ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XV [2017] – Fascicule 3 [August]

ISSN: 1584-2665 [print; online]
ISSN: 1584-2673 [CD-Rom; online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

[1.]George IPATE, [1.]Gheorghe VOICU, [1.]Filip ILIE,
[2.]Marian BOGOESCU, [2.]Marian VINTILA, [3.]Eugen MARIN

NATURAL AMBIENT LIGHT MONITORING IN GREENHOUSES WITH POLYETHYLENE FILM ROOF

[1.]Universities Polytechnic Bucharest, Faculty of Biotechnical Systems Engineering, ROMANIA
[2.]HORTING Bucharest, ROMANIA
[3.]INMA Bucharest, ROMANIA

Abstract: The advantages that modular electronic devices offer nowadays are almost unlimited and, to a great extent, this diversity is based on the existence and usability of different types of sensors to some low costs. In our work, the combination of Arduino, different light digital sensors, a Bluetooth module and a mobile device, can provide valuable assistance to small entrepreneurs in vegetable and horticulture industry. The results indicate that this system of monitoring natural ambient light in a greenhouse with a sensitivity similar to other electronic devices, however without purely scientific accuracy instruments, but enough for someone without much experience. This shows that robust research prototypes today can obtain promising results with a very low cost, offering an alternative to limited budgets.
Keywords: ambient light, greenhouse, Arduino, Android

1. INTRODUCTION

Horticultural crops represent an important sector of the economy, generating approximately 25% of total crop production in our country. The vegetable food and ornamental crops in the greenhouse industry impose their own needs, which significantly affect their ambient conditions in a nonlinear way. Product supply and market demand determine wholesale prices that growers can expect to receive for their horticultural products. The contribution of smart technology device to agriculture has been a real revolution to traditional agriculture that has made possible the increases of productive areas of the world with the incorporation of areas with unfavourable climatic conditions.

According to several papers from the specialty literature (Kolhe et al., 2011; Fitz-Rodriguez et al., 2010; Montoya et all., 2013; Hastriyandi et al., 2014), advances in the field of Internet has opened up new challenges as well as opportunities to fulfil the increasing needs for up-to date and precise information in agriculture. Nowadays web tools have been developed for numerous applications in agriculture such as the diagnosis of diseases of the oilseed-crops, and for modelling and simulation of greenhouse environments under several scenarios. The developed web application allows improving the quality of life of farmers; due they do not need to be in situ so long to control their greenhouse climate parameters.

As described in the paper (Ipate, 2015), plants respond strongest to blue and red light for photosynthesis and to red and infra-red light wavelengths for photoperiod growth responses and germination control. Within the chloroplasts of plant cells, light energy is used to convert atmospheric carbon into carbohydrates in a process called photosynthesis (Raven, 1999). Photosynthesis, flowering, climate response and plant shape are strongly influenced by the intensity, duration, direction, and spectral quality of light radiation that plants receive. Because light is essential to plant growth and life it is absolutely necessary for us to know, maintain or improve its quality.

This paper presents an independent mobile system based on Arduino and Android app for monitoring natural light ambient quality in the greenhouse. The system was designed based on analysis of the existing solution. Open source software such as MIT App Inventor was used to develop the Android application. The app stores some of the most common field test parameters in a greenhouse like air humidity and temperature, natural light intensity, light spectrum, UV radiation. The data are saved and stored online in an experimental data visualization web application from Google Research named Fusion Table. Our application, as a part of the national agriculture strategy, provides to farm managers a wide range of possibilities in computer modelling and data storage. For this reason, the decision makers in government must find mobile apps like App Light Greenhouse Data a supplement to keep farmers informed. It is also an example of the versatility of personal mobile computing and its use in research, education and outreach. Cloud systems in urban agriculture settings also allow high efficiency and high utilization of pooled resources. The success of these new approaches will be decided, by the viability of the agricultural strategy models. Field testing conducted in our campus verified the functionalities of the mobile network and its practical application in the actual environment, and they meet greenhouse management standards. Results show that proposed solution is able to collect and present data in a mobile environment.

