Forestry in situ monitoring and data management

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Abstract

The new monitoring methods play important role in conservation of Forest Management Unit of forest stand from previous production cycle and also in protection of forest mainly in case of forest fires. This paper describes solution, which is developed in integration of projects Humboldt, c@r, Earthlook, Winsoc and Geokrima.

The focus of solution is on line data collection and updating in the terrain. There is a requirement for client, which could be represented by PDA or eventually by sensors, the connection to the server. The distance between the server and the thin client may vary from a few hundred meters in case of mobile server to almost unlimited distance in case of the stationary server. The data compiled is being transferred between the client side and the server so the data transfer is rather low. The data volume in backward transfer is also very low (from client to server). There is no running application necessary on the client side except the internet browser. Possibly connected sensors and GPS (are served by applets and all the gathered data is being preceded on the server side. The thin is connected either to the stationary server or to the mobile server. The majority of the gathered geospatial data is processed on the remote application server according to the preset rules. This server will be placed in the LAN or Wan network environment. The possible communication could run trough mobile networks or trough transportable satellite receiver in car. The application server is accessing to the local or remote data sources and all the application logic is running on the server side. The data and applications must be accessed to the user via standard internet/internet connection. Interoperability is significantly extending the reuse possibilities of the information systems and so their value is increased.

Keywords: Forest communication, Mobile data management, Sensors technology, Dynamic Geovisualisation, Risk management
Introduction

The designed solution for Forestry in situ monitoring and data management is focused on forest fire protection and it is based on principles of (AMI) for forestry and agriculture and which will lead to more flexible and effective forestry management.

Forest fire can be defined as a fire which breaks out and spreads on forest and other wooded land or which breaks out on other land and spreads to forest and other wooded land. The definition of ‘forest fire’ excludes: prescribed or controlled burning, usually with the aim of reducing or eliminating the quantity of accumulated fuel on the ground. Forest fires are caused by human activities or by natural phenomena such as lightning or volcanoes. Managing forest fires effectively depends on information (that can vary according to the user of the information) the characteristics of the geographic region, and the current and evolving phase of the specific fire. Suppression planning and prioritisation of areas for surveillance requires assessment of the forest fire potential (risk and hazard mapping) in the fire-prone areas. During the crisis phase, it is necessary to know the exact position of the fire (detection), how it is developing and spreading (behavior), how it has progressed over time (monitoring), and how it is likely to develop into the future (behavior prediction). After suppression it may be necessary to examine the type and extent of damage and to plan for recovery actions (assessment, mapping, and rehabilitation).

Different phases of the combustion process can be identified. In the simplest approach they are pre-ignition, ignition, combustion and extinction. These phases are continuously occurring during a forest fire, for which the flame front is moving in space always finding new unburned fuel. There are main typology of fires can be identified according to Armonia [2] project classification: ground fires, surface fires, crown fire.

Objectives

Current fire detection systems can be classified as either predictive or supervised. Predictive systems are based on the knowledge of the environment and of its history. They are based on a database system that gives information that is used by models to predict fires in the interested area (or fire parameters as: probability of fire event, fuel consumption, fire intensity, fire description, fire area, growth area, . . ). Predictive systems in combination with geographic information systems (GIS) modeling. Use of sensors: a sensor network is developed to support measurement of parameters allowing the prediction of forest fire danger. These data have to be measured in testing areas that will be selected as areas with high potential forest fire risk identified by the above mentioned GIS methodology.

Substantial part of signaling originated from the public and even today the majority of sightings are done with human intervention. Other technological systems are based on ground sensors like video, IR or on satellite. Active forest fires can be satellite-detected by either sensing their thermal or mid-infrared signature during the day or night, or by detecting the light emitted from the forest fires at night. The sensors must also have frequent over flights with data available in near real time. The spectral, spatial, and temporal resolutions of current satellite platforms do not adequately meet the need for real-time detection of forest fires.

The use of wireless sensor networks could contribute to overcome some of the above mentioned drawbacks. Assume that a network of low-cost wireless sensors has been deployed in the fire-prone areas identified. Sensors could be also installed in fire fighting vehicles or even can be carried out by personnel involved in surveillance and extinguishing activities. Then, mobile sensor issues are relevant in the scenario.
The application of wireless sensor networks to fire detection has been proposed by different authors [4]. In fact sensor nodes capable of detecting high temperature or heat exist. It could be also possible to use other sensors (i.e. carbon monoxide) to detect physical phenomena related to the presence of a forest. The new and promised technology seems to be Smart dust sensors, which could be distributed from aircrafts during forest fire events [5], [6], [7], [8].

