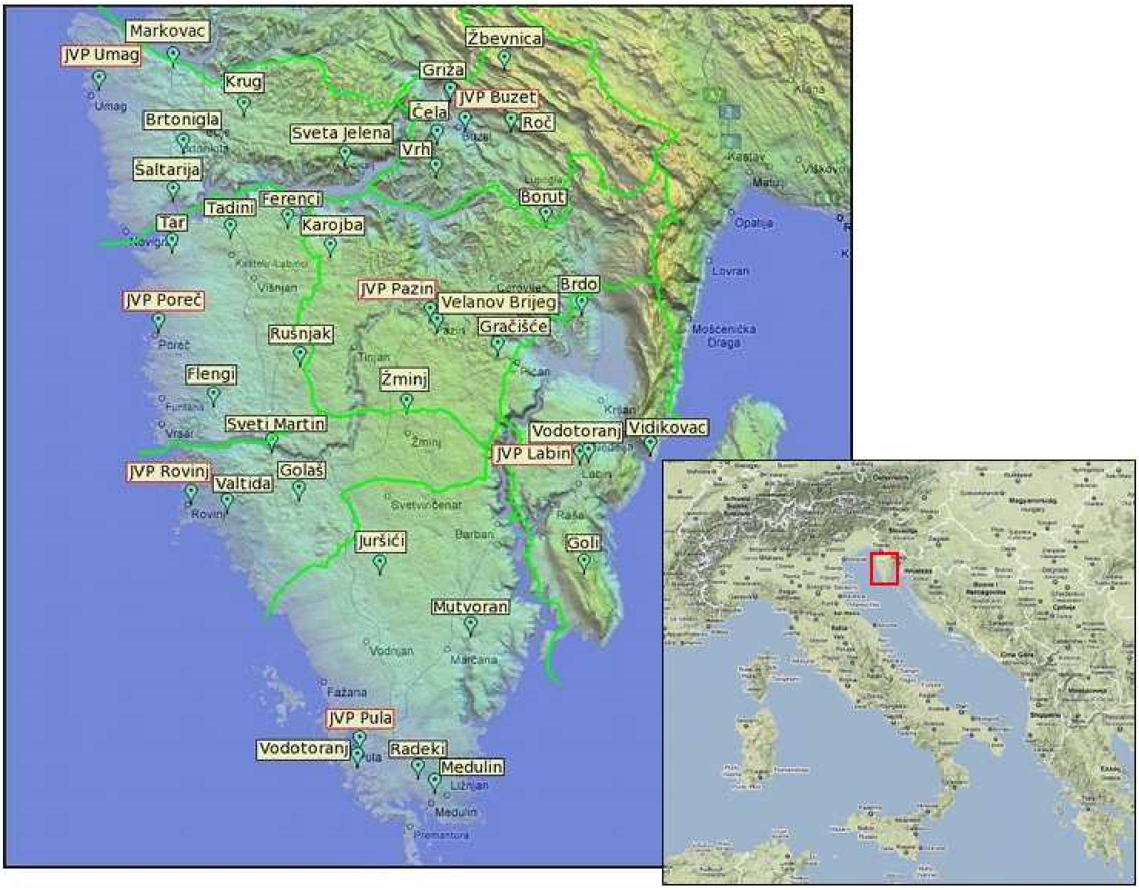

Figure 3. Istria iForestFire Net. Operation centers are in red rectangles.

The main feature of **Istra iForestFire Net** is that it belongs to Web Information Systems (WIS) and it forms Future Generation Communication Environment (FGCA). Both of them are advanced and emerging technologies in ICT sector. FGCA is used to describe the advanced communication and networking environment where all applications and services are focused on users. The "user" in this case is the natural environment, having as a main task the environment wildfire protection. The system belongs to Web Information Systems because all communications between monitoring stations, control centers and users are based on Internet protocols and the only user interface to all system functionalities is the standard Web browser.

