UV Data Analysis and Navigation

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Abstract- Pedestrians exposure to UV Radiation depends on many factors, most importaant of which are geographic location and environmental properties. UV radiation in moderation is beneficial to human health like production of Vitamin D. However, overexposure to UV Radiation can lead to many health problems including skin cancer. The purpose of this project is to provide user with a path from the source to the destination , that has minimum UV exposure, thus reducing the health risks. UV data is gathered using a circuit which contains sensors for UVA and UVB. Further, statistical analysis is performed on the data. Data analysis is then done to determine what the minimum number of UV samples is to assert the UV exposure on a path. The aim here is to obtain an accuracy of above 75% for UVA and above 95% for UVB. A method is also devised to estimate UV data from the neighboring road segments if the number of samples for a given road segment is lesser than the minimum number of UV samples required for analysis. A Web Service is built to cater the developers to use the system in order to get the best path to route a pedestrian with minimum UV exposure. A web application is also built to consume the web service.

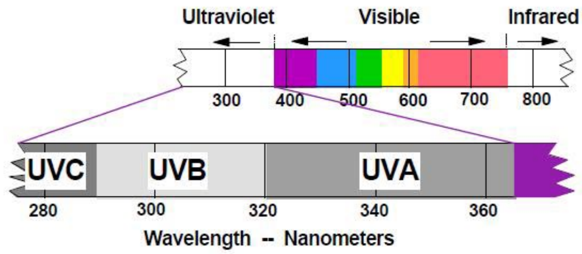

Figure 1: *UV Spectrum*

1 Introduction

Scientists have come to a similarly dichotomous recognition that exposure to the ultraviolet radiation (UVR) in sunlight has both beneficial and deleterious effects on human health. UV exposure is beneficial to humans in a optimum amount since it is necessary for the production of Vitamin D in the body. Unlike other essential vitamins, which must be obtained from food, vitamin D can be synthesized in the skin through a photosynthetic reaction triggered by exposure to UV radiation [1]. So, it is necessary for humans to get an optimum amount of UV exposure. However, over exposure of UV have a lot of bad implications on the body like skin cancer and sun burns. These health effects could have been worsened due to the depletion of the ozone layer resulting in increase in UV radiation [2]. The effect on human health of solar UV at the earths surface depends on many factors like geographic location and environmental properties.

The UV spectrum, shown in Figure 1 is divided into three wavelengths: UVA 315-400nm, UVB 280-315nm and UVC 200-280nm [4]. The ozone layer of earth blocks UVC radiations where as UVA and UVB radiations pass through the atmosphere. UVA radiation penetrates deeply into the skin, where it can contribute to skin cancer indirectly via generation of DNA-damaging molecules such as hydroxyl and oxygen radicals. Sunburn is caused by too much UVB radiation; this form also leads to direct DNA damage and promotes various skin cancers. Erythema is caused primarily by the UVB [3]. It causes reddening of the skin by damaging the epidermal layer. The amount of UV radiation that is absorbed or scattered is determined by a number of factors. For measurement of UV Radiation, there is a metric called UV index [5].

Since over exposure of UV on humans has several adverse effect, exposure to UV radiation should be avoided. The paper highlights a web service to route users through routes with minumum UV exposure and thus reducing the amount of UV exposure on pedestrians. It also showcases a prototype to consume the web service by building a web application.

In order to estimate the UV levels on a route, analysis was done in order to determine minimum number of samples necessary to assert the UV levels on a particular route. The analysis plays a crucial role in the navigation application since there needs to be a certain confidence in estimating the UV levels on a particular route. Another interesting problem that is discussed in the paper is to estimate the UV on a route when the number of samples are less than the actual number of samples required. The UV level in these cases is estimated from the UV levels of the neighbors. Using the results mentioned in [6], it is resonable to estimate the UVA accuracy to 75% and UVB accuracy to 95%.

