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UV Monitoring using Ground based Sensor Node and Remote Computer Applications

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Abstract: ***Ozone layer depletion has been a serious cause of concern for all humans throughout the twenty-first century. This is a widespread reason for several health and environmental problems all over the world. This ozone layer is present in the stratospheric part of the Earth's atmosphere and responsible for acting as an envelope to prevent harmful UV radiations enter Earth. [1] It is thus understood that monitoring the incoming UV radiations is very important. The data can be used to estimate the extent of depletion of the ozone layer leaving us with measurements to stop the damage already been caused. Besides, this the idea is to provide common population with precautions and real time updates regarding the extent of UV exposure in a given location. To achieve this our approach was totheorize a method that would make use of UV capable sensor nodes installed in destined points on earth's surface in a locality creating a sensor network interacting with the base station providing updated UV data to a server. Users can be notified by the use internet connected smart devices.***

Keywords: Wireless Sensor Networks, Ultra Violet Radiations, UV monitoring, Data collection, Data Analysis, User Interface, Simple Web Based Data Processing and Provision

1. Introduction

UV or Ultra Violet radiations are a part of the electromagnetic light spectrum emitted by sun falling in the wavelength range of 400nm to 10nm which is immediately shorter than the visible light. Based on the wavelength range, UV can be classified into three types: UVA (315nm to 400nm), UVB (270nm to 315nm) and UVC (10nm to 270nm). Of these UVB is supposedly the cancer causing and most harmful after reachhing the earth's surface. Although this radiation finds its applications in some industries but being high frequency rays these are harmful to living beings. [2]Evidence also suggests that UVB irradiation helps in development of skin cancer. [3]

Ozone layer wrapping our earth in stratosphere has its own way of protecting us from harmful UV rays emitted by sun. During daytime it absorbs UV to convert to oxygen as follows:[1]

$$2O_3 \rightarrow 3O_2 \quad (1)$$

Likewise the reaction is reversed during night, retaining the ozone for the next day. However due to extreme emission of CFCs(Chlorofluorocarbons) by us, which travel to stratosphere due to less weight and reactivity destroy ozone molecules by consuming oxygen like this:[1]

$$Cl + O_3 \rightarrow ClO + O_2 \quad (2)$$

$$ClO + O_3 \rightarrow Cl + 2O_2 \quad (3)$$

Thus, a concerned citizen will only take measurements to prevent CFC emission but also beware of UV radiation which is already invading our Earth.

Existing UV monitoring techniques and their disadvantages

So far there has been multiple existing UV monitoring that has been proposed and partially successfully implemented. However, these do lack some aspects of monitoring efficiently. There are several techniques such as Satellite surveillance, chemical analysis,wireless sensor networks etc. It is important to provide a systematic way of gathering UV data. Apart from this the UVI of an area depends on several factors such as cloud cover, sun elevation, altitude, geography of the area, latitudes, longitudes, composition of air etc. Monitoring via satellites measures the quality of ozone present in the earth's atmcphere and linearly derive the amount of UV entering the ‹th's atmosphere. It also uses image processing based on the intensity of sun light entering earth. This is not only inaccurate but also inexpensive. [4, 5] The chemical analysis method involves use of a colour changing chemical, which is very inexpensive but is very fuzzy.[6] Thus, data analysis may be a concern. Wireless Sensor Networks can therefore be presumed to be the most optimum technique so far being inexpensive as well as efficient. Wireless Sensor Networks have been applied in different places hower haven't been able to fully address all aspects of UV monitoring.The commercially available sensor motes as well as wireless sensor network setups are quite expensive. [7]Accounts of research based projects can also be found that implemented Wireless Sensor Networks for UV and environment monitoring however didn't takto considerat ion the provision of this data to users. [8, 9, 10]

