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Full Research Paper

Animals as Mobile Biological Sensors for Forest Fire Detection

Yasar Guneri Sahin

Izmir University of Economics, Department of Software Engineering, Izmir-TR
+90 (232) 488 8173
E-mail: yasar.sahin@ieu.edu.tr

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Abstract: This paper proposes a mobile biological sensor system that can assist in early detection of forest fires one of the most dreaded natural disasters on the earth. The main idea presented in this paper is to utilize animals with sensors as Mobile Biological Sensors (MBS). The devices used in this system are animals which are native animals living in forests, sensors (thermo and radiation sensors with GPS features) that measure the temperature and transmit the location of the MBS, access points for wireless communication and a central computer system which classifies of animal actions. The system offers two different methods, firstly: access points continuously receive data about animals' location using GPS at certain time intervals and the gathered data is then classified and checked to see if there is a sudden movement (panic) of the animal groups: this method is called animal behavior classification (ABC). The second method can be defined as thermal detection (TD): the access points get the temperature values from the MBS devices and send the data to a central computer to check for instant changes in the temperatures. This system may be used for many purposes other than fire detection, namely animal tracking, poaching prevention and detecting instantaneous animal death.

Keywords: Forest fire detection; Biological sensors; Mobile sensors; Animal tracking

1. Introduction

Forest fires are the most prevalent type of disasters studied in the literature since they are relatively easy to prevent, and with the threat of global warming they are gaining increasing importance. Early detection of forest fires, containment at the beginning of the fire, and extinguishment before spreading have vital importance [1].For this reason, for many years, a large number of academic and theoretical studies and practical applications have been conducted on early detection of forest fires. Simultaneously, many environmental studies have been conducted on creatures that live in the forest habitat, especially those which are under the threat of extinction.

Although both animal studies and studies in forest fire detection have been conducted independently, both have focused on the forest environment. Combined efforts from both areas of research into a single would be very fruitful. This paper presents a proposal that addresses the idea of using classified animal tracking data and thermal data for forest fire detection, using animals as MBS. The MBS approach needs versatile devices that can be used as effective thermal sensors on animals, GPS devices, access points for a wireless network, and animals themselves.

The main objective of the MBS approach is not to create an alternative to current forest fire detection systems but to support these systems by simultaneously using sensors attached to animals.

1.1 Related Works

Since this proposal suggests the use of animals as MBS, both the use of sensors with animals and the existing forest fire detection systems have to be investigated. This section, therefore, gives some information about existing fire and animal behavior detection systems.

Animal behavior research using sensors has been carried out for some time. A great deal of scientific research has been conducted with regard to the existence and habitat of the marine and land animals. One such study has collected data about oceans. ”UC Santa Cruz researchers are using marine animals outfitted with sensors to collect oceanographic data. For example, sensors on California sea lions collect the animals' location, speed, and dive data along with ocean temperature and salinity information. The data is then transmitted to the researchers via satellite” [2,3,4]. In another study, the first effective method was based on a pyro-detector which sensed the temperature contrast between the animal’s body and the surrounding pasture [5]. There are similar studies related to animal tracking using sensors. The main idea is therefore to show the existence of many investigations into animal tracking using sensors.

There are many existing techniques used for detection of forest fires. One of the most important is described by Harden et al [6]. Their paper outlines a model which can be readily adapted for analysis of any forest, and has actually been used to examine various fire detection strategies for the Footner Forest in Northern Alberta. Some research is based on image processing techniques, capturing camera segments and processing and classifying these images for fire detection. Using image processing methods, Roy and UNEP have used a satellite for capturing images from forests and, have detected whether there is a fire possibility or not [7,8]. Another satellite application in forest fires detection is by Lafarge et al. They present a fully automated method of forest fire detection from TIR satellite images based on the random field theory where preprocessing is used to model the image as a realization of a Gaussian field. This study shows some interesting properties because the fire areas considered to be in the minority are considered as anomalies of that field [9]. Nakau et al. developed a fire detection information system from receiving AVHRR satellite to output fire detection map and validated the early detection algorithm using AVHRR satellite imagery. Forest fires were detected using an algorithm; two-dimensional histogram method by Prof. Kudo [10]. A further study presents a system called Integral Forest Fire Monitoring System (in Croatian IPNAS) [11]. Another study is computer-vision based forest fire detection and monitoring system where fixed cameras are used [12]. Furthermore, there is a great many forest fire detection studies and systems [13-16].

Research involving the use of thermal and radiation sensors for fire detection and early warning systems can also be found. In his study, Hefeeda addresses the Fire Weather Index (FWI) System, which notes that different components can be used in designing efficient fire detection systems FWI [17]. Ollero et al. have studied a scheme using multi-sensorial integrated systems for early detection of forest fires. Several information and data sources in Olleros's study were used, including infrared images, visual images, data from sensors, maps and models [18]. Casanova et al. present the MSG-SEVIRI sensor's ability to detect forest fires and subsequent fire monitoring [14]. There are a number of similar studies on fire detection using sensors.