2 Approach

Work is mainly divided into the following parts:

- Route Selection
- Sensor Device Selection
- Data Collection
- Data Analysis
- Web Service Development
- Navigation Web Application

For the project to be a success, the most crucial part is selection of the route for the experiment. The route that is selected needs to have a good mix of trees, buildings and open spaces. A major criteria was to also select a path which has alternate routes so that decision on suggesting a route can be taken by comparing the options based on the UV levels. After the route selection, a selection was to be made for selecting the devices to collect the UV data. A requirement for sensor selection was that device should have sensors to measure both UVA and UVB data. Also there needs to be an interface to transfer the data collected to the computer. A GPS device is also necessary to keep a track of the latitude and longitude points where the UV data is collected.

After the data was collected, analysis was done on the data to determine the minimum number of samples necessary to assert the level of UV on a particular route. After the analysis is completed, a web service is developed to incorporate the analysis done so far, and help the developers to create platform independent navigation system on top of the system created. The main idea being the users of the application uploading data to the common server and the web service provides an API to the external world developers. Finally, a web application was also created to consume the web service and provide as a basis for other application developers.

3 Implementation

3.1 Route Selection

Selecting a route was extremely crucial for the project since UV exposure is affected by geographic and environment properties like trees and buildings. A route should be selected with a good balance of open spance, trees, buildings, and a mixture of all previously mentioned objects. After guaging different route options, a route was selected around UCLA area which had a mix of open space, buildings and trees. Our source was 606 Levering Ave and destination was 11020 Kinross Ave 2. The alternate routes were as follows

- Via Veteran Ave
- Via Levering Ave and Gayley Ave
- Via Weyburn Ave

Veteran Ave route had a good mix of buildings and trees, while Levering Ave/Gayley Ave and Weyburn Ave routes had a good mix of buildings and open spaces.

