UVis

Final Report

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Abstract

The UV Shield is a small handheld device that assists users with being safe under the sun. The device works by using an ultraviolet (UV) filter and camera to display a live video feed so that users can identify areas of their skin that are not properly covered with sunscreen. Ultraviolet light from the sun is the number one cause for skin cancer [1]. People spend time under the sun for many different reasons, they may have an outdoor job, play sports, or they are attracted to having a glowing complexion from getting a tan. The problem is that too much sun exposure can increase the aging process of your skin, leading to more wrinkles, age spots, and even skin cancer [1]. One great method to staying safe under the sun is properly applying sunscreen to exposed areas of skin. The Harvard medical school reports that proper sunscreen usage is proven to reduce the risk of skin cancer from sun exposure [2]. Currently there are two types of commonly used sunscreen, chemical and physical based sunscreens. Chemical based sunscreens absorb UV radiation and converts that radiation into energy before it can harm the skin. Physical based sunscreens, known as mineral based sunscreen, uses zinc oxide and titanium dioxide to provide a protective layer over top of the skin [3]. Chemical based sunscreens have been the more popular choice as they come in a sprayable form, and don't leave a thick white paste on skin like physical based sunscreens [3]. The UV Shield device only works with chemical based sunscreens as physical based sunscreens reflect the UV light, which does not display properly on the device's screen.

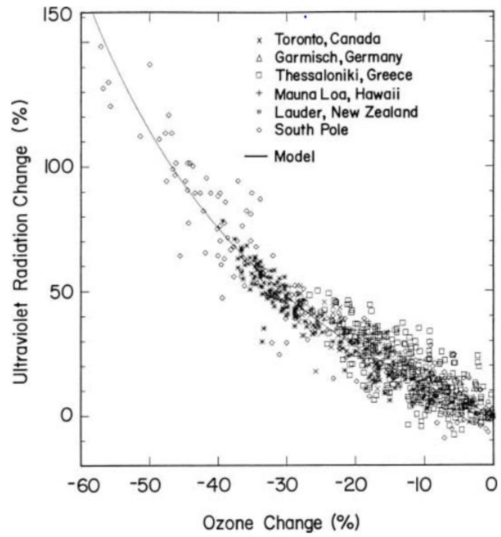
Introduction

UVis is a team of five undergraduate students that are studying computer engineering at the University of the Florida. UVis's goal is to assist individuals with proper sunscreen application to help address the problem of sun exposure and skin cancer. According to the Cleveland Clinic the number of diagnosed skin cancer cases continue to rise year after year [1]. UVis's goal is to assist individuals with proper sunscreen application to help address the problem of sun exposure and skin cancer. The solution the team proposed is a handheld device called the UV Shield. The device uses a UV camera, filter, and LCD screen to provide users a real time video feed of themselves. Users can then begin to apply sunscreen to exposed areas of skin, then by looking at the device they will be able to see properly covered areas of skin begin to darken on the screen. The darkening on the screen represents the UV light being successfully absorbed by the sunscreen, indicating that the skin is being protected from UV radiation. This visual effect allows users to see which areas of the skin are still exposed so that they can continue to properly apply the correct amount of needed sunscreen. In addition to the device's main functionality, the UV Shield will also consist of smaller features such as a UV light bar to assist users while applying sunscreen indoors, and other quality of life features that are detailed later in the report.

Skin cancer is one of the most common cancers [4]. Though skin cancer is common, it also is undeniably caused by a single environmental carcinogen, the sun. UV light is the main cause to the three most common types of skin cancer [5]. UV light has a shorter wavelength than visible light, from 100-400 nanometers, allowing it to pierce through and damage the DNA of the skin. Fortunately, the more dangerous UV light, UV-C (100-290 nm) and around 95% of cancer-causing UV-B light (290-320 nm), are completely absorbed by the atmosphere. UV-A(320-400 nm) is the main cause of collagen breakdown that accelerates the aging of skin [6]. Complete everyday coverage of exposed areas on the skin is essential to blocking the remaining 5% of UV-B light and 100% of UV-A light.