The Istra iForestFire Net could be used in various firefighting activities before fire (BF), during fire (DF) and after fire (AF). Let us emphasize the most important of them:

BF – Before Fire

- 24-hours video and meteorological monitoring with automatic early wildfire detection based on data, information and knowledge fusion performed on real-time video signals captured by cameras in visible and near-IR spectra and real-time meteorological data using several knowledge bases and results of various simulations. The system has open, component-based architecture, so it could be easily augmented with other sensor types like thermal video cameras, various sensory networks or advanced fire detection sensors in the future.
- Prediction of fire risk index on micro-location scale taking into account meteorological, vegetation and sociological parameters and results of meteorological simulations.

DF – During Fire

- Advanced augmented reality distant video presence and user-friendly multiple cameras control using geo-referenced maps and panorama images enhanced and augmented with data and information obtained as results of Geographic Information Analysis (GIA) and various simulations.
- Simulation of possible fire spread and intensity based on meteorological simulations and real time meteorological data integrated with the fire fighting decision-making and fire-fighting strategies development.

AF – After Fire

- Post-fire analysis of fire damage and impact of fire using various possibilities of Geographic Information Analysis.
- Post-fire analysis of fire fighting procedures enhanced by “what-if” analysis based on fire spread simulation application.
- Training and teaching of fire fighting decision-making and fire fighting strategies development using simulations and data from stored meteorological database (serious fire fighting game).

The system has four working modes: manual mode, automatic mode, archive retrieval mode and GIS based simulation and calculation mode. All of them are based on three different data types: real time video data, real time meteorological data, and geospatial information stored in GIS databases, enhanced by various external services.

Digital video stream is used in both, automatic and manual mode. In automatic mode the video stream is a source of images for automatic wildfire detection and in manual mode it is used for advanced distant video presence and distant video inspection. The **real time meteorological data** is used for false alarm reduction in post-processing wildfire detection unit, but also for wildfire risk calculation during the monitoring phase and fire spread estimation during the fire-fighting phase. Main meteorological parameters are measured on monitoring locations using high tech ultra sound mini meteorological stations, but in parallel external services are also used, as for example, twice a day the results of meteorological simulations performed by simulation model ALADIN-HR are automatically collected from the servers of Meteorological and Hydrological Service of Croatia. The meteorological simulation results are particularly important for fire spread simulation and calculation of micro location fire risk index. **GIS database system** stores, not only information on pure geographical data (elevations, road locations, water resources etc.), but also all other relevant wildfire information related to a geographic position, like fire history, land cover – land use, local forest corridor map, tourist routes and similar. User-friendly multiple camera pan/tilt control uses GIS data, but such kind of information is also quite useful for fire fighting management activities. GIS data is important for fire behavior modeling, forest fire spread simulation and calculation of micro location fire risk index.

A lot of various **intelligent and advanced data processing technologies** are implemented in system. Let us emphasize the most important of them:

- ***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 perceive 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. There are various algorithms working in parallel based on advanced motion detection, advanced image segmentation, fire smoke dynamic pattern analysis, color-space analysis and texture analysis. Few of them were described in (Krstinić *et al.,*2009). Typical detection result enhanced with augmented reality features for monitoring station located in Buzet region shows Figure 4.
- ***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 is 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, as Figure 4 shows but fire spread simulation results could be shown, too. This feature could be quite useful, particularly in training and teaching of fire fighting decision-making.

In system design phase particular attention was given to user-friendly interface. All system 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 final system user, the firefighters were involved in experiments with system prototypes. The final user interface was designed taking into account their advices. Figure 5 shows a typical camera control screen. For appropriate decision making about firefighting intervention, both early fire detection and appropriate judgment about the potential fire danger are important. That is the reason why, from the firefighters point of view, automatic detection and manual camera control are almost of equal importance, particularly if the whole region is covered by monitoring network like in Istria region.

