GEULMóvil – Real-Time Ultraviolet Radiation Index Mobile Network

Briozzo Carlos, Diaz Berenguer Alvaro, Kugelmass Freddy, Peri Eduardo, Premuda Gianfranco and Simini Franco
Núcleo de Ingeniería Biomédica de las Facultades de Ingeniería y Medicina, Departamento de Medicina
Universidad de la República y Hospital Pasteur
Montevideo, URUGUAY
fkugel@fing.edu.uy, simini@fing.edu.uy

***Abstract*— GEULMóvil captures real-time solar ultraviolet radiation index (UVI), from moving vehicles. For the first time, geographically referenced UVI radiation is measured from the earth as opposed to indirect satellite UVI estimation. Time stamped UVI, along with GPS data, is included in a standard SMS message sent to a server. A web application displays real time UVI maps. GEULMóvil consists of a UVI sensor, a GPS, a modem and is designed around an Arduino. GEULMóvil has an estimated cost below U$S 1000, in small quantities. GEULMóvil allows to be reprogrammed remotely for administration and maintenance.**

Keywords——"UV Index", "geolocalization", "Ultraviolet", "Geographic Information Systems", "SMS", "TCP".

I. INTRODUCTION

Ultraviolet radiation causes have been associated with skin disease [*1*], and yearly incidence has increased considerably in recent years, all around the world [*2*] [*3*]. The incidence is such that awareness of the problem is one of the key issues to tackle the problem at the global health policy level: an increase of an average of 4% since 1970 in United States [*4*], and similar figures in Great Britain [*5*]. In Uruguay, consequences of excessive UV exposure are increasing because a significant portion of the population is affected: about 1000 people contract skin cancer every year, and 100 of them die.

The UVI [*6*] is an irradiance scale computed by multiplying the CIE irradiance in watts/m^2 by 40, using the method described by McKinlay, A.F. and B.L. Diffey [*7*].

In Uruguay, despite public awareness campaigns, people still go to the beach in summer, at times when UVI is maximum, exposing considerable proportions of population to its harmful effects. There are few local UVI sensors in operation [*8*], and the information is not disseminated.

Clinicians are worried by the growing incidence of some types of skin cancer and set the goal of having geographically specific information of UVI distribution. The tool to be defined would allow conducting research associating populations with their exposure habits and place of work with disease distribution. Existing UVI data available in internet have a low resolution both time wise and place wise, as they are derived from indirect satellite images, corrected by knowledge on crops and land occupation. Different studies shows differences between direct measurements and satellite observations [*9*] [*10*].This background led us to define a system that would collect data from anywhere in the Country at all time during the day in order to have an accurate UVI database. We named GEULMóvil the capture and telecommunication element to be located on moving vehicles (such as trains, trucks, cars, milk collection tankers, etc.) and GEULMAPA the web application and server which would receive all the timed GPS-stamped UVI data to provide both instantaneous and accumulated maps of absorbed doses derived from the UV radiation received. Moreover, UVI time series would be available for research and daily UVI map information could be made available to the general population, as evidence to abide to medical recommendations. All this will lead to the possibility of correlation studies between professions, geographic areas and skin diseases.

This paper describes GEULMóvil, while a companion paper will refer to GEULMAPA. [*11*]. The two complementary projects were developed simultaneously

II. GEULMÓVIL SPECIFICATION

GEULMóvil is to be installed on the exposed surface of any vehicle traveling on all types of roads, highways or vicinal tracks. The function of GEULMóvil is to capture ultraviolet information through the UV index (UVI) and to send it in real time to a central server for processing, storage, and representation in real time maps. Specifications are:

- To determine UVI in all weather conditions.
- Easily installed in trucks, buses or train wagons.
- Modular so as to be compatible with other sensors.
- Send UVI data to GEULMAPA every 20 min.
- To use Open Source tools.
- With easy and remote maintenance management.
- With a simple user friendly interface.

The 20 minutes time frame is small enough to follow the evolution of the UVI along the day, as shown in Fig. 1. In the figure, corresponding to one of several series of all day long measurements, the plotted curve looks like a Gaussian, with measurements made once every hour. Three measures every hour will give enough detail upon the evolution of de index along the day.

