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DESIGN OF ADVANCED SYSTEM FOR MONITORING OF FOREST AREA AND EARLY DETECTION OF FOREST FIRES USING DRONES, CAMERA, AND WIRELESS SENSOR NETWORK

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Abstract: Forest fires can cause significant damage to human and natural resources. Early detection of forest fire can drastically reduce the consequences. Therefore, the prevention and timely dealing with forest fires becomes essential. The concept of the paper is an effort to present an automated real time early warning system as a tool to prevent forest fires, through detecting early signs of fire using drones, camera, and wireless sensor network for data collection and acquisition of those data at existing Crisis Management Information Systems (CMIS). These systems will help European CMS to implement different methodologies for initial stage warning, localization and organization of the firefighting teams and tactics to suppress the disaster.

***Keywords**: forest fire, sensor networks, information systems, wireless sensors.*

Introduction

Forest fires, also known as wild fires, are uncontrolled fires occurring in wild areas and cause significant damage to natural and human resources. Unintentional causes such as lighted cigarettes, short circuits, explosions, high temperatures can cause fires that would lead to disaster.

Most unintentional fire in this initial phase can be controlled with water, but in a more advanced phase it requires the use of a chemical retardant which is mixed with water and is spread by helicopters. It is known that in some cases fires are part of the forest ecosystem and they are important to the life cycle of indigenous habitats. Therefore, the early detection of forest fire, prevention and timely dealing with forest fires becomes essential.

The goal of the paper is to develop advanced concepts for early detection systems of forest fires that integrates sensor networks and mobile (drone) technologies for data collection and acquisition of those data at existing Crisis Management Information Systems (CMIS). The mobile (drone) technologies will allow to cover much larger areas to raise the percentage of forest fires detections in area of importance, to monitor area with high fire weather index, and to monitor areas already affected by forest fires.

In first section of the paper the design of the system for monitoring forest is described which consists of sensor networks, mobile (drone) technologies for data collection and cameras. In second section, early detection of forest fires by using drones is explained. Third section is the part in which using camera with reliable vision algorithm for smoke detection is explained which can detect forest fires early. In last part wireless sensors network is described which sense physical parameters such as the temperature, pressure, and humidity, as well as chemical parameters such as carbon monoxide, carbon dioxide, and nitrogen dioxide for early detection of forest fires.

Design of the System for Monitoring Forest Area

The system contains 12 sensors (1) with 2 routers which connect the sensors (2) (Figure 1). The sensors collect information using 4 sensors probes for following:

- Temperature
- Humidity and Pressure
- Carbon Dioxide (CO2)
- Carbon monoxide (CO)

They collect the data on specific time interval and send it via router while the rest of the time they hibernate. Each sensor uses solar power from external panel so it recharges the battery and the energy consumption on the sensors is kept low.

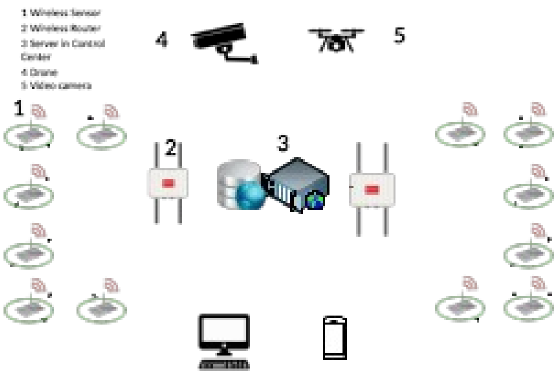

Figure 1 Design of advanced system for monitoring of forest area and early detection of forest fires using drones, camera, and wireless sensor network

The data is sent from sensor to a router using XBee-PRO Zigbee communication protocol. XBee-PRO Zigbee interface has 2.4GHz Frequency, 50mW TX power and 7000 m range. If the interface fails, the data is sent by other interface or it can be send to other sensor which will retransmit the data to the router.

The router should collect the data from the sensors using the XBee-PRO Zigbee interface and it should also have option to use different interfaces in case the main interface fails to connect and then send it to the server (3) via 3G modem. The data from each sensor is stored in PostgreSQL database. The application in the control center has the exact location of each sensor and the information it collects. If values are high there is a possibility for fire so it alarms the employees on the phone or PC. Therefore, they should check on the camera (4) or using the drone (5) for fire. The application visually shows the map with all the sensors and their values. The data from the server in the control center is also sent to Macedonian Forest Fires Information System (MKFFIS) server which is in Crisis Management Center (CMC) in Skopje via the Internet.

