STUDY OF VARIOUS FOREST FIRE DETECTION SYSTEMS

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Abstract

There are numerous techniques to detect the occurrence of forest fire, developed since inception of forest fire fighting, have been summarized. All-important methods for detection of forest fires based on different principle and technology are discussed and reviewed almost all the detection techniques available in the literature. Technologies behind every detection method are elaborated. The reasons responsible for the incidents of forest fire in different forest areas are not the same. So, that applicability of a particular forest fire detection technology is not common for all cases of forest fire.

Introduction

Over the past few years, there is a tremendous increase in the count, occurrence, and severity of wildfires across the world, and is a serious threat not only to the forest wealth but also to the entire regime to life cycle also disturbing the bio-diversity and the ecology and atmosphere. Fires are a root cause of forest degradation and have wide ranging adverse ecological, economical and social impacts, including: loss of biodiversity and extinction of plants and animals, loss of wildlife habitat and depletion of wildlife, loss of natural regeneration and reduction in vegetation, global warming & increase in percentage of CO_2 in atmosphere, loss of carbon sink resource, soil erosion affecting productivity of soils and production, ozone layer depletion. There are various reasons causing forest fires including natural and anthropogenetic origin. Some of these are as: high temperatures raise the flammability of dry grass, leaves, trunks, or pine tar, strong winds speed up wildfire spreading, climate change and droughts intensify and prolong forest fire seasons, lightning provokes ignition in dry forest trees.

Forest fires can usually be divided into three categories: (a) Ground Fires (GF) -These occur in the humus and peaty layers beneath the litter of composed material on the forest floor and produce intense heat but practically no flame. (b) Surface Fires (SF): Surface fires occurring on or near the ground in the litter, ground cover, scrub and regeneration, are the most common type in all fire-prone forests countries. The spread of fire is regular and usually depends on wind speed. (c) Crown Fires (CF): These occurring in the crowns of trees, consuming foliage and usually killing the trees. Crown fires are the most dangerous fires for a forest, spread rapidly and widely. Forest fire detection has been a focus of many researchers for the last decade because of increased forest fire case reports from all over the world due to severe damage to society and the environment. Timely information about the appearance of fire can reduce the number of areas affected by this fire and thereby minimizes the costs of fire extinguishing and the damage caused in the woods. So that early detection of forest fire is very important and various technologies for this purpose proposed by many researchers[1] are as follows:

1. **Sensor Based Techniques WSN[2] (Wireless Sensor Networks System):** A WSN consists of several sensing nodes which gather information (variations of temperature, humidity, light intensity, CO_2 density, in its vicinity) from the surrounding environment and communicate with each other to send the measured data to a base station for further processing. The most important requirements to develop a WSN node are small form factor, to reduce the visual effect in the area where sensors are distributed, and low-power low-voltage (LPLV) operation. For this, an appropriate energy handling is essential to achieve a long battery life, requiring low power electronics for sensors, conditioning interfaces, microcontroller and transceiver. Furthermore, if the sensor network must cover large areas, distributing high amount of sensing nodes, inexpensive sensors are needed to achieve cost reduction.

Each WSN node comprises several parts: A microcontroller that controls and synchronizes the sensor data acquisition process, the transceiver operation and the memory access and storage, a set of sensors to measure the required parameters. In order to test the performance of several different types of sensor output codification, the nodes include sensors with analog, digital or quasi-digital (frequency-coded) output and a dipole antenna, power supply, which provides the required energy for the node components. An important issue in the design of a sensor node is the protection against environmental conditions.

2. Camera Based Techniques[3] (Image and Video Processing): Video-based fire detection systems are widely used to detect fire accidents and raise alarms automatically. One of the major advantages of video-based detection over the other techniques relying on conventional sensors is that it is able to cover much larger zones. This is particularly useful for long-range fire detection in forests and wild fields, when the possible fires might be several kilometers away from the lookout tower. The surveillance systems based on CCD cameras are often used in the detection. A charge-coupled device (CCD) is a light-sensitive integrated circuit that captures images by converting photons to electrons. A CCD sensor breaks the image elements into pixels. Each pixel is converted into an electrical charge whose intensity is related to the intensity of light captured by that pixel. CCD cameras are typically mounted on the lookout towers that are higher than the surrounding trees and buildings. When a wildfire is detected by a given CCD camera, the fire alarm is sent to the Central Monitoring Station (CMS) and the corresponding fire location is simultaneously presented. The flames of wildfire can be almost invisible from long distances. However, the rising smoke plumes generated by the fire can usually be seen in the viewing field of camera. Therefore, it would be more practical to detect the smoke plumes instead of detecting flames for the purpose of long-distance wildfire detection. The video surveillance with CCD cameras is an attractive means which is simple, cost-effective and easy. A variety of video-based smoke detection methods have been proposed in the last decades. Among these methods, several different attributes of the smoke are exploited to determine the existence of fire, e.g., smoke color, motion and shapes.

