UV Guardian – Real Time UV monitoring in Urban Environment

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ABSTRACT Geographic location, environmental properties, and altitude are factors that contribute to the increase or decrease of the pedestrians' ultraviolet (UV) exposure. Over-exposure can cause severe skin damage, possibly leading to skin cancer. The amount of time a person should stay out doors in sun also depends on one's skin type. Based on the current UV index and the skin type the total time of exposure can be calculated. With protective measures the time outdoors can be prolonged. In an Urban environment the shade provided by the buildings can increase the time outside.

Our application takes the UV index and skin type, it tracks the path taken by the user and gives a prolonged safe time duration for being outdoors. The algorithm will be incorporated into our UV Guardian (UVG) system. For most of the pedestrian path walk experiments conducted, results show that the when including the shade provided by the buildings, the pedestrians can stay 60% more time than by just going based on UV index.

1. INTRODUCTION The sun is the energy source that sustains all life on earth. Ultraviolet Radiation (UV) is simply one form of energy coming from the sun. Sunlight contains 3 types of UV rays. UVA — causes skin aging & wrinkles. It is used in tanning beds. It colors skin and gives false sense of protection from the sun. UVA rays pass effortlessly through the ozone layer. UVB—causes sunburns, cataracts, immune system damage, and skin cancer. Melanoma may be associated with severe UVB sunburns occurring before the age of 20. Most UVB rays are absorbed by the ozone layer. UVC—these rays are the most dangerous. Fortunately, these rays are blocked by the ozone layer and don't reach the earth. Even on cloudy, cool, or overcast days, UV rays travel through the clouds and reflect off sand, water, snow, and even concrete. Clouds and pollution don't filter out UV rays, and can give a false sense of protection. This "invisible sun" can cause unexpected sunburn and skin damage. The sun's light is strongest when it is highest in the sky (normally from 10 AM to 4 PM). UV rays are strongest during the summer. UV intensity is greater at high altitudes. Skiers need to take extra care. Sunburn develops when

the amount of UV exposure is greater than the protection your skin's melanin can provide. The lighter your skin, the less melanin it has to absorb UV and protect itself. All skin, no matter the color, thickens and hardens with continued sun exposure, resulting in wrinkles later in life. The ultraviolet (UV) spectrum, shown in Figure 1 is divided into three wavelengths: UVA 315–400 nm, UVB 280–315 nm, and UVC 200–280 nm. Human skin cells are highly sensitive to UVC, however these wavelengths are blocked by the ozone layer. UVB is more harmful because these wavelengths pass through the atmosphere and are primarily responsible for skin reddening by damaging the epidermal layer. Skin cancer is the most common of cancers and is l argely preventable. Increased outdoor leisure time, less clothing worn outdoors, and decreased ozone levels are partly to blame. Scientists believe sunburns can alter the body's immune system for up to 24 hours after exposure to the sun. Repeated overexposure to UV radiation can cause more damage to the body's immune system, even in people with dark skin. The skin is least sensitive to UVA, which is responsible for tanning by damaging the dermal layer. Over–exposure can cause severe skin damage, possibly leading to skin cancer. More than 1 million cases of skin cancer are reported annually in the United States (Ferguson 2005, Sue 2002). There are three different forms of skin cancer: basal cell carcinoma, squamous cell carcinoma, and melanoma. Non–melanoma skin cancers, such as basal and squamous cell, are the least severe and make up 95% of all skin cancer occurrences. Melanoma is the most dangerous and causes 75% of skin cancer related deaths. There are about 1.3 million new cases of skin cancer in the U.S. each year, resulting in about 9,800 deaths. Melanoma is one type of skin cancer. It is the most common cancer among women between the ages of 25 and 29. Moreover, the incidence and mortality rates of

Melanoma have increased dramatically in the past few decades in the United States (Boscoe 2006).
Figure 1: Spectral wavelengths of Visible Light and Ultraviolet Rays

On the contrary, the benefit of UV irradiance is the immediate synthesis of Vitamin D3 by the human skin cells when 7–dehydro cholesterol reacts with ultraviolet light (UVB) at wavelengths between 270 and 300 nm. Vitamin D helps to regulate the amount of calcium and phosphorus in the blood to form and maintain strong bones. Vitamin D is also important for the human immune system and brain functionality.

