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Internet of things system for ultraviolet index monitoring in the community of Chirinche Bajo

Sistema de Internet de las cosas para el monitoreo del índice ultravioleta en la comunidad de Chirinche Bajo

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ABSTRACT

The impact of the ultraviolet radiation index is becoming more intense and dangerous for the health of the epidermis and eyesight of people, especially for farmers in the Chirinche Bajo (Ecuador) community. Farmers are exposed to the intense sun during their work days in the crops, for this reason, a technological system based on the Internet of Things (IoT) was proposed to inform them of the UV index to which they are exposed and take precautions to go out to do their daily work. A monitoring device was developed and an application in the API of the Thinger.io platform to visualize and manage alarms. During the monitoring time, the system detected a UV index higher than 9 in the morning and afternoon hours (11am to 1pm), which according to the World Health Organization (WHO), is classified as very dangerous: it recommends wearing clothing that covers most of the body, sunscreen, a hat and sunglasses. In the community, the farmers use their traditional hat, which does not cover their faces optimally, and due to the lack of economy, they do not use sunscreen. The project is an initial contribution to create a culture of information and technological development in rural agricultural areas of Ecuador..

KEYWORDS: ultraviolet index, solar radiation, Internet of things, WHO, farmers

RESUMEN

El impacto del índice de radiación ultravioleta cada día es más intenso y peligroso para la salud de la epidermis y la vista de las personas, especialmente para los agricultores de la Comunidad de Chirinche Bajo, Ecuador. Los campesinos se exponen al sol intenso en sus jornadas laborales en los cultivos, por ese motivo, se propuso un sistema tecnológico basado en internet de las cosas (IoT) para informar del índice UV al que se encuentran expuestos y tomen precauciones para salir a sus labores cotidianas. Se desarrolló un dispositivo para el monitoreo y una aplicación en la API de la plataforma Thinger.io para visualizar y gestionar alarmas, en el tiempo de seguimiento el sistema detectó un índice UV mayor a 9 en horas de la mañana y tarde (11am a 13pm), que según la Organización Mundial de la Salud (OMS), es catalogada como de muy alto peligro: recomienda usar prendas que cubran la mayor parte del cuerpo, protector solar, sombrero y anteojos de sol. En la comunidad los agricultores utilizan su sombrero tradicional que no cubre de forma óptima el rosto y por la falta de economía no utilizan protector solar. El proyecto es un aporte inicial para crear una cultura de información y desarrollo tecnológico en las zonas agrícolas rurales del Ecuador.

PALABRAS CLAVE: índice ultravioleta, radiación solar, Internet de las cosas, OMS, agricultores

Introduction

According to data from the National Institute of Meteorology and Hydrology (INAMHI), solar radiation has increased by 50% in recent years, people exposed to the sun for a long time have adverse effects on the skin, such as squamous cell carcinoma, basal cell carcinoma, melanoma and cataracts (Chango Tituaña, 2019).

Solar ultraviolet radiation is a natural element that has a significant effect on the environment. The solar UV spectrum has many beneficial effects on vitamin D production in humans, but it is also harmful if certain limits are exceeded; especially the skin and eyes are affected. Quispe Huamán y Vargas Poma (2019) in their study proposed a prototype for wireless mobile remote monitoring to report solar UV irradiance indices and associated risks. As a result, they obtained a wireless system mobilized by a drone, to visualize its location and radiation level they developed an application for Android and for PC in LabVIEW. Finally, they concluded that the deployed device allows the monitoring and reporting of solar UV radiation indices and associated risk levels to prevent skin erythema damage in people in the municipality of Pampa.

Cañizares Guerrero (2019) implemented a system for monitoring ultraviolet radiation in real time, at the Technical University of Cotopaxi (UTC), the data were displayed on a web page and a mobile application together with a database connected to the internet, the device had two microcontrollers Arduino mega 2560 and Arduino one for processing meteorological data from the sensors, the power supply had two solar panels and two batteries connected in series. With the project they managed to make people aware of the levels of UV radiation to which they are exposed to raise awareness about health care and take protective measures according to the WHO.

Cruz Checa (2020) in their work presented a monitoring system in the city of Arequipa for the measurement of the solar ultraviolet UV radiation index at the wavelength of 280nm to 390nm. The device is equipped with a sensor, a microcontroller and is powered by solar panels. The values obtained are displayed on a web page that sends a message indicating the protection measures to take into account when exposed to the sun.