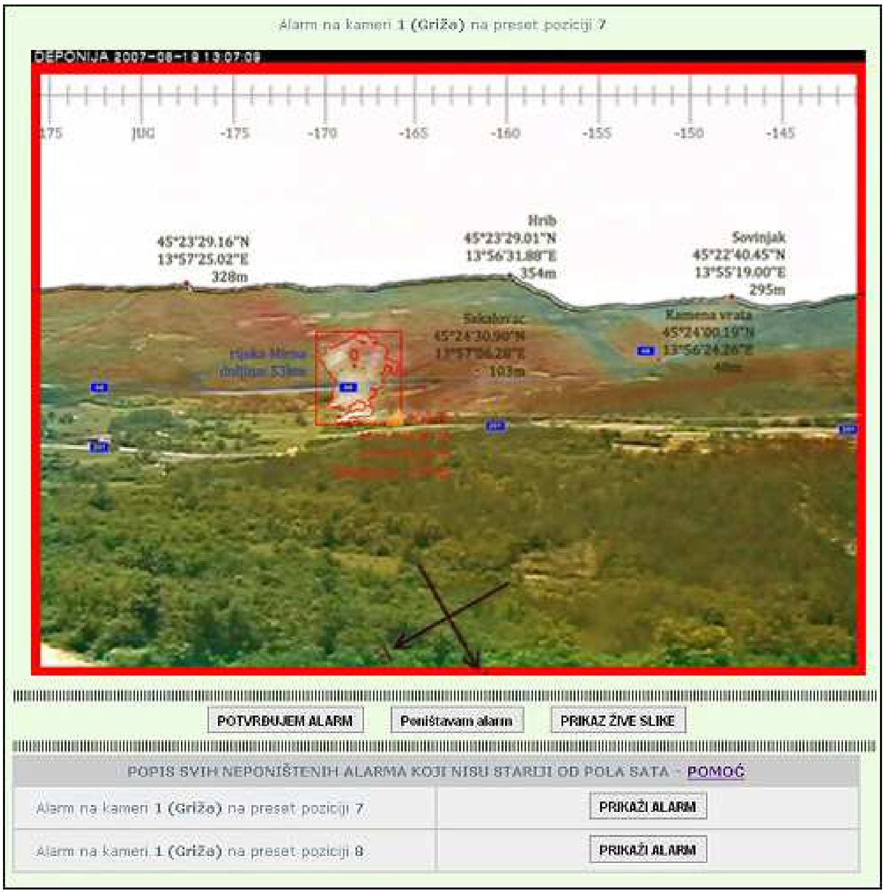

Figure 4. Alarm screen from location Buzet with augmented reality features. The task of the operator is to accept or decline generated alarm.

Istria iForestFire Net has various user-friendly procedures for camera manual control. The most important are:

a) ***Geo-referenced multiple cameras control using region map.*** The user can control multiple cameras by simple clicking on geo-referenced map. After the click, the system automatically calculates the click position in geographic coordinates (target coordinates), the visibility of the target coordinate from various monitoring locations, appropriate target azimuth and elevation angles from cameras in visible range and finally cameras pan and tilt movements. The final result is automatic cameras movement and opening of windows with live images from cameras capable to see the place that corresponds to the target coordinates (Stipaničev *et al.*, 2009).

b) ***Camera control using panorama image.*** On the top of camera screen, the 360^o panorama image is shown. By simply clicking on panoramic image, camera moves to chosen position by both pan and tilt.

c) ***Virtual pan-tilt-zoom commands and joystick emulation.*** Virtual commands are shown on manual control screen. Simple, self-explaining virtual commands for pan, tilt, zoom and other camera controls were implemented, together with joystick emulation.