The use cases of the system include a user login, system parameter setting, real-time video switch, fire detection switch, interaction switch, multi-frame selection, load the geographic information system (GIS) layer, the GIS map operation, interface view shift, screenshots, reports generation and exit (Figure 2).

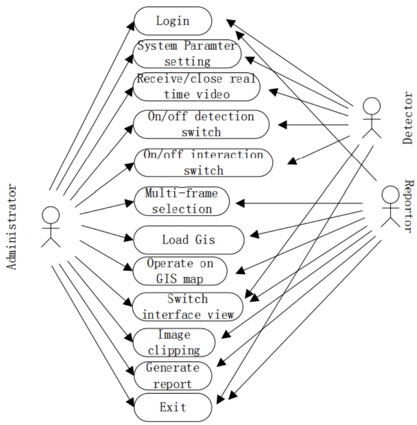

Figure 2 Software Use Case Diagram

Three kinds of users can log in and operate the software. The administrator can access all of operations. The Inspector can access system parameter setting, real-time video switch, fire detection switch, interaction switch, and interface view shift. The reporter can access multi-frame selection, load the GIS layer, GIS map operation, interface view shift, screenshots, and reports generation.

Early Detection of Forest Fires Using Drones

Use of drones to detect fire source is exceptionally significant. The low cost and ease of operating a drone means forests can be monitored far more frequently than with conventional costlier remote sensing technologies (Figure 3).

Figure 3 Drone

Areas difficult to access within a community can be more easily reached by small drones. This would be particularly useful in forest communities with low population densities and large territories. According to the telemetry data, the drone completes the situation assessment and the geographical location of the fire, and ultimately generates fire detection report for the command and control center.

The commercial drone market is increasingly targeting people with little experience flying small drones and the smallest ones are particularly easy to fly by individuals with short term training. According to previously mentioned, it would be appropriate for forest community members after receiving specific hands-on training from the manufacturer of drones to fly them. For instance, besides pre-programming flight paths and manual drone operation (flying, landing and take-off), setting up necessary components (e.g. GPS, photo/video camera) and downloading the acquired imagery onto a computer are relatively straightforward tasks. Also, the geotagged drone images acquired could be mosaicked or overlaid onto Google Earth by community members after training so that they could carry out visual analyses of their forests. Overall, training is relatively straightforward and varies from 1–5 days (in cases where trainees are familiar with computers) to 14 days (in cases where trainees have no prior experience with computers). In practice, the skills, innate ability, and motivation for these technical activities are more likely to be found amongst younger community members. [Paneque-Gálvez; McCall; Napoletano; Wich; Pin Koh, 2014]

The software shows the characteristics of high detection speed, high precision, and wide measurement range, which can effectively provide helpful guidance for the forestry sector, save manpower and material resources, and improve work efficiency.

Network communication using TCP/IP protocol, the transceiver that transfers the remote image from the drone through the network to computer, export to the protocol conversion devise, image transfer to fire monitoring software via switch, or through fiber optical fiber network are presented in Figure 4.

The software includes data receiving module, fire detection module, a video playing module, the fire source location and analysis module, GIS display module and report generation module.

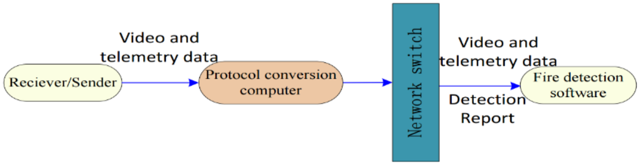

Figure 4 Software interface relationship

The information flow between the modules is shown in Figure 5. Data receiving module receives the video and telemetry data from the drone. Video play module decodes video and refreshes the display. According to the user need to call the fire detection module, to display real-time detection results from the video and to provide screenshot function the fire source location and analysis module calculate the geographic coordinate of fire source according to the test results and the telemetry data. [Zhang; Wang; Peng; Li; Lu Guo, 2015]

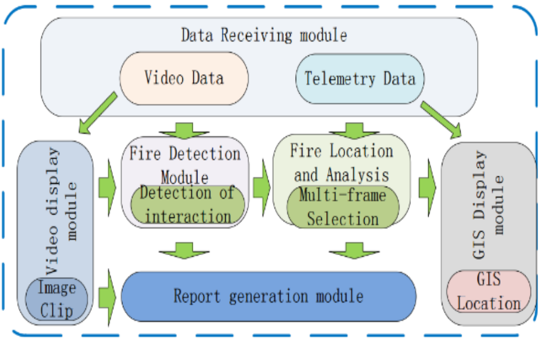

Figure 5 The Information Flow of Software Module

Early Detection of Forest Fires Using Camera

A crucial element in our approach is a reliable vision algorithm.