2**. PROTECTIVE MEASURES** Everyone should avoid overexposure to the sun's rays. UV radiation produces darkening of the skin, or tanning. UV exposure results in both immediate and persistent pigment darkening. Immediate pigment darkening, which is visible and transient, occurs within seconds of UV exposure as a result of the formation of reactive oxygen species and photo oxidation of preexisting melanin, and it resolves in a couple of hours. Some of the preventive measures are using sunscreen lotion, wearing sunglasses, wearing hat, wearing protective clothing and continuous usage of sunscreen lotion. It is essential to choose clothes that cover your arms, legs and neck to ensure proper protection. You won't get too hot or uncomfortable in lightweight fabrics like cotton, hemp or linen. This is important for people who have an occupation that requires them to be exposed in sunlight for long hours. Most cotton and cotton/polyester fabrics protect against 95% of UV, but are less effective if wet, faded, or aged. Dark colors are better at absorbing UV than light colors. If you choose to wear light colors, make sure the fabric is a tight weave, such as canvas. Appropriately designed clothing is great for protecting you from the sun. Sun screen helps in tanning protection. SPF is also applicable to other sunburn preventive measures. SPF is the ratio of amount of time to sunburn with sunscreen compared to time to sunburn without sunscreen As a rough guide, the SPF of a broad-brimmed hat is 3 to 6, while that of ordinary summer clothing is 6 to 7. One can see from their SPF values that the degree of protection is not as high as sunscreen lotions (usually SPF 15 or above).Sunscreen doesn't offer 100% protection. SPF* 30+ sunscreen blocks 96% of UV; SPF 15+ blocks out 93%. Using SPF 30+ instead of SPF 15+ does not mean you can safely double your time in the sun. Apply sunscreen 20 minutes before going outside. In addition to sunscreen, wear a hat, sunglasses, more clothing, and seek shade. The sun's rays are strongest between 10 am and 4 pm. Limit exposure to the sun during these hours. Staying under cover is one of the best ways to protect yourself from the sun. But remember, shade structures do not offer complete sun protection. Shade offers insufficient protection because UV light is scattered and reflected. A fair-skinned person sitting under a tree can burn in an hour Wearing long sleeves and long pants is a good way to protect your skin from the sun's UV rays. A hat with a wide brim offers good sun protection for your eyes, ears, face, and the back of your neck. Sunglasses that provide 99 to 100 percent UV protection will greatly reduce sun exposure that can lead to eye damage.

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3. ABOUT THE UV SENSOR

The UV sensor used in the experiment is the ML8511 UV sensor (see Figure 2) manufactured by OKI semiconductor. It is the first sensor that uses Silicon–on–Insulator technology (SOI), which gives it an extremely small size and low cost compared to Conventional devices. The embedded programmable microcontroller device used to process the analogue output of the UV sensor is a microcontroller board manufactured by Intel. The board contains an Altmega 328P microprocessor that is programmable using the Arduino software development kit. The output of the Intel board is a scaled digital voltage value that represents the observed UV irradiance levels. By applying a known algorithm described in the UV sensors datasheet, this value can easily be translated into an ultraviolet index (UVI). To achieve greater measurement precision, the digital value is used and not the UVI value

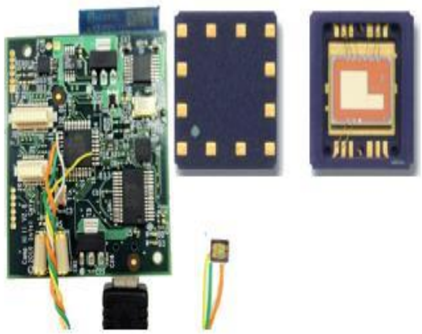


Figure 2: Intel Embedded Microcontroller (left) and the OKI Semiconductor ML8511 Ultraviolet Sensor (right)

4. EXPERIMENTS

4.1 Methods for Gathering Data

The data were gathered using the UV sensor described above. Various measurements were taken at the John Wooden Center, Boelter Hall, JP Morgan Building all located on the campus of the University of California, Los Angeles. These were chosen because the impact of shadow can be analyzed as these have different surroundings. There are no buildings around John Wooden center hence the shadow dimensions of the John wooden center alone can be analyzed. Boelter hall was chosen as it is situated in a crowded environment of buildings. This emulates the behavior of urban environment.

Readings were taken for different hour of the day like 08:00 am,

10:00 am, 1:00 pm, 03:00 pm and 05:00pm. Based on the sun's position the variations in UV index were noted. Readings were taken with the help of two sensors ML8511 UV sensor and the commercially available UV sensor. The analyses were done with the ML8511 UV sensor readings. And the other set of reading taken with the commercial sensor was used for comparison and verification. For each measurement, the sensor was held 1 inch from the surface. Then repeated measures were taken for each building on different days. Experiments were conducted for different weather conditions like sunny, rainy and cloudy environment.

4.2 EXPERIMENTS AND DISCUSSIONS

Experiments were conducted at John wooden center, Boelter Hall and JD Morgan building at UCLA. Figure 3 shows the picture of John Wooden Center.

Figure 3: Arial view of John Wooden Center at UCLA.

UV radiation is not always the same it changes based on Time of day time of year, location, altitude, weather, reflection, ozone layer. John wooden center was taken has open ground in the surroundings hence it is convenient to measure the effect of shadows. The dimensions were computed with the path tracking application. The sun's light is strongest when it is highest in the sky (normally from 10 AM to 4 PM). The curve in Figure 4 explains the behavior of UV index. The UV index increases as time increases. It decreases as time progresses after noon.

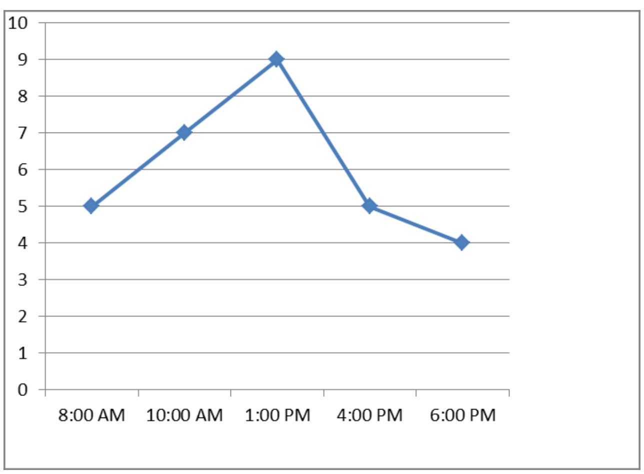


Figure 4: UV Index variation over time of the day.

