KnE Engineering
ICEUBI2019
International Congress on Engineering — Engineering for Evolution
Volume 2020

Knowledge E
enriching | engaging | empowering

Conference Paper

Proposal of an Iot Solution to Fire Risk Assessment Problem

Ana Bernardo, Pedro Silva, and Paulo Fazendeiro

Universidade da Beira Interior, departamento de Informática

Abstract

Several of the fighting weaknesses evidenced by the forest fires tragedies of the last years are rooted in the disconnection between the current technical/scientific resources and the availability of the resulting information to operational agents on the ground. In order to be effective, a pre-emptive response to similar disasters must include the articulation between local authorities at municipal level - in prevention, preparedness and initial response - and the common citizen who is on the field, resides there, and has a deeper knowledge about the field of operation. This work intends to take a first step in the development of a tool that can serve to improve the civic awareness of all and to support the decision-making of the competent authorities.

Keywords: Internet of things, Citizen science, Fire weather index

Corresponding Author:
Ana Bernardo
bernardo.catarina32@gmail.com

Received: 26 November 2019
Accepted: 13 May 2020
Published: 2 June 2020

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ICEUBI2019 Conference Committee.

1. Introduction

Human intervention can play a decisive role in preventing forest fires by combating their origin and limiting their development. The main variables constraining the spread of a fire are related with weather conditions - such as wind direction and intensity, relative humidity, temperature, degree of dryness and type of mulch - as well as with factors related to terrain orography, accessibility to fire site, time for intervention (time between alert and first intervention in fire attack, commonly referred to as initial attack). Planning according to terrain characteristics and knowledge of the real-time risk index can facilitate preventative measures as well as the fight against active fires, thus reducing damage to people and nature.

In this work we report the development of a solution based on IoT (Internet of Things), following an approach based on Citizen Science. We elaborate on the mobile approach proposed in [1] by further enhancing the supporting platform as well as by developing from inception an IoT device specialized in the fire risk assessment and rural fire detection. The main objective is to empower the end user with the ability to collect weather and environmental data (using a smartphone or a dedicated device) that can be used to calculate the fire risk index in real-time and with higher granularity than the

How to cite this article: Ana Bernardo, Pedro Silva, and Paulo Fazendeiro, (2020), "Proposal of an Iot Solution to Fire Risk Assessment Problem" in *International Congress on Engineering — Engineering for Evolution*, KnE Engineering, pages 670–679. DOI 10.18502/keg.v5i6.7088

one that is offered by traditional platforms. We hope this contribution can be used in the near future as a tool for decision-making by the relevant fire authorities, enabling better forest fire prevention and response.

2. Background

2.1. Citizen Science

Citizen Science [2] is a science based on the voluntary, conscious and informed participation of various citizens, who generate, analyze large amounts of data, share their knowledge and results with scientists and other individuals with a purpose of social utility. The practice of involving the public in data collection and analysis is not recent. One of the first reported initiatives took place in 1900 through selective bird counting [3] with the participation of 27 people (in the 109th edition a total of 59,813 observers was involved). Since then several projects have been carried out involving the public in data collection and decision making in management, environmental protection, natural resources management, etc.

Nowadays, the area of citizen science has been widening increasingly due to the increasing wide availability of scientific devices and due to the advances in telecommunications and the Internet. Mobile phones have been used for such projects as a means of collecting data (directly through their increasingly sophisticated sensor array) or recording scientific (typically cost-effective) readings, enabling the general public to participate in research and contribute to scientific knowledge.

2.2. Internet of Things

Internet of things (IoT) concerns the digital interconnection of objects over the Internet. These objects refer to everyday products, as well as cars, lamps, refrigerators, smartwatches, among others. By integrating multiple sensors into these objects, capable of collecting diverse data over time, and connecting them to the Internet allows the creation of cognitive environments that can meet the needs of a user in a more individual way and, on the other hand, enables the prediction of events in advance, such as a car accident, a heart attack, or even a forest fire. Thus, through IoT it is possible to aggregate huge volumes of data that can be analyzed in order to make better decisions, improve performance and even generate profit [4]. When properly scaled up IoT can potentially reduce a city's traffic and energy consumption while increasing its safety and efficiency.