Chango Tituaña (2019) proposed a device based on UV optical sensors to allow the educational community to be informed about UV radiation levels in real time. The device comprised a UV sensor, a Raspberry Pi 3B with a database. A graphical user interface (GUI) was used to visualize the UV index. The objective was to raise awareness and avoid effects when performing outdoor activities.

Arroyo Cornejo & Andrade Lucio (2017) built an ultraviolet radiation meter to assess the implications of prolonged exposure on people, such as the intensity of UV radiation to which citizens are exposed throughout the day, and determined a peak time when radiation levels are at their highest.

Orozco Jaramillo y Ordóñez Mendieta (2019) implemented a system for monitoring solar radiation levels in the city of Loja, Ecuador. The system was based on the development of a network of two ultraviolet (UV) sensors constituted as the nodes of the network that communicate with the base station that sent the processed data to an Android mobile application in real time, it was possible to visualize the UV index with their respective prevention indications and the history of the data obtained.

Villagómez-Pesantez (2019) design a solar radiation (UV) monitoring and alert system with an embedded system, virtual private server (VPS) and mobile application (APP) to visualize the level of solar radiation in real time, the objective of the project was to inform people in the inter-Andean alley of Ecuador when there are high levels of solar ultraviolet radiation, which is considered harmful to the skin and eyes.

1.1 Ultraviolet Index (UVI)

According to the WHO, the UVI is a standardized measure of the intensity of UV radiation on the earth's surface that is related to the effects on people's skin. *Table 1* presents the exposure categories ranging from low to extremely high, related to intervals of integer values and their respective color codes established by the WHO, and *Table 2* presents the recommendations for protection against UV exposure.

Table 1

Ultraviolet Index: exposure categories

Categories	Values	Colors
Download	<2	
Moderate	3-5	
High	6-7	
Very high	8-10	
Extremely high	>11	

Table 2

UV protection recommendations

Table of recommendations	
Index [1 - 2]	
	You can stay outdoors without risk.
Index [3 - 7]	
	Wear a shirt, sunscreen, hat and sunglasses.
Index [greater than 8]	
	Shirt, sunscreen, hat and sunglasses are essential.

The UV radiation index has served to raise public awareness of the risks of excessive exposure and to alert people to the need to use protective measures in accordance with WHO recommendations, so that the population can reduce the time of exposure to solar radiation and reduce damage to health (Pohl et al., 2020).

This article proposes an internet of things system for monitoring the ultraviolet index in the community of Chirinche Bajo, in order to provide a technological tool to keep farmers informed of the incidence of UV radiation, since they are exposed for long periods of time during their days in the agricultural crops in the community. The following sections describe the system design, technologies and devices used for monitoring, communication and IoT platforms. Also, the results of the implemented and fully operational system are presented.

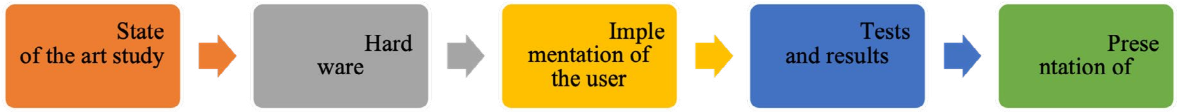
Methodology

To carry out the implementation and development of the internet of things system (IoT) for monitoring the ultraviolet radiation index, the Work Breakdown Structure (WBS) methodology has been chosen, which makes a project more manageable when it is broken down into individual parts, and establishes the project boundaries and scope.

Five work stages have been chosen for the development of the project, which are shown in *Figure 1*.

Figure 1

Work stages according to WBS methodology



2.1 System architecture

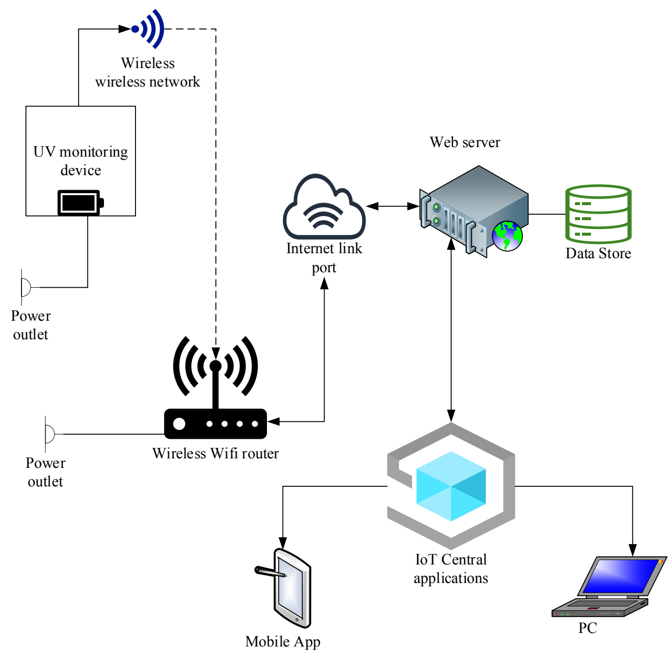
The system consists of a monitoring device that collects UV radiation through the sensor, the equipment is linked to the wireless Wifi router, which relays the data through the TCP/IP network to the IoT platform Thinger.io, where the UV sensor variable is stored, a user-friendly graphical interface is available and early warning alarms are generated to inform the farmer when there is a high UV radiation index. The design was developed based on the architecture shown in *Figure 2*.

