International Journal of Applied Science and Engineering Review

ISSN: 2582-6271

Vol. 3, Issue.5, Sep-Oct 2022, page no. 77-89

To cite this article: Jean-Marie Kuate Fotso, Bénite Isaoura, Guy Phares Fotso Fotso and Pélagie Flore Temgoua Nanfack (2022). MONITORING AND PREVENTION OF URBAN FIRE BASED ON INTERNET OF THINGS (IOT) AND NodeMCU, International Journal of Applied Science and Engineering Review (IJASER) 3 (5): 77-89

MONITORING AND PREVENTION OF URBAN FIRE BASED ON INTERNET OF THINGS (IOT) AND NodeMCU

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DOI: http://dx.doi.org/10.52267/IJASER.2022.3505

ABSTRACT

Cloud computing has made it easier to access various forms of data and services through the Internet. coupling it to sensor networks makes it possible to significantly overcome the storage and computing performance limits of heterogeneous objects in the Internet of Things (IoT). In Cameroon, IoT is not yet very widespread. We use it here to monitor and prevent urban fires in real time, using a set of temperature, humidity, gas, flame and electrical power sensors that are integrated on NodeMCU, in view to detect fire starts and generate an alert. The data collected is stored and processed on Thing Speak; a second analysis is carried out locally. After calibrating the sensors, we analyzed the data and carried out a correlation test to identify the most sensitive data for the alert system. The correlation coefficient of -0.721015 between temperature and humidity allowed us to maintain the system based on data quality.

KEYWORDS: Cloud computing, Fire, NodeMCU, IoT, Urbanization

1. INTRODUCTION

According to the 2019 report of the United Nations Development Program (UNDP), Cameroon occupies the 21st position in Africa with an average development index. This country has seen large movements of its populations towards urban centers, as well as movements of internally displaced persons and refugees. The latter most often have urgent basic needs, such as housing and electricity. It is therefore not uncommon to observe a strong promiscuity causing risky and non-compliant connections, very often a source of fires in urban areas [1] [2] [3].

This promiscuity is also observable in most urban markets. Added to this, we note the negligence, recklessness, malevolence and ignorance of users who are often at the origin of fires [4]. One of the most recent cases is that observed at the Ndokoti market in Douala [5]. However, the premises housing public services are not left out. The fires at the General Treasury and the National Assembly in Yaoundé and especially the most spectacular one on the SONARA oil site (Société National de Rafinage) in Limbé left their mark [6] [7] [8].

For real-time monitoring, immediate management of any outbreak of fire and even the assistance of specialized personnel, a network of sensors coupled with Cloud Computing constitutes an appropriate and efficient set of tools. The Internet of Objects (IoT), through its successful integration into several application areas of everyday life, imposes its technology as being the most promising for the management of problems of this type [9] [10] [11] [12] [13]. Despite the difficulties of re-adapting the mainly security solutions of classical IT for the IoT, current work increasingly defines standards to facilitate the integration of security solutions that are a little more encompassing [14] [15] [16].

A good part of the limits of the IoT is filled by the cloud which allows it, although it is still in full expansion, to present its bright future in the management of natural risks and certain disasters in urban areas [17] [18] [19]. In the rest of this work, we will present an approach that combines processing in the cloud and local analysis of data recorded in real time by temperature, humidity, gas and flame sensors. At the end of these treatments, an alert can be generated. Section 2 presents an analysis of similar work. Section 3 describes the different entities that make up our system. The following section presents the proposed architecture, while section 5 presents the results of our experiment. Finally, section 6 will conclude our work.

2. RELATED WORKS

The increasing trend in the number of fires in cities today is due to the significant increase in industries, population boom and overcrowding of habitats. There is an urgent need to propose intelligent intervention methods in case of fire in cities [20] [21]. However, Cameroonian cities, despite their urbanization plans, are not marginalized from these problems [22]. Urban fires are more and more recurrent.

The use of classical methods such as satellite images, ranger posts and the establishment of fire safety organizations are expensive and inefficient fire detection methods for others [23]. Solutions based on the Internet of Things have been the subject of several beneficial studies [24]. They have indicatively focused on the prediction of natural hazards using supervised learning and multilinear regression [17] [24]. Disaster management in several scientific works has a limit, which is the non-confirmation of alerts in real time [25] [18] [26].