2. MATERIAL AND METHOD

Light is a form of electromagnetic radiation that is visible to the human eye. A small fraction of the total electromagnetic spectrum that includes gamma rays, x-rays, and radio waves (Figure 1), is the radiation that we perceive as sunlight or the visible spectrum. Plants respond strongest to blue and red light for photosynthesis (Figure 2) and to red and infra-red light wavelengths for photoperiod growth responses and germination control (Ipate, 2015).

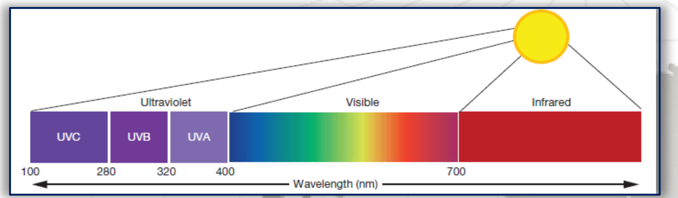


Figure 1. Electromagnetic light spectrum

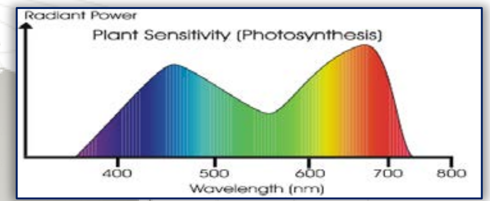


Figure 2. The emission spectrum of plant receives

In the real world the terms intensity and irradiance are sometimes used interchangeably, but from scientific standpoint irradiance is the UV arriving at a particular (cure) surface based on a specified area – in our case of a square centimetre (cm^2).

The proposed monitoring system presented in Figure3 has two main parts, hardware and software. The main component of hardware section is the Arduino Mega 2650, a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The microcontroller ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the boot loader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library). The main board can be programmed flexibly to provide specific features regarding requirement function in the intelligent system, such as data handling (averaging, calibrating and smoothing), data transfer (HTTP protocols) and SD-card storage.

Light sensor information is a key factor in integrated control systems, since the amount of light received influences all growth variables. The VEML6070 UV Light Sensor, provided by Vishay Semiconductors, is an advanced ultraviolet (UVA) light sensor designed with a CMOS process and featuring an I2C protocol interface. The VEML6070 incorporates a photodiode, amplifiers, and analog/digital circuits into a single chip (Figure 4); shows linear sensitivity to solar UV light, which can easily be adjusted by selecting the proper external resistor (Scharr, 2015). The BH1750FVI Sensor is a digital Ambient Light Sensor IC for I2C bus interface. This IC contains an integrating analog-to-digital converter (ADC) that integrates currents from photodiode for obtainment Digital 16bit data. It is possible to detect wide range at High resolution (1-65535 lx). The TCS34725 device (Figure 5) provides a digital return of red, green, blue (RGB), and clear light sensing values. An IR blocking filter, integrated on-chip and localized to the colour sensing photodiodes, minimizes the IR spectral component of the incoming light and allows colour measurements to be made accurately. The high sensitivity, wide dynamic range, and IR blocking filter make the TCS34725 an ideal colour sensor solution for use under varying lighting conditions and through attenuating materials. Air Temperature and Humidity Sensor (DHT22) is a high accuracy sensor used in various conditions. It consists of a capacitive sensor element used for measuring relative humidity and a negative temperature coefficient (NTC) thermistor used for measuring temperature. Small dimension, ultra-low power consumption, more than 20m's signal transmission distance makes it a good selection for various application environments. The accuracy of this module can gets up to 0.3 degree in temperature and 2% in relative humidity.

