Applying GIS and SensorWeb for Monitoring of Fire in Protected Areas

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Abstract – **Natural disasters are more often main news topic. Environmental concern is present all over the world and the need for developing efficient monitoring systems for observing natural phenomena' behaviour and collecting field data is increasing. In this paper we will present GINISSENSE system for monitoring environmental phenomena and collecting information regarding features of interest. The system is based on GIS and Sensor Web concept, which is a type of sensor network adapted for environmental monitoring, and it is designed in accordance with Open Geospatial Consortium's (OGC) set of specifications named Sensor Web Enablement (SWE). For the purposes of better demonstration of GINISSENSE system's capabilities we will present the application of the system for monitoring wild fires parameters in protected areas and give a review of existing wild fires monitoring systems.**

Keywords – **forest fire, sensor web, GIS, environmental protection.**

I. INTRODUCTION

Environmental protection is an important matter that covers a wide variety of issues, including clean air, water quality, chemical security, forest preservation, etc. The current state of the environment is the result of many pressures, which are mostly linked to human activity.

The forest fire protection is especially important in countries where the forest covers more than one third of the country territory. The percentage of forest cover in Serbia accounts for 34.0% [1]. According to a research conducted by the State Enterprise for Forest Management "Srbijašume" [1] in the period 1998-2008, 853 forest fires were registered with the burnt area of 16.357 hectares. The consequences of such events are enormous, both ecological and economical.

There are several methods for fire prediction and preservation of protected areas. They are mostly based on meteorological parameters and fire spread models. Using them together in an integrated and unified system, we can provide monitoring and control of forested regions based on decision-making models and meteorological analysis. Active care of the environment and improvement of its status can be incorporated with modern technologies for enabling continuous care for its state. Many existing systems, as those listed in [2], use new technologies and achievements in various scientific areas and attain high accomplishments. Although the performances of such systems are high, they are also very expensive and therefore hardly affordable.

In this paper we propose a GINISSENSE system for monitoring and control of the wild fire, particularly forest fire, in a way that reduces risks to wildlife and people. The system relies on web based technologies for data gathering and alerting, and meteorological models for calculating forest fire risk. The paper gives an overview of existing solutions along with comparison to our system, emphasizing its advantages.

II. SENSORWEB AND GIS

Key concepts in disaster response are level of preparedness, response times, sustaining the response and coordinating the response [3]. That is why Sensor Web is important as sensing tool, and GIS as coordination tool.

The Sensor Web concept was firstly described at NASA Jet Propulsion Laboratory, as the developmental collection of sensor pods that could be scattered over land or water areas or other regions of interest to gather data on spatial and temporal patterns of relatively slowly changing physical, chemical, or biological phenomena in those regions [4]. The popularity of the concept has been increasing over the years. Sensor Web must be differentiated with the term sensor network. While the term "sensor network" often stands for a computer-accessible network of many spatially distributed sensing devices, a "sensor web" refers to web-accessible sensor assets that can be discovered and accessed using standard web protocols, encodings, and interfaces [5]. Sensor Web represents an intelligent network of connected sensor devices, scattered over sensing area, capable of observing and measuring relevant features of observed phenomena, sharing information with other connected devices and sending data through the network. It can perform intelligent autonomous operations in uncertain environments, respond to changing environmental conditions, and carry out automated diagnosis and recovery through the World Wide Web, enabled by standard encodings and services [6].

Open Geospatial Consortium (OGC) has most contributed to a development of Sensor Web by establishing Sensor Web Enablement working group that has developed a set of specifications named *Sensor Web Enablement (SWE)* [5], which fully describe a Sensor Web system. SWE relays on Web Services and XML technologies and standards. Sensor Web, however, represents an excellent interface for accessing

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sensors, but for the system to be complete, it is necessary to display and analyze received sensor data. The most logical approach to this problem is visual.

The Geographic Information System (GIS) as an information technology, which combines geographic locations of natural and artificial objects as well as other types of data in order to generate interactive visual maps and reports, is often used in combination with Sensor Web technology. If used as a data source in a Web-based GIS application, Sensor web gains a visual dimension. Information gained form measured values coming from the sensor is increased greatly by adding the GIS component that contributes to it in a geographical sense.