In Figure 5, we observe that under the shadow of the building the UV index drops to 2 or 1 irrespective of the value outside. The UV index is 0 indoors.

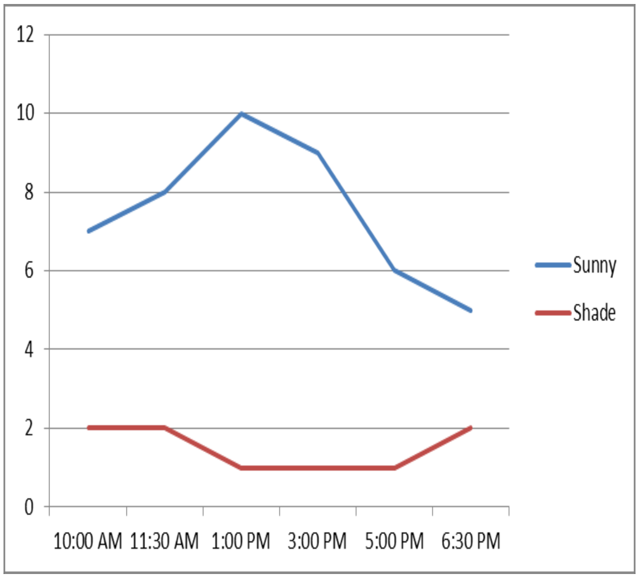


Figure 5: Experiments with and without the shade of the building. In Figure 6, the effects of shadows are analyzed.

The UV index value is measured on all four sides of the building.

h = s * tan(a)(MAgnitude)

where,

h= Height of the building,

a- Altitude angle of the sun s- Shadow length

The shadow length will be more during sunrise and sunset. At noon the shadow length is short. And the user would probably walk in the shadow of the building during morning and evenings.

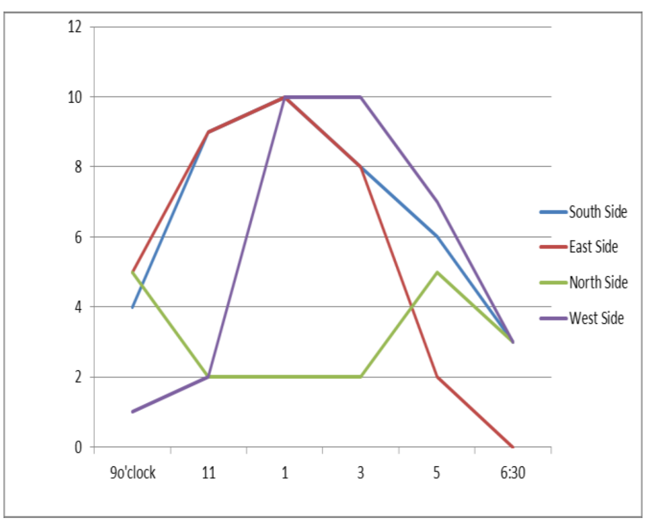


Figure 6: UV index on four directions of the John Wooden Center.

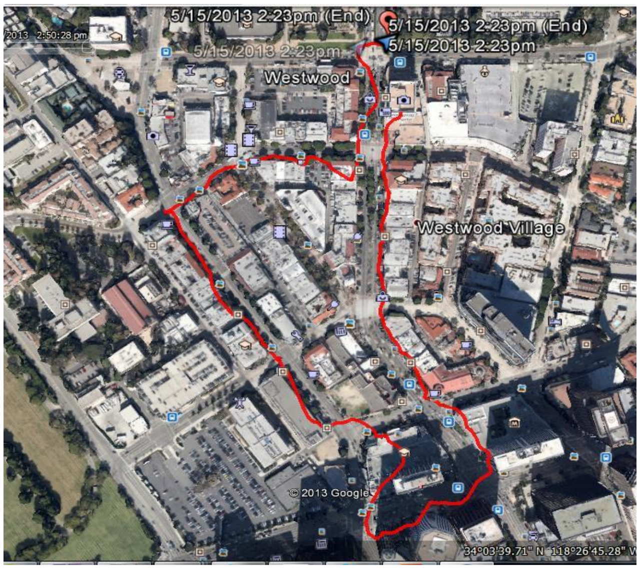


Figure 7: Path taken in an urban environment at Westwood, Los Angele.s

The idea is to reduce the cumulative amount of UV exposure by taking a path that has the maximum shade provided by the buildings in that path. We took a 1.2 mile path in Westwood, Los Angeles. Our application is integrated with a path tracking feature that gives the path in that area, along with the average speed of the user. We measured UV index in the non-shade and the shade regions with respect to time. A cumulative UV index is calculated.

Time in sec UV Index

Time In Sec	UV index
55	0
12	9
21	8
60	2
11	7
32	0
18	5
50	9
30	9

Table 1: Measurement of UV index with respect to time From the Table 1,
UV index – 9
Distance covered - 1.2 miles
Cumulative UV Index = ∑time x UV Index / ∑ time
Cumulative UV index – 5
If the UV index is 9 the time to burn 17 minutes and when cumulative index was calculated with respect to time. The cumulative UV index is 5. This allows the user to be outdoors for 45 minutes for the skin type 1.