The Proposed System and its advantages

To execute the monitoring of UV according to this paper, the following system is proposed. The system consists of three primary modules and the involvement of three entities. The sensor node, central data base server and a front end. Likewise the three corresponding entities are the sun, the data analysis and management team and the users. The sensor is the input device here responsible for collecting UV associated data to the system. The sensors are kept exposed to the sun in the area of deployment. The sensor node is required to transmit the dynamically, meaning on afrequent time period basis, to the nearest base station or the database server by the means of a feasible mode to transmission.[11] This data is stored in a database within the server. The server is centralised, rather than being distributed in nature. The data analysis and management team entity should consist of a DBA (database administrator), scientists understanding the significance of this data (and perhaps sending this to an environment science research facility for review), and a team of developers managing the user interface for the front end where the gathered data can be showcased. They organise this data in a presentable format. This entity can also be replaced with a similarly capable software. The server then broadcasts this information for the users to view via a user friendly front end. The users are likely to get notifications when UV data depicts hazardous state of environment to the locality, prompting them to take suitable precautions. The major advantages of this architecture includes the use a cost efficient method, surface UV data gathering, a systematic method for data collection and analysis, facilitates real-time analysis and involvement of not just scientist but also common everyday user population.

2. Literature Survey

It is evident that ozone layer has been depleted to a great extent over the past couple of decades. Since early 1980, there has been a long term ozone layer depletion in the Antarctic polar vertex. About 20% of ozone reduced in lower stratosphere in March 1993, now leaving as much as 50% today of original density. [12]

A study in 1998 shows that, there is an increase in surface erythema due to UV radiation relative to values in 1970 estimating an increase of 7% at Northern Hemisphere mid-latitudes in winter/spring; about 4% at Northern Hemisphere mid-latitudes in summer/fall; about 6% at Southern Hemisphere mid-latitudes throughout the year; about 130% in Antarctic during spring and 22% during spring in Arctic. The study is also on the basis of demonstration and quantification using ground based instruments depicts the correlation between increase in surface UV-B radiation and decrease in the overhead ozone. However, the surface readings are highly vary from the satellite-derived readings as the intensity of UV radiations vary upon many factors like cloud cover, aerosols, angle of incidence of sunlight, elevations, water-depth and surface reflection. The ground based study showed a difference of 40% of UV irradiances during summertime between mid-latitude Southern and Northern hemispheres contradicting satellite based yields estimating only a difference 10-15 %. Thus, concluding the significance of ground based study.[4]

Now, this UV rich sunlight we receive in the daylight is carcinogenic in nature. UVB is known for its DNA damaging effects leading to skin cancer. Human body has the capability of producing apoptotic keratinocytes also known as sunburn cells, as a defence mechanism against carcinogenic effects of UV irradiance. However, prolonged exposure to UVB causes an imbalance in the defence mechanism of these sunburns cells, causing skin cancer. [3] Other studies have found that even under friendly conditions like pollution free and sober temperature, reef-building corals face induced beaching upon increased magnitude of ultraviolet radiations. [13]

Thus, monitoring the incoming UV radiations is of great importance. It has been found that a dye chemical poly vinyl butyral containing acid sensitive bromophenol blue and chloral hydrate is a UV sensitive indicator developed and capable of successfully measuring integrated UV irradiance. Upon exposure, a film containing this dye changes colour from blue to green and then to yellow. [6]

Lack of computerization may delay this calculation, analysis and distribution of UV data to a large extent. Ozone depletion is more in the Polar Regions and minimum close to equator. However, at lower latitudes, sunlight exposure is more, and so is the UV irradiance. NASA's satellite with Total Ozone Mapping Spectrometer has helped with all the estimates associated with ozone concentration values in the atmosphere. [5]

Wireless Sensor Networks can be used for Environment Monitoring. A cluster of nodes made of Micro-Electro-Mechanical-Systems attached with environment reading sensors and able to send necessary data using wireless networks can prove to be very handy. This is an energy efficient, low cost and accurate method for monitoring the environment in a computerized way. With Adaptive Sensing, the redundant nodes can be put into a passive state acting as auxiliary ones sustaining the system lifetime. [9, 14]