When monitoring the fire in protected areas, it is important to be aware of methods that can help in predicting the fire. It is essential to identify the physical phenomena that influence the creation of fire, as well as type of vegetation that influence its spread.

III. WILD FIRES MONITORING

A. Meteorological methods for predicting and preventing wild fires

In order to develop efficient systems for prediction and prevention of forest fires, it is necessary to understand parameters that are direct or indirect causes to these events. Even though most of the fires are caused by people, accidentally or by deliberate actions, these are the causes that couldn't be predicted by a software system. That is why we will be focusing on weather conditions and parameters that can be observed and processed.

Several different types of environmental parameters initiate the ignition of forest fires. Meteorological studies have shown that there are several weather indices that could be used for the purposes of calculating the possibility of such events. According to [7] these indices can be classified as structural and dynamic. Structural indices are also called long-term fire risk indices as they are calculated from variables that do not change over short time periods. Dynamic indices, on the other hand, are short-term indices that are used for computing the probability of fire ignition and spread. There are two types of dynamic indices: meteorological and vegetation. Meteorological indices are computed directly from meteorological factors, while vegetation index shows the state of vegetation provoked by those factors. For the purposes of this research, we will be focusing on meteorological factors and indices. Several different types of meteorological indices are in use nowadays for calculating forest fires risks [7]: Behave Index, The Canadian Fire Weather Index (FWI), Portuguese Index, Spanish ICONA Method, Sol Numerical Risk and Italian Fire Danger Index. They are all computed from temperature, humidity and other meteorological parameters' values and used for forest fires prediction. Most commonly used in Europe is The Canadian FWI.

Fire Weather Index is a numerical indicator that shows current state of a forested area and the potential of fire in that area [8]. It is a complex component, comprised of six subcomponents, which determine the effects of fuel moisture and winds on forest fires behavior, based on observations of weather conditions and parameters.

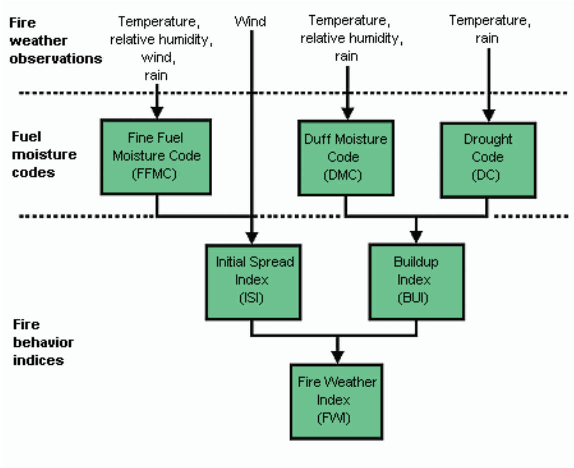

Figure 1. Canadian Forest Fire Weather Index System

FWI is a combination of Initial Spread Index, which represents the combined effect of wind speed and moisture content of fine fuel, and Buildup Index - BUI, which is the indicator of fuel moisture content. The calculation of these values is performed accordingly to WRF-NMM numerical model. Based on its value, there are five FWI categories: very low, low, moderate, high and extreme. Fig. 1 shows the structure of FWI and meteorological factors that are essential for its calculation.

TABLE I
FIRE WEATHER INDEX (RHSS)

	Date					
	1.07.2009.		02.08.2009.		23.08.2009.	
Weather station	**FWI**	**Risk**	**FWI**	**Risk**	**FWI**	**Risk**
Crni Vrh	0	Very low	14	Moderate	10	Moderate
Zlatibor	0	Very low	21	High	8	Moderate
Kopaonik	0	Very low	10	Moderate	5	Low
Nis	8	Moderate	30	High	24	High
Vranje	2	Very low	35	Extreme	34	Extreme
Novi Sad	0	Very low	33	Extreme	27	High

Republic Hydro-meteorological Service of Serbia (RHSS) [9] provides an online service for reviewing FWI values for weather stations in Serbia. Table I shows the RHSS report for three measurements taken during the summer in 2009. The report shows that there is increased risk of forests fires during summer months, especially in the beginning of august, when temperatures are very high, and precipitation and humidity very low. The monitoring of forested areas should be increased in that period.