Using animals for disaster detection is not a new idea but it has been limited to a few of disaster types such as earthquake. Yeung describes an example of observing animals' behavior for early earthquake alert, but the author gives no guaranty that his study works correctly for every earthquake [19]. Kahn suggested an idea that the best and the cheapest biosensors are already distributed globally but generally ignored: They're called animals [20]. Kahn's idea leads the scientists to start new investigations to be made on animals. An important research, which is similar to the study proposed in this paper, has been conducted by Lee et al. [21]. In their study, they offered a Bio-adhoc sensors network for early forest fire warning system for mountain areas, and they used animals as wireless adhoc nodes. However, the proposal presented in this paper is based on the usage of many access points explicitly constructed in the forests instead of an adhoc network structure. Although it may not seem to be feasible to install sufficient number of access points to cover whole forests, some critical points which are highly under the risk of fire, can be selected for the access point locations. Moreover, the usage of the access points would remove the risk of interruption of communication (network failure) that usually occurs in adhoc networks, if animals are used as wireless nodes. Furthermore, Lee et al. in their study focused on the usage of animals' behavior only for detection of fire possibilities this paper, however, focuses on using both animal behavior classification and thermal detection methods.

In this paper, a proposal for a fire detection system combining methods from both animal tracking and current fire detection systems is presented. The system proposed does not claim to detect every possible fire, and can readily be used to augment others.

1.2 Motivation

Both the previously stated methods and others which are similar in regard to animals tracking and early fire detection may be successful in their own right, but, applying these into a single homogenous system would have significant return. While scientists are tracking animals to gather information on their daily habits, such as hunting or mating, forest rangers can use the gathered data for fire detection. In addition, unifying these methods into a single system may alleviate the overall cost and economic burden on governments.

In addition, this paper offers a solution to problems stemming from using static sensors and satellites in forest fire detection. Using satellites focused only on a forest causes many extra costs and, of course it requires a satellite to exist. Using thermal and radiation sensors attached to fixed coordinates, restricts the effective detection areas and this situation therefore, requires too much sensors to be set up for a hectare of forest. In the same way, using fixed cameras with image processing techniques for detection requires multiple cameras per hectare and, these use limited to areas with full light, so it may be useless for shadowed areas, densely forests, and cliffs. Thermal cameras are unable to be used in the daytime because of heat from the sun.

These problems are needed that is a new method of setting up sensors, the use of mobile sensors. Using animals as MBS resolves the problems related to fixed sensors. The proposed system, additionally, has a classifier which built-in measures to use animal action (panic) to signal a fire alarm in situations where thermal sensors usage is inappropriate. Furthermore, this system may assist in preventing poaching, monitoring animals' death, and understanding animals' group behavior.

2. Animals as Mobile Biological Sensors

Since this study proposes the use of animals as MBS, before introducing the system, an explanation is needed about which animals and sensors may to be used for different kinds of forests.

2.1. Appropriate animals and sensors for certain kind of forest' fires

Animals and sensors should be chosen in accordance with characteristic the forest such, as climate zone, natural specifications, and density. Selection of animals which are native to the forest areas, and the choice of sensors depend on which method (TD or ABC) will be applied. The usual pattern of fire spread for a particular forest is another criterion in the selection of animals and sensors. Figure 1 shows examples of animals that can be used as MBS (these animal species can vary in accordance with the territory's specifications), and Figure 2 shows sample sensors which can be attached to animals [22-26]. The most important issue in the selection of sensors is that they must all have GPS features with both methods (TD and ABC).

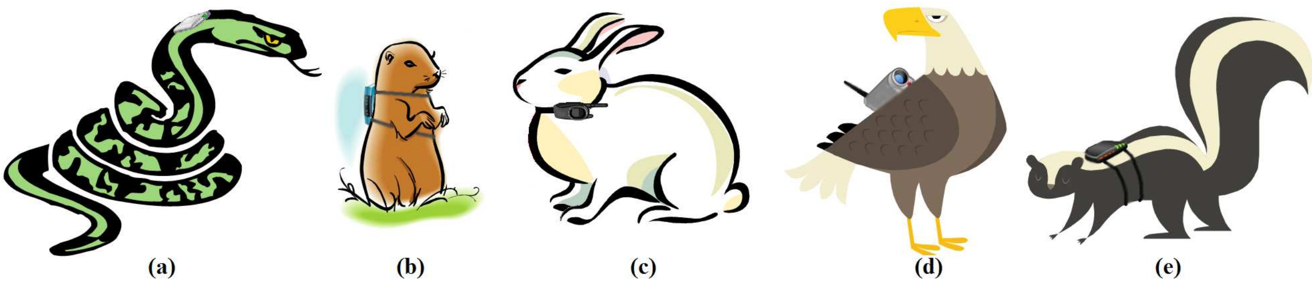

Figure 1. Some animals that can be used as MBS in the system.