There is now in cooperation of three projects Winsoc, EarthLookCZ and GeoKrima designed and implanted solution, which supported:

- on line in situ monitoring on data for early forest fire detection using wireless sensor network (Winsoc)
- integration of this monitoring data with existing digital maps on the principles of GMES (EarthLookCZ)
- new methods for advanced visualisation (GeoKrima)

The realized research and development used previous mentioned experience, but introduces completely new complex methodology for monitoring. The implementation and testing is realized in European conditions, but the results could be with some potential modification transferred also to other parts of world.

**Methodology**

As it was mentioned in previous chapter, the new solution is based on new algorithms for information extraction from sensor network integration of sensors measurement with existing SDI and Earth observation data and support for their accessibility using new methods of dynamic adaptive visualisation.

**Smart dust sensors and sensors network**

The future utilization of sensors technologies in crisis management will be mainly based on "Smart Dust" which is an emerging technology made up from tiny, wireless sensors or "motes". Eventually, these devices will be smart enough to talk with other sensors yet small enough to fit on the head of a pin. Each mote is a tiny computer with a power supply, one or more sensors, and a communication system. A sensor network is defined as a computer accessible network of many, spatially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, vibration, pressure, motion or pollutants.

WINSOC introduces novel, ad hoc strategies for information extraction are presented, specifically tailored for the protocol-free type of nodes. The behavioral model of the node is presented, along with the general requirements of the implementation of the information extraction methodologies. Based on general behavioral models, the possible strategies have been presented for both the event-driven and the query driven information extraction, along with the results of simulations performed at waveform level for the effectiveness of the methodologies, also confirming the feasibility of the node design with very low duty cycles, capable of a timely delivery of the information. The problem of the delivery of the location information has been faced by providing different solutions, depending on the system requirements and constraints. [9].
Observation integration

As the critical management is starting to be still more actual according communication with GIS tools the OGC starts to release the SWE (Sensor Web Enablement) that should become a standard in integrating of variety kind of sensors into one communication language and well defined web environment. The goal of SWE is to creation of Web-based sensor networks. That is to make all sensors and repositories of sensor data discoverable, accessible and where applicable controllable via the WWW.

Dynamic adaptive visualization in forest fire protection

Forest fire protection is typical case for the geo-collaboration of heterogeneous user groups. There is possible to define very different groups varying in roles, skills and knowledge. Every group is possible to describe by ontology, list of tasks, spatial extend of authority and place of operation.

Sensors technology

To facilitate the development of smart transducers and promote its use in different control networks the IEEE 1451 standards were created. With the objective of addressing the problem of the fragmented market, they set out to specify a set of common hardware and software interfaces between the smart transducers and the control networks. The goal is to allow the separation of the transducer’s project from the choice of the control network, promoting the development of network independent transducers (IEEE, 1997). The IEEE 1451 standards were developed to address the need for a common set of interfaces between transducers and control networks. The IEEE 1451 actually represents a family of standards that work for the same goal: define a set of common interfaces for connecting transducers to microprocessor-based systems, instruments, and field networks in a network-independent fashion.

Satellite transportable VSAT systems

The VSAT offers a two-way satellite based solution enabling Broadband IP and multicasting applications. With DVB standards and extensive IP capabilities, the platform is ideal for businesses of any size requiring extremely fast downstream and upstream throughput for multimedia applications, large file delivery and rapid access to the Web. The Satellite Transportable system provides automatic satellite acquisition and alignment of mobile satellite antennas. This eliminates the need for certified technicians on-site. It is possible to attach the Transportable system to any vehicle or mobile office. Once on-site, simply push one button for broadband satellite communications. The Transportable Features are:

- Automatic satellite acquisition with a single button push
- Rapid deployment and operation on the service coverage (96cm & max 2W)
- Broadband satellite connection within less than 10 minutes

Web architecture

Web environment is built with four-tier architecture (data store including sensors measurement, map server, context service, and client) with possibilities to extend it into n-tier architecture. Adaptive map is created on client side; server side ensures context cartographic visualization process.
**Used OGC standards**

The importance of the standard procedures for communication were recognized by the Open Geospatial Consortium (OGC) which is currently addressing an extensive set of interoperability initiatives and standards (WMS, WFS, SWE) and the OGC An OGC Web Map Service (WMS) produces maps of spatially referenced data dynamically from geographic information. The OGC Web Feature Service Standard (WFS) provides an interface allowing requests for geographical features across the web using platform-independent calls. Geographical features can be seen as the source data behind a map, whereas the WMS interface or online mapping portals like Google Maps return only an image, which end-users cannot edit or spatially analyze. The XML-based geography markup language (GML) furnishes the default payload-encoding for transporting the geographic features, but other formats like shape files can also serve for transport.

