IoT System for Ultraviolet Ray Index Monitoring

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Abstract

This paper presents an ultraviolet index monitoring system using IoT applications. The goal is to assist in the prevention of diseases caused by ultraviolet solar radiation through warning messages with preventive measures with each change in the ultraviolet index level over time. UV index monitoring is of fundamental importance for the prevention of various diseases such as skin cancer, cardiovascular disease, lack of calcium and others. The system presented good results in the UV index monitoring, presenting measured values of UV indices according to the solar radiation observed during the experiments, classified according to the World health organization (WHO).

Keywords*: *Ultraviolet rays, Skin câncer, Internet of things, UV index, cloud monitoring.

1. Introduction

According to Albreem et al. [1], the expression “Internet of Things” or “IoT” emerged first proposed by Kevin Ashton in a presentation in 1998. Saha et al. [2] said that Internet of Things (IoT) technology is making this “network of autonomous object” a reality. Additionally, it has become an enthusiastic theme, with a solid cloud computing structure, supported by a perfect union of sensors and actuators with the surrounding environment.

Business models in the technology industries will change as they adjust to new realities and technological progress, for example, the adoption of IoT enables us to collect important data from all aspects of our lives, such as the environment, infrastructure, health, and sports, which enables the generation of new business opportunities [3].

The IoT technologies have been considered a key component in the environment monitoring and health-care applications. For example, wearable sensors are used to monitor physiological signals, such as blood pressure [4], electrocardiography [5], and others heart diseases [6]. In addition to health applications, IoT systems can also be used to monitor environmental conditions around people, such as approaches to measure CO concentration [7] toxic environmental volatile organic compounds (VOC) [8], and air pollution. Knowledge of such information can be useful in order for the user to have a deep understanding of their surroundings. For instance, overexposure to solar ultraviolet (UV) radiation is a risk for public health particularly for outdoor construction workers because of the typical detrimental effects such as sun burning, long-term risk of skin cancer, and eye diseases [9].

In this context, this paper presents an IoT application to monitor the incidence of ultraviolet rays in order to prevent diseases caused by a long period of exposure to solar ultraviolet radiation. According to WHO [10], skin cancers caused by sun exposure are squamous cell carcinoma, basal cell carcinoma and cutaneous melanoma.

The main prevention of these, and any other type of skin cancer, is the care in sun exposure, especially during childhood and adolescence. Also, according to Religi et al. [11], ultraviolet solar radiation (UV) has a dual effect on human health, while low doses of UV promote the absorption of vitamin D and regulate calcium and phosphorus metabolism. In addition, as previously mentioned overexposure to UV rays causes skin cancer, along with eye disease and premature skin aging. Depending on the duration of exposure, two types of effects can be distinguished: acute and chronic effects. The first is characterized by a fast beginning and short duration (sunburn, tanning, vitamin D production); the latter is usually gradual and long lasting (photo aging, skin cancer).

Vitamin D ingestion is very important for human health. The main source of vitamin D is ultraviolet rays, but absorption of this vitamin has to be done safely. Osmancevic [12] States that vitamin D3 is produced in the skin because of 7-dehydrocholesterol (7-DHC) ultraviolet radiation and D2 is produced by ultraviolet radiation from plant sterol ergosterol.

This paper aims to implement an ultraviolet index monitoring system to assist in the prevention of diseases caused by solar ultraviolet radiation through warning messages with preventive measures for each change in the ultraviolet index over time.

The rest of this paper is organized as follows. Section 2 describes the literature review on technologies and approaches for monitoring the ultraviolet index, section 3 describes the methodology used in this paper, section 4 describes the results and implementation, and section 5 describes the conclusion.

2. Literature Review

In this section, we will discuss the technologies and approaches researched through this systematic literature review. Using the Parsif.al tool, a total of 199 papers were searched, out of 199 papers, eleven (11) papers were selected while conducting the systematic review, 5 (five) have UV measurement systems, while the remaining 6 (six) are theoretical studies presenting the following studies: market protection level of sunscreens; relative importance of sun exposure and vitamin D ingestion in the elderly; survey on consciousness, understanding, use and impact of UV index; estimation of total UV radiation of total solar irradiance and epidemiological studies; application of phototherapy technique for vitamin D injection in patients with psoriasis disease; and the effects of the hole of the Ozone layer on the skin of humans.