for smoke detection in the scenario. Numerous vision algorithms for forest fire smoke detection have been reported in the literature. All of them analyze images coming from remote cameras surveying large areas. They should deal with cloud motion, dust etc. to reduce the false alarm rate. In the system above proposed, however, the sensors watch small areas and most of the pixels of the images that are processed will therefore correspond to nearby vegetation. This means that the potential sources of false alarms are different. The movement also must be filtered is that of tree leaves, birds or even people walking around. We would also like to point out that, from a more general point of view, smoke detection is a case study in dynamic texture recognition. As a preliminary step, the image plane is divided into regular regions with a size of W×H pixels.

Figure 6 Camera stations

The processing is then focused only on the mean value of the pixels corresponding to each region. Despite its simplicity, we will demonstrate that such reduced scene representation suffices for reliable smoke detection. Moreover, this objective can be achieved very efficiently by using one of the processing primitives implemented by our smart imager. In terms of image processing, the main effect caused by smoke rising against a vegetation background is the increased luminance in the regions affected. Indeed, if RGB images are being processed, the effect would be not only the increase of each component but also their equalization [Chenm; Yin; Huang; Ye, 2006]. Going one step further, we have found that the most sensitive component to the presence of smoke in such conditions is the blue component. We have marked a zone within a scene in which the background mainly comprises vegetation. The intensity histogram of the RGB components and the luminance is then represented under two situations: without smoke and with the presence of smoke. Without smoke, most of the pixels of the B component present the lowest intensity values. When smoke appears, the RGB components and the luminance increase and equalize their intensities. Detailed graphs could be seen in [Berni; Caramona; Martínez; Rodríguez, 2012].

Early Detection of Forest Fires Using Wireless Sensors

The line of sight and the early stage of the fire process problem could be solved with the second type of sensors. A new technology called wireless sensor network (WSN) is nowadays receiving more attention and has started to be applied in forest fire detection. The wireless nodes integrate on the same printed circuit board, the sensors, the data processing, and the wireless transceiver and they all consume power from the same source. Unlike cell phones, WSN does not have the capability of periodic recharging. The sensors are capable of sensing their environment and computing data. The sensors sense physical parameters such as the temperature, pressure, and humidity, as well as chemical parameters such as carbon monoxide, carbon dioxide, and nitrogen dioxide. The sensors operate in a self-healing and self-organizing wireless networking environment. One type of wireless technology is ZigBee which is a new industrial standard based on IEEE 802.15.4. This technology emphasizes low cost battery powered application and small solar panels and is suited for low data rates and small range communications. Wireless sensor networks have seen rapid developments in many applications. This kind of technology has the potential to be applied almost everywhere therefore, the research interest in sensor networks is becoming bigger and bigger every year.

Forest fire detection and prevention are real problem faced by several countries. Different methods for monitoring the emergence of fires have been proposed. The early methods were based on manned observation towers but this technique was inefficient and not entirely effective. Subsequently, camera surveillance systems and satellite imaging technologies were tried but this also proved ineffective at being able to efficiently monitor the initial start of the surface fire. For example, camera networks can be installed in different positions in the forests but these provide only line of sight pictures and may be affected by weather conditions and/or physical obstacles.

The revolution of WSN technology in recent years has made it possible to apply this technology with a potential for early forest fire detection. These sensors need to be self-organized and follow an efficient algorithm, interfaced with other technologies or networks. Several studies have considered using WSN in wood fire systems. [Alkhatib, 2014]

Sensors integrated into structures, machinery, and the environment, coupled with the efficient delivery of sensed information, could provide tremendous benefits to society. Potential benefits include: fewer catastrophic failures, conservation of natural resources, improved manufacturing productivity, improved emergency response and enhanced homeland security.

However, barriers to the widespread use of sensors in structures and machines remain. Bundles of lead wires and fiber optic “tails” are subject to breakage and connector failures. Long wire bundles represent a significant installation and long term maintenance cost, limiting the number of sensors that may be deployed, and therefore reducing the overall quality of the data reported. Wireless sensing networks can eliminate these costs, easing installation, and eliminating connectors [Rodoaplu; Meng, 1999]. The ideal wireless sensor is networked and scalable, consumes very little power, is smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term, costs little to purchase and install, and requires no real maintenance. Battery life, sensor update rates, and size are all of major design considerations. Examples of low data rate sensors include temperature, humidity, and peak strain captured passively (Figure 7).

