# UV Alarm

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1. Introduction

The objective of the project is the construction of a prototype that can alert human beings about the degree of danger of UV rays in a certain period of time.

The prototype can be transported or simply installed in many locations (near pools, beaches, parks and other locations where people are subject to more exposure to UV rays)

There are three main types of ultraviolet rays that are emitted by the Sun. UV-C rays, the most dangerous ones, are completely absorbed by the ozone layer. The remaining types, UV-A and UV-B, have different effects on the human body and those effects depend on the time of exposure to them.

UV-A radiation (wavelength between 400-315 nanometers) does not cause sunburns. However, they it penetrates deeply into the inner layers of skin, where it damages the connective tissue, causing premature aging, wrinkles and loss of skin elasticity. Moreover it is also responsible for tumors in the ocular region and cataracts.

The majority of the UV-B radiation (wavelength between 315-280 nanometers) that hits earth's atmosphere is intercepted by the ozone layer. However, the reduction of this layer has been leading to the rise in the amount of UV-B rays that hits earth's surface. Due to their low wavelength, UV-B rays penetrate outside layers of the skin, damaging the DNA and prompting the skin to tan as an attempt to protect itself, forming a brown pigment (melanin), producing melanocytes (pigment cells) located in the junction zone between the epidermis and the dermis. If the dose of UV-B radiation is too strong, the skin will suffer a sunburn and become inflamed, turning red as a sign of alarm emitted by the skin cells. That occurs when incident UV radiation exceeds the capacity of protection of the skin's melanin. The concentration of this pigment varies widely between people, but in general, people of darker skin have more melanin that those of lighter skin. Consequently, the occurrence of sunburns among individuals of darker skin is lower. The resulting metric erythema irradiation is calculated considering the measurements of solar irradiation as well the experimental measurements of erythema activity. When the result is represented graphically, there is a peak in 308nm. At a cellular level, UV-B radiation causes damage on the DNA, which can be passed along several generations of a progenitor cell, leading to a rise on the risk of dermal cancer. Na "incident" of a burn with blisters doubles the risk of getting a malign melanoma. The risk of sunburn rises with the proximity to the earth's equator. However, even in intermediate latitudes, and especially near reflection zones (sand and water), we have a rise in exposure to the skin.

It is important to reference that the risk can also be augmented by medication that makes the user more sensitive to UV radiation. Certain antibiotics, contraceptives and tranquilizers have this effect and it is very important to disclose and monitor these effects. Redheads and/or people with freckles generally have a bigger risk of suffering sunburn than others, due to their lighter tone of skin so they need to have increased care.

The sun tan, which appears naturally in some individuals as a defense mechanism against the sun is desired by many in the west. This "trend" leads to an increase in incidence of sunburns without, in the majority of cases, people having real consciousness of the problem and of the risk. A study from 2003 revealed that 36% of western adults get a sunburn at least once a year, and that 50% of them had suffered sunburn at least once in the months prior to the study. In the past few years, the occurrence and severity of these sunburns has increased all over the world, which raises concern about the effects of radiation in medium and long term.

The behavior of people when exposed to the sun is considered to be the biggest cause of rise in the occurrence of skin cancer. A rise in outdoor activities and a change in sun bathing habits have led to an excessive exposure to UV rays. However, minor quantities of UV's are necessary and essential to the production of vitamin D. The radiation is also used in treatment to various diseases, but with medical supervision.

Awareness programs with sun exposure alert systems are necessary to the increase of knowledge in the public eye about the harm that UV rays can cause and to the change in behaviors so to prevent the occurrence of skin cancers, cataracts and other eye problems.

