REAL TIME ULTRAVIOLET INDEX METER WITH INFORMATION SYSTEMS TO GENERAL PUBLIC

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Abstract: The radiation emitted by the sun known as ultraviolet radiation is related to several problems that might affect the human being. Most of times, people are well warned about the effects caused to the skin by the solar radiation overexposure but not about the effects to their eyes. This work aims at developing a real time ultraviolet (UV) index meter and a series of information systems that can educate people about the risk of overexposure to the sun, the effects to their skin, eyes health and how to protect themselves. An UV sensor was installed on the rooftop of a building and a radio transmitter circuit communicates the voltage value measured by this sensor to two radio receiver circuits, one attached to a panel, which is responsible to show the real time UV index and other plugged on a computer. The UV index, recommended protection and other information are shown on the screen. All measures transmitted from sensor are saved on the hard disk of the computer and on an online database. A graph of UV index variation per day can be plotted by the software on computer and a website shows the last UV index measured. It was noticed that general public didn't have enough information about the effects of UV radiation for skin and even less for the eyes. The system is public available at USP. Next steps of this project will aim at developing a mobile phone app and a downloadable version of the UV index software and a website.
Keywords: UV index, UV sensor, eye's health, radio communication, Python programming

Introduction

Part of the total radiation emitted by sun, in the 280nm to 400 nm range, is known as ultraviolet radiation (UV). The biological effects of UV radiation are studied worldwide and for example, it is known that vitamin D is produced by the body when skin is stimulated by UV radiation. There is also known that excessive exposure to UV radiation may cause skin burn and, at long term, skin cancer. The effects of this radiation for the eyes are studied by many researchers and a relation between eye's diseases, for example photokeratitis, cataract and pterygium, could be observed, for instance [1].

Most of information about effects of UV radiation is related to the skin, so most of people are aware of the risks and recommended protection to avoid sunburn. Yet there is not a consensus about risk of UV to the eyes, little information reaches general people regarding recommended and correct protection to the eyes and the possible diseases they may be exposed to over the years if they do not protect themselves. The aim of this work is to develop an UV index meter system, a panel and software to display this information on real-time and also record data about UV radiation incidence on city. As the UV panel and the computer screen should be positioned both on a place with a considerable flow of people, anyone could stop and read the information about risks and precautions about UV radiation. This situation will help educating people about risks from solar overexposure.

To inform people about UV radiation, it is adopted the Ultraviolet Index. This index consists in a measure of solar UV radiation level, which contributes to cause sunburn on skin, also known as Erythema.

$$UVI = \mathrm{C} \int_{280nm}^{400nm} \mathrm{E}\lambda \, \varepsilon\lambda \, \mathrm{d}\lambda \qquad (1)$$

Equation 1 represents the calculation of UV index. The interval of calculation is the UVB and UVA range, $\mathrm{E}\lambda$ is spectral irradiance [W/m^2/nm], $\varepsilon\lambda$ is the erythemal action spectrum, which represents the human skin response to UV radiation and C conversion constant that values 40 W/m^2 [2].

The UV index is represented as an integer number, and following recommendation from WHO (World Health Organization), the values are grouped by intensity categories, as shown on Table 1.

Table 1: UV index categories

Category	UV index
Low	1, 2
Moderate	3, 4, 5
High	6, 7
Very High	8, 9, 10
Extreme	More than 11

The absolute UV index should be measured and calculated for a clear sky condition, i.e. without clouds. The UV index is influenced by various factors, for example: time of day, local, altitude, thickness of the ozone layer, presence of clouds, latitude, etc.

Materials and methods

It was used the UV Cosine sensor, from SGLUX, which is a waterproof sensor for outdoor use purposes and it was built with correction of zenith angle. This calibration was made for the latitude of São Carlos- SP, Brazil (21.87° S) which is the city where the measures would be performed. Other features of this sensor are its output (0 to 5V) and its broadband response, which means it is sensible for UVA, UVB and UVC radiation [3]. The output of the used sensor (Figure 1) is a voltage proportional to the UV index. Even the maximum output voltage from the sensor is 5 V, a smaller value is proportional to the maximum UV index which is considered on most of related works, and this value is 14. A table is used to convert the output voltage from the sensor to an UV index value (Table 2). These values were the result of a calibration carried out by the authors on previous works.

Figure 1: UV-Cosine sensor, from SGLUX.