Another project was carried out involving a transportable spectroradiometer which can transported to certain destined location in Europe and the analysis of UV irradiance was carried out. To summarise, they had a sophisticated device for measuring UV exposure, which was used in their field trip across Europe to gather UV data. It helped the local laboratories of these selected sites to represent a scale to be taken as the European irradiance reference. [15]

3. Commercial Survey

There has been commercially available solutions to address problems that this paper shares in common only in a more expensive way. Waspmote is one such device than is embedded with UV sensors and ZigBee wireless interfaces to gather ground based UV data for analysis purpose. It is commercially available product which is highly expensive, not open source in nature and doesn't have a front end for users.[7]
There are also many wearable devices such as wrist watches that have UV sensors embedded in them, however being a commercial aren't available open to all. [16, 17, 18]

Likewise the Samsung Galaxy Note 4 has a small UV sensor mounted on the back side of the phone claiming to sense UV and give its measurement to the user. Then again it's a smart phone of 8/10 price group thus not affordable by everyone. [19]

4. Design

The architecture of this system takes into consideration multiple parameters. This would include the type of hardware, the compatibility of hardware with communication modules and their capability of transmitting data to the centralised database server. Further, it must take into consideration the geographical location where the motes shall be installed and how the users can receive the required information.

For the sake of experimentation the design we chose had our surface based sensor node made of components like Arduino UNO with ATMEGA328 microcontroller as the processing unit[20, 21], GUVA s12sd, a GaN/Al_2O_3 based Schottky Photodiode as the electronically compatible with Arduino as our UV sensor[22]and other components like a 16x2 LCD display unit[23] which would display the output for easing the field operation when it comes to maintenance or error checking. Ideally in all wireless sensor networks there is a sort of transceiver that takes care of the communication part and in most cases the sensor nodes are required to communicate with each other to pass on the information following some sort of path determining algorithm assuming these sensors nodes are placed in close proximity to each other; communication modules like Zigbee or RF modules are used.[24, 25] However, in our case we are to design an experimental setup in an inexpensive way to arrange communication between sensor nodes directly to the base station or the data server (the base station is simply a gateway to connect motes to the data server).The architecture overview can described in the figure 1.

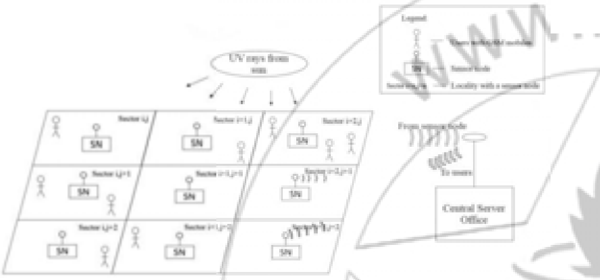

Figure 1: Architecture Overview of the system to be implemented

UV irradiance in a particular locality depends on various factors. Thus, the distance between two sensor nodes should be such that at a given instance of time, the difference between the readings of these two sensors should be significant but minimum as well under all circumstances. Now, UV depends on factors like the type of surface, the variation of readings across a plane surface would differ from the variations across a hilly surface with respect to same area of plane.[2, 4, 5, 7] For the simplicity of our study we are considering an area of plane surface to expect a consistent variation leaving only factors like weather conditions, the time of day and the geographic coordinates to effect the readings. The weather conditions effect the readings in cases where there is more cloud cover, the UV readings are likely to be less and therefore UV irradiance will be less. The UV irradiance is maximum when and where the intensity of light is maximum. Thus, at noon, with sun at zenith the UV is maximum for that locality and likewise the places close to the equator where the exposure of sun is more gradually UV readings become more.