B. Brief overview of wild fires monitoring systems

The fire prediction systems can be classified as follows:

- Terrestrial systems
- Air systems
- Satellite-based systems

Terrestrial systems use different types of sensors to detect fires: Meteorological sensors, video cameras, infrared cameras (IR) and LIDAR (Light Detecting and ranging) systems that can detect laser light reflected from smoke particles.

Air systems are used to cover large areas (using the aircraft), however a fundamental lack of such systems in terms of reliability is the presence of strong wind and low clouds.

Using satellite-based systems has some advantages and disadvantages. Satellites that are in geostationary orbits are highly effective for the detection of forest fires, but the disadvantages are reflected in the lag-time and in some cases the efficiency of detection of forest fires in the presence of clouds. A detailed overview of all types of prediction systems can be found in [2].

Here we would like to particularly single out one system called DEDICS (Distributed Environmental Disaster Information and Control Systems). DEDICS [10] is an integrated sensor network (of regional character), established for the purpose of improved management and control of arising emergencies in cases of natural disasters. The DEDICS has found the largest use in the early detection and control of the forest-fires spread. An implementation of the DEDICS system, for fire prediction, prevention and control, has been carried out at the University of Seville. The system has three main blocks: the *sensor interface block*, the *image processing block* and the *decision function block*. The sensor interface block is responsible for communication with the sensor stations. The *decision function block* combines the information from images, maps, meteorological data and the database with heuristic knowledge based on rules to produce a forest-fire possibility value. The output of the decision function block is a value in the range [0, 100] that represents the forest-fire possibility and the potential danger of the alarm. If the forest-fire possibility value is above an operator-selected alarm threshold, which is normally 0.5, the alarm will be considered as a forest fire. Otherwise, the alarm will be rejected.

IV. APPLYING GINISSENSE FOR WILD FIRES MONITORING

The most important drawbacks of existing automatic forest-fire detection systems are high false alarm rate, low functional coverage and high cost of infrared cameras and maintenance. GINISSENSE system for monitoring of forest fires is proposed as a simple solution that overcomes those obstacles and achieves high efficiency. GINISSENSE architecture is based on GIS and Sensor Web technologies, described in the second section of this paper, and it fully applies OGC SWE set of specifications and recommendations. Detailed overview of this architecture is given in [11]. The application of GINISSENSE architecture for monitoring of forest fires is presented in Fig. 2. The core of the system is comprised of a set of Web Services, responsible for data processing and communicating with sensors. They involve all of the system's functionalities and are hosted on a system server. This enables universal availability of system's capabilities and ease of access. Client applications, responsible for querying and visualizing of collected data, are installed in Control Centers and are used by operators for monitoring of observed parameters. Meteorological sensors are main data sources in the system, providing weather parameters measurements, but the system also has other sensing devices such as video cameras for real-time streaming of observed forests. Each sensing device is equipped with GPRS module and is therefore capable for sending its measurements to the server unit over the network. Sensors perform measurements at defined time intervals and send them to the system for further analyzes. They can communicate with each other and share relevant information regarding observed phenomena and for the purposes of performing some basic data pre-processing.

As elaborated in the third section, Fire Weather Index has proved to be a very efficient method for determining the risk of fire in forested areas. This index is calculated accordingly to meteorological data collected from weather stations, positioned in critical regions. Each weather station consists of temperature, wind, precipitation and humidity sensors, which collect data at specified intervals (e.g. every six hours) and send them through the network to the server component. The data is accepted by a server service; relevant information is extracted and then sent to a DMA component for further analyzes. DMA is an intelligent component, based on a set of reasoning rules, that uses collected meteorological data and terrain information in order to produce meaningful conclusions about the risk of forest fire in a certain area. Terrain data contains information about forest fuels and land topography, both extremely important for determining the forest fire risk. System databases store and preserve previous weather stations' measurements, as well as information regarding characteristics of terrains of forested areas. Combining stored data with actual measurements, DMA can generate accurate conclusions regarding the forest fire risk.