5 Vitamin D

Vitamin D sufficiency, along with diet and exercise, has emerged as one of the most important preventive factors in human health. Hundreds of studies now link vitamin D deficiency with significantly higher rates of many forms of cancer, as well as heart disease, osteoporosis, multiple sclerosis and many other conditions and diseases. Although vitamin D is commonly called a vitamin, it is not actually an essential dietary vitamin in the strict sense, as it can be synthesized in adequate amounts by most mammals exposed to sunlight.

But the question arises is how much quantity of Vitamin D is needed for a person in a day ?
Studies have shown that Daily 2000 IU is needed for a person. It is also known that Vitamin D is also not harmful till 10000IU are grabbed This time varies with the skin type and intensity of Sun rays . A type 1 (fair) person at UV index 10 obtains this amount in 10minutes .
We have calculated the time which the person requires to be in the to acquire the adequate Vitamin D

```
Time(in min) = 10*type*maxvalue / uvindex
```

Table

In this Table UV index =12

Type	Time
1	10min
2	20min
3	30min
4	40min
5	50min
6	1hr

6. ALERT SYSTEM

i VitaminD

The total time to particular UV index not only depends on the UV Index at the location but also the user's skin type. Our application takes both the UV index value and the type of the skin as the input and alert the User whenever he has acquired the Suffieicient UV .

ii SUNBURN ALERT SYSTEM

The total time to particular UV index not only depends on the UV Index at the location but also the user's skin type. Our application takes both the UV index value and the type of the skin as the input. Skin types are categorised from type 1 to type 6 with type 1 being pale and type 4 naturally dark. Sunburn develops when the amount of UV exposure is greater than the protection your skin's melanin can provide. The lighter your skin, the less melanin it has to absorb UV and protect itself. For a UV index value of 0,1 and 2 the time to sun burn and redness are infinity.

The Sunburn alert feature of the application gives an alert notification when the user's skin starts burning. It also suggests the protective measures that have to be taken.

iii Sunscreen Alert System

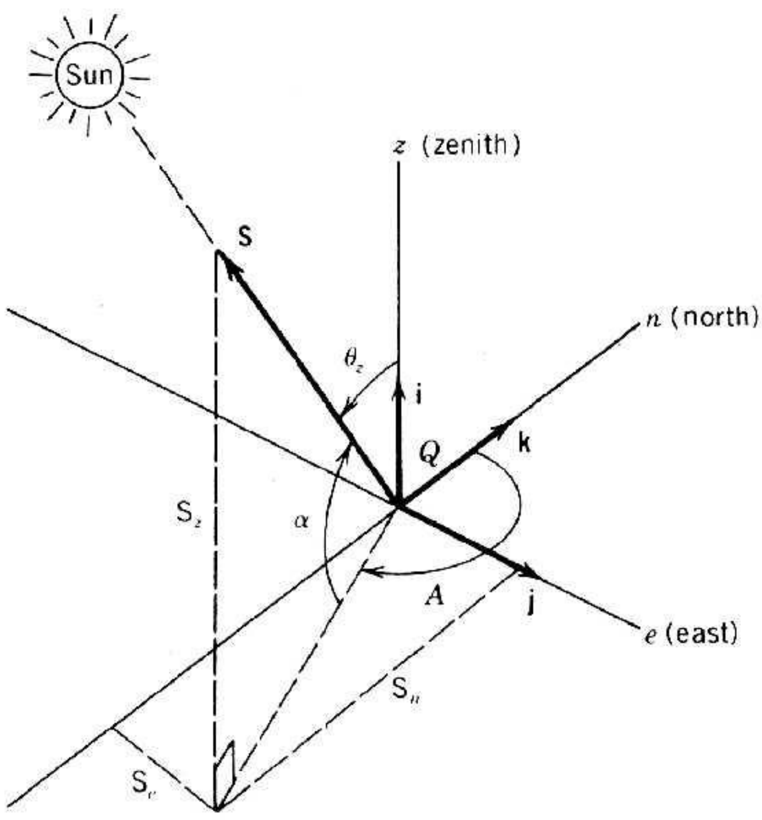
The user is also informed to apply sunscreen after interval of two hours to avoid the sunburn . It informs the user apply to apply sunscreen on his face even during the initial hours and leaving arms and legs to acquire sufficient VitaminD . After the user is alerted about the Vitamin D . he can apply sunscreen on legs and arms too.

7. Shadow Calculation

For Calculating the shadow of a pole Sun position is really necessary. So the next section makes you aware of the Sun position

i Sun Positon

When we observe the sun from an arbitrary position on the earth, we are interested in defining the sun position relative to a coordinate system based at the point of observation, not at the center of the earth. The conventional earth-surface based coordinates are a vertical line (straight up) and a horizontal plane containing a north-south line and an east-west line. The position of the sun relative to these coordinates can be described by two angles; the *solar altitude angle* and the *solar zenith angle* defined below. Since the sun appears not as a point in the sky, but as a disc of finite size, all angles discussed in the following sections are measured to the center of that disc, that is, relative to the "central ray" from the sun.