The IoT system for UV index radiation monitoring is integrated by:

- UV radiation monitoring device
- Wireless Wifi router
- IoT platform, for user interface development.

Figure 2

IoT system architecture for UV radiation monitoring



2.2 Materials for the design of the monitoring device

A ML8511 UV detector module, TTGO ESP32 LoRa-OLED (V1) microcontroller, LM2596 power regulator and a 2-cell LiPo battery were used to develop the device.

2.2.1 ML8511 UV detector module

The ML8511 sensor detects light with wavelengths from 280 to 390 nm, covering the UVB and UVA spectra. The analog output is linearly related to the intensity of UV radiation. (Naylamp Mechatronics SAC, 2021). *Figure 3* shows the module.

Figure 3

ML8511 UV detector module

2.2.2. Microcontroller TTGO ESP32 LoRa-OLED (V1)

It is a microcontroller based on the ESP32 board model and has Bluetooth connectivity protocols, wifi and a Semtech SX1276 transceiver chip integrated on the board and a SSD1306 OLED display (Ordoñez Obando y Ruiz Quimis, 2021). The TTGO model is shown in Figure 4.

Figure 4

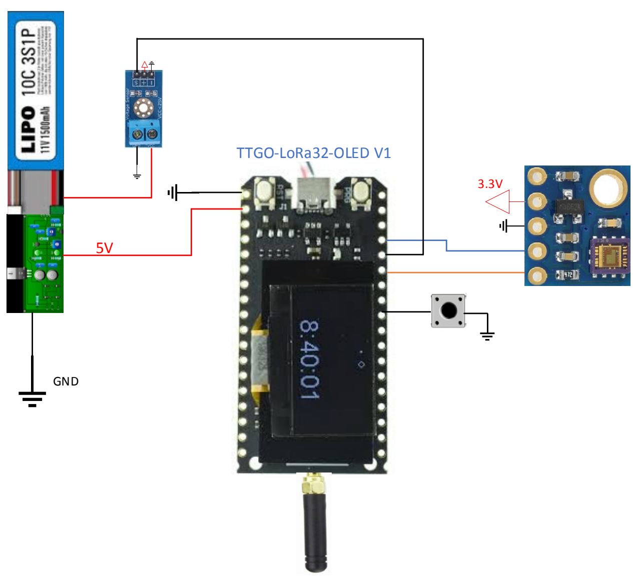
TTGO ESP32 LoRa - OLED (V1)

2.3 Monitoring device architecture

The device is composed of the TTGO ESP32 LoRa-OLED module that works as a microcontroller and data transmission device of the ML8511 module, through the Wifi protocol to the thinger.io platform, the schematic design is shown in *Figure 5.*