Although still a growing area, there are current projects that rely on the setup of a wireless sensor network for fire prevention and detection (e.g.[5-7]). The IT for Nature SmokeD device [8] consists of a fire detector equipped with multiple sensors and a microcomputer. In addition, it has a camera responsible for capturing images of the area to be protected, which will later be analyzed for smoke detection by artificial intelligence. The data after being analyzed by the microcomputer is transmitted to the cloud server where it can be consulted by the user. Insight Robotics InsightFD device [9] focuses on fire detection through real-time image analysis using artificial intelligence. It combines optical and infrared sensors with machine learning algorithms and is one of the preferred systems for detecting fire in national parks and forests in Europe, America and Asia.

Like both examples presented, the vast majority of solutions on the market represent high precision devices, targeting large organizations and governments, and are not as accessible to the vast majority of smaller customers due to the high cost of the services presented.

2.3. Fire Weather Index

The Weather Index (FWI) [10] was created by the Canadian Forest System Service and is being used by several countries around the world, notably Portugal. The calculation of this index takes into account the values observed at 12 hours UTC (Universal Coordinated Time) of air temperature, wind speed, relative humidity and precipitation over the last 24 hours. This index is cumulative, i.e. it is based on data recorded on that day as well as observed data from the previous day. It is organized into 5 risk classes: low, moderate, high, very high and maximum. For the calculation of FWI the following components are taken into consideration:

- Fine Fuel Moisture Index (FFMC): classifies fast drying dead fine fuels by their moisture content;
- Initial Propagation Index (ISI): Indicates the value of the initial evolution of a fire. This value is influenced by FFMC and wind intensity.
- Drought Index (DC): Contains the amount of moisture in combustible materials that is 8 to 20 centimeters below the ground. This is calculated by precipitation over the last 24 hours, temperature, humidity and the day before humus index.
- Humus Index (DMC): corresponds to the numerical value of moisture in forest fuels (humus and large materials) up to about 8 cm deep. It is calculated from

the values of the rainfall that occurred during these 24 hours, the air temperature and the DC value of the previous day.

- Available Fuel Index (BUI): presents the evaluation factor of the total fuels that can feed a fire, it depends on DC and DMC.

The final index FWI is calculated from the ISI and BUI subindexes. This rural fire hazard index combines the values of the average moisture content of the ground fuel and the fuel available for combustion and the intensity of the frontal fire with the effects of wind (fire spread rate). Increasing any of these factors increases the danger of a putative fire.

2.4. Related Work

During the development of this work, some projects related to the theme of fires were analyzed as well as mobile applications alluding to the subject of citizen science. In the following we briefly introduce the ones that, in some regards, have been inspirational in the development of our prototype. The Fogos.pt application, shows all active forestry fire occurrences in mainland Portugal detailing information about the state of occurrence, the number of firefighters, land vehicles and aerial means in the place. The Windy.com website has a number of important weather data. Provides interactive weather forecasting services worldwide. Different types of data can be viewed across the map from anywhere in the world with the possibility to see extended data forecast up to 10 days.

The Agropolis Foundation PlantNet application (https://identify.plantnet.org/), alluding to citizen science, allows you to collect data, make notes and search images to help plant identification. This application also contains an automatic plant identification system from photos compared to images from a botanical database. The Picture Post platform allows users to capture images that will later be stored in a database for analysis and to measure vegetation change over time. Photos are dated, geotagged, uploaded, and shared on site (https://picturepost.unh.edu/).

3. IoT for Climate Data Collection

3.1. Introduction

With regard to forest fires, an IoT based solution has the potential to be one of the most effective regarding fire prevention, detection and management, helping to reduce the number of fire incidents. By collecting and analyzing data such as air temperature, humidity and wind direction and speed, from forests, shrubs and other areas of high vegetative volume. It allows not only the prediction and detection of fires, but also the triggering of other actions, such as alerting and providing data to authorities, as well as notifying civilians in the vicinity of the fire. The IoT device will be able to calculate the FWI Fire Risk Index in one place (fixed or mobile) and the combination of data collected from other devices connected to the same platform will contribute to a better perception by decision makers of the actual risk in the territory of interest. In addition by complementing the functionality of the device with the ability to detect new fire outbreaks allows more effective combat contributing to lessen human and material losses.

3.2. System Architecture and Design

The developed system will be able to alert authorities and citizens to the risk of fire in a given area, using cloud technologies for data storage and various sensors for collecting data on the surrounding environment. With respect to data collection, it should be able to obtain data on ambient temperature and humidity, wind direction and speed, precipitation intensity and infrared flame detection. Once data has been collected, it should be stored in the cloud to be accessible to all other users and devices connected to the Internet (with their respective privileges). The fact that several devices are interconnected allows not only the collection of large data, but also the sharing of these with other devices of different natures, such as warning and prevention devices.

