Amun-Ra Sun Exposure Detector

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**1 Introduction**

Photo detection and measurement is a well understood field within electrical engineering. Converting solar energy into electrical current is fundamental for solar power. Our project will implement this technology for quantifying harmful sun exposure. This is accomplished by detecting the amount of power generated by a photodiode and communicating this information to a mobile app on a smartphone via Bluetooth. Our application will interpret, compile, and track sun exposure not just over the course of a single day, but instead over months and even years. The idea is that when people are aware of what exposure levels require sunscreen and are able to track exposure on a given day, they are more prepared and motivated to apply safe levels of sunscreen. In addition, since sun damage is most dangerous when strung together with multiple events spread out over long periods of time, people are able to be made aware of their risks. The application of our project will meet the needs of families, recovering skin cancer patients, and anyone who spends a lot of time outside. Skin cancer is known to be the most prevalent as well as most preventable form of cancer and it is time that technology starts to address the concerning numbers of skin disease cases.

**2 Problem Statement**

As has been mentioned above, the primary problem that Amun-Ra addresses is the concerning prevalence and trends in skin cancer cases. Skin damage due to exposure to harmful high energy ultraviolet radiation generated by the sun causes 86% of melanoma, the most severe skin cancer, cases. Shockingly, melanoma is the only life-threatening, major form of cancer to actually have an increasing rate of incidence despite it being considered the most preventable form of cancer by taking necessary precautions.

The problem with skin cancer, including melanoma, is that it is caused by an invisible enemy that most people feel they have no control or awareness of. This is largely true; skin that looks tan and hasn’t had a large number of sunburns is very possibly in an unhealthy, at-risk condition. In fact, people are very poor at judging whether they are at risk. In addition, single incidences are not necessarily the best indication that skin is unhealthy. This means that for people to responsibly monitor their sun exposure, they must keep track of serious as well as moderate skin damage over long periods of time. There is abundant evidence that people do a very poor job of doing this responsibly.

While the pharmaceutical industry has worked extremely hard to find treatments and cures for patients with cancer, Amun-Ra proposes a radically simple and comparatively inexpensive solution that most common form of cancer in existence. Concrete data and tracking of events over long periods of time is the least invasive, least expensive, and easiest manner to lower the risk of skin cancer. The ease of having a small device that is able to be attached on clothing, be low power, and be interfaced through a smartphone is a realistic and practical solution for many people. The intention is for the device to simply detect and communicate while the heavy analysis of the data and long term tracking to be undertaken by the phone which allows the device to stay small while still having large capability and a platform that will allow the important notifications to be delivered in an actionable way. Therefore, all the user has to do is turn on a device and the app, and Amun-Ra will take care of the rest.

**3 System Requirements**

There are a number of functions that the system needs to be able to demonstrate. Starting at the most basic functionality, the device must be able to measure the dosage of ultraviolet radiation exposed to it. To do this, we will need a semiconductor based device that has a known band gap energy. The energy would preferably be selective to high energy photons corresponding to ultraviolet radiation. This can be achieved by selecting a semiconductor that needs an optical excitation of at least the ultraviolet radiation in order to generate photocurrent, or by filtering the lower energy photons out by passing the light through a specialized light filter, or by using an algorithm that is able to make use of the uniformity of the black body spectrum to know what percent of the photocurrent is due to ultraviolet light.

The system must be able to amplify the photocurrent with high fidelity in order to produce a useful signal that the processor will be able to register. The signal at the output of the photodiode is unlikely to be strong enough to meet the minimum input requirements of the processor so there must be some form of amplification or circuitry that will produce a more substantial signal that is a precise recreation of the signal produced by the photodiode. This means that the signal must reach the pin with a voltage between Vdd and Vss for use with the PIC32 that we have been using this semester.

Then the system must convert the analog signal of the photodiode into a digital piece of data that can be transmitted to the smart phone. The amplifier will produce a signal and become an input to the microprocessor. The microprocessor is then tasked with producing a digital representation of the signal over a number of different time samples. Once the signal is digitized, it must be transmitted.