Figure 5

UV radiation monitoring device architecture



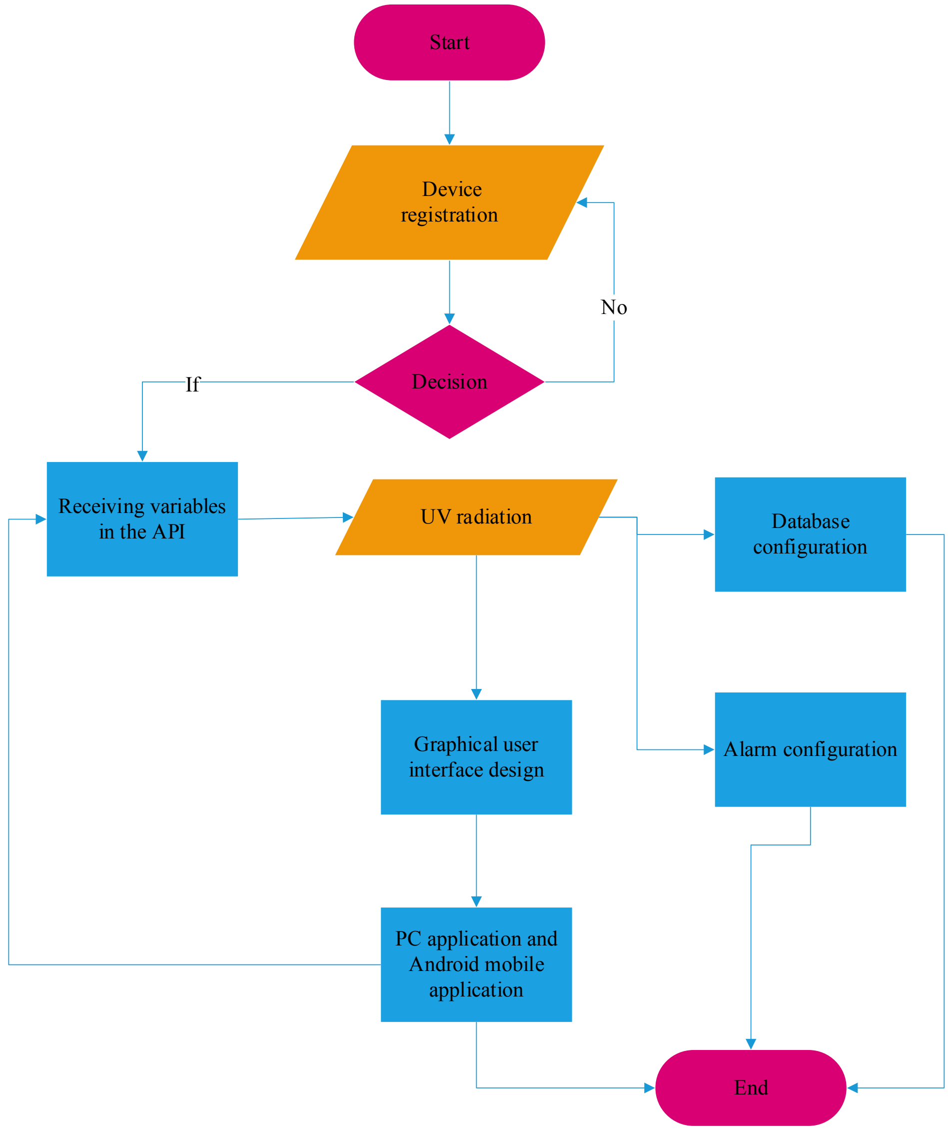
2.4 Graphical user interface design

IoT platforms are an important component of the Internet of Things ecosystem, allowing to visualize, manage and control devices. For features such as: subscription with free account, monitoring and control, update time up to 1 second per reading, adaptability to different development boards, GUI configuration, database and alarm management, the thinger.io platform is used.

Figure 6 presents the flowchart of the graphical user interface design; first the device is registered and configured to obtain the access credentials to the Thinger.io platform; then the HMI is designed, and the database and alarm are configured.