A study on SPF application shows that, on average, participants typically miss around 10% of their face when applying sunscreen. This area is typically within the eyelid region, which is unfortunately an area of skin most prone to cancer. After their first image of sunscreen application, participants were informed of the importance of sunscreen application in sensitive areas. Though they had the knowledge of important areas prone to cancer, there were still areas of the skin left uncovered in a second recording [7]. This problem can be solved with a simple idea; what if people could see the missed areas on their skin before going outside? This is where the idea for UVis comes from, an affordable device that uses UV imagery technology to detect sunscreen application.

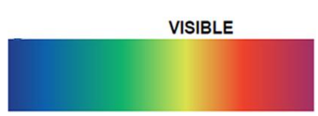
Another topic that motivated our team to complete this project is the slow depletion of the Earth's ozone layer. As our planet's ozone layer thins, increased amounts of UV radiation can be detected at ground level [8]. The image below shows measurements of UV-B radiation from different points on Earth. The X-axis of the graph represents a decrease in percentage of the Ozone layer in that area. The Y-axis shows the exponential increase of detected UV-B radiation in those areas.



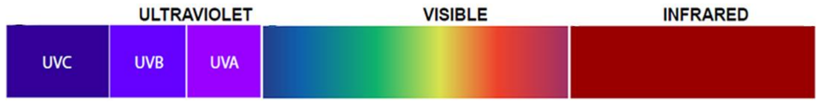
Overall UVis's goal was to create a device to help protect users against UV radiation from the sun. We believe that our product contributes to humanity by providing safety for its users and helps to address changing environmental factors on Earth. The UV Shield device is simple to use, anyone that can operate a smartphone can easily use the device. In addition, we hope that when people use our product and visually see UV radiation hitting their skin that they too will be motivated to help stop the depletion of our atmosphere's ozone layer.

Background

Unlike bees, humans cannot see ultraviolet light, making the use of cameras and software essential for observing the UV spectrum [11]. Digital cameras typically come with a filter that blocks UV and infrared (IR) light so only the visible spectrum we normally see is shown. Because of this, viewing UV light would be impossible without removing the filter or ordering a camera without it. We chose to order the NOIR camera V2 for the raspberry PI, which comes without the UV/IR blocking filter [9]. Without those filters the NOIR camera allows users to see the UV/IR light spectrum. The images below show the light spectrums that cameras can detect. As you can see a normal camera with filters only shows the visible light spectrum, while the camera without a filter shows all available spectrums including UV and IR.



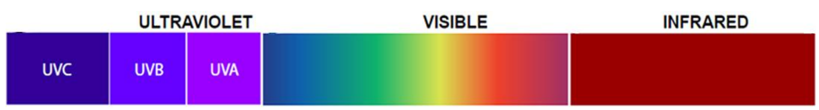
Camera with UV/IR Blocking Filter



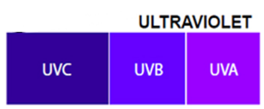
Digital Camera with no filter

To visualize sunscreen on the skin, we must view an image strictly in UV light. An important distinction to make is the difference between a chemical and mineral sunscreen. Chemical sunscreens function in protecting against the sun by absorbing UV light, which appears as a darker area in the UV spectrum, but mineral sunscreen reflects UV light, which appears brighter [3]. Because of this limitation, our design was strictly tested with the use of chemical sunscreen. A sunscreen of at least 30 SPF can block up to 96.7% of UV-B light [12]. It is important to block both UV-A and UV-B light, which is indicated by a “broad spectrum” label on a sunscreen.