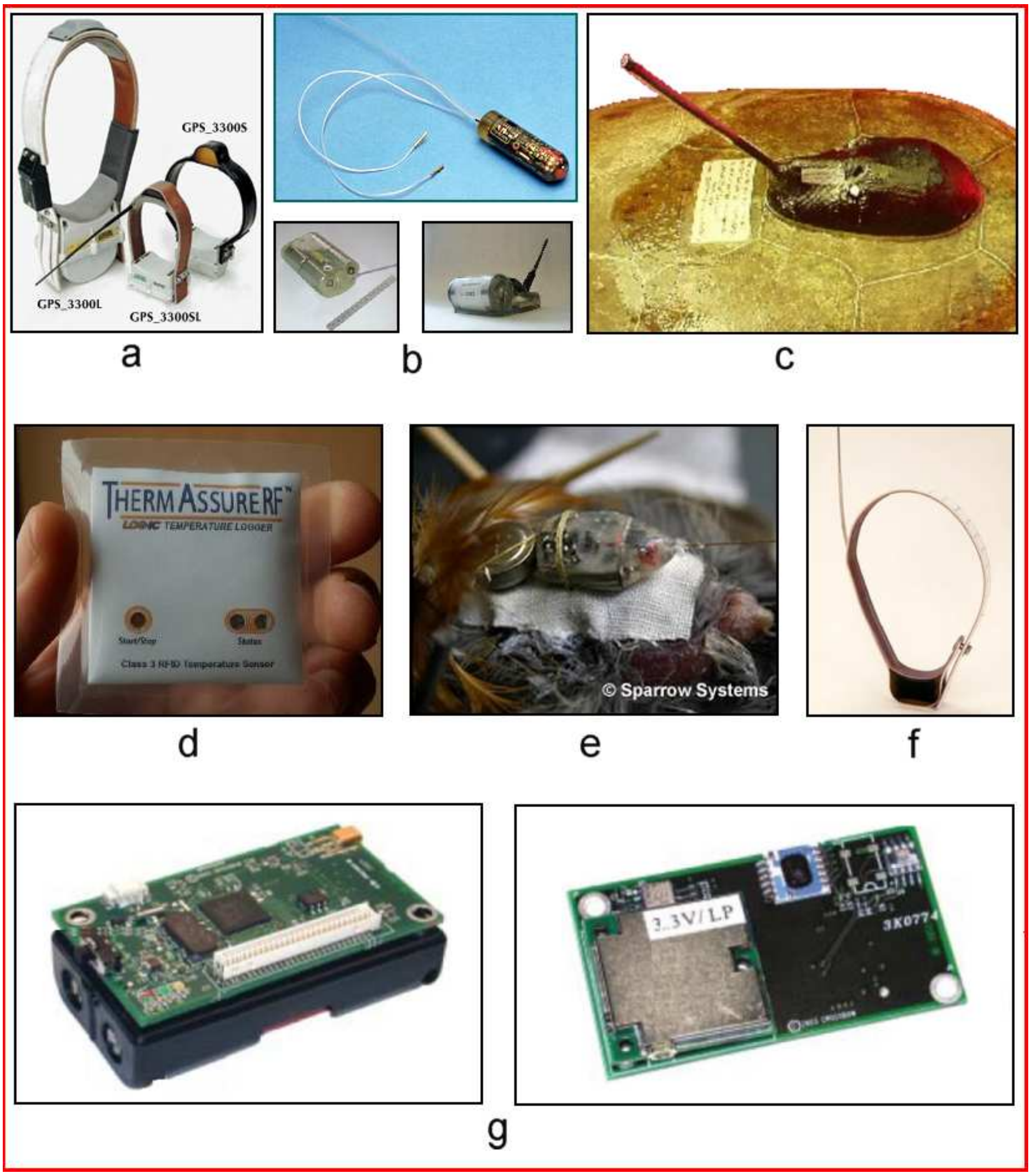

Figure 2. Sample sensors that can be used in the system [22-26].

Selection of proper sensors depends also on animal specie that will be used for the system. Figure 2 shows some samples of sensor that can be attached to the MBSs. Figure 2 (a) and (f) show collar type sensors which are usually used for mammals and large terrestrial animals, sensors in (b), (c) and (e) are used for reptiles and some naval mammals and fish, sensor in figure 2 (e) is used for avian animals, especially big insects. Figure 2 (d) shows an RF-ID tag that measures the temperature, but this sensor must be combined with other sensors having GPS feature. Installation of sensors to the animals is also shown in the figure. Figure 2 (g) shows the peripheral devices used in collars and sensors boxes. These sample sensors have different operational specifications such as battery life, weight, burst rate etc. as shown in Table 1. There are, in fact, many other sensors that can be used in the system with long life batteries and different features. If battery life of the selected sensors is short, the batteries must, therefore, be recharged periodically.

Table 1. Sample sensor specifications for the system.