Solar Altitude, Zenith, and Azimuth Angles

The solar altitude angle (α) (α) is defined as the angle between the central ray from the sun, and a horizontal plane containing the observer, as shown in Figure 3.6. As an alternative, the sun’s altitude may be described in terms of the *solar zenith* angle (θ_z) (θ_z) which is simply the complement of the solar altitude angle or

$$\theta_z = 90^\circ - \alpha \qquad \text{(degrees)}$$

The other angle defining the position of the sun is the *solar azimuth angle (A).* It is the angle, measured clockwise on the horizontal plane, from the north-pointing coordinate axis to the projection of the sun's central ray.

So for the Suns position we need the azimuth and the altitude angle to find the exact location of Sun at any place and at any time. Astronomical Application Department maintains the record of both of these angles daily. So we have got our data from them and we have automated our application with this site.

Shadow Length

Now that we have developed the appropriate way to define the direction of the sun on any day, any time and any location, *lets know focus on the shadow*

An important use of your understanding of the sun's position is in predicting the location of a shadow. Since sunlight travels in straight lines, the projection of an obscuring point onto the ground (or any other surface) can be described in terms of simple geometry.

shows a vertical pole on a horizontal surface. The problem here is to define the length and direction of the shadow cast by the pole.

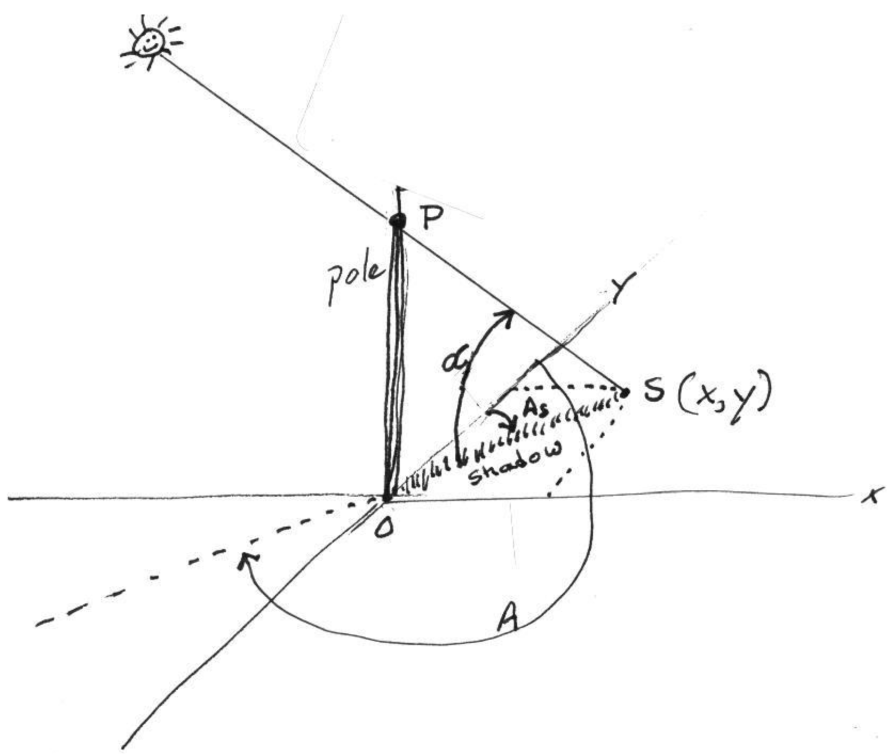


Figure 3.12 Shadow cast by pole OP showing x and y coordinates of shadow tip, and shadow azimuth *(A_s).*

In polar coordinates, for a pole height, OP and the shadow azimuth, θ_s defined in the same manner as the previous azimuth angles i.e. relative to true north with clockwise being positive, we have for the shadow length:

$$OS = \frac{OP}{\tan \alpha} \qquad (m)$$

and for the shadow azimuth:

$$A_s = A - 180^o \qquad \text{(degrees)}$$

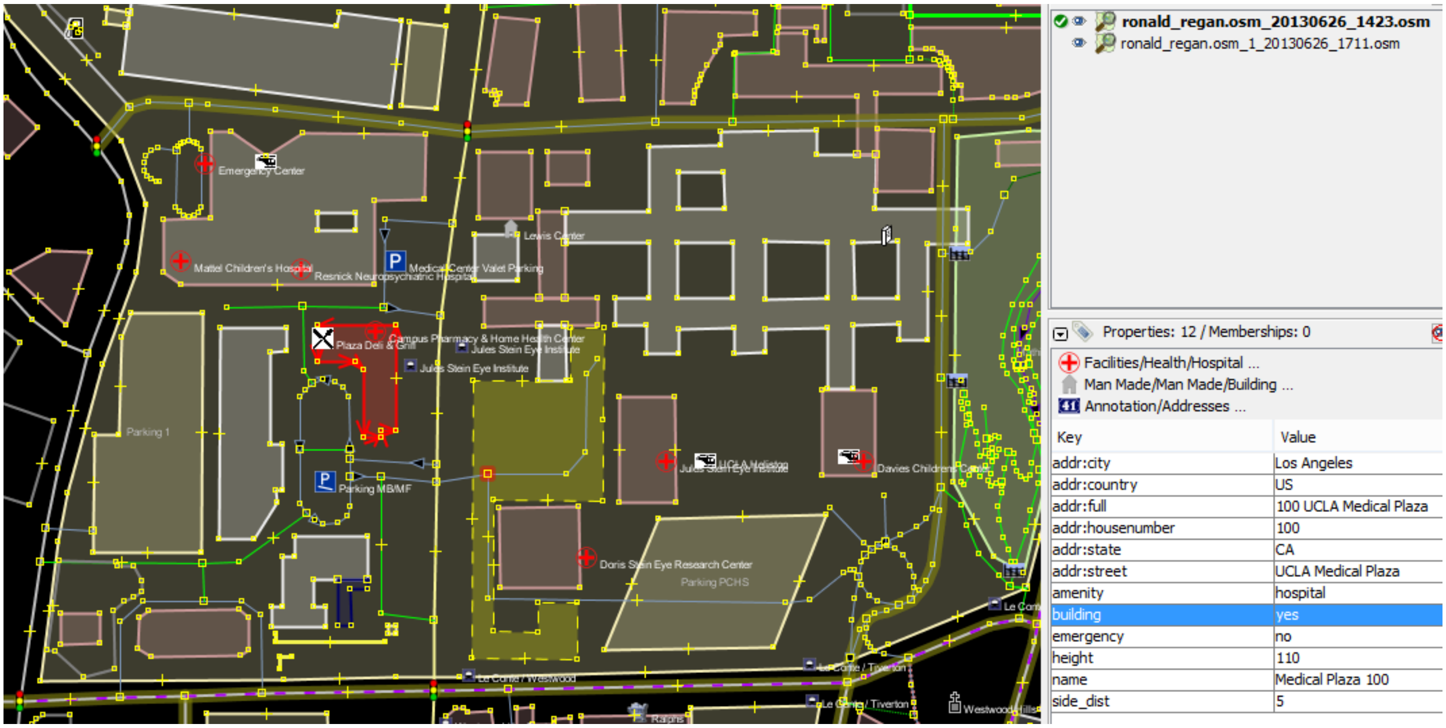
In terms of Cartesian coordinates as shown on Figure ,with the base of the pole as the origin, north as the positive y-direction and east the positive x-direction, the equations for the coordinates of the tip of the shadow from the vertical pole OP are:

$$x = OP\left[\frac{\sin\,(A - 180^o)}{\tan \alpha}\right] \qquad (m)$$

$$y = OP\left[\frac{\cos(A - 180^o)}{\tan \alpha}\right] \qquad (m)$$

8. Experimental Setup

For the experiment we have chosen the area shown in the figure . This area is near Ronald Regan.
To test our application under different buildings heights and even the distance of the building need to vary to test whether a building will cast a shadow or not .
For this purpose we have chosen this area as height and distance of sidewalk from building here varies significantly.
Height 40 -144ft
Sidewalk Distance 0-150ft
For this purpose we edited the Open Street maps and these changes are now even seen on OSM website . We have added 2 tags for all the buildings that are in the area of experiment . These tags are Height and Sidewalk Distance as you can see in the right bottom corner of the image.



OSM Screen

For the experiment person will have a walk covering approximately 1mile with the locale of buildings of varying height. Then the UV exposure over the whole walk will be calculated .

9. Buildings

a)

Out of all the amenities there in the city only concerned area will be the housing area and the industrial path.

i Housing Area.

In this area , the major difference between the housing area is that there will be greenery in front of every housing .Hence Side walk wouldn't be just next to the house. Also the Building Height will be limited . We checked across the housing In Los Angeles . los Angeles City planning has restricted the housing height based on various constraint and the maximum height is just 50feet and this much height will cast a shadow but less significant to casted by tall buildings. Even the shadow casted would be casted on the greenery not on the sidewalk .So a person taking a walk in the peak hours i.e 11am to 3pm would be always under the shadow if he is crossing the housing area.

ii Industrial Area

In contrast to housing area Industrial area are permitted to have tall buildings which cast a significant shadow even during the peak hours . even the sidewalk is just next to the building in most of the cases. For eg. Building with a height of 100ft cast a shadow of 20ft magnitude at 1pm when the sun is just next to overhead at Los Angeles which is sufficient to cast a shadow on the person . So a person taking the path in this area will under the shadow of buildings during his trek . Hence the UV exposure would be quite less as to the exposure UV exposure as even shown during our complex walk in the city mentioned above.

b) Building Dimaensions

i Height Measurement

For measuring the height of a building we looked around to get the dimensions of all the building but was not successful. So finally we found the way to approximate the height of a building. We just tried to calculate the height of a block instead of the whole building and then sum it up over the total number of blocks.Then we even cross checked our method with some application and the result was pretty good.

