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Low-Cost Environmental Monitoring Station to Acquire Health Quality Factors †

Ioannis Christakis *, Vasilios A. Orfanos, Pavlos Chalkiadakis and Dimitrios Rimpas

Department of Electrical and Electronic Engineering, University of West Attica, P. Ralli & Thivon 250, 12244 Egaleo, Greece; vorfanos@uniwa.gr (V.A.O.); pchalk@uniwa.gr (P.C.); drimpas@uniwa.gr (D.R.)
* Correspondence: jchr@uniwa.gr
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Abstract: With the exponential development of MEMS (Micro Electro Mechanical Systems) in the last decade, emphasis has been placed on the construction of IoT devices in conjunction with an appropriate information system to assist citizens in various fields (transportation, trade, etc.). More specific on health, there are specific IoT devices which can monitor a patient's health condition or provide environmental data for the area, information which affects the health quality conditions. In densely populated areas and especially in large cities, environmental pollution, apart from the known issue of air pollution, there is also the exposure of citizens to solar radiation (ultraviolet UVA UVB radiation), as well as noise pollution in an areas where people live and work. Ultraviolet radiation, especially during the summer months, is responsible for skin cancer and various eye diseases, while noise pollution can create mental disorders in humans, especially to the underaged ones. In this article, a low-cost solar radiation and noise pollution monitoring station is presented. The parts that consist this implementation are: a microcontroller (TTGO-OLED32) with an integrated LoRa device, an ultraviolet radiation sensor and sound sensors. In addition, a mini ups device has been used, in case of power failure and a GPS device is utilized for the location point. The measurements are obtained by the sensors every ten minutes and are transmitted via the LoRa network to an application server in which the user has direct access to the environmental data of a specific area. In conclusion, the data obtained from such IoT devices help in the study of cities to optimize factors in people's lives.

Keywords: IoT health system; ultraviolet radiation; noise pollution; sensors

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1. Introduction

Issues regarding environmental pollution, health quality, specifically in developed large cities, has been the subject of various studies in recent years [1–4]. In general, the term health, is referenced to terms like the wellness of the body and the effects on human life [5–8], however, mental health also proved equally severe [9–11]. In the everyday environment, where someone lives and works there is a set of pollutants, such as atmospheric pollution with increased greenhouse gases, but also other forms of pollution such as noise and light. Regarding atmospheric pollution, the air quality in densely populated areas has shown an impact on human health, both from gaseous pollutants and from particulate matter [12–14], which are the result of human activities such as the development of industry, residential heating systems, traffic, etc. In addition, there are other forms of environmental pollution, like the acoustic noise of an area, originated by industrial or residential activities, leading to the degradation of life quality, as well as the appearance of mental disorders. It greatly contributes to human mental disturbance [15] and although it has not been proven to be connected with mental diseases, a correlation of residences near airports that show strong symptoms of depression is evident [16]. Subjective health symptoms, such as fatigue and headaches, are consistently reported more often by children who live near an airport facility or go to school in noisy areas [17]. There are issues reported, where the light pollution of an area with ultraviolet radiation can be harmful to humans. Researches have shown the harmful effects of human exposure to ultraviolet radiation from the sun, as it causes skin cancer in a very large percentage [18]. UV radiation can also affect vision as it carries higher energy than visible light and high dose exposure to UV radiation causes direct cell damage, which plays an important role in cancer development [19]. In the last decade, the rapid development and construction of electronic circuits has resulted in the creation of reliable microcontrollers and low-cost sensors. This aspect offers feasibility to build affordable environmental monitoring systems, both in terms of air quality monitoring [20] and environmental conditions such as acoustic noise and light pollution of an area, giving citizens precious information for their residential area. As a communication carrier, a LoRaWAN [21] network can be used to ensure the precise linkage of monitoring stations without fees in a spatial coverage of 3 km. This paper presents the study and implementation of a low-cost, environmental monitoring station which includes both noise and light pollution sensors. The retrieved values of the noise level are measured at dB for noise pollution, while the level of ultraviolet radiation is measured as a UV index of light pollution. Due to rapid technology development, there are many reliable low-cost systems that meet low power consumption and excellent processing standards such as the TTGO@ESP32 microprocessor [22]. These systems offer sufficient local data analysis with low power consumption and LoRa wireless connectivity. This article is organized into the following sections: II the materials and methods, III the results and discussion and, IV the conclusions.

2. Materials and Methods

Three sections compose the IoT architecture [23], Perception, Network, and Application, as seen in Figure 1.