According to the results obtained, the following technologies and approaches on measurement, protection and absorption of ultraviolet rays (UV) were found. For a better understanding of the analyzes, the papers were divided into two groups: (a) theoretical study group, see Table 1 and (b) experimental study group, see Table 2.

a) Analyzes of the papers of the theoretical study group

The papers in the theoretical study group address issues the care that human beings have to take to prevent diseases caused by long exposure to ultraviolet rays and address treatments for diseases caused by vitamin D deficiency by ingesting vitamin D in a timely manner provided by ultraviolet rays.

Leccese et al. [13] describe a comparative analysis of two methods, method (A) and method (B), which are used for UV index prediction. Method (A) is based on estimation of total UV radiation from total solar irradiance and method (B) is based on measured UV regression models. Studies have shown that method (A) is more suitable for epidemiological or climatic studies, i.e. studies related to causes of disease in humans and climate, and not to predicting the daily UV index. On the other hand, the UV prediction of method (B) is more suitable for daily UV index prediction because they are able to estimate daily UV index variation than group (A) methods. The accuracy of the method (B) is better because take into account seasonal and daily Ozone concentration variations derived from satellite measurements.

Osmancevic [12] presents the application of the phototherapy technique for vitamin D injection in patients with psoriasis disease, which is the disease in which skin cells accumulate and form dry itchy scales and spots. Studies have shown that vitamin D inhibits inflammatory processes by suppressing the increased activity of immune cells taking part in the autoimmune reaction, and vitamin D injection has improved psoriasis in the patients being treated. Monitoring the UV index can safely absorb vitamin D, thus preventing various diseases such as psoriasis, cardiovascular disease, lack of calcium and others. The work of Brouwer-Brolsma et al. [14] present the relative importance of sun exposure and vitamin D ingestion in Dutch elderly. Studies have shown that inadequate vitamin D ingestion is the reason for vitamin D deficiency (25OHD) in the elderly. The elderly population, including this study, has been shown that exposure to UVB radiation, vitamin D ingestion, and genetic composition related to vitamin D contribute considerably to variability in vitamin D (25OHD) concentrations.

Osmancevic [12] and Brouwer-Brolsma et. al. [14] point out two justifications for UV index monitoring. The first presents a study to treat inflammatory diseases through vitamin D ingestion, the second presents a study to treat diseases in the elderly, and knowing the UV index, one can make the decision to treat diseases and injection, and adequately regulating vitamin D (25OHD) concentration in the elderly.

Heckmana et al. [15] present a systematic review on awareness, understanding, use and impact of the UV index. This study aims to clarify the importance of the UV index for disease prevention, i.e., to raise public awareness of the dangers of overexposure to the UV index. The other aim of this study is to develop a UV index monitoring system using IoT, in that the user may have alert messages on his smartphone with guidelines and recommendations aimed at preventing diseases caused by overexposure to ultraviolet rays. This is of utmost importance in making people aware of the dangers of overexposure to ultraviolet (UV) exposure. Finally, the work of Chakraborty et al. [16] presents a study on the effects of the Ozone layer hole on human skin. Studies have shown that people should be more careful and aware that the emission of gases and chemicals that destroy an ozone layer must be reduced, thus protecting the earth from the harmful rays of the sun, including UVB, resulting in a decrease in the mortality rate caused by excessive exposure to ultraviolet rays. The study also showed that skin cancer is steadily increasing, and in addition to preventative measures, some advanced diagnostic and treatment measures must be taken to provide high quality treatment at a reasonable time and cost.