The processor then supplies a Bluetooth transmitter with the digital signal and this signal is communicated with a Bluetooth receiver in a smartphone. This is going to require a Bluetooth send and receive protocol to occur between the device and the phone and for a successful transfer of the data into the memory of the phone which can then be accessed by the software of the smartphone application. The requirements are that the Bluetooth will be able to make a reliable connection over a distance that will be seen when the device is in use.

On the application end, our software must be able to access stored data, run algorithms to properly quantify exposure, and generate a user interface to convey the risk level quickly and clearly. The data that is input from the Bluetooth receiver must be stored and the address communicated to the application such that it can be called upon later. The data, which corresponds to the intensity of the sun that struck the device, is then run through an algorithm that generates how much damage has been inflicted on the user. When threshold has been met based on the UV index, there should be a push notification sent to the user to notify them that they are experiencing harmful exposure. This is going to have to use some statistical modeling for outlier control and also compare the exposure to skin sensitivity. The information then needs to be communicated to the user in the form of a notification when a dangerous amount of radiation has been encountered. Lastly, long term data needs to be stored to the phone associated with the user. This stored data, over any period of time, also needs to be able to be referenced by the user, this can be accomplished by the app having the ability to call on this saved information and print graphs, tables, or some infographic to communicate the historical data.

The last requirements refer to the system as a whole. The system is going to be used outside by definition so a protective casing is going to be required to keep the device in working condition. The system needs to be very simple on the user end or else it won’t be largely adapted. Last, the system needs to be power efficient because needing to recharge the battery too often will render the device useless for its purpose. As such, we need a battery that can supply 8 hours of constant use.

**4 System Block Diagram**

4.1 Overall System

The system can be broken down into five main subsystems. The subsystems are the photodetector system, the microcontroller system, the Bluetooth system, the power system, and the android application system.

4.2 Subsystem and Interface Requirements

4.2.1 Photodetector System

The photodetector will consist of an ultraviolet photodiode, a signal amplifier, and an output interface. The photodiode should be able to detect from about 100 nanometers to about 400 nanometers, which encapsulates the entire ultraviolet spectrum. When the photodiode absorbs a photon, it excites an electron to a higher energy energy level. The excited electrons can then be removed from the diode by metal contacts. The movement of electrons across the contacts creates a current, which will serve as our signal for interpreting the light intensity. More ultraviolet rays shining on the photodetector corresponds to more electrons being excited to higher energy level. Based on the amount of current our photodiode produces, we can determine the intensity of light. The current out of the photodiode, however, will be a small signal based on the small area of our photodiode, so it will need to be amplified. In the photodetector system, we will also require an amplifier, which will require power from our power system.

4.2.2 Microprocessor System

The microprocessor system’s main job will be to convert the analog signal received from the photodetector system to a digital signal to be given to the Bluetooth system. The implementation will utilize a microcontroller with an analog to digital converter, similar to Software Assignment 8, when we took advantage of the analog to digital converter in the PIC32MX microcontroller. In addition to the analog to digital converter of the microcontroller, the microprocessor system will also require an input system for the photodetector and output system for the Bluetooth device, a temporary storage system, and USB power input. The input system for the photodetector can be as simple as a pin input that is soldered to our photodetector system. This will also be similar to Software Assignment 8 in which we utilized the pins to connect to a potentiometer and received the analog signal through that method. The output to the Bluetooth, however, will require a more complicated SPI interface. In our sub-system demonstration, we showed that we could transmit data via Bluetooth utilizing an SPI interface from our microcontroller. This is the same process we will utilize for our project. We will utilize a temporary storage system to store values received from the photodetector until a device pairs with our Bluetooth antenna. Our total system should be able to operate apart from a paired device, and then when a device is paired, it should be able to transmit all the data it collected in a given time span. For this reason, our microprocessor system will need an element of memory to store the extra data collected. The USB power input will be used as a recharge device for our power system.