Now, there are 360 degrees of Earth's longitude that rotates through a span of 24 hours with varying intensity of sunlight throughout. Thus sun travels from one longitude to the other in 4 minutes, relative to the motion of earth. This distance is roughly 111km at equator. There are 60 minutes between two consecutive degrees of longitude. Thus, there is a significant and minimum change of UV index every 10 minutes, i.e. 1/6th of the distance between two consecutive longitudes. The distance between two longitudes vary with every latitude. It is more in the equator and less in the Polar Regions. This is due to the spherical shape of the earth. The difference between two consecutive latitude is however consistently close to 111km throughout. This is because earth is not a perfect sphere rather an ellipsoid and the axis of rotation is across the Polar points. The alignment of the longitudes and latitudes of the globe and India are depicted in the figures 2 and 3 respectively.[26, 27]

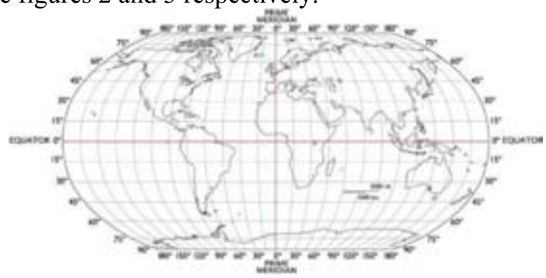

Figure 2: Longitudes and latitudes across the globe. The longitudes and latitudes are along the vertical and horizontal axes respectively.[26]

Figure 3: The longitudes and latitudes passing through India.[27]

Considering the above factors, and assuming that the surface is smooth the ideal location of sensor nodes should be 6 per every longitude and 6 per every latitude. On at the intersection of every 10 minutes of longitude and latitude. The sensor nodes across every latitude may be almost equidistant but it may not be the same case across every longitude. Thus, 36 sensor nodes should be deployed at an area enclosed by two consecutive longitudes and latitudes. In an area close to equator, this distance would be nearly 18km across the latitude and nearly 18km across the longitude. The figure 4 depicts the change of distance in kilometres between corresponding latitudes and longitudes respectively as one passes from equator (0˚) to either of the North or South Poles (±90˚) longitudes with respect to latitudes.

ϕ	Δ^1_{Lat} (km)	Δ^1_{Long} (km)
0°	110.574	111.320
15°	110.649	107.551
30°	110.852	96.486
45°	111.132	78.847
60°	111.412	55.800
75°	111.618	28.902
90°	111.694	0.000

Figure 4: Length of a degree of longitude[26]

Thus, to make communication between two sensor nodes wouldn't be possible without the use of expensive and sophisticated high range Zigbee modules. Besides, it wouldn't be required as the data manipulation is going to take place in the data server, instead of letting the sensor nodes do itself by communicating to the neighbouring node. Thus, the use of GSM modules is going to be made that is capable of sending the data directly to the data server. [28, 29]

If this were to be a nationwide project or at least a state/provincial project then the sensor node are to be placed as described above and each node fitted with a locally compatible GSM SIMs within the GSM module. The type of network (2G, 3G or 4G), shall be based on the population and technological advancement of that locality. Thus, the sensor nodes are to continuously gather the UV information and send it time periodically to the data server via SMS which is to be received by a GSM modem that will receive the data and update to the database and await further processing by the server thereafter.[30, 31, 32, 33, 34] There are cheap softwares that can identify the SMS received through the GSM modem and insert it to the required relation in the database. Now the sensor node is to be programmed for a threshold check of the UV data it receives. If it is greater than the threshold value, the sensor node must send an alert SMS to the data server, based on the extent of the danger, prompting it to notify the user of the locality with an alert message concerning the danger of UV exposure at that time along with some safety measures.Based on the extent, of the UV exposure, there can be different colours assigned according to the danger such as green, yellow, orange, red and violet representing low, moderate, high, very high and extreme respectively and users will be prompted to take measures accordingly.[35]