With a camera that can observe a broader spectrum of light, the camera needs to be limited to viewing only UV light. This can be done with a filter that only allows the ranges of UV light to come through, though this is notorious for being difficult to manufacture. Most inexpensive UV bandpass filters have some leakage of visible and IR light [13]. At first glance this seems like it would only slightly alter the picture, but the abundance of visible and infrared light is much greater than the UV light, which effectively saturates the image. Since sunscreen is only designed to reflect UV light, it will reflect the more abundant visible and IR light, returning the sunscreen to a lighter color and removing its distinction from the skin. It was important to find a cheap enough filter without compromising the image.



Camera without external filter



Ideal camera with external filter

If you are not outside or next to an open window, a UV camera will display a dark image. To ensure functionality inside, a powerful UV LED must be used to illuminate the face. To prevent the light from the LED, or and any other light from saturating the image, the camera must be housed in a case that only allows light from the filter to come through. It was imperative that the only light getting to the NOIR camera was UV light being passed through the filter.

Timeline

January 5th – 18th, 2022

Our teams first milestone in this semester was to get the camera to run properly upon device bootup. Originally the device would boot-up to the homepage where a user would have to click on the python code application to run the live video feed. Initially we tried to implement this feature using Crontab, a provided feature within Raspberry Pi OS. This method proved to be faulty as the camera was not initializing as Crontab would try to call the camera when the initial bootup wasn’t completed. To work around this, we used

LXSession a standard session manager that automatically starts applications on a working desktop environment.

January 18th-20th, 2022

The second milestone to complete was the button functionality. The UV Shield device consists of two buttons. One which switches on and off the power for the UV LEDs, while the other shuts down the device. The buttons were wired to the GPIO ports of the Raspberry Pi. Once wired, python code was developed to set the GPIO pins to inputs or outputs, and then coded to read passed in parameters when pressing the buttons. This code was easy to produce but created a major issue. The camera would not run while trying to run the code for the GPIO pins

January 20th- 31st, 2022

To fix the issue, our team decided to use threading to allow both the camera and code for the GPOI pins to run at the same time. Threads are included in a python library function that allows for two or more instances of a program to run simultaneously. Creating threads allowed our camera to run while the program checked for any changes from the GPIO pins.

February 1st-9th, 2022

During this time our group prepared for the first presentation for the semester. This period involved soldering the UV LED bar, creating the initial housing design, and wire-wrapping components to provide reliable communication between devices. Our team made attempts to get all vertical slices of the device working to showcase functionality. The housing was developed using SolidWorks and was printed through UF Marston Library. Once the case was printed and received the device was constructed for demonstration purposes.

February 9th-23rd, 2022

Following the presentations our team decided we needed to address issues such as IR leakage and lack of device features. The original filter that we anticipated to use for the project did not work under certain conditions. Although it was properly filtering UV light, it was allowing for some IR light to pass through. Since IR light was passing the user's skin would still appear a bright color even when applying sunscreen. During this time, we determined the correct filter, the Kolari Vision UV bandpass filter, would be needed to complete the project successfully.

In addition to the UV filter, we concluded that our project needed to include additional features to increase user satisfaction and project complexity. We decided to incorporate three new features, touch screen functionality with a still image capture, printing a PCB board to communicate between hardware components, and changes to the boot process to provide a more user friendly experience.

February 24th- March 10th, 2022

During this period our team worked on developing the PCB design, implementing the touch screen functionality, and drafting a finalized case. The PCB was designed using Altium software. The PCB was developed so the two switches, eight UV LEDs, and various small hardware components could be connected through a board. Once the PCB was completed it was sent off to Advanced Circuits for printing.

The touch screen was enabled using pygame, an open source library for python applications. The pygame application window is loaded first and covers the whole screen, The camera preview is then loaded over the pygame hiding its window. When a press is detected on the touch screen window, the camera captures an image and closes the video feed displaying the still image. Once the screen is tapped again the image closes and the video feed resumes.