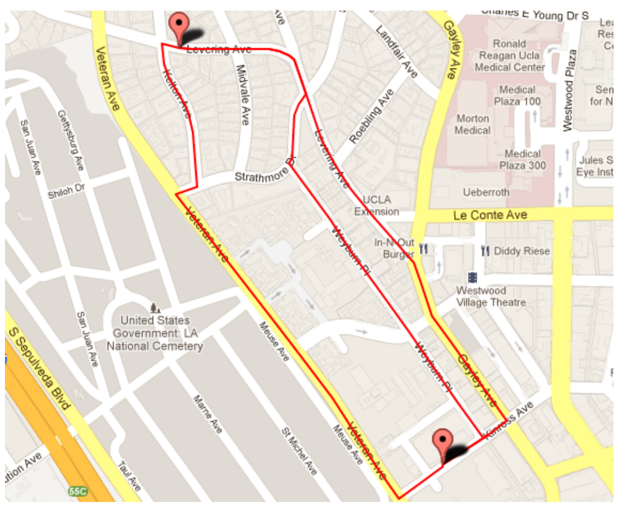

Figure 2: *Routes taken for doing the analysis.*

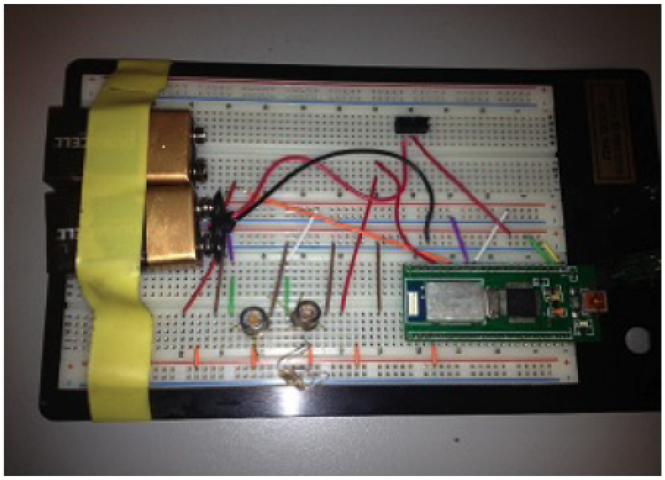

Figure 3: *Sensor to collect UV Data.*

3.2 Sensor Device Selection

Data collection had two main components, UV readings and GPS readings. For UV Readings, a sensor built at UCLA was used 3. The reason for selecting this sensor was the fact that all our requirements were satisfied. The device had 2 sensors for measuring UVA UVB each. The device also had a bluetooth which facilitated transfer of data from the device to a computer. Since there was no GPS device built on the UV sensor, Android device was used to collect GPS readings. After guaging various options for a GPS software on the android market, GPS logger software 4 was finally selected to log the GPS data since it was very flexible and provided different options to log the data. GPS logger used to log the GPS readings, which were at a later stage merged with the UV sensor readings to get the UV exposure at specific latitude and longitude points.

3.3 Data Collection

For collecting the readings, actual walks were done on the selected route 2. The walks were done by holding the sensor device, a laptop to transfer the readings and an android phone to collect the GPS readings. Readings were taken between 9a.m. and 11a.m. on couple of sunny days with clear sky. Protection from the sun rays may be different on different sides of the road depening on height of the buildings, presense of trees, time of days etc. Thus, readings were taken by

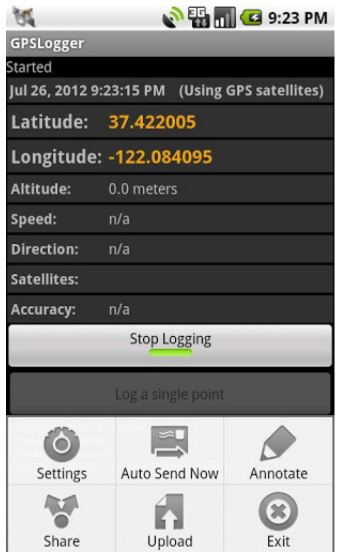

Figure 4: *Software to collect GPS Data.*

walking on both sides of the road wherever possible. Figure 5 shows a plot of points where readings were taken by walking along the road.

3.4 Data Analysis

3.4.1 Data Cleansing

Data cleansing is the most important step of any project where data analysis is involved since analysis can only be performed on clean data and that noisy data should be removed. There were UV readings taken by one device and the GPS readings were taken by another device.So, a script was written to merge the readings so that exact UV readings were collected on the logged GPS points. The UV sensor device sends raw readings which are unreadable by humans. A sample of the raw readings is shown in Fig: 6. A script is written to transform these raw readings to humanly readable readings. The readings then contains the UV data at each second. There are four files produced by running the script. A sample of the data is shown in Fig 7. The GPS readings from the GPS logger software are shown in Fig 8. A scipt is written to join the GPS sensor readings and UV sensor readings. A sample of readings after joining the GPS readings and UV Sensor readings is shown in Fig 9. Also, there were couple of sensors for both UVA and