Table 1. Theoretical Study Group Articles

Authors	Kind of study	Researched Technologies and Approaches
Leccese et al. (2018)	Theoretical	Theoretical study on the estimation of total UV radiation of total solar irradiance and epidemiological studies.
Osmancevic (2012)	Theoretical	Study on the application of the phototherapy technique for vitamin D injection in patients with Psoriasis disease.
Brouwer et al. (2015)	Theoretical	Relative importance of sun exposure and vitamin D intake in the elderly.
Heckmana et al. (2019)	Theoretical	Systematic review on awareness, understanding, use and impact of UV index.
Chakraborty et al. (2017)	Theoretical	Study on the effects of the ozone hole on the skin of humans.

b) Analyzes of papers from the experimental study group

Osman et al. [17] and Tajuddin et al. [18] presented a study on the use of polysulfide films, polyethylene oxide films and EBT3 film respectively, with UV meter to measure ultraviolet indexes using the spectroscopy technique. The works gave a good response with increasing absorbance of the film with the exposed UV. In other words, UV solar dosimetry can be performed using polysulfide films, polyethylene oxide films and EBT3 film, because the color changes of the films are strongly correlated with the accumulated UV dose of the film.

Lonnqvist et al. [19] and Park et al. [20] feature mobile devices for outdoor UV measurement using Arduino module, with different sensor models, but with the same goal, which was to make people aware of the growing risk of getting skin cancer. Mazzillo et al. [21] feature a plate for UV measurement using silicon carbide (4H-SiC) Schottky photodiodes as UV light sensors. This plate measures and signals the UV index under different lighting and climate conditions, thus enabling monitoring of ultraviolet rays for prevention of skin diseases. As can be seen in the applications of both works, although they use different hardware technologies, both works have the same main objective, i.e., the prevention of skin diseases.

Vilela et al. [22] present an analytical process for sunscreen formulations. In this process, the authors used the substances Benzophenone-3, octyl methoxycinnamate and octyl salicylate. The aim of this work was to demonstrate the need to develop methods to further evaluate the level of protection provided by a sunscreen formulation. This study is of fundamental importance as it analyzes the level of protection of sunscreens in the market. The experiments performed in this work showed that the commercial formulations of sunscreens tested did not present an important mechanism to inhibit all oxidative stress pathways triggered by irradiation of UVB. By monitoring the UV index, you have the possibility to make the decision to use the right sunscreen.

Table 2. Experimental Study Group Articles.

Authors	Kind of study	Researched Technologies and Approaches
Osman (2016)	Experimental	UV meter using polysulfone films and polyethylene oxide films.
Tajuddin (2017)	Experimental	UV meter matching with EBT3 film.
Lonnqvist et al. (2017)	Experimental	Features mobile device for UV measurement using Arduino module.
Mazzillo et al. (2011)	Experimental	A plate for UV measurement using Schottky silicon carbide (4H-SiC) photodiodes as UV light sensors.
Park et al. (2018)	Experimental	Features mobile device for UV measurement using Arduino module.
Vilela et al. (2016)	Experimental	Study on the protection level of sunscreens.

At the end of the analysis of the five papers, it was observed that they do not have applications with IoT, that is, the measured results presented are not monitored by an IoT platform, and they are only monitored locally in the developed system.

As observed in the analysis of the 11 papers, research has shown that it is necessary to develop work in this line of research, because the excessive exposure to ultraviolet rays increases the number of people with skin cancer, as well as the lack of vitamin D in the body of humans causes various diseases.

3. Methodology

This section presents the methodology used for monitoring the ultraviolet ray indices. The monitoring of the ultraviolet ray indices was performed by taking measurements on clear days, i.e. in the absence of clouds, where the maximum value of the UV index can be measured, which the scenario with the highest likelihood of skin disease is occurring in humans, such as skin cancer.