## 2. Development

The prototype used in this project is composed by various systems. Visually, its outside is comprised by an isolated box, generally utilized in the protection of equipment or electric boards, a photovoltaic panel and various supports to keep both parts together as a single block. Holes were made in the box so that four cable glands could allow the passage of cables to its interior. This selected box can house diverse system components in a safe and sealed manner. Then, inside the box was placed a Raspberry Pi 3, a small computer used in this project that allows for total control over the device. The Raspberry Pi 3 presents the following characteristics: the Broadcom BCM2837 chip which has the following components: CPU, GPU, DSP, SDRAM, USB port; The CPU is an ARMV8 64bits quad-core that works at 1.2GHz; The instruction set is 32bits RISC; The GPU is a Broadcom VideoCore IV; 1GB of SDRAM (shared with the GPU); 4 USB 2.0 ports; Video ports Conector MIPI CSI; HDMI video outputs; audio outputs with a 3.5mm connector and HDMI; Built in storage: Micro SD; Network connections 10/100 Ethernet (RJ45) via USB hub, Wifi 802.11n, Bluetooth 4.1; low level peripherals: 17 x GPIO, SPI, I2C, UART; does not have a Real Time Clock.

A memory card ( MicroSDHC, 16GB, class 10) was used to install the operative system. The card was put in a PC using a SD adapter. The download of the operative system, Raspbian Jessie, was made through the web site. The OS was installed using the windows 10's recording software Win32DiskImager and using the image file (ISO).

A small window was made in the box so that an analog sensor for reading UV radiation levels could be placed. Although this sensor (ML8511) does not go through all wavelengths, it can input a voltage that is linearly related with UV intensity (mW/cm2). Thus, calculations were needed to obtain, through the radiation values, an approximation of the effective UV index.

Beyond that, a calibration of the sensor was also done using a measuring device.

The sensor is protected in a way so that it does not suffer humidity damage from the exterior. It was placed inside the box, in a window so that it was possible for light to pass. This small window was sealed using silicone. The window is made of 93% pure quartz in order to enable the UV light to pass through it and to reach the UV ray sensor in the necessary wavelength (UV-A between 315 and 400nm ; UV-B between 280 and 315 nm)

Since the sensor is analog and the Raspberry Pi only has digital ports, an analog digital converter (ADC chip MCP3008) was used. A breatboard was utilized to construct a circuit to which the UV sensor, the MCP3008 and the Raspberry Pi ports (GPIO) could be linked to connect to a Serial Peripheral Interface Bus in the Raspberry Pi.

The MCP3008 chip converts analog data to digital data and sends said data to the Raspberry Pi, which has software capable of reading these data and make an approximate calculation of the UV index. The data from the sensor is sent once every 15 minutes to an online database called Firebase.

To allow the public to access this data, a phone app (Android) was developed, giving access to a database updated in real time on the cloud. This application has the name "UV Alarm" and allows registered users to access the figures sent by the sensor.

Since the system has to work with internet access, the data are sent through the wireless board that is connected to an access point. However, in places where that possibility is non-existent, it is possible to connect a Modem 3G board or an USB stick.

To make the system independent energetically, a solar panel was place on top of the box (50 watts, 12 volts) and it was connected with two cables (positive, negative), passing through the cable glands, to the photovoltaic solar controller. A rechargeable gel battery was also connected to the controller so that discharges could be avoided. An electronic component that made the conversion from 12v to 5v was used to power the Raspberry Pi. Thus, the continued functioning of the whole system is secured during cloudy days and even during the night.

The Raspberry Pi only needs to be switched on while there is visible light, otherwise it can go into idle mode or suspension to save energy, as the readings of UV rays after a certain hour are minimal or even null.

Automatically turning the power on or off in the Raspberry Pi isn't, however, a linear operation. In other words, the OS, running and using the SD card, cannot be powered off suddenly. The command to shutdown has to be executed to allow for the termination of all running processes and prevent corruption of the files and data. That way, a new board was necessary, to enable cycle scheduling that allows to turn the Raspberry Pi on and off in a controlled way. The coupled board was the Witty Pi 2 that has an RTC (Real Time Clock) to keep the correct time and date when the system is powered off and to allow for the cycles to be completed. The communication between the RTC and the Witty Pi 2 is done via protocol I2C. The board has a button that allows for the Raspberry Pi to be switched on/off physically and shuts down the system in a controlled manner.

Since it is only necessary to storage the UV sensor figures once every 15 minutes, a scheduling cycle is arranged in a way that it is possible to save energy and battery lifespan. Another alternative would be to power on the Raspberry Pi for certain periods of time, for example, powering on at 8:00 a.m. and shutting down at 10 p.m.