The sensor node which primarily consists of an Arduino UNO microcontroller board, is to be powered with a 5V DC source, preferably using a battery. This architecture involves maintenance plans requiring someone to change batteries and check for fault in the sensor nodes, since there are only a few in a locality. The continuously powered Arduino UNO receives analog UV data from the GUVA s12sd UV sensor which is directly exposed to sunlight and powered by a 3.3V DC outlet from the Arduino UNO board[20, 21, 22], which is undergoes two processes. First, a threshold check, if the falls under one of many ranges of the extent of danger lead to an alert SMS with the value of the danger associated along with the analog UV value. Otherwise, it undergoes the second process where it is added to a variable inside the microcontroller to calculate the sum average of a fixed time period (an hour in our case) followed by sending this value through the GSM module. The GSM module also requires a 5V DC power supply which can be provided using parallel connection to the battery. Then it has two pins known as the TX and the RX pins which are to be connected to the RX and the TX pins on the Arduino UNO board respectively. These are for the transmission and reception purpose. GSM module is our transceiver.[28] The GSM module must have a SIM card present on it just like any GSM mobile phone. To send the message the Arduino UNO is programmed to identify network and establish connection with service providers nearest tower once the sensor node is deployed and activated, any failure should be taken care of by the maintenance. Since, the experiment is small scale we chose a windows laptop that would act as a remote data server. There is a modem also fitted with a SIM whose task is to receive message. This is a USB modem we are talking about and is connected to the data server, our laptop of concern.[36] The connections in the sensor node can be understood by referring to the circuit diagram present in figure 5.

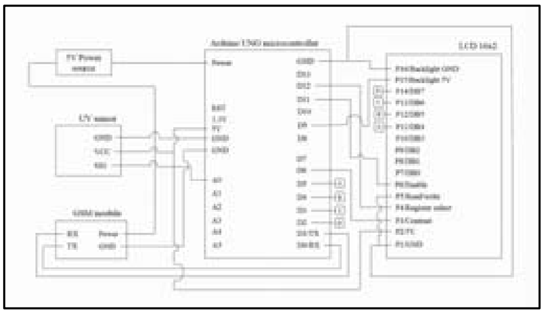

Figure 5: Circuit diagram of the sensor node

Ideally, once the data is processed, it is broadcasted to the users through the web and can also be fetched via an app designed to do so when connected to the internet. The user is likely to receive the danger alert as notification on their android hone only when connected to the internet.

In our case, the model of the data server involves the use of a laptop connected to a modem for input messages with UV data and a remote desktop server software, another software that can insert values automatically upon received to the database and a Wi-Fi hotspot hardware and software with the intension of broadcasting. The devices that are connected to this laptop can access the web page by entering the IP address of the laptop. The app in this case has to use the android smartphone Wi-Fi to connect to this laptop instead of the internet in order to access the web site and also to receive notifications concerning alert.[36, 37]

The SIM present in the sensor node in our case is a registered Airtel LTE SIM local to Hyderabad. Ideally it should be a toll free service, but in the experiment it is credit with an active SMS pack providing sending of multiple SMS for a month. The Arduino code is aware of the contact number of the SIM present on the modem that is connected to the laptop. This is also a registered Airtel 4G SIM local to Sikkim, only that it doesn't concur any roaming charges due to an existing roaming pack. It doesn't require to be credited with an SMS pack since it is on the receiving end. A software named SMSenabler which is paired with the MySQL database software present on the laptop connected with a MySQL database connector, is used to identify the SMS received from the Modem and update the tables.[38]

The use of an open source bundle software named XAMPP[39] is done to facilitate web page designing and buildingusing PHP server side scripting language, MySQL database management system, apache server and other services that won't be required in this project. The Wi-Fi module present in the laptop hardware can be used for the broadcasting purposes, by manipulating it using netsh[40] and wlan[37] commands in the command prompt in administrative mode to start a hostednetwork. This will ask to assign an SSID to the created network. The external user devices will be required to find this SSID and connect to it. The network can and should be made password protected. Based on the laptops capacity, theoretically almost a hundred devices can be connected but practically it is within the range of 20 to 40.

There shall be multiple relations in our database in the MySQL within data server concerning this project. PHP is a server side scripting language, it can be used to manipulate data in the database as well as function the web pages. For designing the web pages HTML and CSS are made use of.[39] So a PHP code segment is responsible to convert the analog UV value to genuine digital data in the form of UV index into another relation. The analog value is linearly proportional to the UV index and vice versa. The datasheet of GUVA s12sd UV sensor explains this linear equation.[22] Hereafter, this data can be displayed in real time, that is as soon as it is updated is goes live, and also this data may be forwarded to the scientists who may analyse and perform heuristic as well as statistical studies helping them draw further conclusions or predictions concerning UV irradiance in that locality as well as globally.