Table 2: Sensor's Voltage to UV index conversion

Voltage (mV)	UV index
0 to 6	0
7 to 19	1
20 to 32	2
33 to 45	3
46 to 59	4
60 to 72	5
73 to 85	6
86 to 98	7
99 to 111	8
112 to 124	9
125 to 137	10
138 to 150	11
151 to 163	12
167 to 177	13
> 178	14

The sensor was installed on the rooftop of Electrical Engineering Department building and connected to a radio transmitter circuit (Figure 2). This circuit is controlled by a pic 18f4550 microcontroller, which has the task of converting the analog output voltage from sensor to a digital value. The converted voltage is then sent to a radio transmitter module, which is attached to the transmitter circuit.

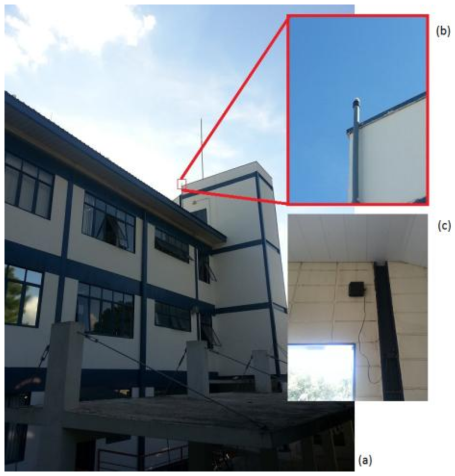

Figure 2: (a) Sensor installed on rooftop; (b) sensor detail; (c) Radio transmitter circuit inside building.

The module is a XBee PRO S2, with 50mW of output (+17dBm) and is able to operate over a range of 1 mile (1600 m), which is more than the necessary distance used in this project. The transmission is done over a serial protocol, operating at 9600 baud, 8 bits with no parity. The transmitter circuit (Figure 3) was installed inside the same building as the sensor, protected from the weather and constantly connected to the power supply. The sensor's output voltage value is transmitted each 21 seconds, and this value is an average of all values measured during this interval.

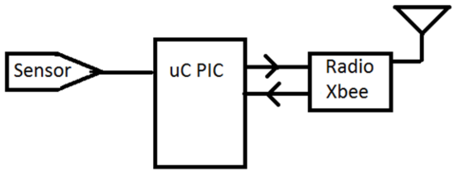

Figure 3: Transmitter circuit: block diagram.

There are two receiver circuits, both using the same radio module from the transmitter circuit, and one of them is attached to the UV index panel and the other to the USB port of a computer containing the UV index software.

The UV index panel was developed by previous works of the research group (Figure 4). It shows a scale from 1 to 14, representing the possibilities of measured UV index measured by the previously mentioned sensor. When the voltage of sensor's voltage is zero, it corresponds to 0 UV index, and at this situation panel lights are turned off. To indicate the present UV index, a blue light composed of two lateral LED strips is turned on. The dimensions of panel are 170cm height, 85cm width and 8cm depth, plus about 20 kg weight. Receiver circuit is attached to the back of the panel, inside a black plastic box. This circuit is also composed by a radio module, a microcontroller and current drivers for turning on LED's of the panel (Figure 5).

Figure 4: UV index panel.

The second receiver module is connected to one of the USB ports from a computer present on the laboratory (Figure 6). This computer is running a software specially developed for doing the task of display the measured UV index, show information about risks and precautions about exposure to UV radiation and manage all measured data. As the computer is never turned off, all measures being taken are saved on a text file, with about 4100 measures per day. Each line of the file contains date, the time when measure was taken, voltage from sensor and correspondent UV index value and each new day, a new file is created. Besides saving on text file, all measures are saved on an online database using MySQL. The software is written on Python programming language using TkInter graphical interface module (Figure 7). Another function of the program is to generate a graphic of daily UV index variation using the measured values as data source and the interval of plotted points can me chosen by the user.

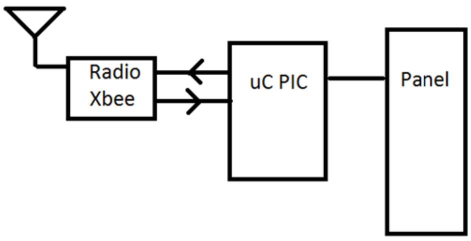

Figure 5: Panel's receiver circuit: block diagram.