Several works have used approaches such as the detection of the flame from a combination of motion analysis, the detection of flame colors and video images, a system with GPS for the prevention of alerts by GSM, a solutions smart home automation management of the connected kitchen for fire prevention through digital sensor values as well as video confirmation of the flame [25] [26]. Although these solutions are similar, it is important to note that there is too much dependence on the functionality of these applications which is often impacted by the deployment environment, the internal or external factors considered as well as the hardware used. In Cameroon, the main source of urban fires remains electric current, which is not addressed in previous work. However, monitoring electrical power continuously is a high-risk task for a human. Of our time, today there are several cloud services such as IBM bluemix, Carriots, Xively, Cayenne and Thing Speak, which have a fundamental role for the creation and management of IoT applications [27] [28] [29] [30] [31]. Thus, the results of this work highlight the efficient services provided by Cloud Computing which allow users to meet the challenges of data flexibility, scalability and viability, energy efficiency and optimization of the use of hardware and software resources [32] [33] [6].

Table 1 Comparative study of the functionalities of existing systems

System and Features	[34]	[25]	(Wei-Ling, Ji-Yun, Chien-Shiun, & al, 2019)	[35]	[36]	Our System
Gas	Mq2, Mq5	Mq2	Mq4	Mq2	Mq2	Mq2
Temperature	no	DHT11	DHT11	DHT11	LM35	DS18B20
Humidity	no	DHT11	DHT11		no	DHT11
Flame	Yes	Yes	CSE0005-1	Yes	no	ky-026
Local access	no	No	no	no	no	WampServer
Remote access	Yes	Yes	IFTT	no	no	ThingSpeak
Data analysis	no	No	no	no	no	Correlation study
Prediction	no	Yes	no	no	no	Yes
Presence detection	no	PIR motion sensor	no	no	Yes	no
electric power	no	no	no	no	no	Yes

The table1 above presents all the experimental results. The particularity of our work is noticeable in terms of accessibility, efficiency and reactivity because our solution uses the ThingSpeak platform, which makes the data exchange faster and more reliable. Some works do not report sensor data values and focus only on the characteristics of the sensor and its calibration to assess the level of accuracy of the system, which does not inform on the functional capacity of these solutions [34] [25]. However, the values taken by the system in some works with a similar collection environment show alert values identical to our [26] [35]. The sensors used for some solutions are insufficient for the idea presented [36].

3. SYSTEM DESIGN

For the design of the fire prevention system, several materials were used. In addition to the computer that allowed us to write the source code for the microcontroller, the following modules and sensors were also used:

- the ESP8266 microcontroller. Chosen for its WiFi functionality, it facilitates the sending of data as well as the integration of the various sensors of our system. The sensor is the electronic device that detects a condition and provides an electrical signal proportional to the observed characteristic.
- CD4051BE is an 8-channel analog multiplexer/ demultiplexer. It allows to multiply the number of analog inputs or outputs of the NodeMCU.
- to collect the ambient humidity of the 'Test Environment, we used DTH11 sensor.
- the DS12b20 sensor allowed us to collect the ambient temperature of our environment. A 4.7k ohm resistor was used to regulate the intensity of the electric current in order to ensure that the DS12B20 module was correctly supplied.
- the ky-026 sensor was used to assess the measurement of the electrical signal produced in the presence of a flame. To avoid overloading the modules of our microcontroller, the connections were made using an electronic breadboard.
- the Mq2 sensor, made it possible to detect the range of liquefied petroleum gases.
- the ACS712 sensor, ensures the detection and the control of current which constitutes a fundamental requirement of our study. It is used to measure the overcurrent's of the installation.
- the Wi-Fi modem acts as a gateway between the remote database and the collection nodes.

4. ARCHITECTURE

The architecture that we present below consists of two layers. A physical consisting of all the sensors for collecting data, another called network layer is made up of our microcontroller, the Wi-Fi Modem and the remote database called ThingSpeak. The open source API uses a simple HTTP protocol to transfer, store and analyze data from different sensors. Its analysis results can be viewed on a computer or smartphone. A local database has been set up with WAMP Server. It allows us to retrieve our data on ThingSpeak, to perform additional analysis and to facilitate user decision-making. The use of WAMP Server as a mirror database allows us to have a system always available even in the event of no access to the cloud.