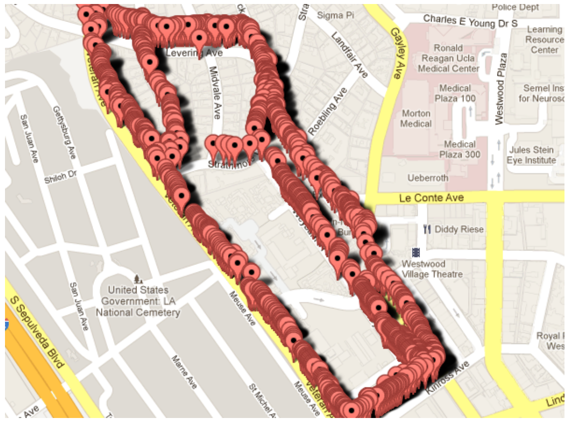

Figure 5: *Data points with UV Readings.*

```
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1350247281.345033 0x00eb 0x00fb 0x0002 0x005e 0x00bf 0x009f 0x0003 0x0002
1350247282.382826 0x00eb 0x0100 0x0002 0x005f 0x00bf 0x00a2 0x0003 0x0002
1350247283.420161 0x00eb 0x0102 0x0002 0x0060 0x00bf 0x00a3 0x0003 0x0002
1350247284.472712 0x00eb 0x0102 0x0002 0x005f 0x00be 0x00a2 0x0003 0x0002
1350247285.524966 0x00eb 0x00fb 0x0002 0x005f 0x00bf 0x00a4 0x0003 0x0002
1350247286.579939 0x00d9 0x0000 0x0000 0x0020 0x01cd 0x0189 0x0003 0x0003
1350247287.640052 0x00da 0x0000 0x0000 0x0020 0x01cd 0x0193 0x0003 0x0003
1350247288.685420 0x00d0 0x00b4 0x0002 0x0062 0x00c1 0x00b3 0x0003 0x0002
1350247289.724062 0x00da 0x0000 0x0000 0x0020 0x01cd 0x018d 0x0003 0x0003
1350247290.776644 0x00eb 0x00ff 0x0002 0x005e 0x00be 0x00ae 0x0003 0x0002
1350247291.836590 0x00e9 0x00e1 0x0002 0x005d 0x00c0 0x00ab 0x0003 0x0002
1350247292.883822 0x00e9 0x00e5 0x0002 0x005d 0x00c0 0x00a7 0x0003 0x0002
1350247293.926665 0x00e8 0x00e5 0x0002 0x005d 0x00c0 0x00a7 0x0003 0x0002
1350247294.963833 0x00e9 0x00e0 0x0002 0x005d 0x00c0 0x00a3 0x0003 0x0002
1350247296.020190 0x00d8 0x0000 0x0000 0x0020 0x01ce 0x0188 0x0003 0x0003
1350247297.057730 0x00e8 0x00e3 0x0002 0x005d 0x00c0 0x00ad 0x0003 0x0002
1350247298.096677 0x00d1 0x00eb 0x0002 0x0077 0x00c0 0x00a9 0x0003 0x0002
1350247299.133819 0x00cf 0x00e5 0x0002 0x0065 0x00c1 0x00a5 0x0003 0x0002
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1350247304.347671 0x00c7 0x00ef 0x0002 0x00fc 0x00c1 0x00a3 0x0003 0x0002
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1350247308.501760 0x00c7 0x00e9 0x0002 0x00cf 0x00c3 0x00a2 0x0003 0x0002
1350247309.540475 0x00c8 0x00ec 0x0002 0x00e4 0x00c2 0x00a1 0x0003 0x0002
1350247310.579079 0x00c8 0x00eb 0x0002 0x00c7 0x00c2 0x00a0 0x0003 0x0002
1350247311.616501 0x00ca 0x00ea 0x0002 0x0080 0x00c3 0x00a3 0x0003 0x0002
1350247312.654295 0x00ca 0x00ea 0x0002 0x007f 0x00c2 0x00a0 0x0003 0x0002
1350247313.709215 0x00c6 0x00ea 0x0002 0x0146 0x00c2 0x009e 0x0003 0x0002
1350247314.751480 0x00c7 0x00e6 0x0002 0x00ce 0x00c3 0x009f 0x0003 0x0002
1350247315.787750 0x00c6 0x00e6 0x0002 0x0136 0x00c2 0x009d 0x0003 0x0002
1350247316.846456 0x00c6 0x00ec 0x0002 0x0123 0x00c2 0x00a0 0x0003 0x0002
1350247317.882696 0x00e4 0x00e4 0x0002 0x00c3 0x00c2 0x009f 0x0003 0x0002
1350247318.926591 0x00ea 0x00e5 0x0002 0x0090 0x00c2 0x00a1 0x0003 0x0002
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1350247323.088197 0x00eb 0x00e7 0x0002 0x0068 0x00c2 0x00a0 0x0003 0x0002
1350247324.129192 0x00ea 0x00e9 0x0002 0x005c 0x00c1 0x009c 0x0003 0x0002
1350247325.166554 0x00ec 0x00e6 0x0002 0x005f 0x00c1 0x009e 0x0003 0x0002
1350247326.204394 0x00ea 0x00f4 0x0002 0x005d 0x00c1 0x00a0 0x0003 0x0002
1350247327.243113 0x00c9 0x00b6 0x0002 0x00cf 0x00c3 0x00a0 0x0003 0x0002
1350247328.281830 0x00e5 0x0114 0x0002 0x005d 0x00bf 0x009f 0x0003 0x0002
1350247329.319352 0x00cc 0x00b6 0x0002 0x00aa 0x00c3 0x00a1 0x0003 0x0002
```