978-1-4673-6386-0/14/$31.00 ©2014 IEEE

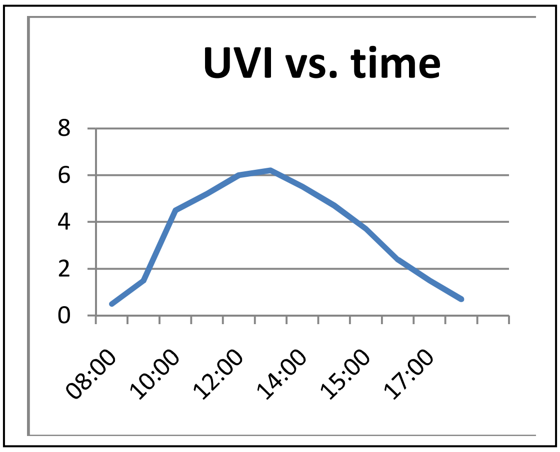

Fig.1 Evolution of the UVI during the day.

III. SYSTEM ARCHITECTURE

GEULMóvil is based on Arduino [*12*], an open source hardware platform, with a micro controller and a development environment. The hardware consists of a board with an Atmel AVR ATmega1280 microcontroller [*13*], with input/output connectors to a GPS module, a communication module and the UV sensor.

The chosen hardware platform is open source, so that it may be duplicated or modified without restrictions. It is also part of a hardware family constantly growing and expanding, with a history of backward compatibility, and larger microcontrollers available if more processing power is necessary. The micro controller requires 5VDC supply: there is an onboard 5VDC regulator powered by 7 to 12 VDC [*14*].

The communication module is a model GL865 [*15*] based, a chip by TELIT [*16*], which provides GSM / GPRS [*17*] in 800/850/1800/1900 MHz bands. There is a dual chip on all boards, includes TCP / IP and accepts AT commands. The GL865 responds to 3GPP release 4 standards, and has low power modes. The development kit purchased for the project integrates a standard RS232 interface, so we implemented a level converter with a MAX232 [*18*] which provides 4 channels of communication, two RS232 to TTL and two from TTL to RS232. The development kit is powered by 6 to 40VDC.

The GPS module is made by SkyTraq company [*19*], from the Venus series, a Venus638FLPx [*20*]. Is small, powerful and has low power consumption, fast initial acquisition (TTFF) and good performance in urban canyons. It can follow simultaneously up to 65 satellites and has very good accuracy. The chip includes technology to overcome multipath problems generated by urban canyons. It uses a magnetic externally mounted antenna with SMA connector which can be passive or active. Communication with the Arduino is done via serial port. GPS module works with 3.3VDC, while Arduino has a 5VDC power source. Nevertheless, it was not necessary to perform level conversion since the traffic is from the GPS module to the Arduino, and the minimum value of VOH 3.3V logic is LVTTL 2.4DCV, while the minimum value of HIV in 5V TTL logic is 2.0V, so no conversion was required.

The UV radiation sensor chosen is made by German SGLux [*21*], based on a SiC-compliant CIE087 photodiode. It is the Eryca TOCON E1 [*22*], housed in a PTFE packing [*23*], which is a dust repellent packaging and IP68 waterproof type.

The Arduino recommendation output impedance of a sensor to be used with the ADC is 10k maximum for good analog-to-digital conversion [*24*] [*25*]. For this reason, a buffer was implemented using a Texas Instrument OP07C [*26*], a low noise precision operational amplifier, with low offset voltage and that requires no external components, used in Op-Amp follower configuration.

Power source was developed around an LM317 regulator [*27*], which provides 7V DC, which is the minimum value compatible with both Arduino hardware board and the Telit module. The controller works with either 12VDC or 24VDC, normally found in buses, trucks and trains. Although some trucks work with 24VDC, and trains with 72VDC, both have 12VDC outlets available, since the majority of mobile consumer devices is made for 12VDC. The calculated consumption of GEULMóvil is about 240 mA, with maximum sporadic peaks of 300mA. This brings the power dissipated in the regulator to 2.8W in 12VDC systems and 5.6W in 24VDC systems. To maintain both the regulator within power limits, a heat sink is used. Considering that GEULMóvil will be installed by unqualified personnel, a diode is used to provide reversed connection protection, and over-current protection is provided by a 1A fuse. See Fig.2.