Thus, the technology used in the construction of this prototype was as follows:

- Raspberry Pi 3 B processing unit, with 4-core, 1.4GHz, 64-bit processor and wireless LAN connection.
- DHT11 temperature and humidity sensor due to its small size, low cost and data gathering sufficient accuracy.
- A module with an infrared sensor, with the capability of directional flame detection.
- A web platform for complementary collection of other weather data (e.g. wind speed and direction and rainfall intensity). In the developed prototype was used Dark Sky API [11] able to return a large amount of data (in JSON format).
- Firebase Realtime Database storage [12] for real-time storage and management of data, making it available to other users securely.

Different technological alternatives have been considered which, although not implemented in the present prototype, may in the future be easily incorporated into the modular structure shown in Fig.1.

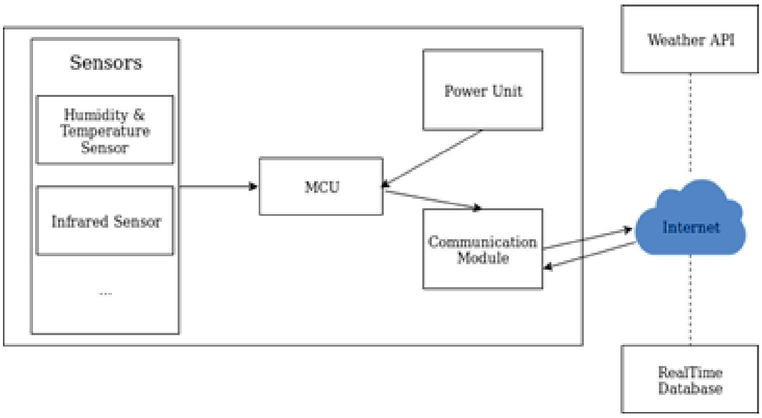


Figure 1: Device Architecture

Regarding the design of the device, it was designed for the purpose of providing shelter for several small birds and includes all the necessary space for the Raspberry Pi, sensors and other components outlined in Fig. 1. This design, shown in Fig. 2 is intended to result in a friendly device to the surrounding fauna and flora. It takes advantage of the fact that in the original FWI calculation proposal the recommended height of weather data capture is 2 meters, suggesting its installation on a tree trunk.

Figure 2: Prototype design

4. Fire Risk Analysis Platform

4.1. System Architecture

Two mobile applications for Android devices have been developed: (a1) for data collection and visualization, and (a2) for analysis and decision making. The collection application allows to notify fires, capture georeferenced photographs, collect environmental data allowing the calculation of the fire hazard index. The administration application allows the construction of heat maps with risk index values and also allows the management of information and users. These applications will communicate through data stored on the Firebase server. Fig. 3 represents the overall system architecture.

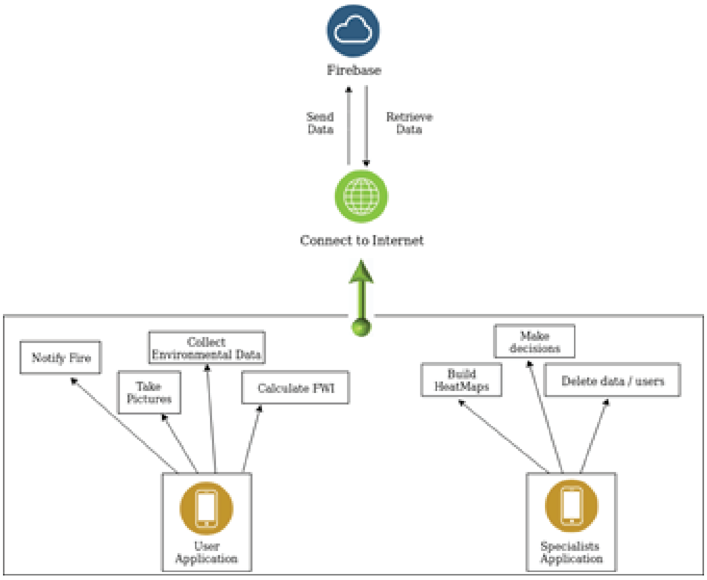


Figure 3: Application system architecture.