The methodology adopted was divided into the following phases:

a) Conducting a systematic literature review
b) Choice of microcontroller for data processing
c) Choice of UV index detection sensor
d) Choice of IoT platform for UV index monitoring
e) Conducting experiments
f) Analysis and interpretation of the collected data

Below are the stages for the development of this research:

a) Conducting a systematic literature review

Systematic literature review was performed following the method [Kitchenham and Charters, 2007] to identify, evaluate, interpret, and synthesize available studies to address specific research questions on the use of IoT systems to monitor ultraviolet radiation. We use web-based automated tool to support the systematic literature review process [23], performing literature searches on various sources such as IEEE Digital Library, Science @ Direct, Springer Link, Intechopen.

b) Choice of microcontroller for data processing

For processing and interpretation of the measured data, the ESP32 microcontroller was chosen for its specifications and its consolidated in IoT applications. ESP32 microcontroller specifications are: Programmable Dual-Core 32-bit LX6 CPU, has 2.4Ghz WiFi connection, Bluetooth BLE 4.2, 448 KBytes ROM memory, 520 KBytes RAM memory, 4 MB Flash memory, and low power consumption. ESP32 microcontroller allows creating various applications for IoT projects, such as data monitoring, remote access, webservers and data loggers among others. The microcontroller was programmed in C language using the Arduino IDE.

c) Choice of UV index detection sensor

In this application, the UVM-30A sensor was chosen as UV index detector, with 3-5V operating voltage, 0-1V output voltage, 0.06mA standard current and +/- 1 accuracy.

d) Choice of IoT platform for UV index monitoring

The IoT application development environment chosen for this article was ThingSpeak. ThingSpeak is an IoT analytics platform service that enables you to aggregate, view and analyze real-time data streams in the cloud. ThingSpeak creates instant visualizations of real-time data, send alerts using web services such as Twitter and Twilio, and perform preprocessing, visualization and analysis in MATLAB software. ThingSpeak allows engineers and scientists to prototype and build IoT systems without setting up servers or developing web software. The web service used in this application to send alert messages is the social network Twitter.

ThingSpeak uses the Representation state transfer (REST) architecture. REST architecture is a type of architecture designed as a request-response model that communicates over HTTP protocol in the client-server computational model. ThingSpeak is an IoT platform that uses the REST API called GET, POST, PUT, and DELETE to create and delete channels, read and write channel data, and clear data on a channel. A web browser or client sends a request to the server, which responds with data in the requested format. Web browsers use this interface to retrieve web pages or send data from remote servers.

e) Conducting experiments

To perform the experiments, the devices were positioned on a roof of a residence on clear days, i.e., in the absence of clouds, in order to cover as many ultraviolet rays as possible over time.

f) Analyzes and interpretation of collected data

The analysis and interpretation of the collected data were performed following the guidelines of the World Health Organization (WHO), see Figure 2.

3.1 Proposed System

Figure 1 shows the working flow of the developed IoT application. The proposed system is powered by 3.3V Lithium battery. The UVM30A sensor reads the intensity of the ultraviolet rays and sends it to the ESP32 microcontroller. The ESP32 microcontroller processes and calculates the UV index and sends via wi-fi network it to the IoT ThingSpeak platform. UV index measurements can be monitored from either the computer (notebook or PC) or the ThingSpeak App on the mobile phone, and alert messages are sent to the Twitter App. The messages inform the system's users of the UV index level and guide which preventive measures to take for each UV index level over time. The goal is to educate the user to protect themselves from the harms of exposure to ultraviolet rays.