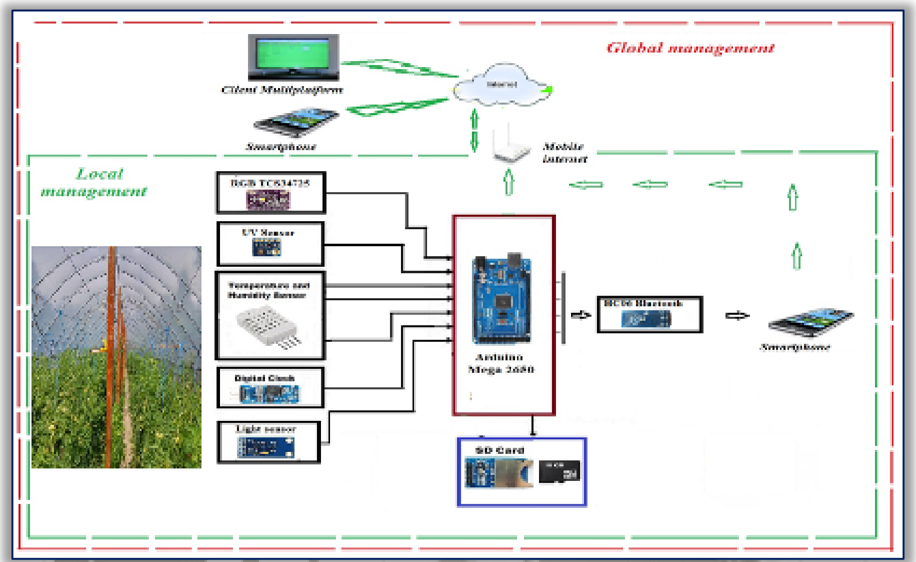


Figure 3. Block diagram of ambient light monitoring system

The DS3231 RTC chip is a low-cost, extremely accurate I^{2}C real-time clock (RTC) with an integrated temperature-compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input, and maintains accurate time keeping when main power to the device is interrupted. The integration of the crystal resonator enhances the long-term accuracy of the device as well as reduces the piece-part count in a manufacturing line. HC-06 Bluetooth module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Blue core 04-External single chip Bluetooth system with CMOS technology and with Adaptive Frequency Hopping Feature (Ipate, 2016).

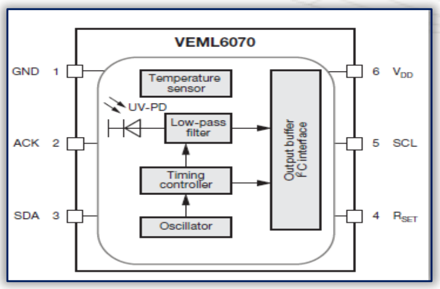


Figure 4. Block Diagram of VEML 6070 UV sensor

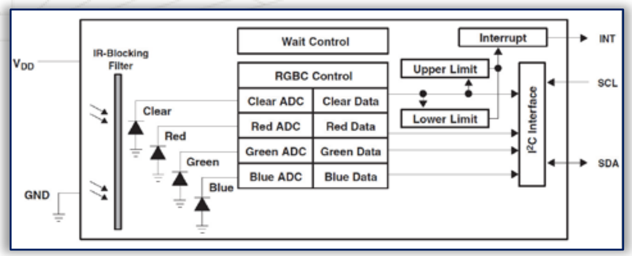


Figure 5. Functional Block Diagram of TCS 34725 Colour Light-to-Digital Converter sensor

Software implementation of our control system uses Arduino software and MIT App inventor. The program code is writing in Arduino Software, which supports the Arduino packages. The MIT App inventor software is used to develop the Android apps. The data are saved and stored online by using the mobile app which is designed for this project.

The ArduinoCode is implemented in the Arduino software. Firstly, we initialize the variables that control the input pins of the sensor signal and declare variables that will be used for communication with the mobile app. Then we define the pins which are used to serial communication. The communication must setup to 9600bps because we configured the Bluetooth module to that speed.