## 2.1 Power calculation of the photovoltaic panel, battery and discharge controller.

It was necessary to estimate the power the Raspberry would need to work without a mouse, keyboard and a monitor. Thus the result of 2 watts (~0,35*5,2) was concluded. It would take 2 Watts to power the Raspberry Pi for 7 days a week, 24 hours a day.

The Raspberry Pi needs a 5V power supply and taking costs into consideration, a 12v solar panel, as well as a 12v battery, was selected. The battery selected is a stationary, deep cycle, gel battery since it is the most adequate to a solar charge system and a sealed box.

The system will have wastes, even with an efficient system in terms of voltage regulation. Therefore, and assuming 80% efficiency, Raspberry Pi will use 2.5 Watts from the battery.

With a 12v battery, 2.5 Watts correspond to a current of 0.2 Amperes. Each hour the Raspberry Pi works, 0.2 Ah of current will be withdrawn from the battery. This results in 4.8Ah for every 24 hour period, which is the average current that a solar panel charges the battery with every day.

Although during the summer it is expected to have many hours of sunlight, during the winter, the opposite occurs, days can go by without sunlight reaching the solar panel.

With 2 hours of sunlight, winter average, per day, the battery will be charged with 200Wh will be charged by a solar panel of 100 Watts

It takes 5Ah to charge per day. And taking into consideration 2 hours of sunlight per day during the winter, it will take a solar panel that can give 5/2 = 2.5 Amperes. For a system of 12V that means that a panel with a power of 12 x 2.5 = 30 Watts is necessary.

In order to have a safety margin, a panel of 40 Watts or more should be considered.

The battery must be of deep cycle, thus it cannot lower its charge under 40%, and should be maintained fully charged or near full charge.

The Raspberry Pi consumes 5Ah of the battery's charge per day, and the battery should have a clearance of some days (2 days) without sunlight so that its charge will not drop under 40%, thus, 2x5=10Ah. However, to keep the battery's charge at 60% it would take at least 10/0.6=17Ah.

Obviously, if the charge is higher, than the clearance until the battery goes uncharged is also higher.

The solar charge controller is a device that prevents the battery's overload. A controller of 10 amperes was chosen.

## 2.2 Software Development

### 2.2.1. Raspberry Pi 3 software

An app was developed using python v3.4.2, to allow for the reading and submission of the UV sensor figures to the cloud (to the Firebase). This program is executed as soon as the Raspberry Pi is turned on and is always running.

The sensor ML8511 is analogic and uses the SPI protocol to communicate with the Raspberry Pi.

The circuit was assembled using the breadboard and the MPC3008 chip to enable ADC conversion. The whole circuit was defined and the figures read by the ADC were tested.

The Adafruit_MPC3008 and Adafruit_GPIO.SPI libraries were used to read the ADC values.

The SPI protocol was used through hardware configuration. Thus, port 0 and device 0 were used. 8 readings were made, and their average calculated.

In order to send the data the Firebase, on the cloud, it was necessary to write a heading of configuration where apiKey, authDomain, databaseURL, projectId, storageBucket, messageSenderId were defined. These data were picked from the Firebase configuration console. Thus a connection to the Firebase is created, using the defined configuration.

The next step is the definition of the user authentication data.

The values of the sensor are read, the UVI is calculated and the data to be sent to the cloud is defined (date, time and UVI). All of this occurs in an infinite loop (this routine is always being executed).

### 2.2.2. Android smartphone software

The first version of the android smartphone software, created using the Firebase and IDE Android Studio, has the capability of visualizing the data sent by the Raspberry Pi in real time. With the app created for Android smartphones it is possible to read/delete data (Date, Time and UVI) from the Firebase, authenticate users through email and password and create new users.

Every aspect related to the definition of reading/writing of data permissions as well as validation of data in the server, is controlled on the Firebase console.

The first step was the configuration of the project in the Android Studio. A project was created with the name of UVAlarm with a minimal SDK of 15 API.

Before the start of the project, an account was created at firebase.google.com. After logging in, an UVAlarm project was created in the console to store the app data. Afterwards, the country and region of the project was chosen.