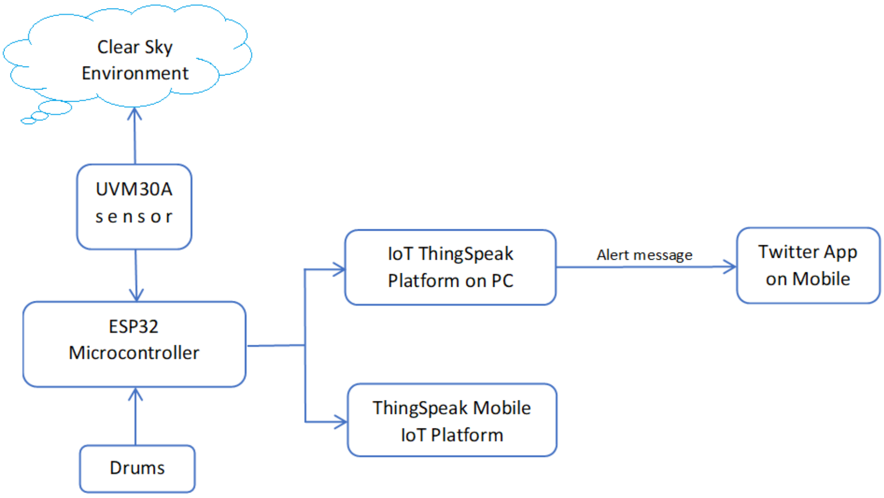

Figure 1. Operating diagram of the implemented UV Index measurement system

The methodology of this work follows the guidelines of the Center for Weather Forecasting and Climate Studies (CPTEC), the National Institute for Space Research (INPE). Alert messages on UV index levels comply with CPTEC/INPE according to the World Health Organization (WHO), see Figure 2.

Index UV	UV INDEX 1	UV INDEX 2	UV INDEX 3	UV INDEX 4	UV INDEX 5	UV INDEX 6	UV INDEX 7	UV INDEX 8	UV INDEX 9	UV INDEX 10	UV INDEX 11^{+}
Level	Low		Moderate			High		Very high			Extreme
Maximum Exposure Time (minutes)	---		45			30		15			10
recommended protective measures											

Figure 2. UV Index Rating. Source: WHO (2019)

4 Results and Implementation

The experiment was carried out in Manaus City, Amazonas, Brazil. Figure 3 depicts a screenshot of Manaus map, on the banks of the Amazon River.

Figure 3. Screenshot of Manaus Map, experiments location.

To perform the experiment, the device was installed on the roof of one residence with the objective of covering as many ultraviolet rays as possible over time. The installed device is connected to the internet using the Wifi of the own residence. The experiment lasted for four hours. The system uses the interfaces of the ThingSpeak IoT platform to view data collected in real time. The system also used the Twitter App to receive UV index level alert messages (see Figure 4).

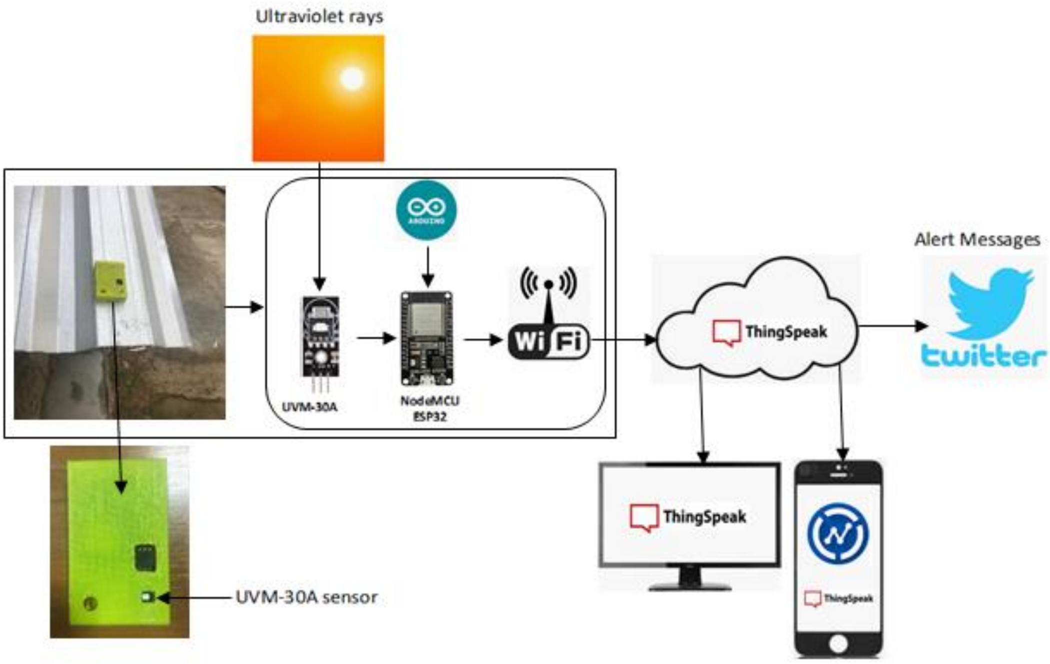

Figure 4. System developed in operation

We evaluated the proposed system on one experiment. The experiment was carried out on 10/28/2019 (12:00 - 16:00 hours).