4.2. Data gathering and visualization

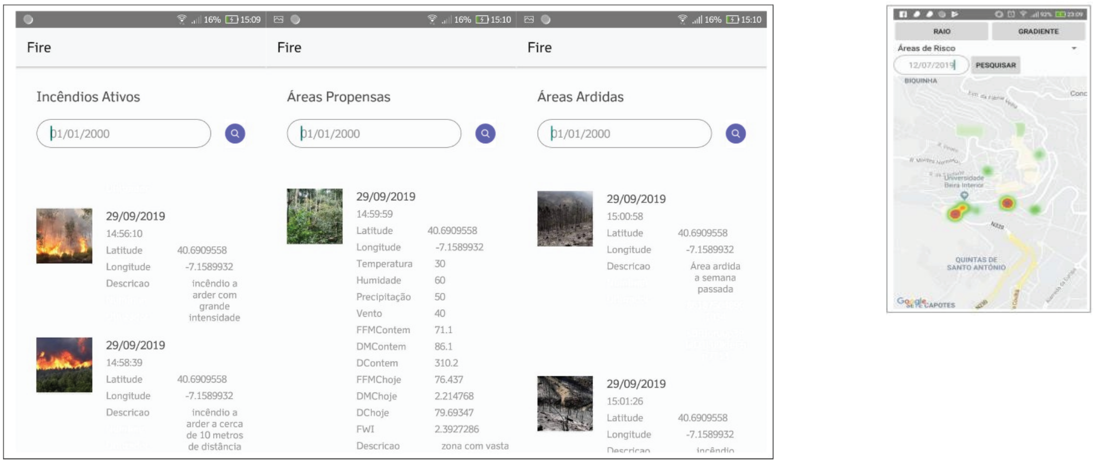
Initially, users should create an account and login to the application. The screen displays a map with the user's location, you can go to a menu containing several options: register a Raspberry Pi, take photos, notify fires, add records, view all records made by all users as well as view heat maps. The ”Register Raspberry Pi” activity allows volunteers to register a device that will collect weather data, registration is done by scanning the device's Quick Response code, the user's location (where the device will be located) and the phone number for emergencies. In the ”Add Records” activity users have two options: (1) prone areas or (2) burned areas. In the first option, Fig. 4, the user selects an image captured on site and enters the weather data (temperature, relative humidity, wind and amount of precipitation in the last 24 hours). This data, used for the calculation of the FWI, may be collected using the Raspberry Pi already registered or may be entered manually based on measurements made by the user (e.g. from portable weather station). As the calculation of the FWI index requires values from the previous day in their absence (e.g. first use) these are automatically populated with the average of these indices in the same period of the previous year [13].

Pretende utilizar os dados do Raspberry Pi?
Tem a certeza que pretende utilizar esses dados?

Localização
Latitude:
40.2773429
Longitude:
-7.5028977
Data: 10/07/2019
Hora: 22:55:23
Ambiente
Temperatura: 30
Humidade: 60
Precipitação: 50
Vento: 40
FFMContem: 84.896385
DMContem: 6.8343096
DContem: 111.88821
FFMChoje: FFMChoje
DMChoje: DMChoje
DChoje: DChoje
FWI: índice de risco
Descrição

Figure 4: Prone areas record.

In the second option, users have the opportunity to collect data where fires have already occurred. In the ”View Records” feature users can access all data added by others. Fig. 5A demonstrates this functionality.



Incêndios Ativos
01/01/2000
29/09/2019
14:56:10
Latitude 40.6909558
Longitude -7.1589932
Descricao incêndio a arder com grande intensidade
29/09/2019
14:58:39
Latitude 40.6909558
Longitude -7.1589932
Descricao incêndio a arder a cerca de 10 metros de distância

Áreas Propensas
01/01/2000
29/09/2019
14:59:59
Latitude 40.6909558
Longitude -7.1589932
Temperatura 30
Humidade 60
Precipitação 50
Vento 40
FFMContem 71.1
DMContem 86.1
DContem 310.2
FFMChoje 76.437
DMChoje 2.214768
DChoje 79.69347
FWI 2.3927286
Descricao zona com vasta

Áreas Ardidas
01/01/2000
29/09/2019
15:00:58
Latitude 40.6909558
Longitude -7.1589932
Descricao Área ardida a semana passada
29/09/2019
15:01:26
Latitude 40.6909558
Longitude -7.1589932
Descricao incêndio

(A) (B)

Figure 5: User interface.

Regarding the heat maps, the user can filter the map by date and can see the areas of highest risk of fire according to data submitted by volunteers. These aim to warn and make the community aware of the risk of fire present in the different areas. Fig. 5B represents an example of a Heat Map for July 12 this year with data collected at Covilhã near the University of Beira Interior.