For eg. For a building on Wilshire Blvd.
No of blocks =9
Height of each block 13ft
Height = 117feet

Application Showed 34.7m which is nearly 115feet

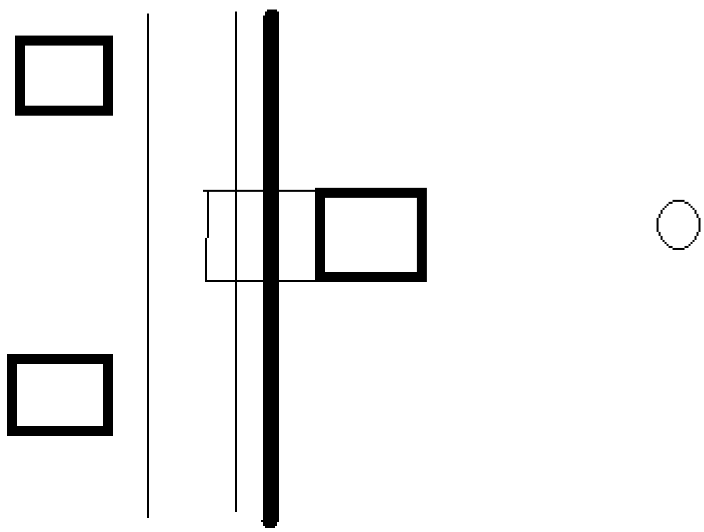
ii Distance Measurement

For distance measurement two different approaches are used .
1 Distance between the 2 geographic points by knowing its latitude and longitude.
2. Method is used when we are concerned with distance not the displacement . this will let us know the actual distance covered by person instead of displacement for which I used the average speed of the person and the difference bbetween the time stamp.

10. Building Effect

Now let us consider a building in the locale of the person trek will cast a shadow or not .
First of all let me explore the simple case first .

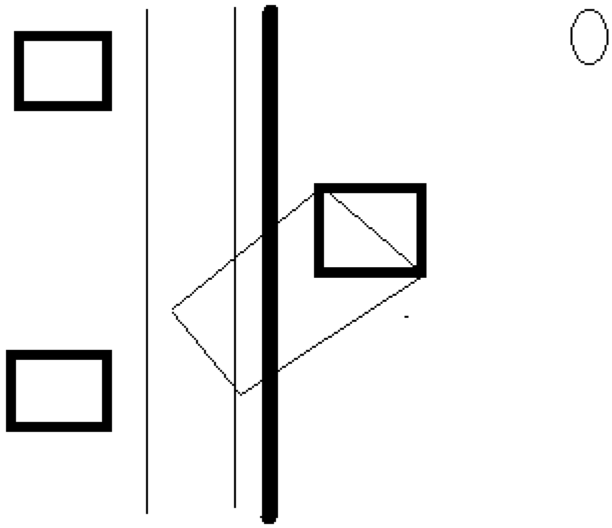
i)



When Sun rays are along one of its Dimension.

In this case if length of the shadow(magnitude) is more than the distance of the sidewalk from the building we can say that the building is will cast a shadow and the person will receive UV index under the building.
Even the distance under which the person would be under the shadow will be equal to the width of the building.

ii)

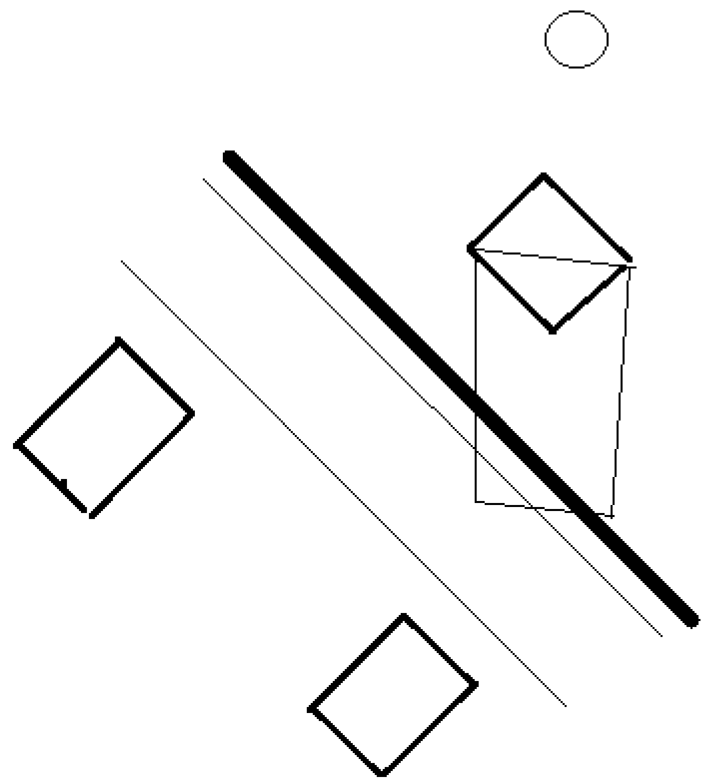


<u>When sun is at some angle with the building and is along Latitude or longitude</u>

In this case if shadow along one of the axis (in this case xaxis)is more than the distance of the sidewalk from the building we can say that the building will cast a shadow and the person will receive UV index under the building and the shadow we have calculated is calculated in both of the dimensions.