The google-services.json file was downloaded to the app folder.

The JSON file contains the configuration that the Android app needs in order to communicate with the Firebase servers.

The project requires the creation of a gradle file with the JSON file data. In order to achieve this, an update is made to include the Google services plugin.

Necessary tasks to create the app on the Android Studio: Project definitions, change of content_main.xml's behavior, setting of the data access security guidelines, Authentication, data clearance and validation, recording and reading of data and users log off.

### 2.2.3. Cloud Backend

The Cloud Backend creation for the Android app uses the Firebase. With the Firebase, it was possible to save and synchronize data in the NoSQL database on the cloud. The data is stored in JSON (JavaScript Object Notation- saving and exchanging data in text form) and synchronized with every client in real time. It also keeps the data available even when the app is offline.

APIs are made available allowing for the users authentication via email and password, Facebook, Twitter, GitHub, Google, anonymous auth, or integrated with another available authentication system.

Other services made available: Cloud messaging, Storage, Hosting, Remote Config, Test Lab, Crash Reporting, Notification, App Indexing, dynamic Links, Invites, adWords, adMob.

The Firebase gives access to tools for high quality app development and to the upscaling of user base.

## 3. Conclusion

The sun is a renewable energy source, reaching Earth in the form of radiation (electromagnetic wave). Solar energy can be utilized to produce electric current, when a photovoltaic panel is used. Photovoltaic cells are sensitive to radiation wavelengths between 300nm and 600nm, which includes visible light. The panels should be placed in a way that allows for maximum solar radiation. In Portugal, they should be facing south and have a tilt angle of 45 degrees.

The energy must be stored in batteries, to allow usage during the night or in days when there is no direct sunlight. A controller is needed to protect from discharges.

Of the total solar radiation that reaches Earth's atmosphere, some is absorbed by it (19%) some is reflected (30%) and the remainder is transmitted (51%). The amount of UV radiation that reaches a spot on Earth's surface depends on factors like: Time of day (between 10 a.m. and 4 p.m. is when the radiation is more intense), latitude (the level of radiation is higher near the equator), season (higher levels during the spring and summer), altitude (higher the altitude, higher the levels of radiation), the transparency of the atmosphere (clouds can block or reflect some of the radiation), surface reflection ( increase of rays) of: water, sand, snow, pavement, buildings and grass.

Awareness of the ultraviolet index as a way of prevention against excessive sun exposure cannot be confined to a certain date and time in a city/district. Exposure to ultraviolet radiation is a risk factor for the occurrence of skin cancer. Due to the depletion of the ozone layer (apparently it is temporary), the population is more exposed to UV radiation. The index measures the level of radiation on Earth's surface. The figures vary between 0 and higher than 11, so the higher the figure, higher the potential of skin and eye damage and lesser the time necessary to cause said damage.

Raising awareness about the risks of excessive exposure to UV rays and the need to adopt protection measures is of the upmost importance for public health. The nefarious effects on the health of the public and the cost of medical treatment will lower if the public is encouraged to adjust their exposure to sunlight and UV radiation.

Usage of adequate clothing is the best way to protect the skin. Non covered zones of the skin should be protected with sunscreen with UVA and UVB filters.

It is important to notice that the effectiveness of sunscreen does not depend solely on the quality but also on how it is applied. A sunscreen with Sun Protection Factor (SPF) of at least 15 should be applied generously every 2 hours for it to have protective effect. It should also be applied before sun exposure and after swimming in the sea and on the pool. If used correctly, sunscreens can be a good way of protection against erythema, cancer and photoaging.

Sunscreens attenuate the transmission of UV radiation to the skin. The SPF (presented by the sunscreens available in the market) is determined based on the ratio of UV radiation necessary for sunburn to occur, with and without sunscreen. It is important to know that this level of protection does not increase linearly with the SPF. For example, a sunscreen with SPF 10 lowers by about 90% UVB radiation, a SPF 20 sunscreen lowers UVB radiation by 95% and a SPF 30 lowers the level of UVB radiation by just a bit more.

Images and references (link to internet)