Figure 6

Graphical user interface design flowchart

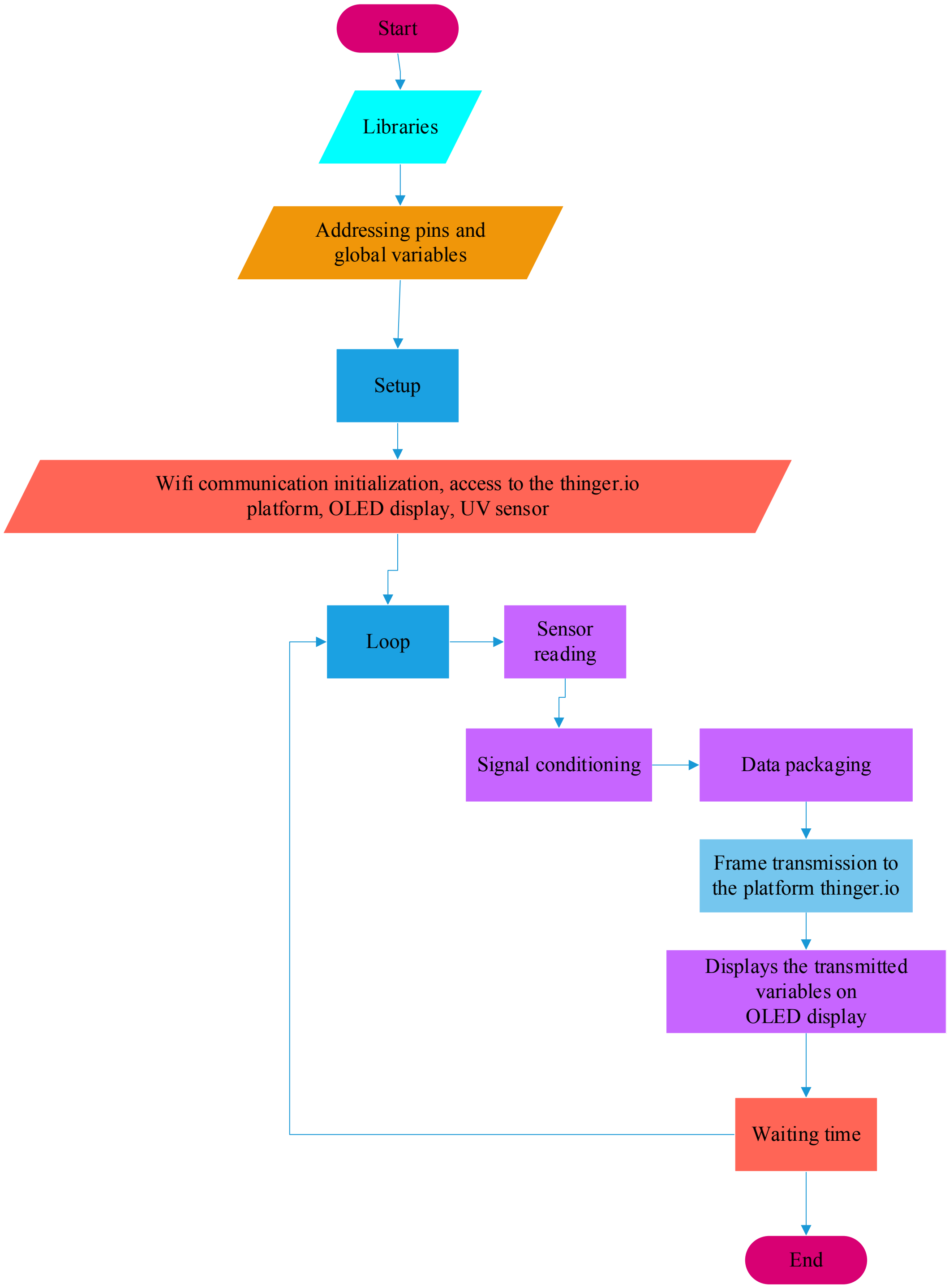


2.5 Algorithm architecture of the UV radiation monitoring device

Figure 7 shows the flowchart of the algorithm developed for the acquisition of the UV radiation sensor signal. The structure consists of libraries for access to the wireless Wifi network, OLED screen, etc.; pin addressing, global variables; configuration and initialization of communication as a transmitter; UV sensor reading, signal conditioning, data transmission in 5-minute intervals and display of variables transmitted on the OLED screen.