3. Neural Networks Based Techniques[4]: The computer vision methods for recognition and detection of smoke and fire, based on the still images or the video input from the cameras. Deep learning method “convection neural network” can be used to find the amount of fire. Neural networks are mathematical models that use learning algorithms inspired by the brain to store information. Since neural networks are used in machines, they are collectively called an ‘artificial neural network. Machine learning is often used in this field and is the scientific discipline that is concerned with the design and development of algorithms that allow computers to learn, based on data, such as from sensor data or databases. A major focus of machine-learning research is to automatically learn to recognize complex patterns and make intelligent decisions based on data. Hence, machine learning is closely related to fields such as statistics, data mining, pattern recognition, and artificial intelligence. Neural networks are a popular framework to perform machine learning. Similar to the brain, neural networks are built up of many neurons with many connections between them. Neural networks have been used in many applications to model the unknown relations between various parameters based on large numbers of examples.

4. Satellite Based Techniques[5]: Recently, mainly due to the large number of satellites launched and the decrease of associated costs, there are many research efforts to detect forest wildfires from satellite images. Specifically, a set of satellites were designed for Earth observation (EO). Depending on their orbit, satellites can be broadly classified into various categories, (a) the geostationary orbit (GEO), (b) the low Earth orbit (LEO), (c) the polar sun-synchronous orbit (SSO). Earth Observation satellite systems have been used successfully for wildfire detection, mainly due to their large-scale coverage. The majority of satellites providing earth imagery are either geostatic or in the near-polar sun-synchronous orbit and include multispectral imaging sensors. Sun-synchronous satellites provide data with high spatial resolution but low temporal resolution, while geostationary satellites have a high temporal resolution but low spatial resolution. More recently, advances in nanomaterials and micro-electronics technologies have allowed the use of tiny low-Earth-orbiting satellites, known as CubeSats. CubeSats have significant advantages in comparison with traditional satellites regarding smoke and fire detection, since they are more effective in terms of costs, temporal resolution/response time, and coverage. In addition, they are smaller in size than traditional satellites and need less time to be put into orbit.

5. Unmanned Aerial Vehicles UAV/ Air borne Techniques[6]: Terrestrial imaging systems can detect both flame and smoke, but in many cases, it is almost impossible to view, in a timely manner, the flames of a wildfire from a ground-based camera or a mounted camera on a forest watchtower. An unmanned aerial vehicle (UAVs) can provide a broader and more accurate perception of the fire from above, even in areas that are inaccessible or considered too dangerous for operations by firefighting crews. Either fixed or rotary-wing UAVs cover wider areas and are flexible, allowing the change of monitoring area, but they are affected by weather conditions and have limited flight time. UAVs mostly use ultra-high-resolution optical or infrared charge-coupled device (CCD) cameras to capture images as well as other sensors for navigation, such as global positioning system (GPS) receivers. In recent times, two types of UAVs, a fixed-wing drone and a rotary-wing drone equipped with optical and thermal Sensors cameras are better option for the task of forest fire detection. As soon as the fixed-wing drone detects a fire, the rotary-wing drone will fly at a much lower altitude (10 to 350 m) compared to a fixed-wing UAV (350 to 5500 m), thus having better and more detailed visibility of the area and reducing false alarms through a neural network.

6. Fuzzy Logic Based Techniques[7]: Fuzzy logic is an approach to variable processing that allows for multiple possible truth values to be processed through the same variable. Fuzzy logic attempts to solve problems with an open, imprecise spectrum of data and heuristics that makes it possible to obtain an array of accurate conclusions. Use of fuzzy logic can make real time decisions without having specific information about the event. Since this technique deals with linguistic values of the controlling variables in a natural way instead of logic variables, it is highly suitable for applications with uncertainties. The sensed data is fed to the fuzzy inference engine to infer the possibility of forest fire.