Model	**Sensor Type**	**Physical Specifications**			**Estimated Life (days)**	
		Size in mm (dia x length)	Air weight g.	Water weight g.	2s between bursts	5s between bursts
Sensors for use with SRX 400A / SRX 600 radio receiver family:						
SR-M11-12	Motion	11 x 41	7.7	4.3	59	137
SR-TP11-18	Temp & Pressure	11 x 51	9.0	4.4	142	348
SR-TP11-25	Temp & Pressure	11 x 58	10	5.0	203	497
SR-PM11-25	Pressure & Motion	11 x 58	11	5.2	203	497
SR-PM16-25	Pressure & Motion	16 x 53	18	12	487	3 yr.
Sensors for use with MAP 600 MP, RT, SDL acoustic receiver family:						
MA-M11-12	Motion	11 x 42	7.9	4.0	12	29
MA-TP11-18	Temp & Pressure	11 x 54	9.1	4.7	29	72
MA-TP11-25	Temp & Pressure	11 x 61	10	5.6	41	103
MA-PM11-25	Pressure & Motion	11 x 61	11	5.8	41	102
MA-PM16-50	Pressure & Motion	16 x 81	32	17	137	340
Sensors that work with both radio and acoustic receivers:						
CH-M11-12	Motion	11 x 49	9.0	4.7	19	47
CH-TP11-18	Temp & Pressure	11 x 58	11	5.3	48	120
CH-TP11-25	Temp & Pressure	11 x 65	12	5.9	69	171
CH-PM11-25	Pressure & Motion	11 x 70	13	6.1	69	169
CH-PM16-50	Pressure & Motion	16 x 83	38	21	243	597

As previously stated, one of the important criterion in selection of appropriate animals and sensors is forest fire types. Forest fires can usually be divided into three categories as shown in figure 3. The first is 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. Such fires are relatively rare and have been recorded occasionally at high altitudes in Himalayan fir and spruce forests [7]. This kind of 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 (figure 1 a,b), or turtles because most of them live underground are slow to escape from fire. In the same way, sensors selection should be directed towards thermal and radiation sensors which have the capability to measuring as little as 1°C difference in temperature (almost all of the sensors supports this facility). The best method for this kind of forest fires is, therefore, detection of temperature with thermal and radiation sensors, because tracking slow animals and classifying their actions is problematic.

a) Ground Fires b) Surface Fires c) Crown Fires

Figure 3. Types of forest fires [7].

Another type of forest fire is 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 of the Mediterranean countries. In this type, the spread of fire is regular and usually depends on wind speed, and the proper detection method is ABC. Hence, 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.

The last type is Crown Fires (CF): occurring in the crowns of trees, consuming foliage and usually killing the trees, these fires occur most frequently in low level coniferous forests. Crown fires the most dangerous fires for a forest, spread rapidly and widely. In the possibility of this kind of fires occurring in a special territory, the use of both TD and ABC methods must be applied. 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. Because, it is uncertain as to which part of the forest is under risk by which type of fire, applying both methods simultaneously would be appropriate for all kinds of forest fires. If there is a suspicion of fire in a certain zone, this zone must immediately be monitored.

2.2. Proposed System Infrastructure

The proposed system infrastructure, regarding both TD and ABC methods, can either be simply adapted from existing animal tracking information systems, or a completely new one can be designed. A sample infrastructure is given in Figure 4.

Devices and equipment to be used in the system can vary depending on the characteristics of a forest area. However, some mandatory devices essential to the system are listed below.

1. Communication channels: To build a wireless network in a forest for fire detection, two methods can be considered. One of them is a *Satellite based system:* Using a satellite is fairly complex and requires the satellite to focus on a certain area. In spite of the high cost this system, it has some advantage and can be used for other detection methods such as image processing, that is, TD and ABC simultaneously. When a satellite connection is unavailable or problematic (for example because some points are invisible to the satellite, especially floors in closed forests, and there may be many such blind spots in a forest), the alternative is the use of *Access points.* These are used to collect thermal and movement data from sensors attached to animals (MBS), which are then sent

to the central computer. GSM base stations, high voltage poles, tall, massive trees, forest watchtowers, and poles particularly designed for forest use are possible access points. Frequency of access points depends on forest and territory specification, and type of sensors used in the system. If sensors enable long distance transmission facilities, access points can be set at 3-4 km intervals.

2. A central classifier. This device is used to classify data received from MBS via the access points, and is assisted by a decision support system. This center continuously receives data from access points and stores them in a database. Because there may be thousands of MBS in large forests, computers located in this centre must be large enough to deal with multiple transactions concurrently.
3. MBSs, which are the most important parts of the system as mentioned before, can vary in accordance with method to be used in the system. The essential activity of MBSs is to send changes in temperature or radiation level, and current location of animals to the access points.
4. Trustworthy, robust and highly sensitive sensors must be combined with suitable animals to enhance system reliability and sustainability.