This was the first time that any members of our team would be designing something to be 3D printed. Some of us had background knowledge of SolidWorks, but we had never implemented our parts into a STL file to be printed with a 3D printer. We used the initial case design to obtain the proper measurements and dimensions we would need to house the device properly. The finalized case design featured improvements to cutouts and sizing for the hardware components. The finalized case also allowed for a PCB board to be attached to case providing for a clean and simple internal design.

March 11th- 21st, 2022

The final feature that we wanted to get completed was adding a loading bar to the bootup process. This would allow a user to see that the device was booting up properly, and not just displaying a long blank screen. To complete this process the first thing was to remove the standard Raspberry Pi boot splash screen. Modifications were made to the boot section to stop the original splash image; this was done by opening the "/boot/config.txt" file and making changes to remove their splash image while successfully displaying our developed image. To get the loading bar implemented we made changes to "/etc/rc.local" to allow for a splash video to be inserted in the boot process. Originally, we tried to run the process with a service, which allows a process to run in parallel with the boot process, but it seemed unsuccessful. Modifying the rc.local file to add in the splash video to run during bootup allowed us to successfully show a boot bar during the bootup.

March 22nd- April 5th, 2022

This period was the final stretch for the design project. After the bootup process was finished all vertical slices of the project were completed and a this point the device just needed to be assembled and tested. Testing included PCB functionality, device testing, and filter testing. The PCB was assembled, soldering the 8 UV LEDs and the cherry MX switches. Upon assembly the PCB was wired to the GPOI headers and tested. The final case was submitted to UF's 3D printing labs, but after waiting over a week for approval our team found an individual with a personal 3D printer. We were able to get a case printed successfully, but the personal 3D printer did not have the same print quality as UF's, so we had to make some adjustments with a Dremel and sandpaper to certain areas of the case.

Testing UV filters proved to be the most time consuming and confusing part of this project. Many filters claimed to be a UV filter, but many of them failed to allow the proper light spectrum to pass through. Upon receiving the Kolari Vision filter we were able to properly filter out the unnecessary light, but the video feed was much darker than before. To deal with this we adjusted the camera's settings through libcamera library adjustments.

Design

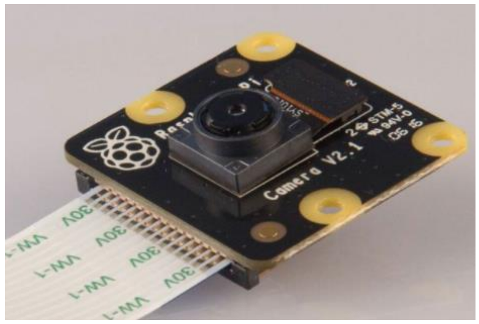
The UV Shield is a handheld device that consists of various hardware and software components. The device is made up of a UV camera, UV filter, raspberry computing board, a portable battery supply, UV light bar, external buttons, a created printed circuit board, and a housing case. For the device to operate properly, software components include a developed python code script, command line calls, and changes to the device's boot process.

Hardware

Below lists the hardware components and their purposes in the UV Shield:

- **Ultraviolet Camera**

  The camera used in the UV Shield is a Raspberry Pi NoIR camera board V2. The camera has a Sony IMX219 8-megapixel sensor and does not have an infrared filter [9]. The camera communicates with the Raspberry Pi via the flex cable shown in the image below. The flex cable is ran to the camera port of the Raspberry Pi.



Raspberry Pi NoIR camera V2 and flex cable

- **Ultraviolet Bandpass Filter**

  The UV pass filter used in the UV Shield is a Kolari Vision 39mm ultraviolet bandpass transmission filter. The Kolari filter has a 50% transmission peak at 365nm, and less than 25% transmission between 340-380nm. The average out of band rejection is 0.005% with a minimum rejection of 0.025% [10]. These parameters allow the lens to properly filter out any IR contamination, which numerous other UV filters failed to do.