Distance under which the person would be under the shadow will be equal to the width of the building and plus the length(full or less) that will also provide shadow .

iii)

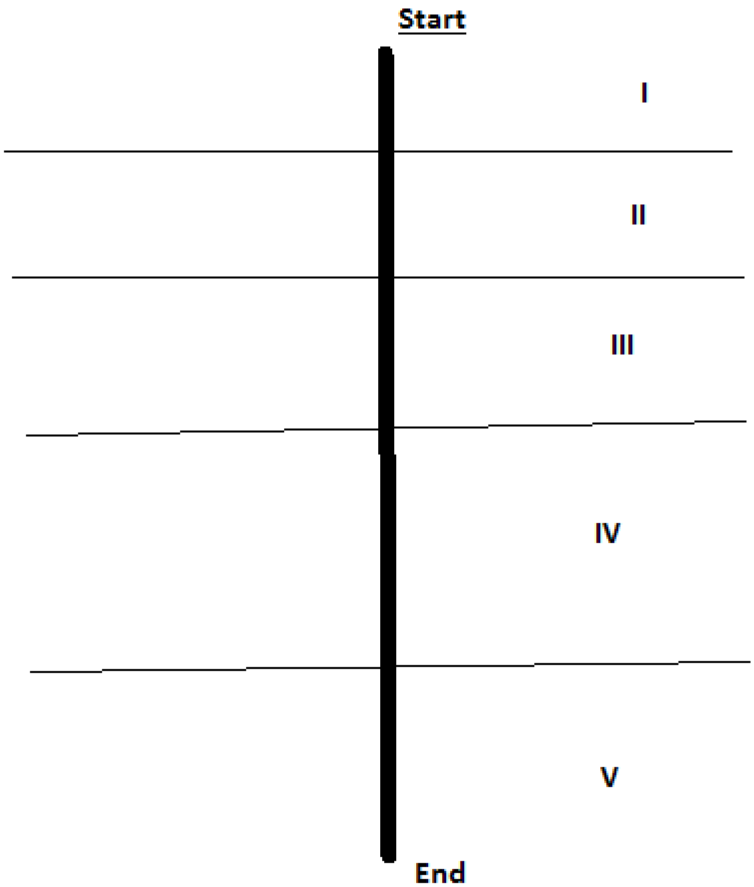


<u>When sun is at some angle with the building and building is also at some angle with latitude or longitude</u>

In this we need to calculate length of the shadow in direction parallel to the building and the sidewalk. For this we can calculate the angle made by the building with x axis by assuming a virtual node point whose co-ordinates will be latitude of one point and longitude value of other point in consideration. With this we calculated the angle as we know 2distance (Point 1 and virual point ,Point 2 and Virtual Point) . And after we are aware of angle we calculated the shadow in this direction .
Now if the length of the shadow in this direction is more than the side walk distance. Building is casting a shadow.
Distance under which the person would be under the shadow will be equal to the width of the building and plus the length(full or less) that will also provide shadow

Scenario in which half of the building is casting a shadow and half not as in the case 3 above . So to account for these the difference between shadow length in the direction perpendular to sidewalk and side walk distanceis calculated. Only this much of the length of the building will cast the shadow. As the remaining shadow wont be over the sidewalk

11. UV Measurement over the whole path



Now let us suppose this is our track . We segmented our path between the two time stamp. Between two time stamp we can segment on the basis of area under the shade and sun . After segmenting we just need to sum our UV over these two time stamps .

Eg Suppose II and IV are in shade

So for this case

Total UVexposure(between 2 timestamps) = UV Exposure I + UV Exposure II + UV Exposure III + UV Exposure IV + UV Exposure V

Take UV_index under sun =10

UV index under shade =1

So total Exposure(between 2 time stamps) =10*t1 + 1*t2 + 10*t3 + 1*t4 + 10*t5

After this we integrated our UV exposure over the total path which gives the total UV exposure over the whole path .

The result shown by the manual sensor shows that building increases the time under which the person can be under sun by nearly 2fold which is considerable.

12. UV PROTECTION ANDROID APPLICATION

We implemented a UV protection system as a part of this project.
Our infrastructure consists of a Samsung Galaxy S2 and S4 phone with Jelly bean, various smartphone applications, and a UV sensor to get the UV index value at particular time.

Our Application accounts all the things discussed in this report. From the UV monitoring to all the alerts which will make the user aware of all the things. Even the precautionary measures are included depending upon the exposure.The path tracker is also there in the application.

12.B PATH TRACKING SYSTEM

To analyze the cumulative effect of the UV index in the urban environment the application should be able to track the path taken by the user. We have integrated the path tracking feature in our application. This feature tracks the path using GPS in the smartphone and embeds the GPS coordinates in the Google earth. It also provides the average speed of the user when the path is taken. With time and speed we have calculated the length of the shade in the path taken.

13. CONCLUSION

Exposure to ultraviolet radiation is harmful for human beings. Being able to understand and quantify this exposure is essential from a preventative care standpoint – people need to be aware of the risks of being exposed to the sun's rays when they step outside in various conditions and at various times of the day. We examined some of these factors, and found that direction was significant. That is being in the path of direct sunlight results in a much higher exposure to ultraviolet radiation than being outside but not facing directly at the sun. And although it may seem intuitive that going out when the sun is not highest in the sky would result in less exposure, we found that that was not the case. People need to be aware of these facts so they can better protect themselves from harmful exposure by using preventative measures like wearing sunscreen with the correct minimum sun protection factor (SPF).

14. ACKNOWLEDGMENTS

I would like to thank Professor Dr Mario Gerla , Jerrid Matthews for giving me the opportunity to work on this project . I would also like to thank Vidhyashri Gnanaprakash for his various inputs in various sections of this report.

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