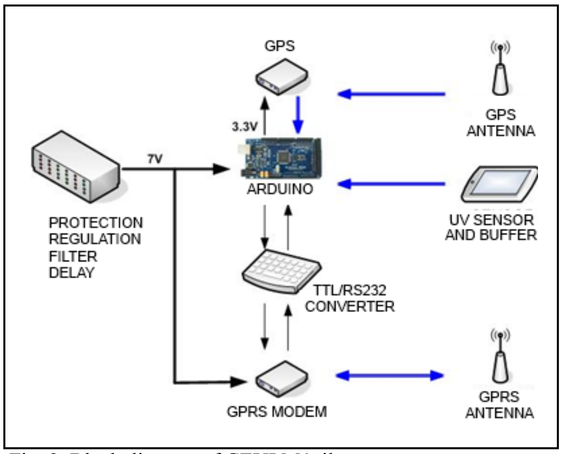

Fig. 2. Block diagram of GEULMóvil

The development platform associated with the Arduino firmware is also open source, widely accepted by the community and in constant expansion to integrate emerging technologies. The firmware programming language that runs on the Arduino is C based, compiled and downloaded to the platform through the development IDE. The IDE provides no tools for debugging. GEULMóvil real-time firmware was developed in a modular fashion, with an infinite loop and attention routines based on predefined and remotely modifiable temporal parameters. Since the GPS module communicates its position information at a frequency of 1 Hz, and since the ADC converter is continuously sampling, the position information is taken as valid "clock" information to read the UVI sensor, and storing maximum UVI reading over a period of 20 minutes. At the end of the 20 minutes period, GEULMóvil thus sends the maximum UVI read to GEULMAPA.

IV. SENDING UVI INFORMATION

The communication module is responsible for sending and receiving information. Various communication mechanisms were studied, among which two were selected: SMS and TCP. This involves the use of the cellular network in the Country, given the low cost and good coverage it has in our country [*28*].

SMS messages are used both to send periodic geographically localized UVI information, as well as configuration and management information. Future developments of GEULMóvil will also use TCP connections to send data and maintenance information of the mobile devices.

Standard AT commands are used to interact with the Telit modem, which makes the entire system manufacturer-independent.

A. SMS

To implement the SMS based communication module it was agreed with the GEULMAPA team to use the GeoSMS standard, defined by the OGC for the exchange of information through SMS [*29*]. The main reason for choosing it is that it is an open standard proposed by the OGC, responsible among other functions, for creating standards to enable the interaction between different geographical systems.

B. TCP

The other communication module implementation was done over TCP (Transmission Control Protocol). The communication component has two parts: a client that opens a TCP socket on a given server port to deliver sensor reading messages, and a server port to deal with incoming connections from an administration system.

This mechanism was also agreed with the GEULMAPA team using the standard Observations and Measurements (OM), also defined by the OGC for the exchange of information via TCP.

V. MECHANICAL AND ENVIRONMENT PROJECT

GEULMóvil operates mounted on a vehicle, and therefore mechanical vibrations must be taken into account during design. The device, once installed on a bus or a truck, is subject to acceleration forces and to constant vibrations. The vibrations are damped to a certain extent by the damping / suspension system of the vehicle. For highway transport, the road surface is not always smooth, and driving over "speed bumps", even at low speed, imposes high stresses to GEULMóvil. Continued use of a device in a vibrating medium can loosen screws, soldering contacts and disconnect connectors. Our design team asked the local bus Company STM (Sistema de Transporte de Montevideo) [*30*] what kind of structure the ticket vending machines located in buses uses, and found that the all providers use a reinforced platform. GEULMóvil was thus built on a 2mm thick aluminum plate, and all components were screwed to it with bolt and screws, and rubber spacers.

The location of GEULMóvil was decided to be in the vehicle cabin, separated from the outdoors UVI sensor. By separating the case from the sensor, all electrical connections are made easier; weather proof is restricted to the sensor, reducing costs compared to using a sealed box. The electrical connection is made by two wires that are inserted in two quick-fit connectors, clearly identified by their red or black color as the positive and negative poles. (See Fig. 3)

Fig. 3. GEULMóvil quick-fit connector panel.

The mobile phone and GPS antenna connectors are both SMA type, clearly identified on the silkscreen of the box (see Fig. 3). For the sensor an especially designed magnetic base was manufactured to be located on the ferrous roof of vehicles.

VI. INSTALLATION

Easy installation and easy replacement of elements were part of the initial specification. The connectors used are industry standard. The antenna connectors are robust, but of delicate treatment. The sensor connector is a three-legged CANON, a commonly used foolproof connection used for microphones.