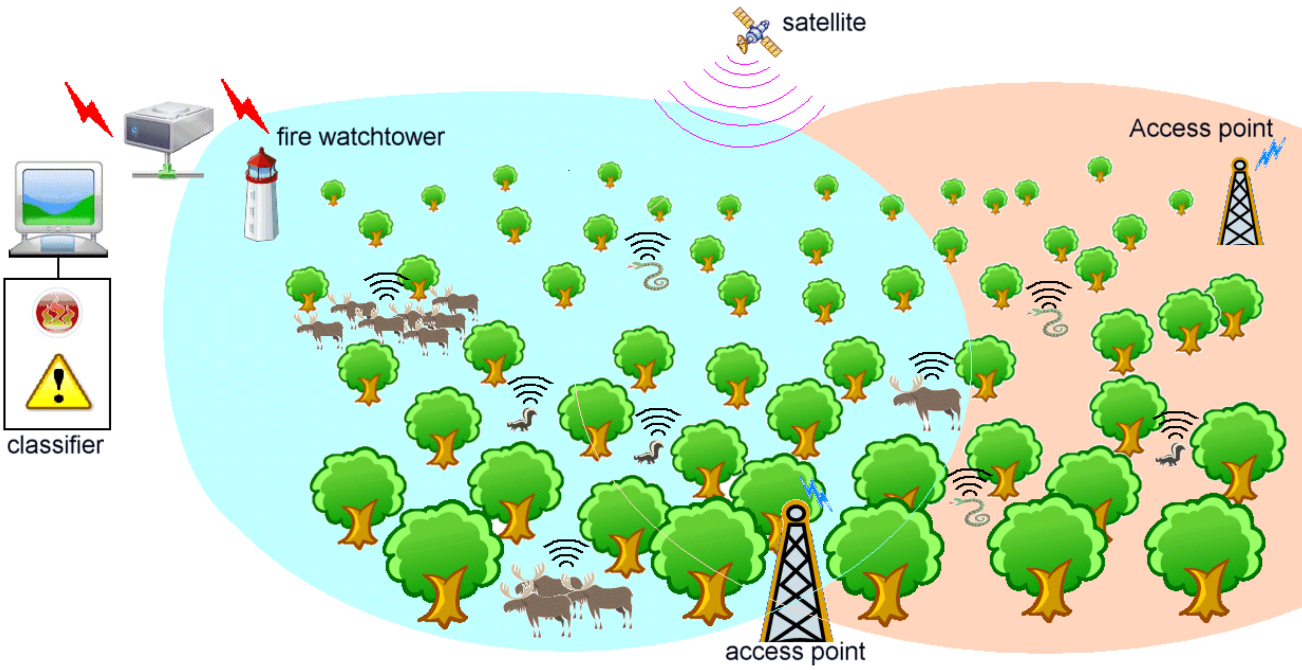

Figure 4. Forest fire detection system's infrastructure.

2.3. Fire Detection Methods in Proposed System

Depending on the type of sensors used in the system, two different detection methods can be implemented. These methods are the Thermal Detection (TD) method to measure instant temperature changes, and the Animal Behavior Classification (ABC) method to classify sudden changes in animals' behavior.

2.3.1 TD - Measuring the instant changes in temperature

TD method is essentially based on the idea that the animals (especially reptiles) know how to escape fire and they play it cool when fire sweeps through the woods. In this method, thermal and radiation data obtained from MBS is evaluated and it is determined whether a forest fire has occurred or not. All the possible constraints including seasonal temperature averages, daily temperature averages, daytime-night temperature differences, must be considered. Some coefficients are obtained from constraints, and they must also be calculated in accordance with animal type (reptile/fast/mammal/etc.), daily feeding habits, general pattern of life, and temperature differences depending on whether they are exposed to sunlight or not. For example, an instantaneous increase in temperature as a coefficient must be greater than difference between under sunlight and shade. Figure 5 shows a sample scenario for animals' escaping in case of a fire in the forest.

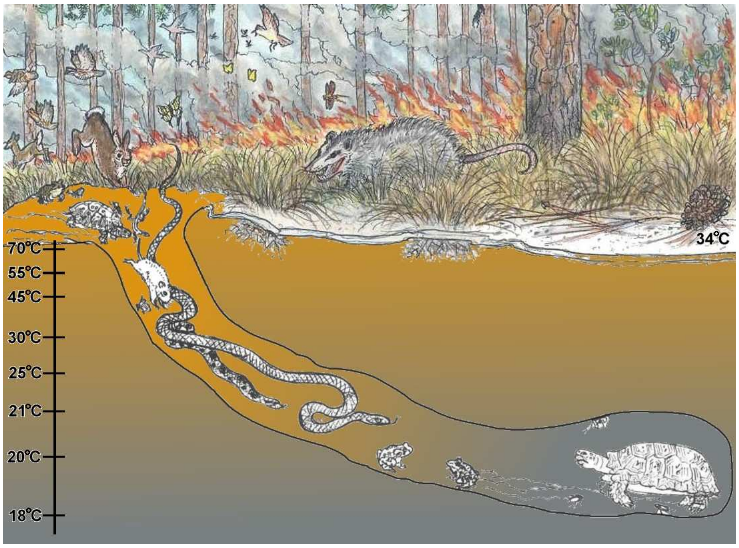

Figure 5. Animals know how to escape fire [27].