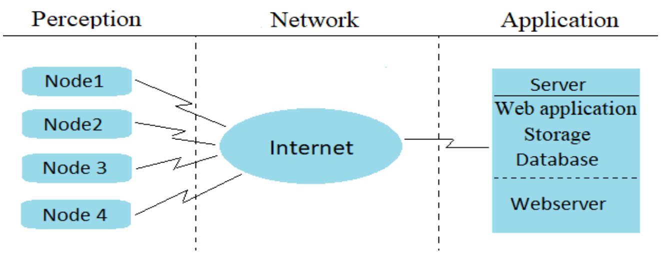


Figure 1. IoT Architecture topology.

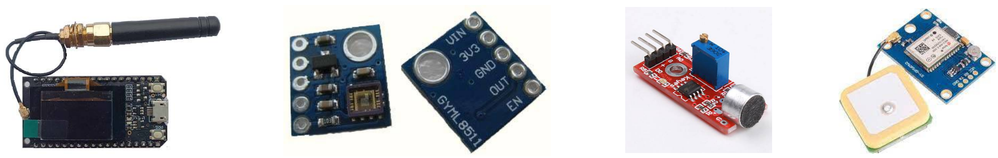
In the case of this work, the low-cost environmental monitoring station constitutes the Perception part, including the microcontroller and sensors. The microprocessor unit (CPU) is the TTGO@ESP32, and as sensors, a GYML8511 UV [24] sensor for light pollution and a sound sensor module [25] for sound pollution were used. The network section, also referred as transparent segment with aiming to connect perception and application sections. This module is responsible for transmitting data from the low-cost stations to a central station (server) that contains the application section. In this work we utilize the built-in LoRa network function contained in TTGO@ESP32. Data transfer has been done using "The Things Network (TTN)" LoRaWAN network. The Application section is the final stage of the IoT system, which provide the services to the end user. This section supports many applications for the development of IoT (Internet of Things) systems. In this work the application section is supported by cayenne application server web portal [26]. The components of low-cost environmental conditions monitoring station are the microprocessor and the sensors. In addition, an expansion board was constructed for the interconnection between CPU and sensors.

- TTGO@ESP32

The main CPU is the TTGO@ESP32 [22] (Figure 2a), that is an open-source Arduino based firmware for IoT implementations. It's an ideal module for IoT devices as it remains highly affordable with a plethora of features, such as: processing capabilities with a fast time response. It can be programmed using the open-source Arduino Software (IDE) providing convenience in coding and uploading to the board, while being a familiar and user-friendly software. This processor satisfies the requirements of communication for the sensors array (25 I/O ports, UART, I2C, SPI interfaces). The CPU data processing speed further satisfies this implementation with low power consumption. The microprocessor integrates the data transfer communication which can be implemented over Long Range (LoRa) network or wireless network (Wi-Fi). In addition, a battery (type 18650) is connected to the integrated charger of the main board for uninterrupted operation in the event of a power failure and voltage stability.

- Sensors

For the environmental conditions, light and noise pollution sensors were utilized, the GYML8511 [24] ultraviolet sensor (Figure 2b) outputs an analog signal in relation to the amount of the UV light, as the sensor is able of detecting wavelengths of 280–390 nm light with high precision. For a Noise pollution validation, a sound sensor module [25] (Figure 2c) of a dynamic microphone (electromagnetic microphone) and amplifier circuit with analog output was exploited. In addition a GPS module (Figure 2d) was used for the station location.

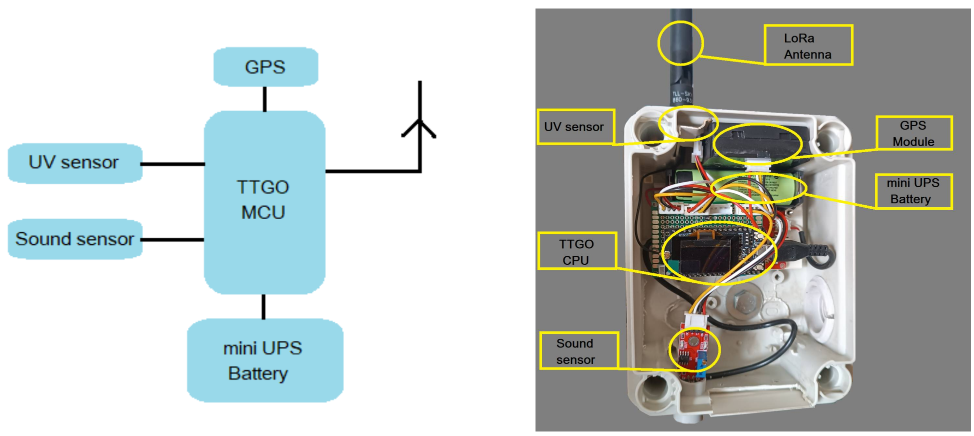


(**a**) (**b**) (**c**) (**d**)

Figure 2. The CPU and sensors of low-cost station: (**a**) The TTGO@ESP32 CPU board; (**b**) the UV sensor GYML8511; (**c**) the sound sensor; (**d**) the GPS module.