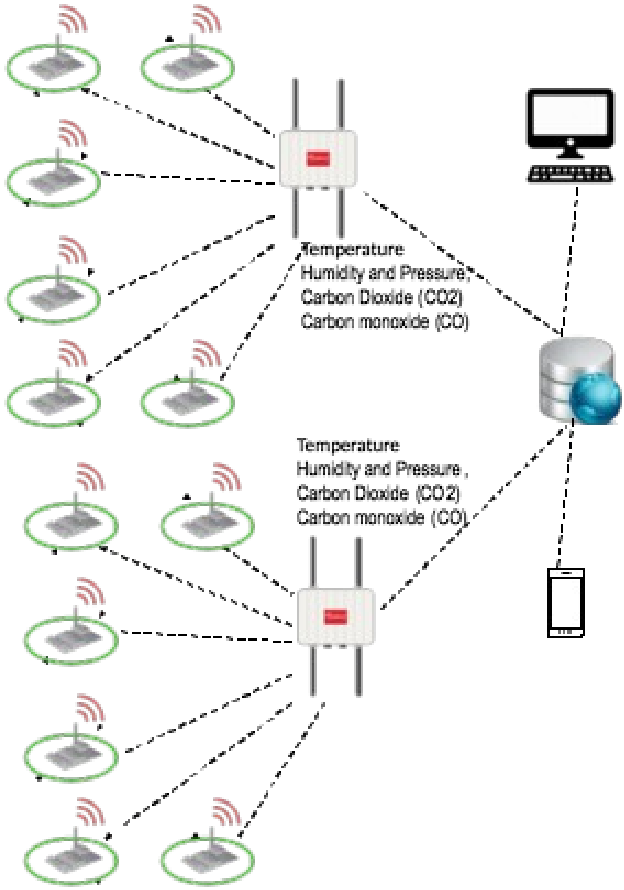

Figure 7 Basic structure of wireless sensor network

Recent advances have resulted in the ability to integrate sensors, radio communications, and digital electronics into a single integrated circuit (IC) package. This capability is enabling networks of very low cost sensors that can communicate with each other using low power wireless data routing protocols. A wireless sensor network (WSN) generally consists of a base station (or "gateway") that can communicate with several wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway [Bulusu; Heidemann; Estrin, 2000]. The transmitted data is then presented to the system by the gateway connection. Wireless Sensor Networks can offer unique benefits and versatility with respect to low-power and low cost rapid deployment for many applications, which do not need human supervision. The system architecture of the forest fire detection system is presented from the sensor node hardware in the bottom to management sub-system in the top and is evaluated in the real-deployment. [Jadhav; Deshmukh, 2012]

The design is defined as a comprehensive solution to environmental measurement, based on information gathered by a wireless sensor network, allows a detailed and centralized analysis of possible fires from starting in the area to be monitored. The main features associated with the service are:

- Capturing information (at least every 100 m2) from sensors deployed depends on the line of sight.
- Information sent through the local wireless network using ZigBee.
- Received information processing based on models of prediction and approximation algorithms.
- Presentation centralized alarms, captured data and predictions obtained from each region through a base station will be located where a park ranger will report in radio there is a fire at the time, through its expertise to handle this event.

Given that the proposed coverage area is large, we propose the use major fields of scientific research: information technology, computer science, clusters of interconnected nodes through their gateways (Figure 8). For proper operation of the network it is necessary to implement the respective mass media reception of data, key management redundancy systems, an efficient and secure management of communication protocols. [Lozano, Rodriguez, 2007]

Figure 8 Clusters of Wireless Sensor Networks proposals

Conclusion

Unintentional factors such as lighted cigarettes, short circuits, explosions, high temperatures can cause fires that would lead to disaster. Damage caused by fires to public and natural resources is intolerable and early detection and suppression of fires deem crucial.

The line of sight and the early stage of the fire process problem could be solved with the second type of sensors.

Sensors integrated into structures, machinery, and the environment, coupled with the efficient delivery of sensed information, could provide tremendous benefits to society. Potential benefits include: fewer catastrophic failures, conservation of natural resources, improved manufacturing productivity, improved emergency response and enhanced homeland security.

A crucial element in our approach are: a reliable vision algorithm for smoke detection in the scenario; the use of drones to detect fire source.

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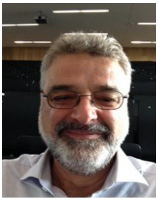

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