Figure 7

Algorithm flowchart

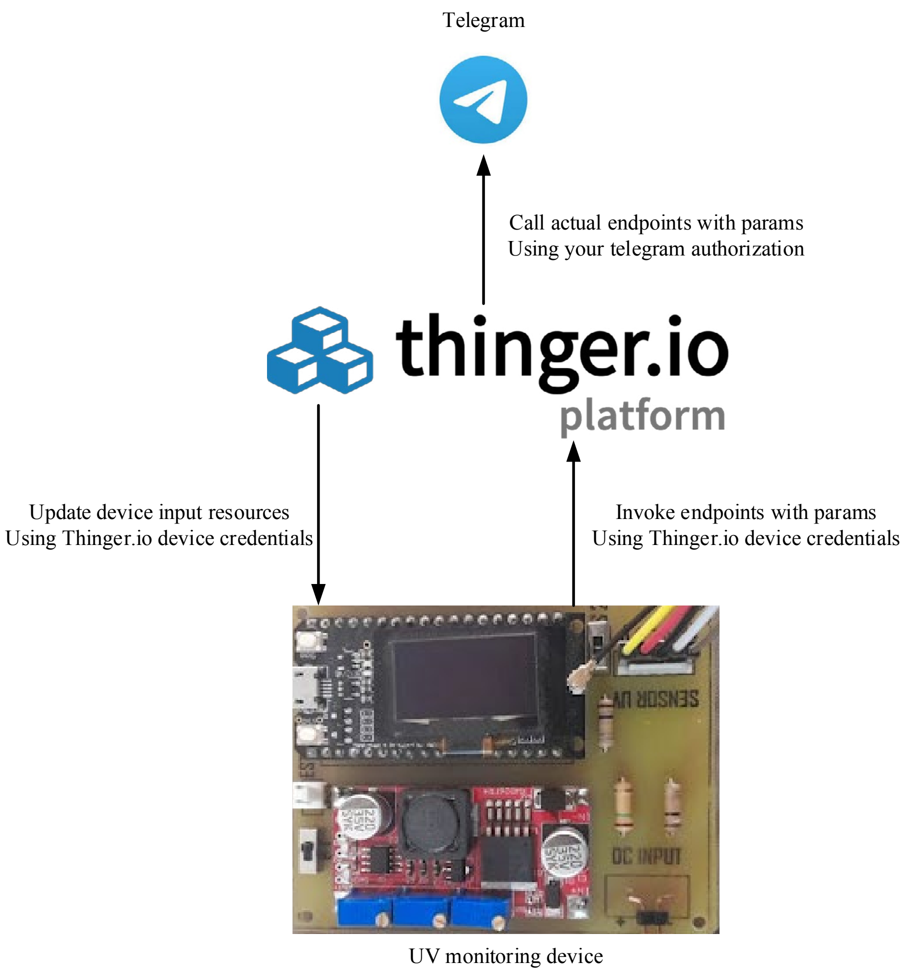


2.6 Alarm management architecture

The UV index monitoring equipment was configured by code to generate alarms when it detects an index greater than 4, so that it invokes the endpoints of the Thinger.io platform and sends a text message to the Telegram account of the farmer who is registered. *Figure 8* shows how to connect to Telegram services and manage alarms from the IoT device.

Figure 8

Alarm management architecture



Results

This section will present the evaluation of the system implemented in the community of Chirinche Bajo located at 2983 meters above sea level, in the city of Salcedo, Ecuador.

Figure 9 shows the device implemented in a strategic location with geographic coordinates (Latitude: -1.082956, Longitude: -78.648369), for UV radiation monitoring.

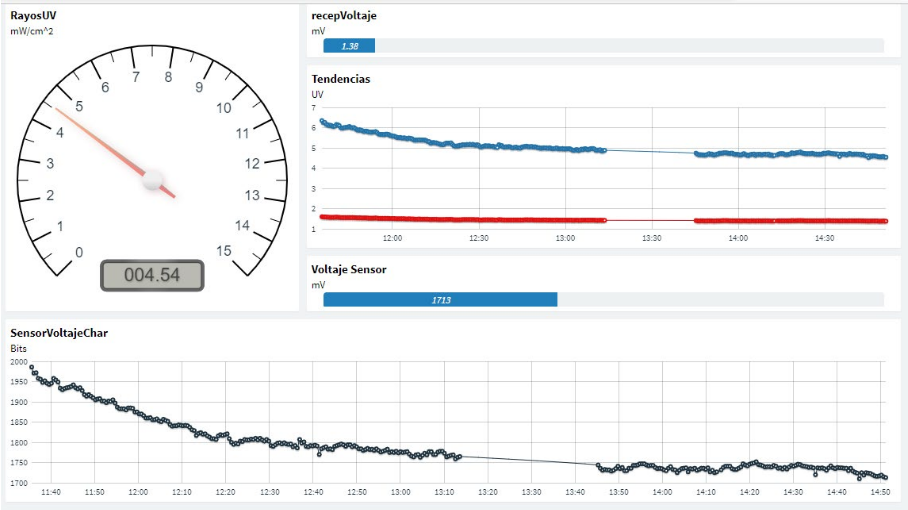
Figure 9

Implemented device

The implemented user interface consists of UV radiation and alarm widgets, as shown in *Figure 10*.