- Station implementation

The diagram of implementation and the final construction of environmental conditions monitoring station are shown at Figure 3a and Figure 3b respectively. The whole device was integrated in a waterproof box type IP66 (with dimensions of 115 mm × 150 mm), which is rather small. The total cost of the station is approximately 80 €. Every ten minutes a measurement is conducted and transferred over the LoRa network through the internet to the Application server.



(**a**) (**b**)

Figure 3. The implementation and construction of low cost station: (**a**) the station components diagram; (**b**) the final construction of the low-cost monitoring station.

3. Results & Discussion

The evaluation and accuracy of measurements from low-cost environmental conditions are presented at this section. This custom-made monitoring layout have been installed on the roof of the building, directly to the sun, at the height of 1.5 m, on a location at eastern Attica in Greece and specifically at the municipality of Agia Paraskevi. On the evaluation of the UV low-cost sensor, the common knowing measurement of the UV pollution is the UV index, the calculation of the output of the low-cost UV sensor give the miliWatt/square centimeter, the investigation of the transformation of output sensor to UV index took place. According to the datasheet of the sensor [24], specifically of the graph of output voltage—UV intensity characteristics can extract the slope of the sensor response. The proposed UV index (Equation (1)) is the result, as the output of the sensor is multiplied to the slope and the result is divided by a correction factor (A).

$$UVI = \frac{\left(calculate\ output\ \left(\frac{mW}{cm^2}\right) \cdot \ slope\ \left(\frac{cm^2}{mW}\right) \right)}{A} \tag{1}$$

The reference data are received by the official monitoring station in cooperation with the National Observatory of Athens [27]. The distance between the low cost station and reference station are 3 km. The follow Figure 4 shows the time series measurements and the correlation of UV index of the low cost monitoring station and the reference station at the last day of June, July and August of 2023.