Figure 6: *Raw Sensor Readings*

```
0.000000 9.719000 0.000000
1.037580 9.719000 10.084240
2.075042 9.719000 20.167333
3.123745 9.719000 30.359677
4.161208 9.719000 40.442780
5.241333 9.719000 50.940516
6.278834 9.719000 61.023986
7.321242 9.719000 71.155150
8.372604 9.719000 81.373337
9.410045 9.719000 91.456226
10.447516 9.719000 101.539408
11.483859 9.719000 111.611624
12.521374 589.144000 422.276346
13.558884 327.344000 897.709041
14.596281 344.669000 1246.281145
15.636299 9.719000 1430.566109
16.673894 9.719000 1440.650495
17.745169 9.719000 1451.062216
18.782552 344.669000 1634.880274
19.821332 9.719000 1818.945853
20.872710 9.719000 1829.164195
21.946365 9.719000 1839.599047
22.983813 9.719000 1849.682004
24.042585 9.719000 1859.972210
25.080203 9.719000 1870.056818
26.117622 9.719000 1880.139494
27.155130 9.719000 1890.223035
28.192732 9.719000 1900.307488
29.233936 9.719000 1910.426949
30.271351 9.719000 1920.509586
31.315139 9.719000 1930.654161
32.352774 9.719000 1940.738937
33.392643 9.719000 1950.845424
34.434430 9.719000 1960.970551
35.476372 9.719000 1971.097187
36.535242 9.719000 1981.388342
37.572641 9.719000 1991.470824
38.611428 9.719000 2001.566796
```

Figure 7: *Transformed Sensor Readings*

```
time,lat,lon,elevation,accuracy,bearing,speed
2012-11-10T18:33:22Z,34.066702,-118.453361,88.500000,21.000000,0.000000,0.000000
2012-11-10T18:33:24Z,34.066692,-118.453387,89.099998,19.000000,0.000000,0.000000
2012-11-10T18:33:26Z,34.066686,-118.453404,89.300003,19.000000,0.000000,0.000000
2012-11-10T18:33:28Z,34.066682,-118.453418,89.599998,18.000000,0.000000,0.000000
2012-11-10T18:33:30Z,34.066671,-118.453455,89.400002,18.000000,250.899994,3.500000
2012-11-10T18:33:32Z,34.066665,-118.453450,91.900002,8.000000,229.899994,1.250000
2012-11-10T18:33:34Z,34.066686,-118.453443,89.699997,9.000000,348.200012,1.000000
2012-11-10T18:33:36Z,34.066672,-118.453453,90.000000,7.000000,348.200012,0.750000
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2012-11-10T18:33:42Z,34.066615,-118.453486,90.099998,6.000000,212.300003,0.500000
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2012-11-10T18:33:47Z,34.066552,-118.453495,87.599998,7.000000,212.300003,0.500000
2012-11-10T18:33:50Z,34.066533,-118.453492,84.599998,6.000000,212.300003,0.250000
2012-11-10T18:33:52Z,34.066516,-118.453487,83.599998,6.000000,0.000000,0.000000
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2012-11-10T18:34:00Z,34.066444,-118.453484,84.099998,8.000000,212.300003,0.250000
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```

Figure 8: *Raw GPS Readings*