Figure 10

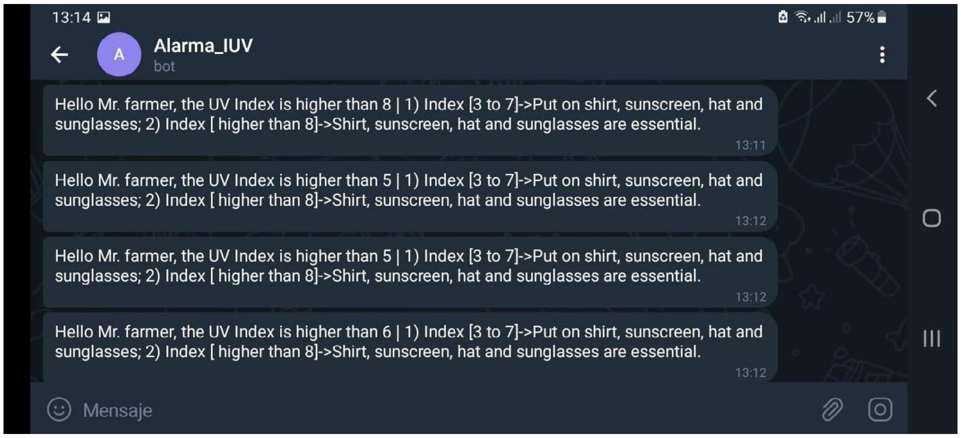
Implemented user interface



The system has an alarm system, which sends a text message to the Telegram of the registered farmer, the criteria for sending the message is when the UV monitoring device detects an index greater than 4. *Figure 11* shows the text messages generated by the IoT system implemented.

Figure 11

Implemented user interface



3.1 Analysis of the monitored UV variable

According to the analysis of the period of global solar radiation 2001 - 2015 and UV radiation 2009-2017, with data recorded by the National Directorate of Meteorology and Hydrology (SENAMHI), they observed a reduction in global solar irradiance, likewise UV ultraviolet radiation had a slight tendency to decrease over time, they also determined the typical behavior presented at 12 noon maximum irradiance records depending on the stations (Chambi, 2018).

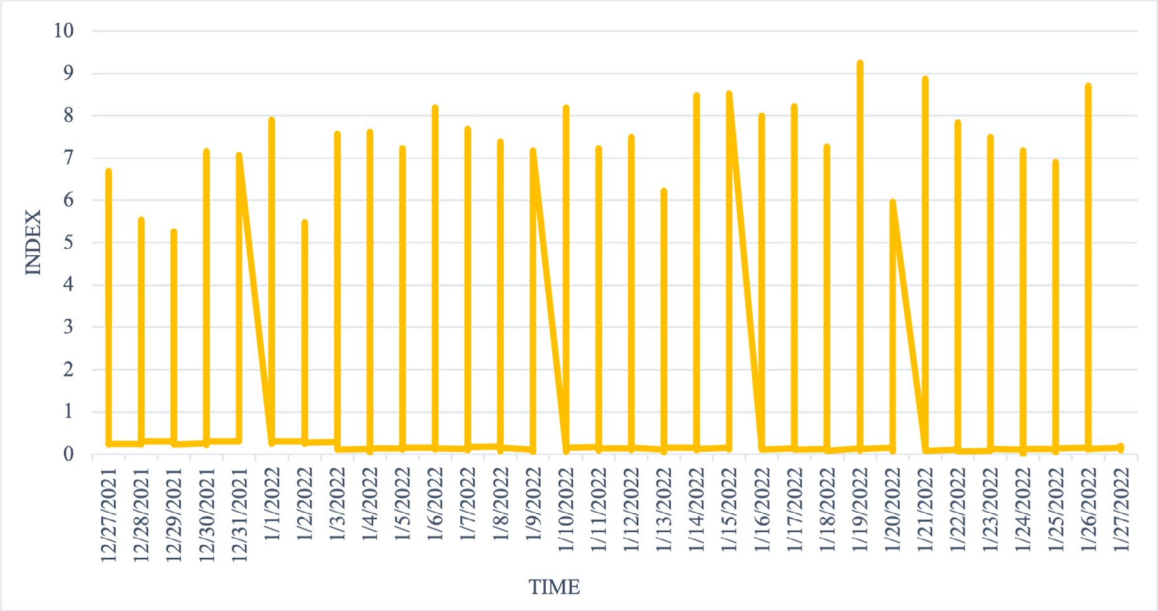
The exposure time when the UV radiation is between 1 and 2 can remain outdoors without risk, for IUV of 11 or higher can be exposed for a maximum time of 10 minutes; the IUV on the earth's surface are also measured in , which for better understanding the WHO has transformed into integer values ranging from 1 to 15 (Acurio Maldonado, 2021).

To analyze the variability of the UV radiation index, the device was kept under monitoring from December 27, 2021 to January 30, 2022.

The behavior of the UV radiation index is an important factor for taking protective measures for the skin and eyes of the farmers residing in the Chirinche Bajo community, which is why the device was kept in constant monitoring of the UV radiation variable as shown in *Figure 12*.