A context service takes a question extended of given context from a client and on its base supplements WMS question next parameters relating mainly with symbology definition, map content etc., so with cartography visualization process. A standard Styled Layer Descriptor (SLD) is used for cartography visualization definition. A communication between the context service and the map server goes also on extended WMS question, but this extension could be standardized by the help of SLD standard. Second possibility is to have direct access to data using WFS.

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**The technological support of Forest Fire GIS solution**

**Pilots description designed by Winsoc**

Wireless sensor network that monitors a field of values, principally it could be vector of values not single value. Important aspect is also, that node could provide measurement, which is not...
directly placed in the position of sensor. On the base of physical conditions, the one phenomena could be observed through different observed parameters. (for example one node could observed smoke, other note will observed radiation. The measurement could be very strongly influenced by notice. The measurements collected by a network composed of N nodes. However, the useful signal field typically belongs to a subspace of dimension much smaller than N. The subspace is also influenced by density of nodes. In design of algorithms it is necessary taken into account question of density of nodes. From physical parameters it is clear, that with grooving distance among nodes will grow probability of noise and will decrease the number of sensors, which will be able to observed concrete event. The design of sensor networks that are able to apply some kind of filtering or smoothing to the data, in order to limit the influence of noise on the final decision has to taken into account this physical facts. Filtering operations has to be realized in a distributed way, i.e. without the presence of a sink node that has to collect all the data to apply the required filtering operation, but after final decision has to be guarantee extraction of the consensus, with detection of position of events. Here are again two facts, higher number of sinks makes information extraction simply, but on opposite side there are grooving demands of electricity consumption and also on the cost of deployment of network. Smaller numbers of sinks require support for transition of consensus about observation. The so called consensus algorithms are able to provide the globally optimal estimate with a network of only locally interacting sensors. The goal is to provide a distributed mechanism to perform a spatial smoothing of a stationary, inhomogeneous field. In practical cases the useful field presents discontinuities. So when algorithms will be implanted it is necessary taken into account not only technical requirements of WSN, but also physical parameters of measurement. For the understanding of problem, we could define three different basic tasks on the base of report D2.1 , Sensor network scenarios, services, and requirements, which will require different approaches for consensus and also topology of network: The physical characterisation of measurement could generate requirements on density of nodes, topology, but also on algorithms. Next three cases describe different examples with very different requirements on algorithms.

Predictive system with focus on risk assessment have to cover large area, where is usually necessary some global consensus. The situation leading to forest fire risk is usually given by weather conditions, and these parameters are more global. For one transducers could be measured more parameters, so there is important not only consensus between sensors, but is necessary to estimate probability of risk on the base of multicrietal decision, so there cannot be used single threshold parameter, but need to be calculate probability of risk on every sensor. The density of sensors in sensor network is more given by possible communication distance, and then by area, which could be covered by measurement of single sensor. Measurement could be local, and algorithms need to find consensus in the network. The time for convergence is not critical, time density of measurement is not critical, but probably there will be critical issue the network synchronisation. The power consumption is also not critical. For topology seems to be suitable tree topology or division of sensors into independent clusters

Sensors: soil moisture (SM)  
air humidity (AH)  
air temperature (AT)  

Winsoc node topology: equilateral triangle  

Distance among Winsoc nodes: practical HF range
Extraction of information could be on demand, or continuously in certain period (for example one or two hours) or driven by event, when on some sensor measurement rich the defined threshold and will wake up network.

Fire detection will be focused on detection of fires in first stage. So it means that the fire could be detected only by limited number of sensors. In combination with fact, that communication is not optimal, there will be high requirement on Win soc algorithms, to guarantee communication and transfer information in network and consensus of few sensors and transmission of information using Alert services. Position of sensors will be fixes and known. In central database is possible to have relation between ID of transducers and position. For detection it is necessary taken into account the physical conditions in forest. It is high possibility, that two sensors will detect forest fire using different physical parameters due for example direction of wind and visibility in forest. From this reason, we expected use simple thresholding for every parameter and consensus provided on the number of reached thresholds.