MIT App Inventor apps implementation. To implement and test this sample code we use a Xiaomi RedmiNote2 phablet (2.1GHz Octa-core CPU, 2GB RAM and 32GB Internal memory) running Android 5.0. We also tested this code using a Samsung Galaxy Young 2 smart phone running Android 4.4.2.

For example, GPS coordinates are entered when GPS is turned on in mobile devices settings and a signal is available. If a GPS signal is not available, triangulation methods using cell towers and known wireless networks are used to estimate position. Sequence of commands that specifies the action to be performed is shown in figure 6.

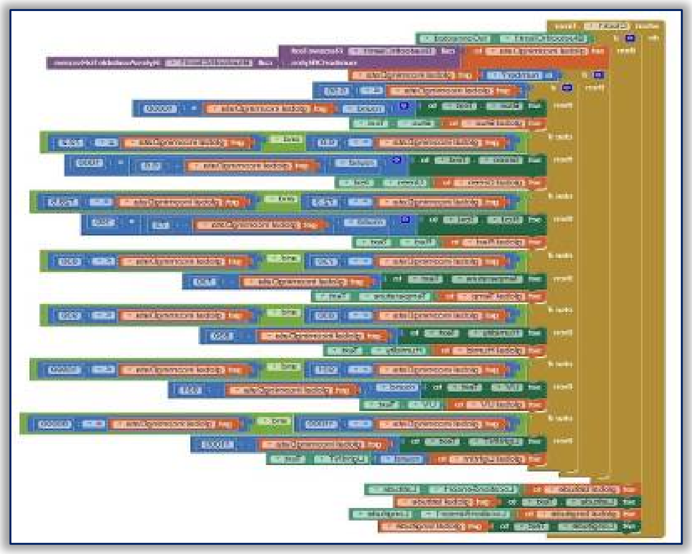


Figure 6. Sequence of block code in App Inventor 2

3. RESULTS

In order to test the use of sensors, we have conducted several series of measurements to check the system and data accuracy. When a change in temperature occurs, optical elements physical size changes, the same as their refractive index. Both changes contribute to an apparent change in distance. This measurement error is a fixed value and is only a function of the change in sensor temperature, not the distance measured.

Figure 7 depicts the VEML 6070 UV sensor test measurements with respect to time. Thermal drift are also presented in the same figure. For this example, accuracy, and short-term repeatability will be determined. This type of optical sensor has a typical thermal drift value of 41.5 μW/cm^2 per degree C. Optics thermal drift can be reduced by either controlling the temperature of the measurement environment or by using sensor that are insensitive to temperature changes.

