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# Line Implementation of a Mobile Application to Control Forest Fires near Residential Areas Using an Artificial Neural Network

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**Abstract**

The following article exposes the design and implementation of a mobile application to detect and control forest fires, developed for the iOS platform; where the Bogotá's bordering forest areas are monitored through a series of weather stations, which capture climate data such as relative humidity, air temperature and wind speed along with their location, sending said information in real time to the user through an REST API service. The system works together with an artificial neural network (ANN) that processes the station's meteorological data and allows determining the probability of existence of a forest fire, since in many cases the sensors can detect false alarms; improving accuracy when reporting a possible emergency, considering that the accuracy index that the artificial neural network showed is quite high (93.67%), thus reducing reaction times and alerting the control organisms in a timely manner.

**Keywords**: Mobile application, Bogotá, Weather station, Forest Fire, Artificial neural network, REST API

## 1. Introduction

The District Commission for the Prevention and Mitigation of Forest Fires (CPMFF), had been developing since 2005, the Emergency Plan for Forest Fires in Bogotá city, which was updated whenever it was considered necessary, the last one being approved in 2008. However, The District System for the Prevention and Attention of Emergencies has a new vision of the problem, establishing a structure of District Operational Plan for the Emergency Response, in which the city has a single Emergency Plan composed of contingency plans by phenomena [1]. In accordance with the Forest Fire Emergency plan, there is no solution implemented that allows a conflagration to be alerted in a timely manner by means of detection devices or systems, and due to the drastic change in the city's climate. The events in the Eastern hills in the city of Bogotá have put on red alert the emergency agencies at the beginning of February 2016 [2], the annual management records of the CPMFF indicate that between 2005 and 2016, 181 events were presented, which consumed 1,395.04 ha. of vegetation [4]. According to the Ministry of Environment, Housing and Territorial Development: "The presence of forest fires in areas close to human settlements can cause the loss or affectation of homes, machinery, infrastructure and equipment, as well as of soils, crops, domestic animals, etc., and the deterioration of the quality of life, by destruction or landscape variation." [3]. So, it is necessary to propose a system that gives direct and timely warning to the entities in charge of dealing with emergencies in a way that streamlines the process and avoids consequences not only for the ecosystem but also for the nearby population.

## 2. Backgrounds

*Prediction and Detection of Forest Fires using Artificial Neural Networks (ANN):* Among the studies that make use of technological tools, there is a detection system composed of a Wireless Sensor Network (WSN) that works together with an ANN in order to predict possible forest fires in wooded areas and dense vegetation [5]. The system works by deploying a network of sensors on the area to be protected with which data is obtained on the evolution of environmental variables related to the risk of forest fires, such as temperature, humidity, level of precipitation and wind speed among others. The precise and continuous monitoring of these variables allows: 1. Estimate the risk of fire at each point in the area of interest. 2. Detect a fire source early. 3. Further examine the possible causes of the fire. In Bogotá city, a work was carried out using a fire and propagation simulator based on the discrete representation of the selected areas, where the fire propagation speed depends on variables associated with locative and climatological characteristics. Considering a discrete classification based on the propagation in each direction, the results show propagation patterns that are quite close with the last real events of forest fires in the region [6].

*Detection from Infrared and Optical Cameras:* A quite efficient method is presented by students of the Lebanese University where a modeling method is exposed, built on the technique of data analysis using an artificial neural network, with the aim of predicting and avoiding a forest fire. It can also be used as a potential guide or basis for decision making, particularly in the prevention of disasters and their undesirable consequences. The artificial neural network is programmed to learn how to filter data repeatedly [7], alerting in real time and offering advantages such as: 1. Exact location of the heat source. 2. Avoid false alarms. 3. Improvement of night vision in front of the one made by a guard. 4. Produces a deterrent effect. 5. It contributes to the decision making in the extinction.

*Using Mobile Applications:* Currently there is an application that allows registering if there is an emergency from any mobile device (iOS and Android) in which any citizen can report not only forest fires but also a threat of any kind, such as earthquakes, tsunamis, fires, tornadoes, etc. The application information is built through the reports made together by users, in the same way that an emergency network works. Although it is a useful tool it has the disadvantage of generating possible false emergencies, since users can register events at any time without any restriction; allowing the user to give reports of a nonexistent situation [8].