As for the application of the administrators, they can only access this if they are properly registered, authorized and authenticated. After login, a menu with the functionalities of ”Fire Alerts”, ”Prone Areas reports”, ”Burning Areas reports”, ”Heat Map generation”, ”User management” appears. In the first 3 options the specialist can see all the data collected (as well as the information of the user that collected it), can delete uninteresting data sets and/or outdated data and have the opportunity to update the information collected by volunteers. The heat maps in this application are meant to make it easier for specialists to understand and help in making decisions regarding the intensity of the fire hazard indicated by the points on the map. Finally the expert has the opportunity to perform management operations of the entire user community.

5. Conclusion

This paper presents a proof of concept that we believe will be in the genesis of a tool/platform that can make an important contribution to decision-making by the competent authorities regarding forest fire prevention, response and combat. The implemented prototype allows the community to collect and send georeferenced multimedia environmental data to the Cloud. These results in the production of heat maps based on the gathering locations and computed FWI values.

In order to reach this endeavour, the Citizen Science facet, expressed by the active involvement of the resident community on the ground, will be of utmost importance. The common citizen can contribute to the preservation of the forest and alert to the occurrence of fires. The smartphone app, which may be associated with a low-cost data collection device, allows these volunteers to share information about fire-prone areas and areas of past and new occurrences. This data will be used by experts to make predictions and make appropriate decisions. The success of this work will depend on community participation, enriching the database with fire alerts and environmental values that will be used to calculate the fire risk index. The calculation of the fire risk index that is usually calculated by fixed weather stations will be used to raise awareness of the risk and serve as a warning to the population. The goal is to appeal to citizen science as a way to allow greater granularity (and consequent operational accuracy) in the calculation of the FWI.

After building the prototype, the main problems identified involve the device's communication with the Internet in remote areas and the use of a durable and self-contained power source in said locations. The prototype developed does not yet address these issues in a definitive way, as the device must have close access to the Internet and be connected to a power source (in this particular case, a powerbank). Subsequently, we intend to implement improvements in both communications and energy autonomy (eg using solar or wind energy).

Acknowledgements

This work is supported by the Portuguese Fundação para a Ciência e a Tecnologia (FCT) under the UID/EEA/50008/2019 Project.

References

[1] J. Bioco and P. Fazendeiro. ”Towards Forest Fire Prevention and Combat Through Citizen Science.” *World Conference on Information Systems and Technologies*. Springer, Cham, 2019.

[2] National Geographic Society. *Citizen Science*. https://www.nationalgeographic.org/encyclopedia/citizen-science/ (25/09/2019)

[3] Butcher, Gregory S., Daniel K. Niven, and John R. Sauer. ”Using Christmas Bird Count data to assess population dynamics and trends of waterbirds.” *American Birds* 59.105th Christmas Bird (2005): 23-25.

[4] Wired Brand Lab. *People are the point of IoT*. https://www.ibm.com/blogs/internet-of-things/iot-people-point/ (14/09/2019)

[5] Molina-Pico, Antonio, et al. ”Forest monitoring and wildland early fire detection by a hierarchical wireless sensor network.” *Journal of Sensors* 2016 (2016).

[6] Yu, Liyang, Neng Wang, and Xiaoqiao Meng. ”Real-time forest fire detection with wireless sensor networks.” *Proceedings. 2005 International Conference on Wireless Communications, Networking and Mobile Computing, 2005.*. Vol. 2. IEEE, 2005.

[7] Aslan, Yunus Emre, Ibrahim Korpeoglu, and Özgür Ulusoy. ”A framework for use of wireless sensor networks in forest fire detection and monitoring.” *Computers, Environment and Urban Systems* 36.6 (2012): 614-625.

[8] IT for Nature. https://smokedsystem.com/about-system/ (25/09/2019)

[9] Insight Robotics:*Wildfire Detection System InsightFD + Insight Globe*. https://www.insightrobotics.com/en/services/wildfire-detection-system/ (25/09/2019)

[10] Van Wagner, Charles Edward. *Structure of the Canadian forest fire weather index*. Vol. 1333. Environment Canada, Forestry Service, 1974.

[11] Dark Sky API: Dark Sky API. https://darksky.net/dev (28/09/2019)

[12] Firebase: Firebase Documentation. https://firebase.google.com/docs (28/09/2019)

[13] C. Gouveia et al. *Apoio meteorológico à Prevenção e Combate aos Incêndios Florestais, Technical report* IPMA, 2018.