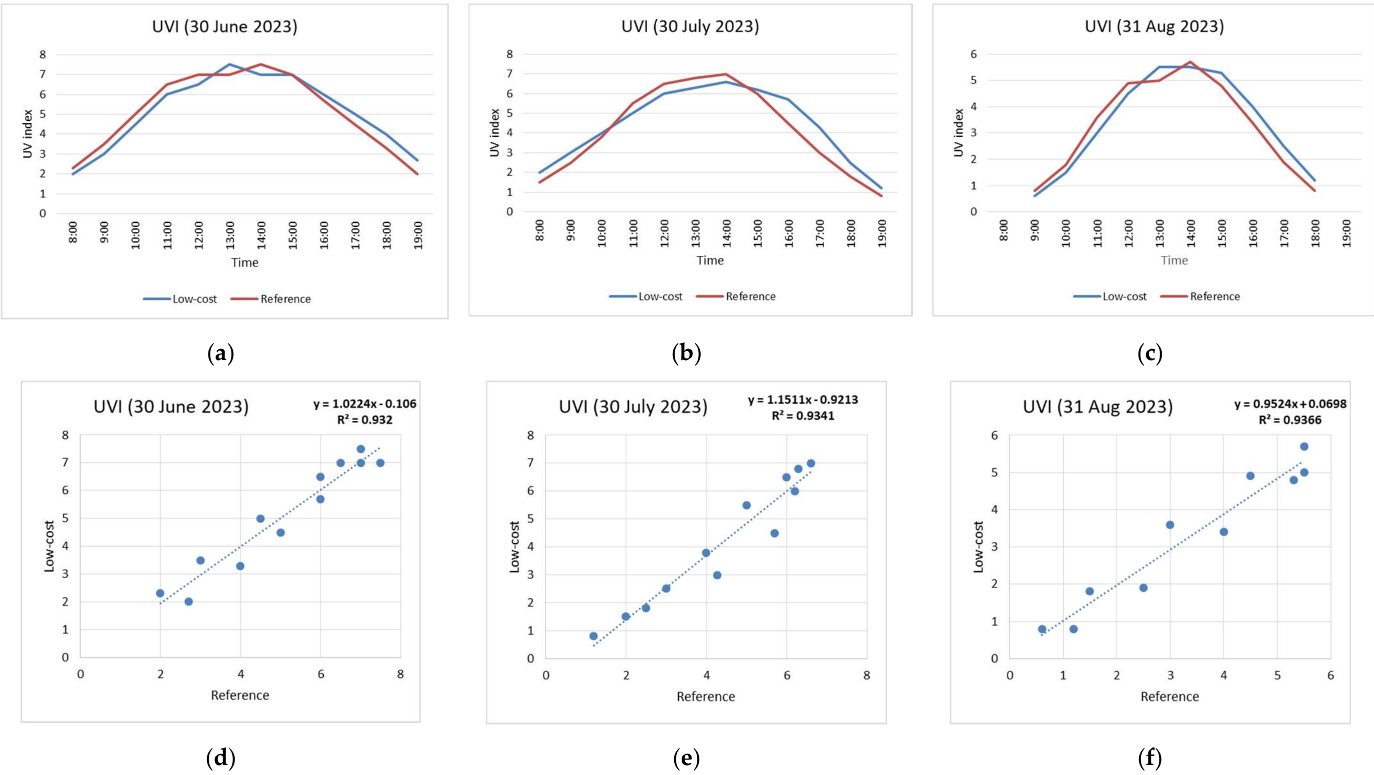
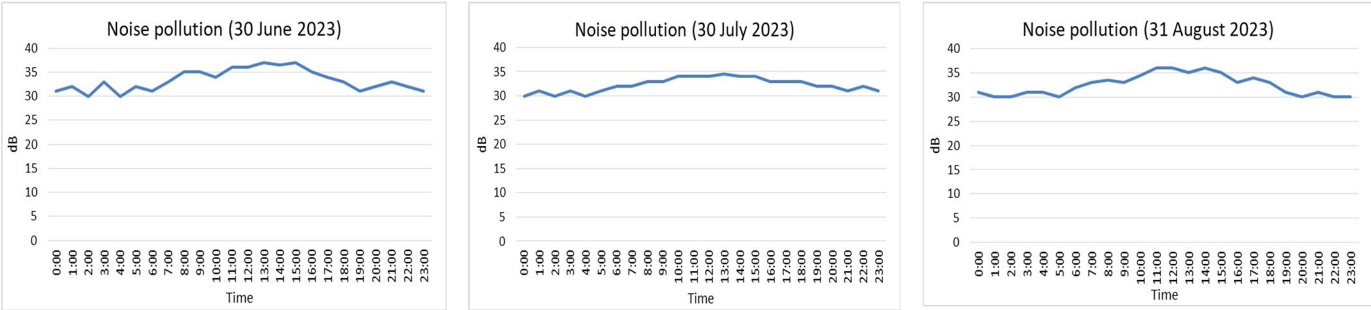


Figure 4. Time series and correlations of measurements of low-cost sensor and reference of UV index: (**a**) Time series of 30 June 2023; (**b**) Time series of 30 July 2023; (**c**) Time series of 31 August 2023; (**d**) Correlations of 30 June 2023; (**e**) Correlations of 30 July 2023; (**f**) Correlations of 31 August 2023.

Regarding noise pollution, the results of the measurements are shown indicatively as there are no reference measurements. The calibration of the microphone module was performed in a laboratory where the noise level decibel (dB) was known by official instruments. The Figure 5 shows the time series measurements of noise pollution for the low-cost monitoring station at the last day of June, July and August of 2023.



(**a**) (**b**) (**c**)

Figure 5. Time series measurements of noise pollution (dB): (**a**) Time period of 30 June 2023; (**b**) Time period of 30 July 2023; (**c**) Time period of 31 August 2023.

4. Conclusions

In the environment, apart from atmospheric, there are other forms of pollution, such as light and noise, which affect human health and wellness. In this article, a low-cost UV radiation and noise pollution monitoring station has been presented. The data transfer has been done through the LoRa network while the visualization is supported by Cayenne, which is an IoT application server on the internet. The measurements have been retrieved in-vivo and the measured values have been corrected using a proposed equation to extract the UV index for the UV sensor and the sound output in decibels (dB) from the sound sensor. The results are encouraging as the low-cost UV sensor shows a correlation coefficient R^2 greater than 90% with respect to the reference data, while the noise value accuracy shows satisfactory results as the station was installed in a quiet neighborhood of northeast Attica. The use of low-cost sensors and their utilization with micro-controllers of new technology, can satisfy a wide range of detection for environmental conditions. The aim is to attract more and more people to actively participate in actions such as public health monitoring which is a common good for all. However, it is a good and affordable solution for the general public to be informed about the environmental conditions where they live and work.

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