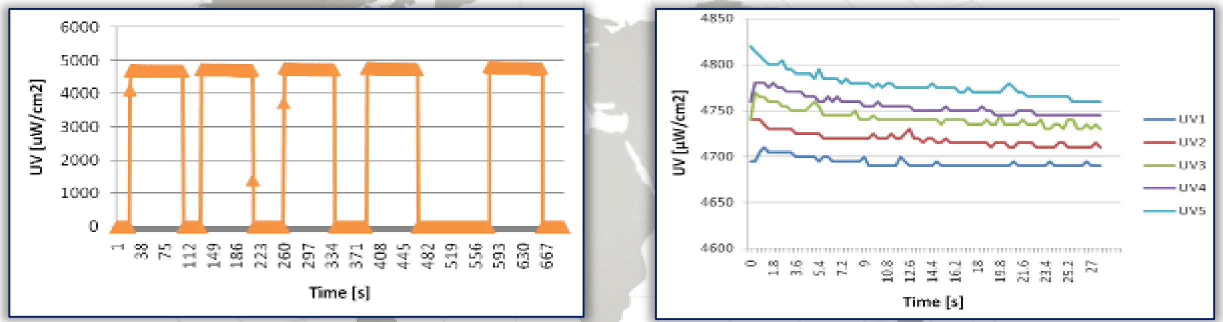


Figure 7. The measurement accuracy and repeatability of VEML6070 UV sensor

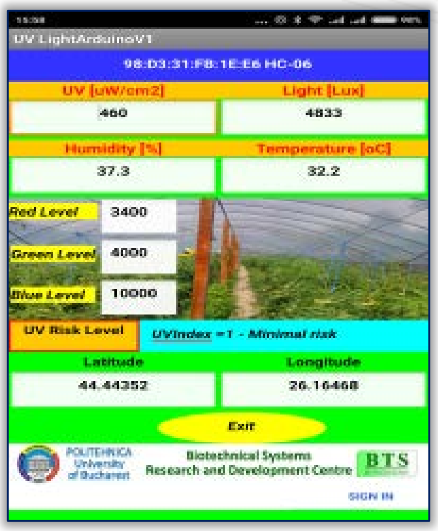


Figure 8. Main screen of LightGreenhouse V1 Android app

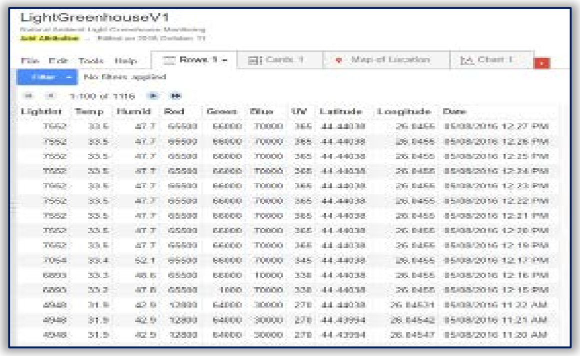
The Android app main screen is shown in Figure 8. The main screen displays a sensor values transmitted via the Arduino board and Bluetooth device, location and risk index measurements of ultraviolet radiation exposure.

Data are saved to a local database, on SD memory card, and an online Google Fusion Table (Figure 9) until the "Reset" button is pushed with a long click. To use the Google Fusion Table, users will need a Gmail account. Users don't have permission to edit the source code of this app. In the Google Fusion Table all associated data will be saved in rows under light intensity, air temperature, air relative humidity, RGB light spectrum, latitude, longitude, and date columns. The rows will be repeated for each data entered. To retrieve data from Google Fusion Table, the file can be downloaded as a csv file.

Figure 10 contains natural ambient light spectrum measurements conducted in the greenhouse located on the campus of Polytechnic University of Bucharest for several hours (10.00-15.00), on 07/21/2016.

4.CONCLUSIONS

Our light monitoring system is a community of stackable, modular and autonomous component modules that combine to create a community of smart sensing instruments that is unfettered by the limits of traditional optical sensing instrumentation. Autonomous instrument modules allow users to



LightGreenhouseV1

File Edit Tools Help | Rows 1 | Cards 1 | Map of Location | Chart 1

Filter | No filters applied

1-100 of 1116

Lightlnt	Temp	Humid	Red	Green	Blue	UV	Latitude	Longitude	Date
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:27 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:26 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:25 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:24 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:23 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:22 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:21 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:20 PM
7552	33.5	47.7	65500	66000	70000	365	44.44038	26.0455	05/08/2016 12:19 PM
7064	33.4	52.1	65500	66000	70000	345	44.44038	26.0455	05/08/2016 12:17 PM
6893	33.3	48.6	65500	66000	10000	338	44.44038	26.0455	05/08/2016 12:16 PM
6893	33.2	47.6	65500	1000	70000	338	44.44038	26.0455	05/08/2016 12:15 PM
4948	31.8	42.9	12800	64000	30000	278	44.44038	26.04531	05/08/2016 11:22 AM
4948	31.9	42.9	12800	64000	30000	278	44.43994	26.04542	05/08/2016 11:21 AM
4948	31.5	42.5	12800	64000	30000	278	44.43994	26.04547	05/08/2016 11:20 AM