Power supply is installed by screwing two wires to a source of 12 or 24V DC. Since all external elements (sensor and antenna) are of magnetic attachment, no modifications are required to the vehicle to carry GEULMóvil: the antennas are posed on the roof; the box is located somewhere in the inside of the vehicle, safe and away from any source of moisture.

VII. TESTING

At prototyping stage various tests were performed on GEULMóvil. The prototype is able to send a text message every 10 seconds in normal network conditions, despite specification calls for one message every 20 minutes. The accuracy achieved with the ADC converter included in Arduino seems to be enough. The acquired GPS module behaved as expected, both under city sky or open sky. GEULMóvil was tested during 40 hours using a family car and send altogether over 1000 SMS to GEULMAPA. During testing a number of bugs were corrected, arriving to the point of satisfaction, prior to systematic and heavy duty testing protocols, still pending.

VIII. CONCLUSIONS

GEULMóvil is operational and thus is a proof of concept prototype in which all components behaved as expected. Some weaknesses were detected, which could be addressed by choosing better sensors. Using cheap sensors has the disadvantage that they need good calibration. Despite mechanical difficulties, the GEULMóvil prototype performed satisfactorily in testing stages, and is ready for further refinement and improvement.

IX. IMPROVEMENTS AND FUTURE WORK

Albeit using separate modules seems appropriate for a first prototype, in mass production it is necessary the use of a single board to minimize noise and to eliminate construction weaknesses.

It is also necessary to have more sensors in order to choose the most appropriate for GEULMóvil. And it would help to purchase pre-calibrated sensors, even at higher cost.

On the software side, more adjustable parameters should be made available for a more efficient operation.

X. BIBLIOGRAPHY

[1] World Health Organization, INTERSUN Programme.

[2] Jean-François Doré; Philippe Autier, "Influence of sun exposures during childhood and during adulthood on melanoma risk," *International Journal of Cancer*, vol. 77, no. 4, pp. 533-537, August 1998.

[3] Health effects of UV radiation. World Health Organization.

[4] MPHa, Jenine K. Harris, PhDb, Carlos Rodriguez-Galindo, MDc, and Kimberly J. Johnson, MPH, PhDb,d Jeannette R. Wong, "Incidence of Childhood and Adolescent Melanoma in the United States: 1973–2009," *Pediatrics*, April 2013.

[5] (2013) Cancer Research UK. .UK skin cancer incidence statistics

[6] World Health Organization, World Meteorological Organization, United Nations Environment Programme, and International Commission on Non-Ionizing Radiation. Global Solar UV Index: A Practical Guide.

[7] A. F. and B. L. Diffey McKinlay, "A reference action spectrum for ultraviolet induced erythema in human skin, in Human Exposure to Ultraviolet Radiation: Risks and Regulations," in *Human Exposure to Ultraviolet Radiation*. Amsterdam: Elsevier, 1987, pp. 83-87.

[8] Facultad de Ingeniería Gonzalo Abal, Montevideo, URUGUAY,.

[9] A. F. Bais, J. Gro¨bner, J. R. Herman, S. Kazadzis N. Krotkov, E. Kyro¨, P. N. den Outer, K. Garane, et al, "Comparison of satellite-derived UV irradiances with ground-based measurements at four European stations," *JOURNAL OF GEOPHYSICAL RESEARCH*, July 2006.

[10] Bhattarai B.K, Sapkota B, Kjeldstad B. Sharma N.P, "Relative percentage difference between ground based and satellite estimation of Solar UV index in four seasons at the measurement sites of nepal," *INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCES*, vol. 2, no. 4, 2012,

[11] Núcleo de Ingeniería Biomédica NIB.

[12] Arduino.

[13] AMTEL. atmega1280

[14] arduino - Arduino Mega 2560 schematic diagram.

[15] Telit corp. Telit GL865.

[16] TELIT Wireless Solutions.

[17] 3GPP Global Initiative.

[18] Maxim Integrated.

[19] SkyTraq.

[20] Venus GPS chipset, SkyTraq.

[21] SGLux.

[22] Pre-amplified SiC UV-Index Photodetector, SGLux.

[23] TOCON_PTFE_housing. SGLux

[24] Different sources on web site. arduino.cc.

[25] arduino.cc forums.

[26] Texas instrument. Texas instrument. op07c

[27] Texas Instrument. LM 317.

[28] Opensignal web site: cobertura antel.

[29] OpenGeoSMS. Standards

[30] Intendencia de Montevideo. Sistema de Transporte Metropolitano.