Figure 5 presents the graphical representation of the collected data. The measured UV index values show compliance with the solar radiation observed during the experiment period, i.e. at times when the solar radiation is very high (eg 12: 00h), the UV index remained with values between 8 and 9, which are considered too high. Similarly, there are times (13:26 to 13:52) when solar radiation is moderate, whose UV values are in the range of 3 to 5; and times when the UV indices are low (13:52 to 15:55) whose UV index values remained between 0 and 2.

According to [10] during the period when the UV index is very high, intense protection is needed to protect against the harmful effects of exposure to ultraviolet rays, as very high UV index can cause skin diseases such as chronic burns and cancer. During the period when the UV index is moderate there is also the need to protect against the harms of exposure to ultraviolet rays, as the moderate UV index also causes skin diseases such as burns, skin aging and cancer. Only when the UV index is low there is no need for protection.

Exposure time for moderate, high, and very high UV indices is 45, 30, and 15 minutes, respectively. It is recommended to wear t-shirt, apply sunscreen, glasses and put on a hat. It is worth noting that warning messages are sent via Twitter during the measurement period.

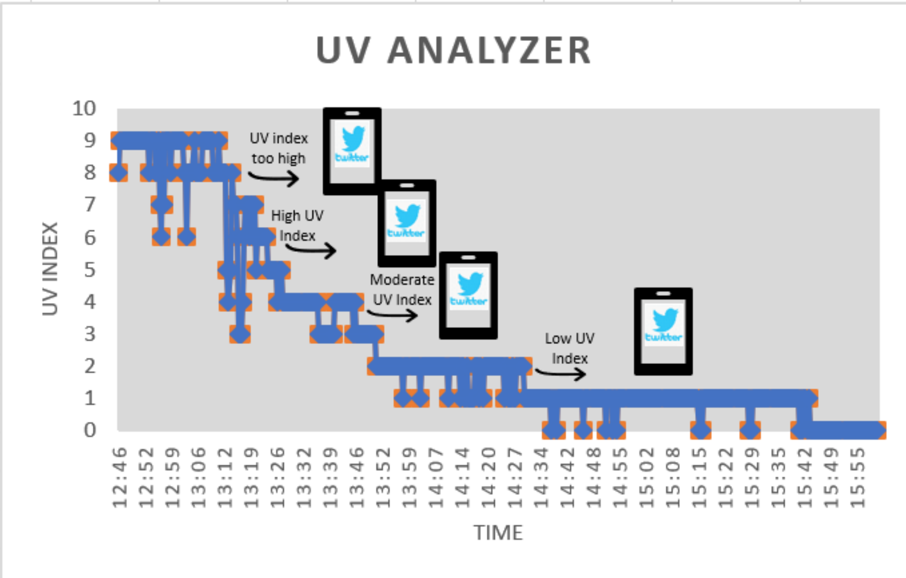

Figure 5. Experiment measurement period

During the measurement period, warning messages were sent to the Twitter App informing the UV index level and preventive measures to be taken. The messages serve to make users aware of the dangers of long periods of exposure to ultraviolet rays. Figure 6 shows three warning messages for very high, moderate and low UV indices.

Figure 5. Warning messages about the UV index via Twitter from experiment. Source: ThingSpeak, (2019).

5. Conclusion

IoT technology has become an indispensable element in daily life due to its application in various fields. In the health field, this technology has stood out with significant contributions. This paper has presented details of the development of a system that monitors the ultraviolet ray indices. The monitoring of UV index measurements was performed using the IoT ThingSpeak platform, in real time and with data stored and processed in the cloud, with expected behavior of UV indices according to solar radiation observed during the day of the experiments. During the experiments the system fulfilled the task of sending warning messages via Twitter to the mobile device, alerting the user which preventive measures to be taken for each level of UV index detected (see Figure 6). Thus, the system proved to be able to monitor UV indices using the internet of things (IoT) technology.

As future work, we intend to improve the robustness of the prototype and carry out new experiments.

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