In the figure, the ground heat is approximately 70°C and the heat decreases dramatically deep dawn. The animals start to escape fire and they run try to enter to nearest burrows or any holes underground. This scenario shows that there must be a certain temperature difference among the member of animals group carrying sensors. This, intern, means that there must be a significant decrease or increase in temperature received from the same sensors for a giving period of time.

Reptiles are cold-blooded and they need to sunbathe periodically in order to keep their body temperature under control, they, therefore, move continuously from shade to sunlight and sunlight to shade. During these movements, the temperature measured by MBS may have 15 °C fluctuations, and this difference can be accepted as normal change. Therefore, critical temperature interval on a MBS may be considered as ± 15 °C. If the central computer measures a temperature difference +20 °C in certain period from a MBS, it must be tracked carefully, and if continuous changes in temperature are recorded, it indicates a potential fire outbreak on the ground. In the same way, an air temperature value received from a MBS exciding 70 °C may also be an indication of a possible fire. In both situations, the MBS which sends the data is identified, then, the current location of the MBS is determined by means of GPS device which is then checked by forest rangers.

Furthermore, in case of strong fluctuations in temperature within a short time period, this would also be an indication that MBS is panicking, thus, pointing an escape event from heat (fire) or a poacher, the location of MBS, therefore, has to be checked by rangers or others. These examples have, of course, been based on simple scenarios, but of course many statistical studies must be made before determining the critical temperature values, fluctuating interval in temperature, and so on.

Both scenarios have been simulated in SIMDL [28]. In this scenario, selections of database and decision support system don't matter. Devices and animals that have been used for the system in both scenarios are as follows:

Animals : 3 Loria Forest snakes, 2 Egyptian tortoises
Sensors : 5 SR-TP11-25 (Temperature and Pressure sensor produced by Lotek Corp)
Area : 1 acre

Figure 6 (a) and (b) show Loria Forest Snake which is a secretive, ground-dwelling species of forests and adjacent grasslands. Sightings are infrequent due to its secretive habits: the species lives amongst the confusing tangle of leaf litter, moss growth and rotting logs of the forest floor [29]. The figure (c) shows an Egyptian tortoise (Testudo kleinmanni), it is a ground-dwelling specie too and it lives amongst the grass [30]. The selection of these animals is very suitable for TD method because of their daily life habits, five of them have, therefore, been selected for simulation. Simulation results and the temperature values received from MBS for 12 minutes are plotted in Figure 7.

(a) (b) (c)

Figure 6. Suitable animals for TD method [29,30].

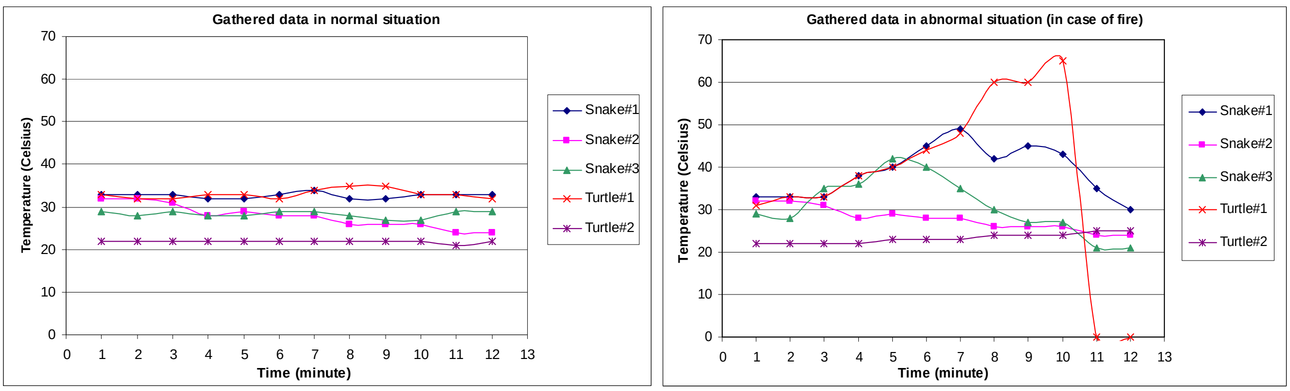

Figure 7. Data gathered from MBSs under both normal and abnormal (fire) conditions.

The diagram to the left of Figure 7 shows the temperature values received under normal conditions from MBSs, and the one to the right shows the temperature values received on the abnormal (fire) situation. In the alter, there is a 60°C value received from Turtle1 in the eighth minute, which is a signal for a problem related to excessive heat. Moreover, the figure shows significant deviations on temperature that can easily be seen between fifth and tenth minutes, and the temperature values are fluctuating for Turtle2 and Snake1-2-3 MBSs, hence, these deviations in the temperatures are possible an indication of a fire. The communication with Turtle1 has been interrupted after the tenth minute, hence, the sensor attached to Turtle1 may have been broken down or it may have run out of battery or it has been burned at the tenth minute. Thus, the location of Turtle1 must immediately be monitored against either a fire possibility or a sensor failure. Actually, a fire initiated at the fifth minute according to the scenario, and fire can possibly be detected beginning from the eighth minute, so this means there is a little delay in detection like three minutes.