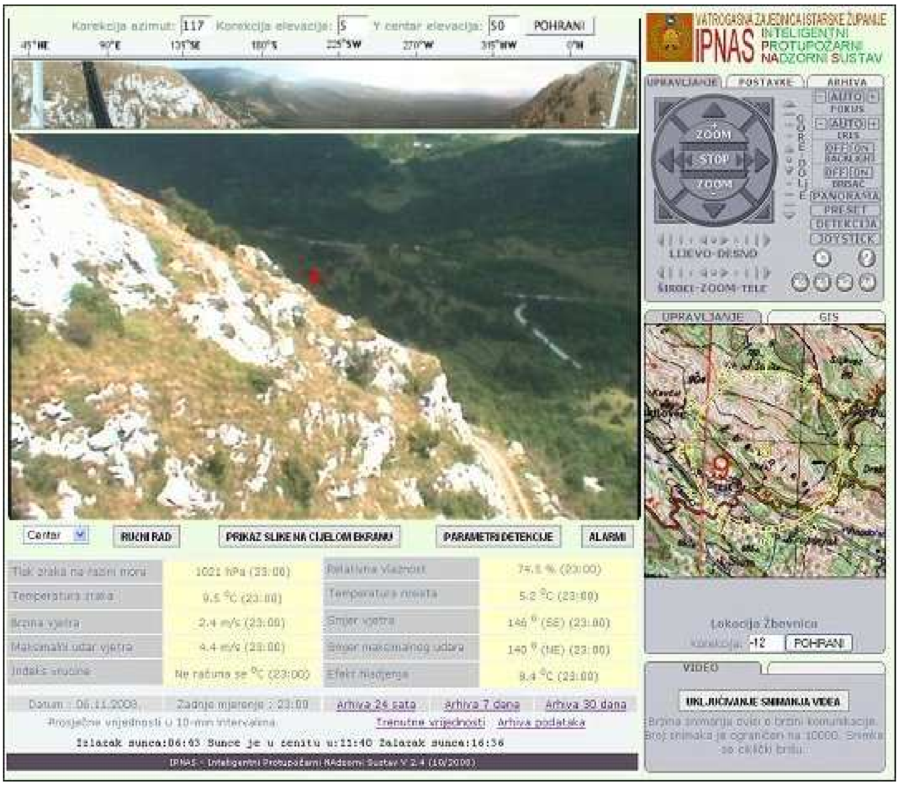

Figure 5. Istria iForestFire Net camera control screen with various user-friendly manual control modes.

The development of system like iForetFire Net is a never-ending story. Continuous improvements in both, detection algorithms and system architecture are performed in ***Center for Wildfires Research*** founded at University of Split.

6. Conclusions

The most effective way to minimize damage caused by wildfires is their early detection and fast reaction, apart from preventive measures. Great efforts are therefore made to achieve early wildfire detection, which is traditionally based on human surveillance. Technically more advanced human wildfire surveillance is based on video camera monitoring units mounted on monitoring spots and distant monitoring from operation centre. The next steps are automatic wildfire surveillance equipped with automatic wildfire detection system and finally advance automatic wildfire surveillance and monitoring that is geo-referenced, coupled with GIS and other services and simulations quite useful for various activities before fire, during fire and after fire.

The paper describes one such advanced system, from its theoretical background based on observer network theory and theory of perception to its realization in the form of wildfire observer network covering the whole Istria region with 29 monitoring stations and 7 processing and operation centers. The system is both integral and intelligent. It is integral because it is based on fusion of different data types (images, meteorological data, GIS, knowledge). It is intelligent because it is based on various artificial intelligence technologies from multi-agent organization to advance detection algorithms, alarm reduction and augmented reality based multiple cameras control capabilities.

7. Acknowledgement

This work was partly supported by the Ministry of Science, Education and Sport of Republic Croatia under Grants TP-03/0023-09 "System for early forest fire detection based on cameras in visible spectra" and 023- 0232005-2003 "AgISEco - Agent-based intelligent environmental monitoring and protection systems", and Split and Dalmatia County authorities through a study „Holistic approach to forest fire protection in Split and Dalmatia County“. In system development the main firefighters adviser was Mr. Tomislav Vuko, the vice commander of Croatian firefighters for Adriatic Coast and Islands. The most important persons for Istria iForestFire Net realization were Mr. Đino Piuti from Istria Firefighting Association and Mr. Dino Kozlevac the Istria County firefighter commander. iForestFire® and iForestFire Net® systems are today in commercialization phase in cooperation with the company Lama from Split, Croatia (iForestFire, 2010).

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