International Journal of Applied Science and Engineering Review

ISSN: 2582-6271

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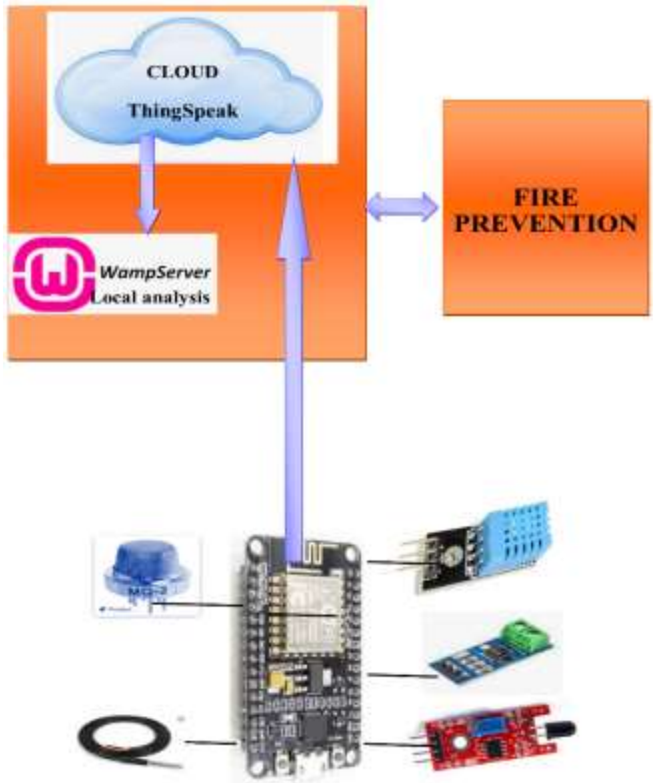

Figure 1 Architecture of the detection system

5. EXPERIMENTATION

5.1 Fire detection

The first experimental tests of our system were carried out over a period of two months (February and March 2021). The values obtained were those of temperature, humidity, presence of gas and flames. All the data collected and stored on ThingSpeak allowed us to highlight several curves.

Figure 2 allows us to observe the temperature values collected with the DS12b20 sensor. This sensor has an accuracy of 0.5% from -10 to +85 ° C with a measuring range of -55 to + 125 ° C. Figure 3 shows the humidity data collected with the DTH11 sensor. The measurement range of this sensor varies from 20 to 100% RH with an accuracy of ± 5% RH. It can be seen that in the presence of fire, these two variables reach larger values.

Figure 4 shows the detection curve for the presence of flame using the ky-026 sensor. This sensor has an infrared detection wavelength between 760 and 1100 nm with a detection angle of 60◦. In the presence of fire its values decrease significantly. Which is a game contrary to the first two curves.

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ISSN: 2582-6271

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Figure 7 gives the appearance on the detection of gases of the LPG type (Liquefied Petroleum Gas), which are also a major cause of fires in urban areas. This measurement is made with an Mq2 physicochemical sensor at concentrations from 300 ppm to 10,000 ppm. It has high sensitivity and fast response time. This sensor detects several pollutants. So, to detect the presence of a specific pollutant, we determine the ratio between the initial resistance (Ro) and the resistance (the analog signal read on ESP8266) that the MQ2 sends back at any time (Rs). Knowing this ratio (Rs/Ro), we use the theoretical extrapolation curve of Mq2 to determine the quantity of LPG each time.

Figure 9, shows the values of the ACS712 current sensor which can accurately detect AC or DC current. Its measurement range varies between -20A to 20A with a sensitivity of 100mV / A. The above measurements are for an Itel phone charger made in China with the following characteristics: Input (100-400V, 50-60Hz, 125mA) and Output (4.2V, 500mA). In this experiment, the values of the electrical power efficiency varied between 19 and 24 watts. other analyzes allowing us to customize our alert system. Thus, we have defined an alert flag presented in Table 2.