4.2.3 Bluetooth System

The Bluetooth system will need to receive a digital signal and transmit it to an android device using radio frequencies. In order to communicate with the microcontroller, the Bluetooth device will need to be initialized to interface using SPI. The software for this communication was developed in our Sub-System Demonstration project and only minor changes will be needed to implement into our main project. The Bluetooth device can be soldered to the SPI port of our microcontroller.

4.2.4 Power System

The power system will need to provide power to the amplifier on the photodetector system, the microcontroller system, and the Bluetooth system. Rather than utilizing a connection to an external device, our power must be generated internally to our system. The two prominent methods for this type of generation are solar powered and battery. Due to size constraints, a solar powered board is not feasible for this project, so we will utilize a battery. This battery, however, will have to be rechargeable because we will need it to be small in order to minimize our project’s overall size. We will utilize a USB power charging module, similar to the kit boards utilized in class, in order to charge our power system.

4.2.5 Android Application System

The android application will need to receive the digital signal from the Bluetooth device, interpret it, and display it on a user friendly interface. The application will need to be calibrated based on research we have found on levels of harmful ultraviolet radiation skin can absorb and based on the blackbody curve of the sun. The data received from the Bluetooth will give us a reading of exposure intensity over time. From that reading, our application can compare the values received to the values researched to be safe or unsafe and provide the user with a recommended course of action. In addition to the recommended course of action, our application can provide the user with a time dependent graph of ultraviolet exposure, which the user can provide to a health care provider.

4.3 Future Enhancement Requirements

There are three significant additions to our product that could improve its functionality. The first is packaging. The board with the microprocessor, photodetector, power source, and Bluetooth device could all be housed in a cosmetically appealing protective casing. This case would be useful because it would allow the product to be used in harsher environments and by a wider variety of users including children. The packaging could be made out of a durable plastic material, which keeps the cost low while meeting the necessary requirements for protection and cosmetic appeal.

The other addition that could be made is to the android application. There is research that indicates that different skin tones absorb ultraviolet rays at different rates and that they have different effects. Our application could ask a prompting question for the user to identify their skin tone. This question could provide a list of tones, of which the user could choose which tone is most similar to theirs. Based on the user’s selection, our comparative values for high and low intensities would be adjusted to provide a more indicative reading for the user.

The final addition that we could make to our overall project is adapting it for IOS. This would require additional cost to design an IOS application, but would open our product up to a wider variety of customers.

**5 High Level Design Decisions**

5.1 Bluetooth System

The Bluetooth system will be required to interface with the chosen microcontroller and an android phone. Through our sub-system demonstration, we have utilized the nRF8001, which has the capabilities to accomplish both these tasks. For our product we will look into using either this component or one extremely similar.

5.2 Power System

Our power system will need to be small, rechargeable and able to power the board, Bluetooth system, and amplifier of the photodetector. The board requires 3.3 volts according to the microcontroller notes on Sakai. The most feasible type of battery to meet these requirements is a lithium polymer battery, which is light-weight, rechargeable, and has a high power output.

5.3 Microcontroller System

The microcontroller system will constitute a microprocessor, an SPI port, input ports for the photodetector system, USB re-charging station, and all other necessary components to execute these tasks. All the placement of these components will take place in the board design phase of our project. The microprocessor will most likely be the PIC32 based on the fact that we have already addressed the protocol for Bluetooth interface and analog to digital conversion for this particular microprocessor, in other words, we know that it will accomplish the tasks we require it to.

5.4 Photodetector System

The photodetector system requires some decision making. Our product could either take advantage of currently existing photodiode and amplifying systems (there are some great Adafruit pieces that could perform this task) or our product could utilize two separate modules. One of the modules would be a 2 prong diode, and the other would be a designed amplification circuit to utilize the photodiode’s signal.

5.5 Android Application System

Most android applications are programmed using Java, and this language is commonly used in industry. Taking advantage of this trend, our team will design the android application using Java.