Kolari Vision ultraviolet bandpass transmission filter (the image displays the 58mm version)

- **Raspberry Pi Computer Board**

  The Raspberry Pi computing board used for this project is a Raspberry Pi 3 B+ with 1 GB of RAM. The Raspberry Pi is the backbone of this product as it communicates with the NoIR camera, LCD screen, and PCB board which drives the button functionality via GPIO headers found on the Raspberry Pi.

Raspberry Pi 3 B+ with 1GB of Ram

- **Portable Battery Supply**

The battery supply used for the UV shield is a Pisugar 2+ 5000 mAH UPS lithium ion battery. The PiSugar has a circuit board that integrates directly with Raspberry Pi board communicating via the VCC, ground, and GPIO headers to power on the device. This battery is large enough to allow the UV Shield to operate for long periods of time without needing to be recharged. In addition, the power supply has a switch to toggle on the power which is used to power on the UV Shield.

Pisugar 2+ 5000 mAH lithium ion battery

- **Ultraviolet Light bar**

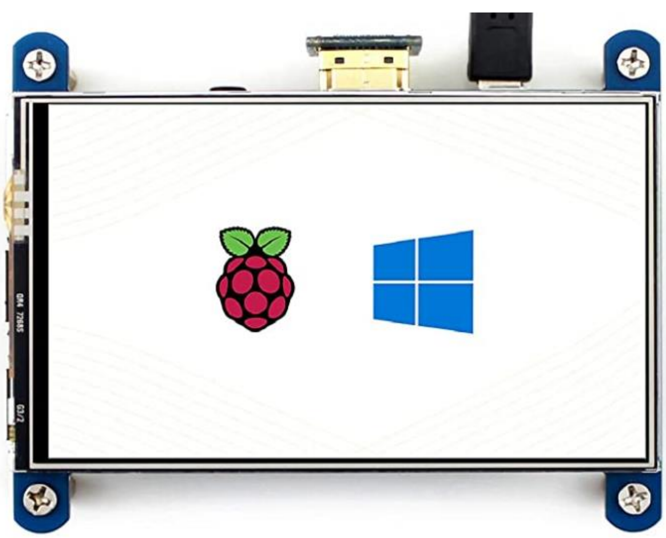
  The UV light bar consists of eight 365nm UV through-hole LED diodes. The LED diodes emit UV light at 365nm which is within the UV spectrum. The diodes were soldered to the PCB board and wired with 100 ohm resistors per diode. The LED diodes are used to create UV light indoors where UV light may be sparse.

365nm UV LEDs

- **External buttons**
  The UV Shield uses two external buttons to function the device. The first button is a power down button, which safely runs a shutdown instruction via the command line. The second button is for the LED diodes, powering them on and off. The buttons are made from Cherry MX switches, which are typical switches that make up a computer keyboard. The switches were also soldered to the PCB board and each switch was connected to a 1K ohm resistor.

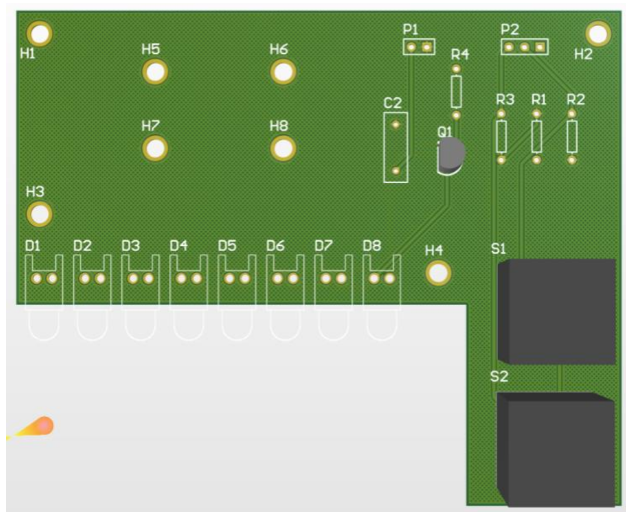
Cherry MX Switch

- **LCD Display**
  The display used for the UV Shield device is a Waveshare 4 inch HDMI LCD display that is 800x480 resolution. The display allows for touch screen functionality which we used in our project to allow users to take a still image of themselves during the live video feed. The display communicates with the Raspberry Pi via HDMI display output and GPOI headers for power and touch screen information.