This scenario is based on the usage of five MBSs for one acre. The amount of such sensors may be increased or decreased according to the type of forest and the risk of fire.

2.3.2 ABC - Classifying MBS actions

ABC method is based on the idea that the fire creates panic on the animals (especially mammals). Each mammal in a group instinctively tries to keep itself closer to others, however, in case of panic (this panic occurs especially in case of fire or blue funk), it runs away to the unpredictable directions. Thus, such observations on the behavior of animal groups can be used for classification.

Classifying MBS actions is rather more complex than TD, and highly dependant on an understanding of animals' psychological reactions to certain events. MBS panic is a relative concept and may change according to animal species so determining what constitutes MBS panic requires a well designed classification method, and may even require the application of artificial intelligence methods. This system works as follows. The access points receive the MBS locations periodically and stores these in a database. The classifier checks the database continuously to determine any abnormalities in MBSs' actions. Continuous panic in MBS shows that a problem with the animal is occurring and should be investigated.

Figure 8 shows a classification flow chart. The Coordinate Repository collects the time and location data from MBSs periodically (every minute) and stores them into the database. The classifier checks the database for MBSs' last five locations (i.e. MBS's actions in last five minutes; however, this interval can vary according to where the system is located). The classifier attempts to determine whether or not there is an abnormality in MBS action compared to learned usual behavior, using for example, an Artificial Intelligence tool. Certain deviations show abnormal behavior. Moreover, when the last 5 locations of MBS show a continuous acceleration in speed and if this acceleration occurs in a group of MBS living the same territory, this shows a potential fire in the territory and the system raises an alarm. The exact location of the fire may be captured using MBSs' initial locations after which the zone must be observed by rangers.

In order to classify behavior of MBSs, the speedy mammals living in groups should be selected i.e. deer, elks or voles. Although the minimum number of MBS for a group may change relatively, at least as much as thirty MBSs are required (because, at least thirty samples are required to make a statistical analysis).

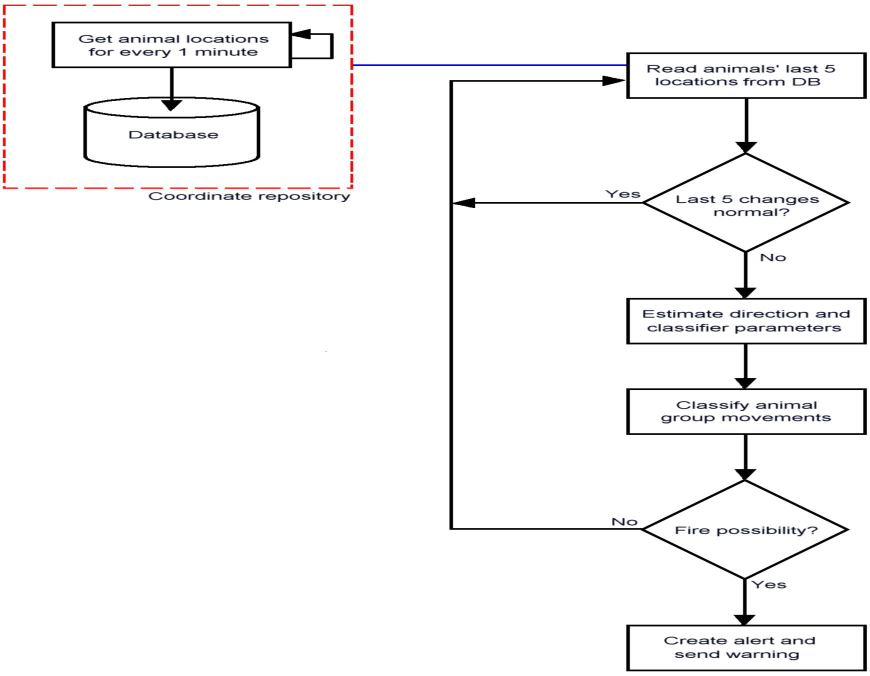

Figure 8. MBS actions classifier flowchart.

Figure 9 shows a satellite forest image indicating simulated locations of MBSs. In the figure, blue crosses show the MBS initial locations and yellow crosses show locations 5 minutes later. This figure clearly shows various locations of MBS in the zone, and their similar behavior in escaping. This is an indication of a panic, and whether the cause is a fire or a poacher, the territory must be monitored. In this simulated scenario, a fire started approximately five minutes earlier.