* allow user to choose a variety of time windows to view data (i.e/ view exposure for last week, for last month, last year, etc)
* allow data for more than 1 user to be stored on 1 app

**6 Open Questions**

There is uncertainty at multiple levels of the design. We know that we do not want to be continuously transmitting data from the photodiode to the phone. It would be draining on the battery of both devices to operate that way. How we optimize the periods of sampling and periods of dormancy is an open question until we are able to finalize the circuit design and see the power losses of each operational mode.

We do not yet know how the app is going to be able to allocate memory for long term events without using too much memory, but also making sure the data is going to be useful. Our group has little experience on back-end coding and so we will have to research to come up with a functional app that meets our requirements.

How are we going to shift information from the processor to the Bluetooth transmitter? How are we going to store sampled values and shift them at the appropriate times to the transmitter?

By what metric are we going to be able measure exposure? Perhaps the easiest way is to find the watt/m intensity and relate this to a dosage. This is going to rely on an algorithm which relates the intensity of light over the amount of time exposed to record how much energy in total has been delivered which will lend itself to the dosage received. How can this information be communicated to the user in a meaningful way?

How would we calibrate the UV module to deal with intensities? Use a UV lamp with known light intensities?

**7 Major Component Cost**

The five main systems of our project, power system, microprocessor system, photodetector system, android application system, and Bluetooth system, will make up the major costs of our product.

The android application system will be our cheapest component because writing an android application is free. If we designed an IOS application, there would be an additional cost associated with licensing.

The next cheapest component is the photodiode. The cost of this component ranges from under $10 to $50 based on quality of the detector. There are some modules that come with a built in amplifier that also affect the cost, but purchasing components to build an amplifier will be under $10 if the team elects to move in that direction.

The next component cost is the Bluetooth system. In our subsystem demonstration, we utilized the nRF8001 component. This component was found online for under $5, indicating that the total cost of our Bluetooth system should be under $10.

The power system cost will simply require the lithium ion battery, because microprocessor system will encompass the USB charging port in our board design. The typical price for a rechargeable lithium polymer battery is between $20 and $50.

The final cost for our product is in board design which will include a USB charging port, the microcontroller, and connector pins for the nRF Bluetooth connection and necessary decoupling capacitors, and resistors. The price for this unit, according to estimates in class, should be around $100.

This brings the total to roughly $200 dollars. The remaining $300 of the budget could be used to buy multiple photosensing devices to test which detector provides the best data. Alternatively, this money could be used for equipment to properly calibrate the photodetector such as a UV lamp.

**8 Conclusions**

We are going to face a number of challenges in the development of this system. Demonstrating early on that each individual piece can function is going to be very important so that issues can be handled in subsystems that are more easily understood. The smartphone application is going to be a huge challenge and require a lot of research; our lack of experience in this area is going to be the largest challenge to creating a functional device. Although our background isn’t focused in computer science, we have the necessary prerequisites to successfully implement the project. Lastly, we are going to have to be able to make the data that we collect is relevant and able to be comprehended by the user. Our project could be an important technological advancement in the prevention of skin disease.

*References*

Skin disease statistics provided by skincancer.org

Possible Links to Use:

<http://gis.cancer.gov/tools/uv-exposure/>

<http://www.who.int/uv/health/solaruvradfull_180706.pdf>

UVC is totally absorbed by atmospheric ozone, has minimal penetration to the surface of the

Earth and thus has little effect on human health. 90% or more of UVB is absorbed by

atmospheric ozone, while UVA passes through the atmosphere with little change. Thus,

the solar ultraviolet radiation of importance to human health consists of UVA and UVB.

While UVA penetrates the human skin more deeply than UVB, action spectra for biological

responses indicate that it is radiation in the UVB range that is absorbed by DNA – subsequent

damage to DNA appears to be a key factor in the initiation of the carcinogenic process in skin.

-From WHO doc, page 4

<http://www.jelight.com/uv-measuring-devices.html>

<http://www.epa.gov/sunwise/uvicalc.html>

<http://www2.epa.gov/sites/production/files/documents/uvradiation.pdf>