- **PCB**

  The printed circuit board created for this project is used to drive the functionality for the switches and the LED diodes. The PCB was made using Altium software and printed through Advanced Circuits USA PCB Manufacturer & Assembly.



UV Shield's printed circuit board

- **Housing**

  The housing for the UV Shield was constructed using Solid works and is made from ABS plastic. The case is designed to have a top cover, and a bottom housing that the UV Shield bolts down to. The top side of the case will hold the PCB and LED light bar, and have an area cut out where the screen display fits. The bottom of the case will have 2 anchor holes which the Raspberry Pi board and LCD screen will bolt down to securing the device. Below is an image displaying the top side of the case, and how some of the internal components will be positioned. The black circle at the top represents the UV filter sitting over the camera. Below that is the UV LED bar, and to the right of the case consists of the two cherry mx switches that drive the lights and shutdown process.

UV Shield top plate

Software

The Raspberry Pi runs off Raspbian operating software (OS). This software was provided and downloaded directly from Raspberry Pi, which is a Linux based 64-bit OS. Using this operating system as a backbone for the project was useful as we could program software functionality via python. In addition, changes to the kernel were better understood with previous knowledge from UF's Operating Software class (COP4600). Concepts were taking from COP4600 and to assist with modifying the Raspberry's boot process.

The UV Shield uses python code, command line calls, and boot process changes to deliver the functionality of the product. The python code is responsible for the camera communication, camera settings, GPOI functionality, and calls to command line scripts. The camera initialization is completed through a standard camera library built for the NoIR. Settings are adjusted within the code to provide optimal clarity for the user when viewing via the LCD screen. Since the UV filter removes all light outside the UV spectrum the image comes through extremely dark. Therefor code was included to brighten the screen and to adjust the camera sensor to display a brighter image. The switches communicate with Raspberry Pi via the GPIO pins and PCB board. The GPIO pins are evaluated for changes within the switch values to operate the LED lights and to run the command script to properly shut down the device. Code base also exists to enable to the LCD's touch screen interface, which will allow us to take screenshots from the video feed via a created snapshot icon on the LCD screen. Once a user presses the screen the UV Shield will capture a still of the current feed and display it back to the user. Once the user taps the screen again the device will return to the live video feed.

Changes were made to the device's boot process so that users can understand that the device was starting up properly upon being power on. Prior to making any changes the device would boot to a Raspberry Pi splash image. After displaying the splash image, the device would sit on a long blank screen until it would finally finish the boot process and go to the homepage of the OS. For us and our anticipated users seeing the long black screen may indicate to some that the device didn't boot properly, or they just would wonder what the device is doing until it reached the homepage. To fix this we started with creating a UV Shield splash image and replacing the Raspberry Pi image with our own. After the splash image the device then boots into a loading bar which runs parallel to the boot process. While the device boots up the progress bar slowly increases until the boot process completes. This will allow users to see that the device is properly loading so that there is no hesitation waiting for the homepage to show up.

Results

Overall, our team was satisfied with the final release of our UV Shield device. We felt that all planned and additional vertical features were implemented in the project, although some might not function as seamlessly as we wanted.

The first vertical that users encounter when using the device is seeing the boot process. Originally the device booted to the Raspberry Pi image, then a long blank screen, and then finally to the OS's homepage where you had to open the python application to run it the video feed. This vertical component was completed as planned. The device now properly displays the UV Shield logo, then to the loading bar, and then starts right into the live video feed.