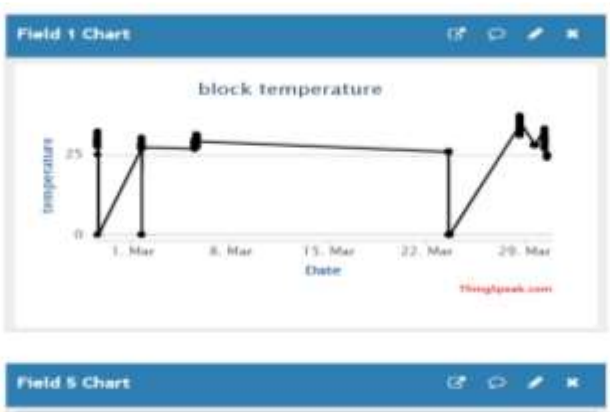

Figure 1 Temperature Data

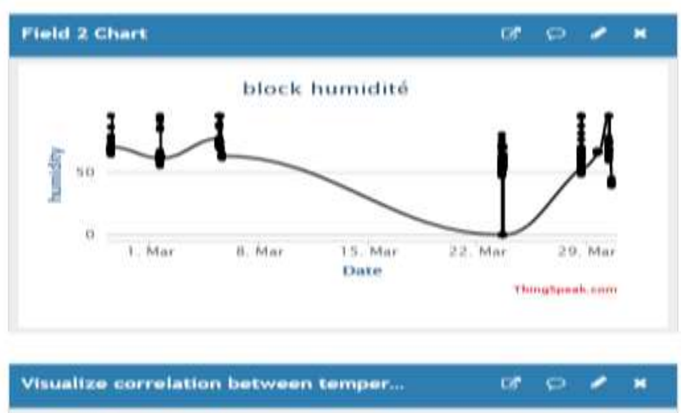

Figure 2 Humidity data

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ISSN: 2582-6271

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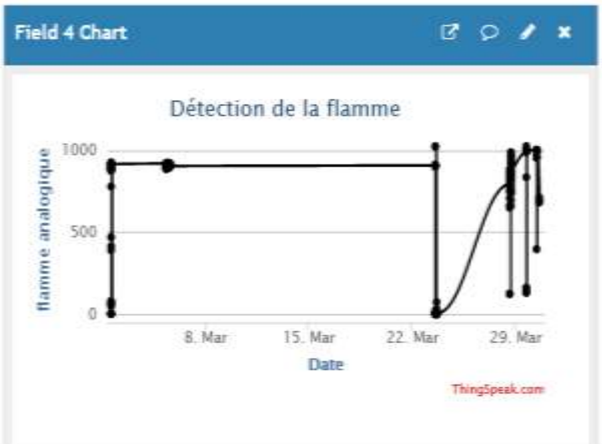


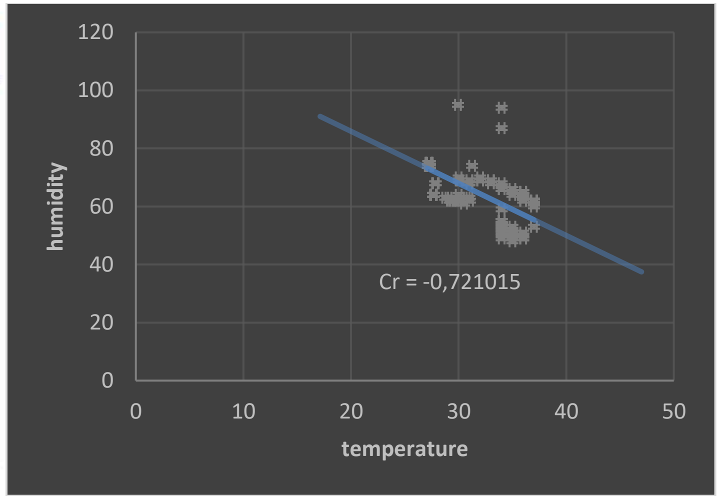
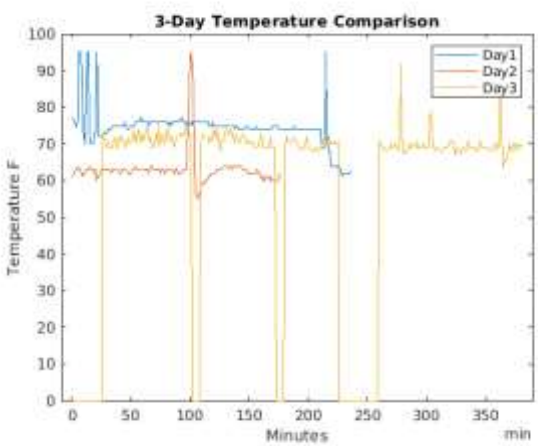