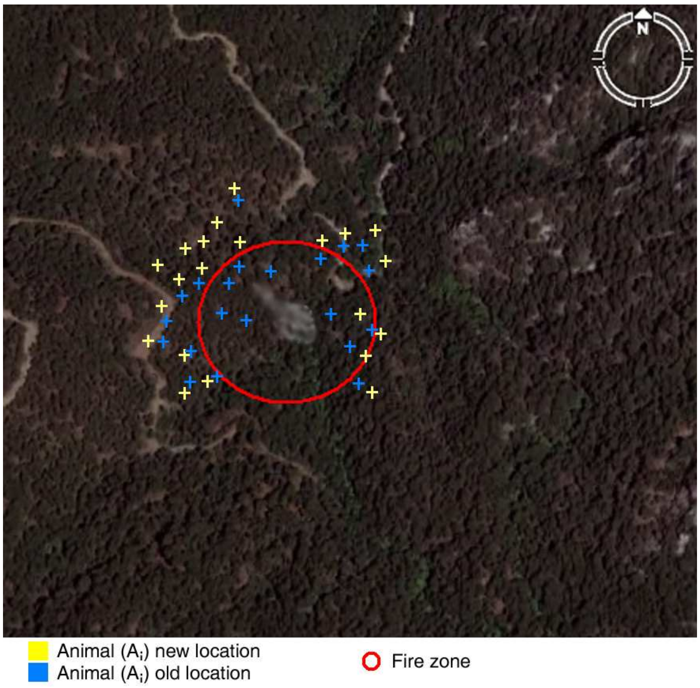

Figure 9. Monitoring animals locations via Satellite.

3. Discussion

This paper presents two different methods of fire detection (TD and ABC), using animals as Mobile Biological Sensors. In determining whether these methods can be applied to particular forest, it may be useful to look at some advantages and disadvantages of them.

Problems and Disadvantages

1. It is neither easy to capture suitable animals from the environment nor equip them with sensors.
2. Animals can be specially trained for this purpose, and while it may seem that using specially trained animals may infringe upon their freedom, in fact the lives of many animals may be saved by forest fire prevention. This needs to be made clear to society.
3. There is a possibility of lack of appropriate animals for special forests.
4. The use of batteries poses several problems. Firstly, those used in sensors may cause environmental pollution, introducing extra radiation and cadmium to the forest and animals. Moreover, each battery needs to be changed periodically, but capturing the MBS to do this is not easy. Furthermore, if the batteries operate incorrectly, the wrong data would be sent.
5. In the thermal detection method, determining constraints such as usual climate conditions, daily temp differences, seasonal normal temp values, etc. are problematic.
6. Determining the constraints using the panic detection method is more difficult than in the thermal detection method, since the selection of animals is very important. Data must be collected on animals' feeding, mating and other habits. In addition, classification of behaviour can only be made for the same type of animals, so exclusive groups of the same animal have to be used for panic detection.

Advantages

1. Proposed methods are very convenient and can easily and usefully be adapted to current forest fire detection systems.
2. Using animals as Mobile Biological Sensors enables a more dynamic and wider detection as compared to fixed sensors.
3. The fewer sensors needed means a significant reduction in cost when compared to fixed sensors.
4. Since animals can go where human can not, previously unreachable areas can now be controlled by MBSs.
5. Applying these systems will reveal more knowledge about different species of animals and their behavior.
6. The methods proposed can be adapted animal tracking systems currently in use, thus, lowering cost.
7. Classification of animals' individual and group behavior can be used for other purposes, in particular, the system may be use to detect poaching, and monitor comprehensive animal deaths.
8. If the access points are constructed as watchtowers in apertures of forest, these can be combined with rainwater collection pools, which can be made available as water supplier to helicopters involved in fire extinguishing.

If the proposed system is being considered for installation in a private forest, the advantages and disadvantages must be carefully reviewed in a feasibility study, and the decision should be made accordingly. While minimum number of animals which may be used in the system depends on the forest structure and the method, at least 30 mammals for ABC and 25 reptiles for TD methods should be used for each hectare.

4. Conclusion and Future Works

In this paper, a method which uses animals as mobile biological sensors, has been presented. The proposed method is based on existing animals tracking systems used for zoological studies. Hence, combining these fields may contribute to developments in both animal tracking and forest fire detection simultaneously. Furthermore, combination of two different braches of research into a single system means low cost and more efficiency. The system presented in this paper can be implemented for all kinds of forest fires and can be executed in every natural environment using many different animal species. This system could detect potentially serious forest fires early, reducing their effect, thus helping to reduce the speed of global warming. Since the system presented in this paper has not actually been implemented in any forest, some additional unforeseen disadvantages may occur, however the advantages suggest it could have implemented with considerable environmental benefits. To improve the system, the following could be carried out based on the proposed methods;

1. A number of investigations can be made regarding animal behavior in case of fire to improve system reliability.
2. A reorganization of classification algorithms to be used for animals' panic detection, could be developed for classification of MBSs.
3. New sensors can be produced or existing sensors can be improved to increase robustness of the proposed system.
4. New wireless technologies and new satellite tracking systems can be adapted to increase the efficiency of the system.
5. Some studies on fire extinguishing such as using CO_2 bombs at the access points for fire spread prevention, can be made.

In summary, forests on the Earth are vanishing rapidly due to fire, and global warming and oxygen levels are also becoming more critical for all living things. This paper aims to present an alternative way to detect fire in its early stages, which seems both effective and economic to use.

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