```
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Sat Nov 10 11:44:06 PST 2012,34.065517,-118.450576,9.719,-1.0,459.261,73.713,null
Sat Nov 10 11:57:25 PST 2012,34.060288,-118.447238,519.844,381.244,548.789,645.537,null
Sat Nov 10 11:59:41 PST 2012,34.061327,-118.448219,515.994,379.319,548.789,800.045,null
Sat Nov 10 12:12:18 PST 2012,34.065838,-118.453179,109.819,-1.0,558.897,106.925,null
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Sat Nov 10 11:35:16 PST 2012,34.065624,-118.453099,9.719,-1.0,563.229,57.829,null
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Sat Nov 10 11:35:56 PST 2012,34.065271,-118.452949,9.719,-1.0,558.897,56.385,null
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Sat Nov 10 11:33:38 PST 2012,34.066653,-118.453468,9.719,-1.0,319.193,59.273,null
Sat Nov 10 11:59:32 PST 2012,34.061283,-118.448129,517.919,379.319,548.789,791.381,null
Sat Nov 10 11:35:14 PST 2012,34.065659,-118.453116,9.719,-1.0,563.229,57.829,null
Sat Nov 10 11:33:24 PST 2012,34.066692,-118.453387,9.719,9.719,440.489,78.045,null
Sat Nov 10 12:12:13 PST 2012,34.065796,-118.453163,221.469,-1.0,582.001,135.805,null
Sat Nov 10 11:43:24 PST 2012,34.065496,-118.45066,-1.0,-1.0,371.177,684.525,null
Sat Nov 10 11:58:21 PST 2012,34.060726,-118.447716,521.769,385.094,550.233,694.633,null
```

Figure 9: *UV and GPS readings joined*

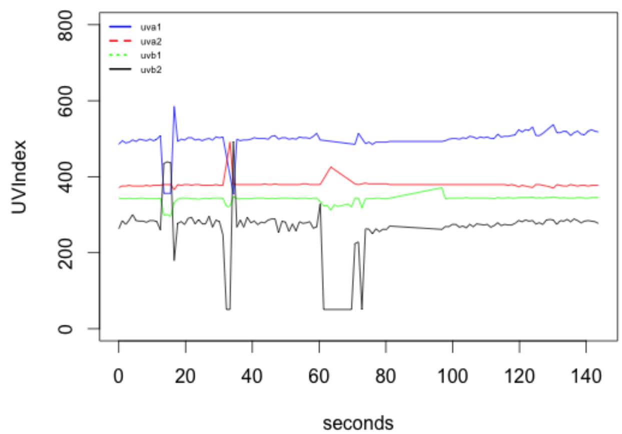

Figure 10: *UV Sensor Data Readings*

UVB each. So the data was analyzed to determine which of the two sensors readings were more reliable. After careful analysis, one of the two sensors was taken into consideration. As seen in the Fig 10, a correlation is obervered between first sensors of UVA and UVB. Hence, reeadings from first sensors for both UVA and UVB are considered and readings from other sensors are discarded. There were also some random erroneous readings reported for the sensors sometimes which were discarded. After perfoming all of the above mentioned steps, the data was clean and ready for analysis.

3.4.2 Determining minimum number of sample points