Figure 3 Flame Data

Figure 4 correlation between temperature and humidity



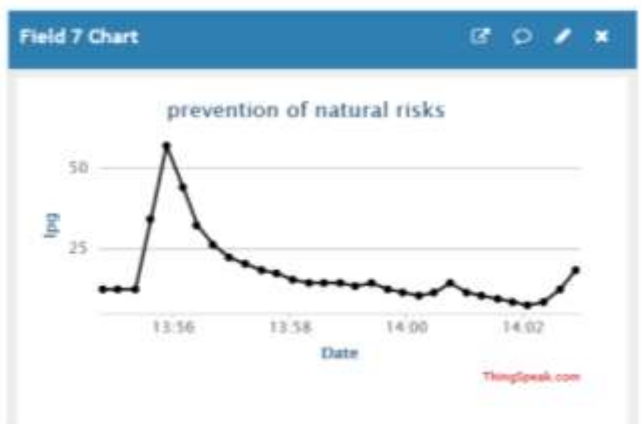


Figure 6 Temperature analysis on (03) three different days

Figure 7 LPG Gas Detection

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Figure 9 Electric power

5.2 Correlation study

Figure 5 illustrates the correlation study which was carried out on two variables of the system (temperature and humidity). Which data is most sensitive to abnormal events? This point cloud curve allowed us to have an assurance on the joint variation of these two variables. The calculated linear correlation coefficient gave us a value:

$$Cr(t,h) = \frac{Cov(t,h)}{S_t S_h} = \mathbf{-0{,}721015}$$

With $Cov(t,h)$, temperature and humidity covariance. $S_t S_h$, represents the product of the standard deviation of the variable's temperature and humidity. This value close to Cr therefore makes it possible to conclude on a strong linear correlation between these two variables. The temperature hovers around 27oC with an average humidity of 72%. Thus, an alert value has been codified to allow the administrator to observe in real time the abnormal shift in values. If cloud access is interrupted, parameter analysis can be performed with the local database described below.

5.3 Alert flag

The large alert management module has been implemented using python code which in turn uses data from our mirror database (WAMP Server). As the data is also collected in real time and continuously in WAMP, this allows us to have other analyzes allowing us to customize our alert system. Thus, we have defined an alert flag presented in Table 2.

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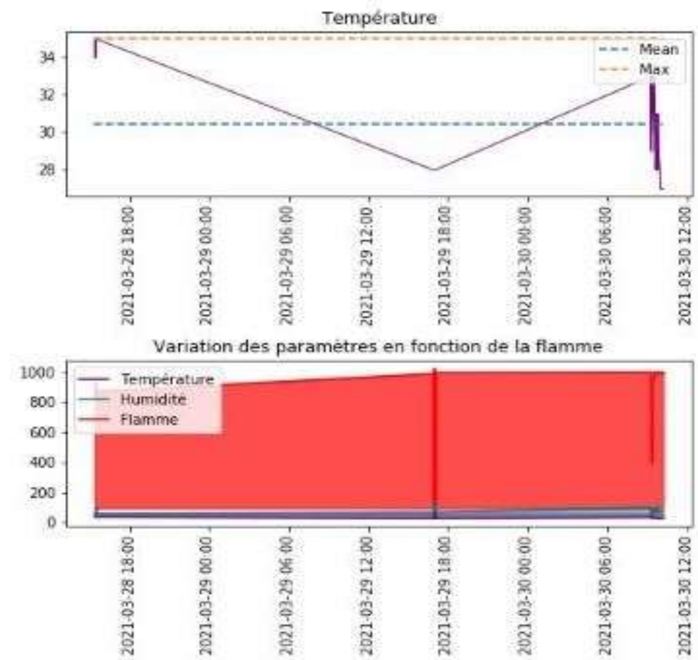

Figure 8 Local alert management system

Indicateur	Alerte
>75	Presence of fire
60-75	Normal functioning
00-59	Abnormal functioning

Table 2 The system's alert levels

The values used are that of humidity. The choice is based on the fact that the humidity of the fuel is a specific data because it plays an important role in the propagation and behavior of the fire.

In figure 8, we observe 03 times in a row, the appearance of fires on different dates. A flame sensor value less than 800 indicates the presence of fire. Thus, during this occurrence, the other parameters (temperature, humidity) have higher values than in the normal case. However, Figure 6 is a comparative temperature analysis between data from three days of collection. This also makes it possible to detect as

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early as possible any risk which can be observed by values which do not corroborate the usual values. It can be seen that the first day reveals more high values than the other two days of collection.

6. CONCLUSION

This study allowed us firstly to highlight the points of convergence between five variables, which are temperature, humidity, flame, gas and the power of the electric current. Second, we have found the impact of IoT on the preservation of human lives and the protection of property against fires to be beneficial. This enabled us to achieve the objective set which was surveillance, through the deployment of sensors, and prevention, made possible by the analysis of the data collected. For the fight against fires in places at risk such as SONARA, Cameroon will be able to integrate this intelligent system in order to facilitate the work of the structures in charge.

However, the risks to people and property in Cameroon are not limited to fires. There is a wide variety of sensors that can detect many natural disasters, which may be the subject of future work.

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