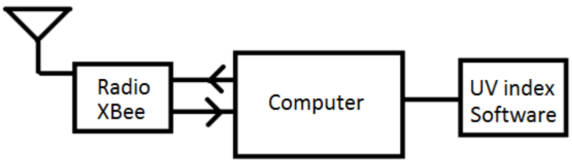

Figure 6: Computer's receiver circuit: block diagram.

Figure 7: UV index software screens: starting menu, graphical tool and real time UV index with information window.

Results

The graphical tool present in the software was capable of plotting the daily UV index variation graph. The behavior of this variation is represented very close to the expected, because a peak during noon is noticed and no UV incidence on the first and last hours of day. An interval of 15 minutes (Figure 8) and 1 minute (Figure 9) between measures is used to represent the UV index variation for date 3rd of June, 2014.

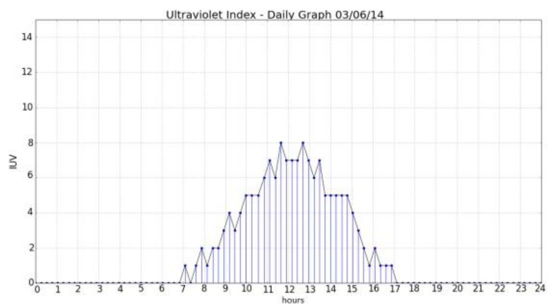

Figure 8: UV index variation (03/06/2014) plotted with 15 minutes interval.

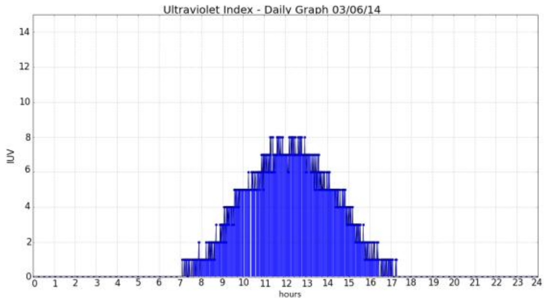

Figure 9: UV index variation (03/06/2014) plotted with 1 minute interval.

The developed UV index meter could be compared with a commercial UV intensity and dose meter, the UV Sens from SGLUX, which has been properly calibrated previously. The comparison between both measuring systems is shown on Table 3.

Table 3: Comparison between sensor and commercial UV meter measures for 16th June 2014.

Time	UVI meter	Commercial UV meter	% Error
12:30	7	7	0
13:00	7	6	16.6667
13:30	5	5	0
14:00	3	3	0
14:30	3	3	0
15:00	2	2	0
15:30	1	1	0
16:00	0	0	0
16:30	0	0	0
		Average error:	1.85185

Discussion

It can be noticed, from UV index variation graph (Figure 9) and real time UV index window (Figure 8), the sensor is very sensible to UV radiation changes. On running software, the index changes as the interval of measures is very short (21 seconds) and this can make a person reading the information a bit confused. This high rate variation can also be noticed by the peaks of on graph. Comparing graphs of 15 minutes and 1 minute interval, it seems more comfortable to see the first one, because UV index variation is smoother than where using a shorter interval. Next software update should use an average calculation method before displaying the UV index value and this will make the information easier to understanding by the general public.

From Table 3, it can be noticed an average error of 1.85185% comparing the measures of the sensor used in this work with measures from a commercial meter. This difference in results might be due an difference on sensitivity to UV radiation on sensor and probably the table used to convert voltage to UV index needs to be changed to give more accurate results.

Conclusion

The comparison between the commercial UV meter and the built system shows that the measures of our system have a high level of reliability. Considering the error rate of 1.85%, as shown in Table 3, the measures of the developed system most of times matches the values measured by the commercial UV meter, which has been calibrated by manufacturer on his factory. To a complete evaluation of the system, a larger number of measures should be taken and compared with the commercial UV meter values. As the developed software is already recording all measures from sensor each 21 seconds interval, a characterization of the UV radiation reaching São Carlos city can be done and used on future works. The wireless communication between sensor and both panel and computer is working since system installation, with no data being lost, except when the host computer, where UV index software is installed, automatically restarts. The panel is fully working and being displayed on university campus, providing information to general public about UV index at current time. Next steps of project will consist on developing a mobile phone app and a website to show UV radiation information.

Acknowledgements

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