UV index is a scale used to measure the intensity of UV irradiance. It ranges from 0 to 11, 11 and 11+ being the maximum. 0 to less than 3 comes under green range (low), 3 to less than 6 comes under yellow range (moderate), 6 to less than 8 comes under orange (high), 8 to less than 11 comes under red (very high) and 11 to everything greater than 11 comes under violet (extreme).[35]

The front end was the last module which will be used by the last entity, the users. The front end can be access in two ways. One is the use of browser which is connected to internet (in our case to the laptop broadcasting the information) and the other is an android app. Android platform was chosen because of its open source nature, the same goes with choosing XAMPP as well as Arduino UNO. Now the layout of the android app makes use of Webview which is going to display the same thing as the website does but in a mobile friendly environment. An additional feature is that when the data server gets and alert SMS, its data is additionally fed to another relation which is a stack, allocating only a single value per location per time. This stack if has a value, the laptop broadcasts and the Android app receives a notification.[41] The user entity is thereby notified by the front end module. This feature is also present in the web page, just that its use is limited, because browser can notify the user but then again the user must be inside a building if using a desktop computer and is anyway safe from UV exposure.

Calculation of UV index

The calculation of the UV index is based on the type and properties of the UV sensor. The value that the sensor returns is a voltage value. It is analog in nature.

Thus, it is required to quantify and convert in to a digital value and then proportionate it into the required value, i.e. the UV index by the means of a suitable function. This function is given in the datasheet provided with the UV sensor[22] and used in the PHP code to manipulate the incoming data.

The resultant of the above steps would give us the UV index of that time instant. For concluding the level and the danger associated with the UV index value on can refer to the following table (Figure 6).

UV Index	Media graphic color	Risk	Recommended Precautions
0-2.9	Green	Low	Sunglasses
3-5.9	Yellow	Moderate	More cover/sunscreen
6-7.9	Orange	High	Sunscreen with sun protection factor above 30
8-10.9	Red	Very High	Recommended to stay out for short period of time only
11+	Violet	Extreme	Recommended to stay indoors only

Figure 6: UV index information [35]

5. Experimentation/Working

This paper primarily focuses on theorizing a system that is cheap, open source and can be implemented locally as well as globally, to monitor UV irradiance assuming the surface is plane and use the data obtained to perform scientific calculations on, and broadcast real time data as well as notification upon danger to the users with smartphones. However, theorizing isn't sufficiently enough to convince the importance of this system. We spent a little time, and tried obtaining all the required components with limited financial resources and managed to make one sensor node, and one laptop based data server and one front end user with android smartphone to simulate the system in a small scale. Primarily, the difficulty we faced was deciding which communicational module to be chosen, since the distance between the two sensor nodes wasn't determined and the method of collection of data by the data server was unknown. But once everything was clear, we made a sensor node on a breadboard connecting the UV sensor to Arduino UNO board which is powered by a 5V DC battery and corresponding connections to a 16x2 display unit and the GSM module with an Airtel 4G SIM. The basic layout of the project is represented in the block diagram as shown in figure 7.

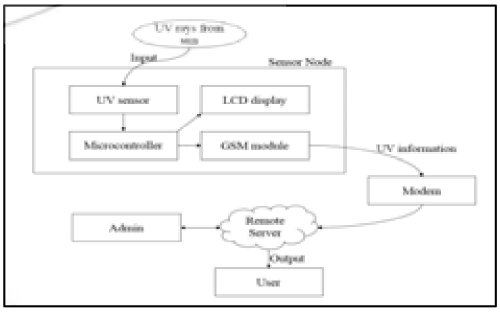

Figure 7: Block diagram of the experimental setup

The location of the experiment when conducted was Sikkim Manipal Institute of Technology campus. The experiment was on for a week and recorded for four days in the month of May 2016. For the 5V DC power source we made use of a 5600mAh power bank connected to the Arduino UNO board using USB cable. This setup was placed in an open space in the campus. To initialise, we were to reconnect the TX and