**Sensors:**
- smoke (1 sensor)
- flame sensor (4 sensors)
- infrared radiation (4 sensors)

**Winsoc node topology:**
equilateral triangle

**Distance among Winsoc nodes:**
measuring distance *1,73 (for flame, infrared sensor)

For practical implementation has to be tested dependence of distance of nodes on the consensus, etc, how many nodes will detect fire on the base of used distance of sensors. This fact will be very important for assessment of usability of technology.

The system is even driven, etc, when will be reached one threshold on one sensor.
Fire monitoring – the simple possible method for fire monitoring could be based on the fact, that will be monitor fact, that some sensor is burning, so, that it stopped communication. First level of simulation could be done only with poor transducers to monitor communication and topology of network. If the sensor will stopped communication, it could be signalisation of the movement of fire line. This fact seems to be most evident. Due the physical parameters, fact that direction of find is to the centre of the fire the measurement of temperature will not give necessary in all cases information about fire. But we expected for second experiment also measure physical parameters. The biggest problem in this case is definition of position of sensors. In real case, there will be not time deployed sensors with detection of position and current experiments with triangulation on the base of few known points don’t guarantee results.
From the previous analyse there were clear next requirements on consensus algorithm and on extraction of information:

1. To be possible provide local consensus in network or on demand or continuously in certain period or event driven. Algorithm could be based on smoothing. The extraction parameters are very important task. Location could be focused on all clusters.

2. To provide local consensus driven by event in large scale WSN for parameters detected by sensors and extract information about the localisation of event. There is necessary analyse results of report [3] and selected the right methods of information extraction.

3. To be possible provide localisation of single nodes in ad hoc distributed network on the base of knowledge of selected point around the WSN. Recommended is to design algorithm, which will propagate information about known position into the centre and then provide averaging, till consensus will be reached. Here is also necessary taken into account the quality of signal, but in forest area also interferences of signal.

Localisation in Ad hoc network on terrain
As is visible from previous analysis in design of node are in accordance with 4.1 necessary taken into account the three different groups of requirements

**SWE integration**

For integration of sensors observation with Web is used Sensor Web Enablement standard, which is now implemented as Open Source software. The software as such is able to communicate through the following services:

Sensor Observation Service - accesses sensor information (SensorML) and sensor observations (O&M)
Sensor Planning Service - tasks sensors or sensor systems
Web Notification Service asynchronous notification of sensor events (tasks, observation of phenomena)
Sensor Alert Service - handles close to real time alerting using a pub/sub paradigm
Results

Proposed approach meets up the requirements on whole system and also helps to the possibilities of reusability and extensibility of whole system in the future. Using satellite communication it could be used also in conditions of Africa. The mobile unit and integration of sensors measurement with SDI is platform for better monitoring. Currently are developed new methods of information extraction from sensors based on WINSOC algorithms [27].

Business Benefits

Most decisions in environmental risk management including forest fires are spatially relevant and based on spatial information and so support for emergency management generally is one of important roles of geospatial data management including monitoring methods. Integration of sensors with spatial data infrastructure usage during emergency situations is demanding highly flexible interactions according to situation dynamic, scope of decision making and various users’ group involved. In situ observation, data management, data analysis and visualization play an important role during emergency situations. The growing need to organize data across different disciplines and organizations and create multi-participant, decision-supported environments has resulted in the concept of spatial data infrastructures. SDI encompasses the policies, access networks and data handling facilities. Using SDI as a framework and a web-based GIS as a tool, emergency management can be facilitated by providing a better way of spatial data collection, access, management and usage.

Conclusions

The paper concentrated on analysis, approaches, and solutions fostering wider usage of data observation and visualization in forest fire protection. Naturally the fundamental item from which all processes start is existence of SDI which is not anymore only static sources of data but more and more getting new dynamic component. These aspects are closely connected with
the possibility to add to the „static“ data also those coming in real time from sensors, remote sensing sources, and other new technological equipments. Delimitation of so called critical infrastructures is one of the key steps to find appropriate solution in emergency situation. Three fundamental ones: interoperability, network, and applications: and five additional ones: open environment, system flexibility, high quality communication infrastructure, information and system interoperability, and intelligent information sparing. Visualization processes and approaches proposed and developed during c@r, Winsoc, GEOKRIMA and Earthlook projects are based on the theory and practice of context mapping. Context mapping services were elaborated and defined on the basis of fundamental research of real users requirements.

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