Figure 12

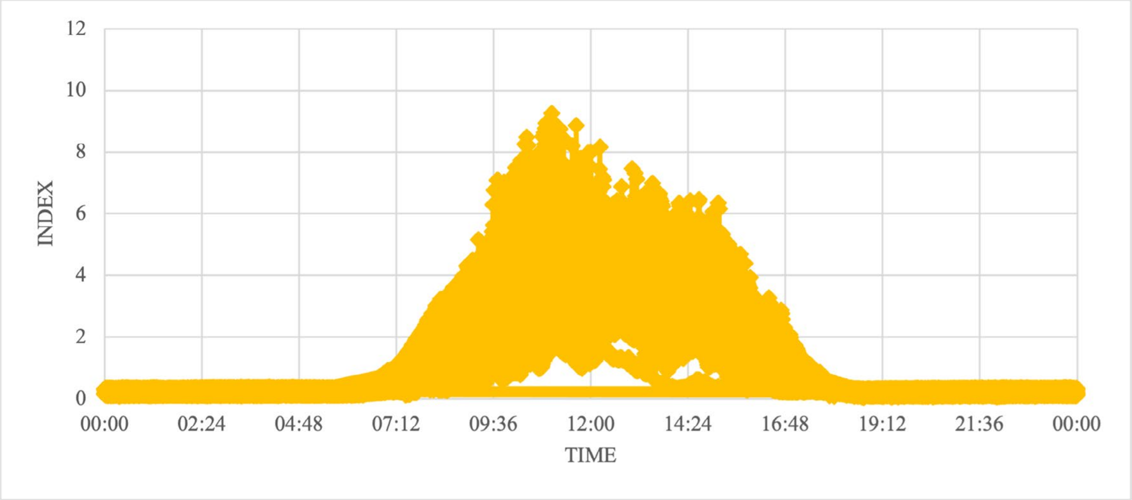
UV index monitoring



A balance of the behavior of the UV index for all days showed that the variability is similar, as shown in *Figure 13*.

Figure 13

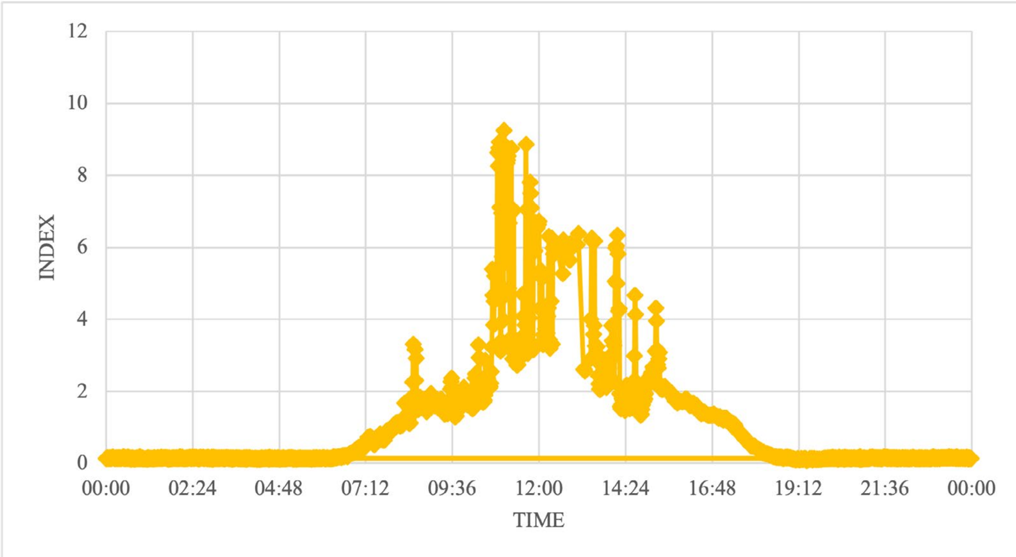
UV index variability



When analyzing the incidence of the UV factor, it was found that on January 19, 2022, the device received a greater variation in the UV index, which was higher than 9, as shown in *Figure 14*.

Figure 14

UV radiation index per day



Conclusions

The designed device complies with UV radiation monitoring standards, which was verified through experimental methodology in the community of Chirinche Bajo. The investment to manufacture the equipment was US$70, which can be replicated and implemented in several communities. The device has a battery with an autonomy of 48 hours. It was found that these technological tools are very useful to generate studies and analysis of climate change as the variability of ultraviolet radiation that every day is more intense and dangerous for the health of the epidermis and sight of people especially for farmers who are exposed to the intense sun in their working days in the crops, the system in the days of operation detected a UV index greater than 9 in the morning and afternoon hours (11am to 13pm) which according to WHO is classified as very high danger; The company recommends wearing clothing that covers most of the body, sunscreen, a hat, and sunglasses. In the community, the farmers use their traditional hats that do not cover their faces optimally, and due to the lack of resources, they do not use sunscreen.

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