RX connections between the GSM module and the Arduino UNO board followed by connected the power source and pressing the reset button on the Arduino UNO board. The setup began working. The laptop acting as the data server was live too. The modem connected to the laptop was tested and capable of receiving SMS and updating the database. The sensor node started sensing UV and sending data. It was programmed to read UV data every second and send and hourly average UV data via SMS to the data server. The database was updating every hour. The app was ready but didn't receive any alert because the UV reading never crossed any threshold value. The app was able to retrieve the UV information as broadcasted on the web page. However, on a user PC that was connected to the server laptop via Wi-Fi was able to access the web pages and view the daily UV index gathered every hour. The expectation from the setup was that the sensor node would read the UV data and display it on the LCD display unit in a per second basis and send SMS to data server on an hourly basis. The experimental setup was behaving as expected. The battery lasted for a week which was also expected considering the amount of energy consumed by the GSM module, Arduino UNO and the LCD display unit. Snapshot of the sensor node is shown in the figure 8.

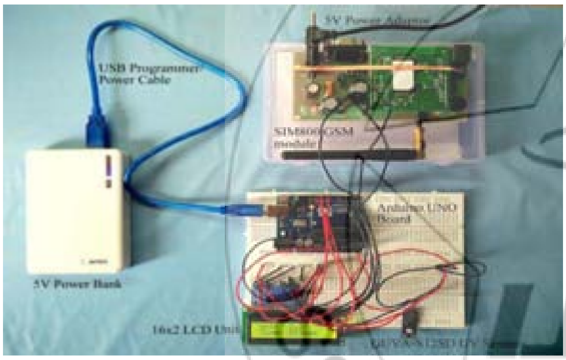

Figure 8: Snapshot of the sensor node setup

The experiment was conducted for six days, morning 9 AM to evening 6 PM. The results were recorded accordingly. The results of the first four days were recorded. Once the sun was set, in spite of lack of complete abundance of UV the display unit should a zero analog reading. On the seventh day, the sensor node stopped working due to emptied DC battery. It has to be replaced with a different 5V power source or recharged again for sensor node to continue working.

The experiment was a failure for a number of reasons. Firstly, the experimental setup was incomplete, considering that there was only a single sensor node and that a laptop was used to simulate the data server instead of an actually purchased domain as a server. After implementing, the UV information that was obtained by the server was completely inconsistent with government provided data. Therefore several error checking and testing of the system were carried out.

This began firstly by checking the PHP codes that were used to design the web pages and manipulating the data in the database. The logical part was fully correct. The PHP codes were not incorrect. Every software sub-module in the data server laptop were positively working producing desirable outputs.

This was followed by testing the communication module, involving sending random SMS from the GSM module to the modem and database connectivity. The test results in this case were also positive. Thus, we fish-boned the problem to the sensor node.

Apparently, the display unit was displaying exactly what it was reading. The Arduino UNO was connected to a programming laptop and the experiment was simulated again. The results found out that the UV readings were not changing irrespective of the environment. Concluding that the GUVA s12sd UV sensor was properly functioning. It has a very low sensitivity to sunlight and therefore had been producing inaccurate analog readings. This analog reading when converted resulted in incorrect UV index generation.

It must be admitted that the choice of the UV sensor was done considering the price and an inexpensive model was purchased which was producing least accurate results. Thus with an expensive UV sensor, the data would be sufficiently accurate for this setup to be a complete success.

6. Results

The results of the four day UV monitoring can be seen in the following figures.