The second vertical component was the functionality during the live video feed. We used threading to allow multiple processes such as the video, GPOI input/output operations, and touch screen features could all run together. These verticals are all present in the project, but when using the touch screen for the still image the device shows an unnecessary message that touch screen interaction was detected.

Another vertical of the component was the hardware and case design. These verticals were also completed as intended, although the quality of the print job for the final case was a little lackluster. First the battery was tested by using the device multiple times to see if we could get more than thirty minutes of use off one charge. After multiple uses the battery proved to provide more than enough power to keep the device running for longer than needed. The PCB was tested by wiring it to the Raspberry Pi testing the button functionality. The device proved to properly switch the LEDs on and off upon hitting the switch, and the device properly shut down when hitting the shutdown key. The final 3D printed case properly housed all the components. The hardware components anchor holes properly aligned with the case to allow use to secure everything. Although it worked as intended, we would've liked for the print quality to be a little better. You could see inefficiencies in the plastic coming together properly, and some holes were filled with extra plastic which caused for needed adjustments.

The major challenges we faced during the project were supply chain issues, faulty components, team collaboration, and 3D printing errors. First, the supply chain issues caused many parts to take way longer than anticipated to receive. This led to delays in certain verticals of the project as we needed parts to finish or work on certain aspects of the project. The second challenge was faulty components. Since we were trying to find affordable hardware and UV filters this led us to many of these components to not work as intended. UV filters would not properly filter out unneeded IR spectrums which led to bad video quality. The original power system did not work as the power bank module would not properly output 3.3Vs to the Pi upon turning on. The next challenge was team collaboration. Two of our team members lived in Ocala while the rest were up in Gainesville. It was difficult to pass around one Raspberry Pi between five members to allow everyone ample time to work on features. To get past this challenge we ordered secondary components and built a second camera system so that we had more than one device to work on. This greatly helped increase group efficiency. The last challenge and a minor one at that was the 3D print quality. The first rough draft case came out great although plastic seemed to fill every hole which was easily removed with a Dremel. The second case seemed to not be to the print standard of the second, and again required a Dremel and sanding to get things properly aligned.

Overall whenever we encountered these challenges the team was always willing to come together and decide on a solution to get us over the hill and moving forward. Our original vertical features were all completed early in the semester which allowed us to add additional features we did not plan for.

Impact

The UV shield assists users with staying safe under the sun. The purpose of our device is to help reduce the chance for skin cancer for people who spend time outdoors. We believe this has many impacts, first and foremost assisting people with their health. Proper skin care is important as increased sun exposure leads to numerous skin problems not just skin cancer [1]. In addition to personal health, we believe our device could also bring awareness to our environment impacts on Earth and to our ozone layer. By allowing people to visually see UV radiation hitting their skin they may become motivated to be more conscientious about their impacts to the environment.

The team at UVis wanted to develop a project that could provide a framework for future projects within this topic. We believe that there exists a place in the world for an application such as ours, but our design does not have all the state-of-the-art features that it could have if our team was able to dedicate more time, money, and resources. By putting forth the effort that we have other teams could alleviate from spending time trying to do research and benchmark testing on different types of UV filtration, in addition they would be able to build off the hardware technology that exists within the project to provide more features for end users.

Conclusion

In conclusion, the UV Shield device provides a purpose that addresses a major need in society, assisting people with avoiding UV radiation to their skin. The UV Shield device allows users to see properly covered areas of skin, so they know they are safe when travelling outdoors. The UV Shield will save users time and emotional distress when it comes to proper sunscreen application. No longer will users spend unnecessary time trying to determine if they are applying enough sunscreen prior to the event, or during the recommended reapplications for longer activities. UV Shield is user friendly, portable, and offers robust functionality. The UVis team is proud to release the UV Shield device. They believe their product is meaningful to society and can help further benefit mankind.

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