*Real-time Detection using Wireless Sensor Networks:* A framework for forest fires detection and monitoring as an application area for wireless sensor networks can be described as a set of elements that gather temperature information in different points of forest which are transmitted to a control center, generally located in the emergency agencies facilities. To detect fire threats efficiently you must have an efficient means of communication, such as Wi-Fi. The energy consumption by the sensor nodes and the physical conditions that may hinder the network activity should also be considered; for this, a cycle of suspension and surveillance is commonly designed, increasing the sensor network useful life [9].

## 3. Analysis and Development

The architectural pattern Model-View-Presenter was established, where the presenter assumes the intermediary functionality between Frontend interfaces and all the Backend logic. Since the system main objective is focused on users that use mobile devices with iOS platform, the Apple's Xcode development tool was used, along with the Swift 3.0 development language, and finally a non-relational database provided by Google Firebase Realtime Database product, which is responsible for storing and synchronizing the data delivered by weather stations through an REST API service supplied by Weather Underground [18] in real time. The detection network basic topology is mainly composed of TX / RX type system such as Wi-Fi, mobile telephony, and communication through the TCP / IP protocol suite, specifically IEEE 802.11.

To define a work frame according to the analysis, CASE tools (Computer Aided Software Engineering) were used together with the requirements, describing the system behavior and adjusting to the expected functionalities. The system architecture is composed of 3 main elements: 1. The weather station, located in the surveillance zone connected to the mobile application through the internet. 2. A database using Google Firebase services, which stores and synchronizes the information collected by the station in a NoSQL database hosted in the cloud. Data is synchronized with all customers in real time and remains available when the app is offline [16], and 3. The mobile application that shows three different views; first, a map of the surveillance zone with the different meteorological stations connected, the current status of each one and a detection range; in the second one the list of connected stations is shown and in the last one a list with the history of each station and the moment in which a considerable change was detected that could generate an emergency.

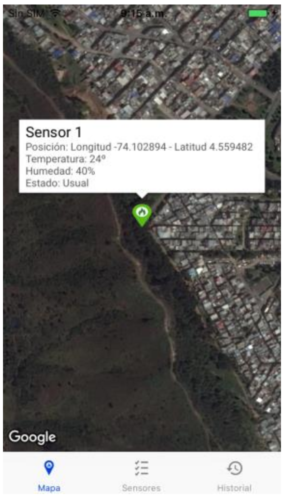


Figure 1. Application initial view that shows the information of a weather station using Weather Underground (iPhone 5S). Source: Authors

To implement a forest fire detection network in Bogotá, considering the costs, maintainability and development, the fire network design based on La Crosse Professional's weather stations connected through Wi-Fi was chosen and a REST API service provided by Weather Underground, sending the data through a POST request in JSON format carrying all the information collected by the station; users can also register their own weather station by accessing the Weather Underground web portal [18], and thus access the information of this station through the API offered by this tool, being registered in the FireGO mobile application, where it can be seen on the map and show the climatic data of the area that you want to monitor. *Artificial neural networks or ANN* The mobile application works together with an artificial neural network, improving the data accuracy thrown by the meteorological station and defining a threshold that determines in what conditions it is most likely to occur an emergency, considering three variables that are keys in the generation of forest fires: Temperature (°C), Relative Humidity (%) and Wind Speed (km/h) and finally a variable that indicates whether or not there was a fire. To build the artificial neural network, 517 repository records were taken (captured to make regressions to the north of Portugal in 2007) [12] and entered randomly, then the database was delimited where the 70 % of the records were used for training the network and the other 30% for training validation.

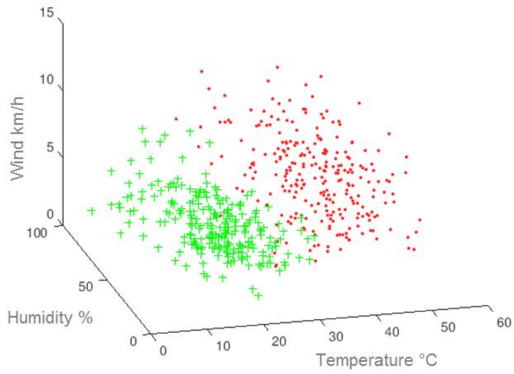


Figure 2. Sample field of information corresponding to the training database (Green: No presence of fire, Red: Presence of fire). Source: Authors