Day 1:

Timestamp	Sensor Value
2016-05-05 09:05:00	1.23
2016-05-05 10:04:00	1.24
2016-05-05 11:05:00	1.28
2016-05-05 12:05:00	1.33
2016-05-05 13:04:00	1.36
2016-05-05 14:04:00	1.34
2016-05-05 15:05:00	1.30
2016-05-05 16:05:00	1.26
2016-05-05 17:05:00	1.26
2016-05-05 18:05:00	1.22

Figure 9

Day 2:

Timestamp	Sensor Value
2016-05-06 09:03:00	1.21
2016-05-06 10:05:00	1.23
2016-05-06 11:04:00	1.24
2016-05-06 12:04:00	1.28
2016-05-06 13:04:00	1.29
2016-05-06 14:05:00	1.30
2016-05-06 15:04:00	1.24
2016-05-06 16:04:00	1.23
2016-05-06 17:04:00	1.21
2016-05-06 18:05:00	1.20

Figure 10

Day 3:

Timestamp	Sensor Value
2016-05-07 09:05:00	1.22
2016-05-07 10:04:00	1.24
2016-05-07 11:05:00	1.24
2016-05-07 12:05:00	1.28
2016-05-07 13:05:00	1.30
2016-05-07 14:04:00	1.32
2016-05-07 15:04:00	1.26
2016-05-07 16:04:00	1.23
2016-05-07 17:05:00	1.22
2016-05-07 18:05:00	1.20

Figure 11

Day 4:

Timestamp	Sensor Value
2016-05-08 09:05:00	1.20
2016-05-08 10:04:00	1.21
2016-05-08 11:05:00	1.22
2016-05-08 12:04:00	1.22
2016-05-08 13:06:00	1.23
2016-05-08 14:04:00	1.22
2016-05-08 15:05:00	1.21
2016-05-08 16:04:00	1.21
2016-05-08 17:04:00	1.20
2016-05-08 18:05:00	1.19

Figure 12

The snapshots of the app from the android phone were also taken and are displayed in the following figure:

Figure 13: Snapshot of the home screen showing the daily UV information

It shoes that the UV index was maximum at the mid-day period and was minimum at the beginning and end of the day. On cloudy days, the UV index remained the same to second decimal point almost throughout the day. There was fairly minimum change in the UV index indoors or outdoors concluding that UV rays can penetrate buildings. The GSM module was successfully sending the hourly average UV index to the data server with an average delay of 5 minutes. This is the time the system requires to receive the data from the sensor node and update it to the database. Better results could be obtained if sensor with a better sensitivity was used. The prototype model of the sensor node that was used was vulnerable to the external environment, suggesting that when a real life implementation is made, it is required that a quality product is to be manufactured.

7. Conclusions and Drawbacks

Future Scope

1) Big data analytics: Big data analytics is the process of examining large data sets containing a variety of datatypes i.e. big data, to uncover hidden patterns unknown correlation etc. It will also help in better decision making.
2) Pattern development with other environmental factors: We can attach some other sensors too with the UV sensors like humidity sensors, temperature sensors etc. With the help of readings from these sensors along with the UV index we can get some patterns which help us analyzing as to how the UV index is changing with the other environmental factors. Thus, people being affected by UV radiations can take the effective measures accordingly.
3) Research: When large amount of data is our hands, we can use it for heuristic and stochastic studies and thus generate prediction related to our environment.
4) Social Awareness: Upon consecutive updating of the website, a social media aspect can be added. The main motto of this is do make people aware of not only what the UV index is but also what people should to in order to prevent further damage to the environment that is causing ozone depletion.

Conclusions

1) So far we have achieved to calculate UV index of a location using the sensor node and display the output to LCD and serial monitor. If the module is behaving as standalone then the GSM module is sending the readings on an hourly basis and this information can be received by the user using the designed webpage as well as the mobile app.
2) Studies confirm that this project is required. As we know that the UV index depends on various factors such as cloud cover, altitude, latitude, pollution levels etc., thus with the help of satellites, we cannot get the accurate data. Thus, ground based module is necessary.
3) Sending the processed data to a remote server and providing an application to read information is done.
4) Developing an interactive website to display the output in mobile or computer is done. This would help the people who are being affected to know the range of UV radiations and take the required measures.
5) We have taken the readings on an hourly basis and it can be seen that the UV index is so far consistent.
6) We have used only one module to show the working but many modules in a WSN network can be created for a large scale accurate and efficient UV monitoring.

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