The Fire Weather Index accounts for about 90% of calculated risk value. This data can also be used for predicting fire propagation. Numerous fire spread models exist nowadays [12], and they can be involved in the system as a tool for predicting and preventing the spread of ignited fires. The forest fire risk in the GINISSENSE system is presented as an integer value, ranging from 0 to 100, where 0 means there is no risk, while 100 means there is extremely high risk of forest fire in observed area. The system will trigger the alarm in case the calculated risk is above 20. There are four alarm groups, based on priorities: low priority (for the risk between 21 and 40), medium priority (for the risk between 41 and 60), high priority (the risk is between 61 and 80) and ultra high priority group (the risk value is over 80). The alarm of low and medium priority will inform only the operator in Control Center about the critical area, while high and ultra high priority alarm will also inform fire fighters units responsible for fire issues in the area.

Beside weather stations, there are also wireless surveillance cameras set in forests, which are used for real-time monitoring of forested area. Operator at Control Center can observe terrain from each camera at any time. A separate service within the system is responsible for receiving a video stream from cameras.

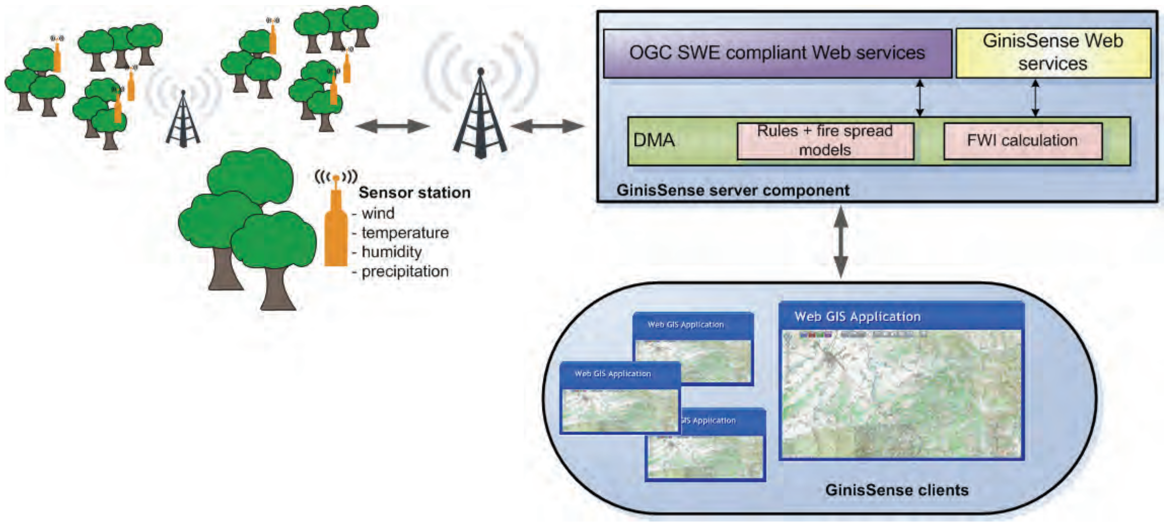

Figure 2. GINISSENSE system for monitoring of forest fires

The operator can trigger the alarm in case he notices a fire on a video, and inform fire fighters about the location of affected areas. Considering the system is intended to be used as a monitoring tool and the calculations based on FWI cannot confirm that there is fire, but only give the risk calculation of fire igniting in a forested area, cameras are the only devices that can confirm existence of fire.

GINISSENSE system has many advantages over existing similar solutions. It is based on popular technologies such as Sensor Web, Web services, XML and GIS, it uses standards for data encoding and communication and relies on sensing devices that come at relatively low cost and are very easy to install and use. The system as a whole provides large area coverage, due to sensors mobility and the possibility of wireless communication between sensing stations and the server component. However, the system cannot confirm if the fire is ignited, it can only give the calculation of the possibility for the fire to be ignited in a forested region.

V. CONCLUSION AND FURTHER WORK

Wild fires issue is increasingly present in Serbia. We have contributed to the solution of this issue, by designing and presenting a GINISSENSE system. The system relies on standards, is easy to implement and uses low cost sensing devices. Despite its sophistication, the system would cost no more than existing, less capable solutions and could reduce total operational costs by providing continual, automated analysis and monitoring. However, the system is only at its beginning and it is expected for this research to continue, evolve and overcome current shortages. Future plans include further Sensor Web exploration for applications in areas of environmental protection.

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