Figure 9. Light Greenhouse Google Fusion Table

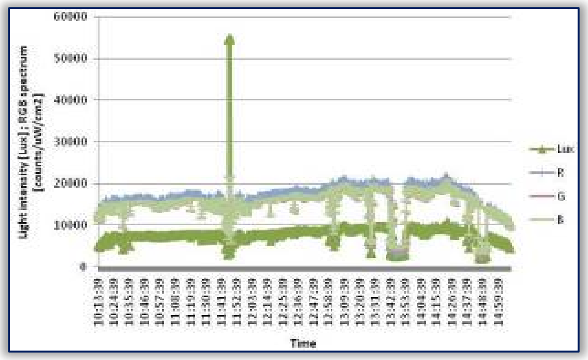


Figure 10. Variations of the average values of static friction

customize the system to their changing application needs, and Wireless connectivity plus SD card data storage capability facilitate remote operation.

Results of experimental tests have shown that the proposed wireless light monitoring system ensures optimal working conditions. This is particularly important for farmers, especially on weekends, because without a monitoring system, the farmer should go in the greenhouse to ensure that everything is working properly. However, in its current state, this prototype system is already prepared for deployment in real-world test beds and is an adequate low-cost alternative for highly expensive industrial light measurement instrument. As a future directive, full implementation of the proposed system must be taken into consideration.

Following the philosophy of open knowledge, anyone interested in the field, specialists or students, can use and/or adapt those presented in this study, because all components are open, hardware and software is open source.

Note: This work is based on the paper presented at International Symposium on Agricultural and Mechanical Engineering – ISB-INMA TEH' 2016, organized by National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, „Politehnica" University of Bucharest – Faculty of Biotechnical Systems Engineering, EurAgEng – European Society of Agricultural Engineers and Romanian Society of Agricultural Engineers – SIMAR, in Bucharest, ROMANIA, between 27–29 October, 2016.

References

[1.] Fitz-Rodríguez, E., Kubota, C., Giacomelli, G.A., Tignor, M.E., Wilson, S.B., McMahon, M., (2010), Dynamic modeling and simulation of greenhouse environments under several scenarios: a web-based application, Computers and Electronics in Agriculture, 70 (1), pp.105–116.

[2.] Hastriyandi H., Seminar K.B., Sukoco H., (2014), A multi sensor system for temperature monitoring in a greenhouse using remote communication, International Journal of Latest Research in Science and Technology, Vol.3, Issue 4, pp.81-87, MNK Publication;

[3.] Kolhe, S., Kamal, R., Saini, H.S., Gupta, G., (2011), A web-based intelligent disease diagnosis system using a new fuzzy-logic based approach for drawing the inferences in crops, Computers and Electronics in Agriculture, 76 (1), pp16–27.

[4.] Ipate G., Voicu Gh., Girleanu C., Voicu P., (2015), Improve Plant Stand and Conserve Energy in Greenhouse With Led Lighting System, Proceedings of TERERD 2015, Posada Vidraru/Romania.

[5.] Ipate G., Voicu Gh., Constantin G., Ilie F., Tudor P., (2016), Research on wirelessly controlled conveyor belt with android application, Proceedings of TERERD 2016, Golden Sands/Bulgaria.

[6.] Montoya F.G. et all., (2013), A monitoring system for intensive agriculture based on mesh networks and the android system, Computers and Electronics in Agriculture, 99, pp. 14–20.

[7.] Raven P.H., Johnson G.B., (1999), Biology - Fifth Edition, Chapter10 - Photosynthesis, McGrawHill.

[8.] Ryer A., (1997), The Light Measurement Handbook, International Light Technologies.

[9.] Scharr R., (2015), Designing the VEML6070 UV Light Sensor into Applications, Optical Sensor - Application note, www.vishay.com