To estimate the existence of fire risks or to detect the occurrence of a wildfire incident is not a simple process that can be executed with complete accuracy due to the uncertainty in environmental data. Fuzzy logic[8] and decision-making methods such as the Analytic Hierarchy Process[9] (AHP) can be used to provide an enhancement in the real-time analysis of environmental data. Nowadays, the combination of fuzzy logic and decision-making methods, such as AHP, produces innovative solutions that may enhance the accuracy in the prevention and detection of wildfire incidents. Garcia et *al*[10] proposes a fuzzy system based on overlap indices to improve forest fire detection through implementing a wireless sensor network and analyzing different variables such as the lightness and the distance to the fire. Regarding the use of decision-making algorithms, the work includes a model of the forest fire risk through integrating fuzzy sets with AHP. In particular, it uses a decision-making method including the Geographic Information System and the fuzzy AHP method[11] to estimate the importance related to each considered causative factor in forest fires.

7. **Animals as Mobile Biological Sensors[12]:** Animals, the best and the cheapest biosensors are distributed globally, to utilize animals with sensors as Mobile Biological Sensors (MBS). The devices used in this system are native animals living in forests and sensors (thermo and radiation sensors with GPS features) that measure the temperature and transmit the location of the MBS. Selection of animals and the choice of sensors depend on either Animal Behavior Classification (ABC) or thermal detection (TD) will be applied for observation. The important criteria in selection of appropriate animals and sensors are types of forests. Ground fires is the most difficult to detect because they are undetectable until they blaze up. Generally, by the time they are detected, the forest undergrowth is already reduced to ashes, killing all the animals that live underground. For this type of forest fire, the most appropriate animals are reptiles, little voles or turtles because most of them live underground but they are slow to escape from fire because tracking slow animals and classifying their actions is problematic. The best method for detection this kind of forest fires is detection of temperature with thermal and radiation sensors. For surface Fires (SF), proper detection method is ABC. Selected animals should be fast and/or living in groups and sensors attached to those animals should have GPS features only. Thus, panicked animal groups can be easily detected and their behavior can be analyzed and, therefore, classified in fire detection. If panic continues for a long time, this may be an indication of the commencement of a fire. In case of Crown Fires (CF) many animals living in the forest should be equipped with sensors (both thermal and radiation) and many access points (GSM base stations and high voltage poles can be used for this purpose) should be set up as wide on area as possible. The use of both TD and ABC methods are applicable.

8. **Radio Acoustic-sound system[13] (RASS)**: RASS is used for measuring the atmospheric lapse rate using backscattering of radio waves from an acoustic wave front to measure the speed of sound at various heights above the ground. This is possible because the compression and rarefaction of air by an acoustic wave changes the dielectric properties, producing partial reflection of the transmitted radar signal. From the speed of sound, the temperature of the air near the Earth surface boundary layer can be computed. The system consists of two main device types: (i) Radars with fire observation tower, (ii) Acoustic sources. While acoustic sources produce sound waves with a certain frequency and a certain power level, Radar continuously scans for acoustic waves. Sound wave velocity is affected by air temperature and humidity. Radar can scan the differences in speed of acoustic waves, generated by acoustic sources, periodically measuring air temperatures immediately above the trees. Software embedded in Radar creates a thermal map of the region and stores thermal data for future use. Then the software checks for instant changes in temperature, and when sudden increases are found, establishes communication with the relevant fire watchtower and warns staff of the location.

Result and Discussion:

Selection of a suitable technology among the available numerous technologies for the detection of wildfire at a particular site depends on geographical feature, available resource. Applied technology must consider important design goals and features such as: energy efficiency, early detection and accurate localization, forecast capability and adaptive to harsh environment conditions. (Earth Observation) EO data, remote sensing (RS) techniques and computer-based technologies have been broadly applied in forest-fire monitoring, risk mapping, and in identifying the potential zones. Besides, high-resolution satellite imagery has gained importance in accurately assessing and monitoring forest fire. EO satellite sensors have been used to detect changes in the emission of energy. Moreover, a new generation of satellite sensors and Unmanned Air Vehicle (UAV) technology has brought in a superior synergy of present and future RS technology, leading to enhanced monitoring of the extent and frequency of forest fires.

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