The main aim of the project is to suggest the best route to the user out of the many routes options he could take. After carefully considering many options online, Open Street Maps [9] and Goolge Maps [7] were the good options to be considered. The choice of selecting Google Maps was the fact that no efforts would have to me made for calculating the actual navigation route since there are many robust API's available which good be directly used out of the box. The only programming effort was required to parse the data and selecting only the information which was relevant for the project.

In order to determine the various alternate route options that can be taken

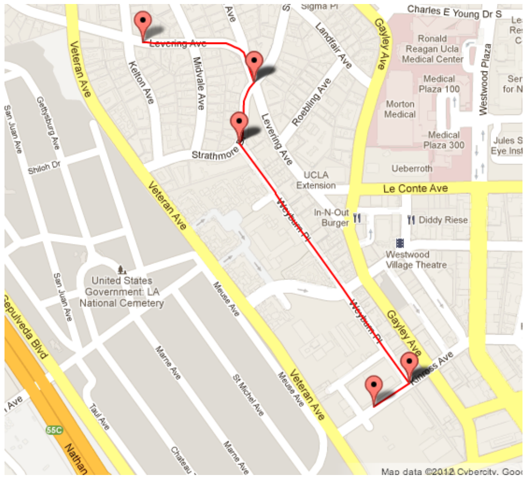

Figure 11: *Steps in a single Leg.*

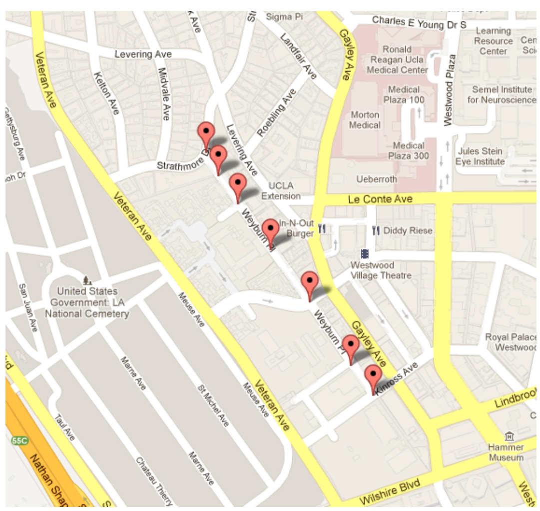

Figure 12: *Segments in a single Step.*

to travel from source to destination, Google Maps [7] data is used. It returns the various routes that can be taken which are called as Legs and the various sections of the roads that changes are called as Steps. In the route selected for the experiment, each of the red lines in Figure **??** indicate each leg and each of the red lines between the markers in Figure 11 indicate each step. Minimum number of points needed to assert the UV level with a certain confidence was to be found. Analysis was initially done by taking one step and finding the number of points required on that step. However after realizing that the step was too big to perform analysis, decision was made to break each step into smaller segments. After analyzing various options an Open Street Map API [10] was used. When passed two end points, the API returns all the nodes in its database which come in between the end points. Thus, a pair of nodes would form a segment. Again, scripts were written to parse the data and extracting the information required for the project. Figure 12 indicates segments within a single step.

Data is analyzed to determine the minimum number of points required to get the accuracy of UVA above 75% and accuracy of UVB above 95%. Bootstrapping method is used to determine the minimum number of points. Bootstraping works as follows:

1. Take the average of all the points on a particular segment which would become our actual average
2. Select one point randomly
3. Calculate the accuracy with respect to the actual averge
4. Select one more point randomly
5. Take the avegare of all the points selected till now
6. Calculate the accuracy with respect to the actual averge
7. Repeat from Step 4 till desired accuract is achieved

Algorithm for Boostraping

Listing 1: R Code for Bootstraping