Afterwards a three-dimensional graphic was created with the MATLAB tool [15], where the whole records of the database obtained from the Machine Learning UCI repository were located [14]. The variables collected by meteorological stations are used as input variables for the artificial neural network, with a hidden layer in turn composed of a topology [3, 6, 3] and an activation logsig function, defined by the equation ($a = \frac{1}{1+e^{-n}}$) which gives a value between 0 and 1. The results obtained showed a sensitivity (ability of the estimator to give as positive cases) index of 94.87%, a specificity (the proportion of cases where there was no fire correctly identified) of 93.51%, an accuracy (indicates the proportion of true values) of 94.19% and a precision (dispersion ratio between the ANN values with respect to the real value) of 93.67%, which generates enough reliability when determining a fire probability. Finally, the validation set was incorporated into the neural network to verify that it has learned and not memorized the data different combinations. Again, sensitivity indexes of 96.05%, specificity of 94.94%, accuracy of 95.48% and precision of 94.81% were obtained. This provide an idea of the possible results that can be obtained when entering the data captured by the weather station's sensors, preventing them from throwing false alarms and improving the accuracy when identifying a possible conflagration.

## 4. Results Discussion

The protection of wildlife and population with the greatest priority, so when it comes to detecting and combating a forest fire, the most important thing is its response time, considerably reducing the damage it can cause almost in its entirety. A red node-based detection usually has a response time of $0.25\mu s$ (microseconds) [9]. The weather station presented in this article has a Wi-Fi transmission range of 80 feet (outdoor) and RF (radio frequency) of 2.4GHz [12]. In the District Emergency Response Protocol the telephone calls to emergency network 123 is mentioned as the only way of Alert [1], with an approximate response time between 12 and 30 minutes. The network of meteorological stations is considered as the best option since the installation of this doesn’t involve a considerable time and facilitates maintainability [10], each node has only one station connected to the network independently and can be replaced if this requires it, as does each component of the network, offering the system the possibility of improvement and extension in the future. The proposed methodology has been applied in eight fires in Buenos Aires, in the 2009-13 period. An emergency of the latest series of conflagrations: the fire of La Sierra de Lujar in Argentina, affected the public forest and private lands [5], which was declared on August 18 and was extinguished on August 22, covering an area of 1290 ha. The magnitude of the damage to vegetation, per the categories defined, resulted in the detection network being the best option when attacking and / or preventing an extreme emergency over vegetation and woodland compared to other systems implemented. Although there are currently no implementations of detection networks in the study area, the climatic conditions of the Sierra and those of Bogotá are very similar at sometimes of the year, which is why it is considered a good application model for the network that was designed in this document, considering that the results obtained in the Investigation of Detection Networks showed an accuracy of 70% in conjunction with the neural network [5]. However, it is known that any device that captures climate data in real time is highly prone to sending erroneous information or reporting false alarms, such problems are mitigated in the great majority thanks to the neural network, as shown in the work done on La Devesa de la Albufera in Valencia, Spain, with the implementation of an artificial neural network, it is possible to optimize the current system based on temperature and infrared cameras, decreasing false alarms by 36% [15], despite the fact that climate and the conditions of the terrain are quite different from those of the city of Bogotá, the result of the network does not change since the objective is the same, to work hand in hand with a detection and prevention system improving the integrated sensors precision, the which will correctly report the existence of fire, thanks to the fact that the artificial neural network implemented obtained very precise indexes (95.48% accuracy) at the time of determining if there is a fire or not.

## 5. Conclusions

The fire detection and prevention network in conjunction with the mobile application is a simple tool that greatly facilitates the task of controlling a fire when it goes out of control, even preventing it from happening; considering that the causes of forest fires in our country are only 5% caused by environmental factors, while in 95% they are of anthropic origin; due to negligence and ignorance of the human being [19], where not only the control organisms are benefited but also the population, which resides near forested areas (San Carlos Forest, San Cristóbal Sur, Bogotá) and awareness for preservation environment. The net costs of the network exposed in this document are not the highest compared to other common control systems (Geographic Information Systems, Image Recognition Systems, Camera and Satellite Monitoring Systems), its main advantage being the time of the implementation, offering the possibility of expansion since you can add as many stations as you wish and the application will show the information of each one of them in real time and the neural network will determine the probabilities of fire depending on the information that is supply in case of a considerable change in climatic factors. With the results shown by the joint work between a detection system and a neural network in the Devesa de la Albufera in Spain, improving accuracy by 64% [15], the installation of an artificial neural network can greatly help to reduce efforts of emergency teams (firefighters), reducing reaction times and avoiding major disasters such as occurred at the beginning of 2016 in the city of Bogotá, which in turn reduces costs as consequences if the conflagration caused material damage (destruction of heritage, forests of structures) and preventing them from happening again.

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