```
route <- read.csv("route.txt", header=TRUE  , sep=",")
for(noOfSample in 1:10){
  trueMean = mean(route$uvb)
  uvb = route$uvb #getUVB Readings
  uvbReadingsVector <- vector()
  for(i in 1:10){
    uvbSample = sample(uvb,noOfSamples)
    sampleMean = mean(uvbSample)
    accuracy =  abs((trueMean-sampleMean)/ sampleMean
       *100)
  }
}
```

Bootstrapping method is chosen since the distribution is completely random and the readings along the segments are not consistent. Bootstrapping is the best method in these cases. For analysis variety of segments are covered by considering different road segments at different orientations and different length of segments.

Detailed analysis of one of a few segments was performed. The segments are considered as follows.

Segment 1 as seen in Fig. 13.
Start Point: 34.060067, -118.449498
End Point: 34.058945, -118.44864.
Total length of the segment was 480 ft.
Time of Day: Between 9am and 10am

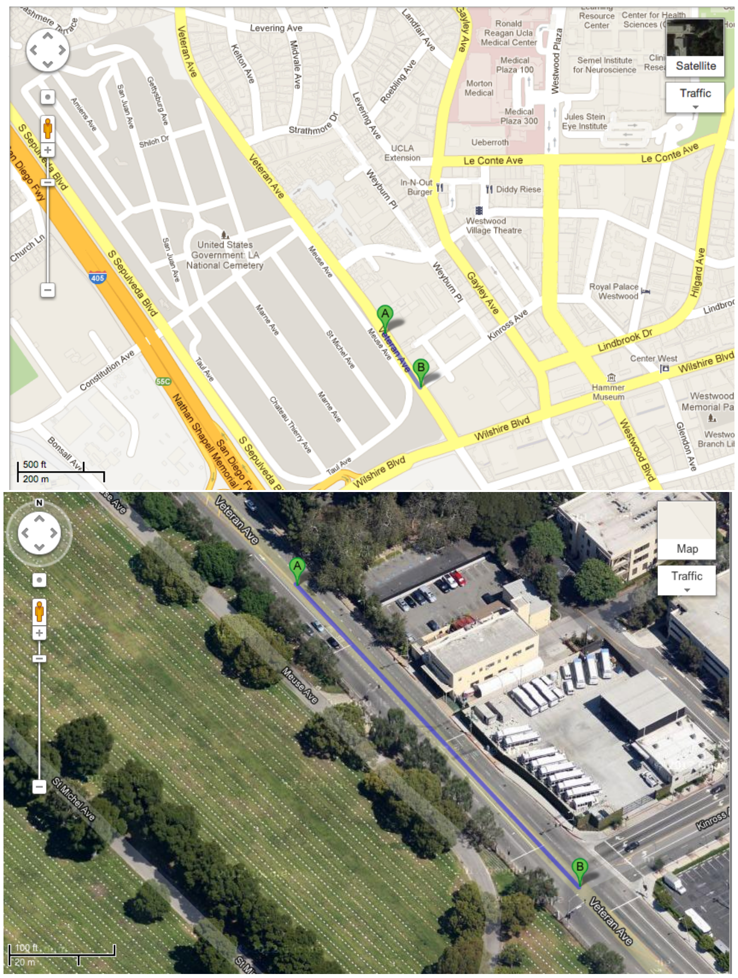

Figure 13: *Sample selected segment map view*

No of Readings	UVA Accuracy	UVB Accuracy
1	72.03039	93.37286
2	72.84915	93.7059
3	73.27921	94.36731
4	78.09173	94.94913
5	76.75012	95.06996
6	77.60953	97.47088
7	78.30137	97.91901

Table 1: *Accuracy table for bootstraping*

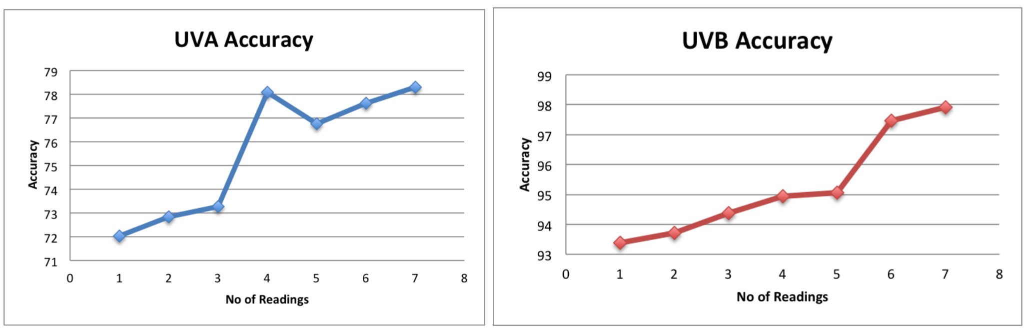

Figure 14: *Accuracy v/s No of Readings for UVB*

As observed from the table that UVA takes 4 samples to reach the accuracy of 75% and UVB take 4 readings to reach the accuracy of 95%.

Segment 2 as seen in Fig. 15.
Start Point: 34.065270,-118.454607
End Point: 34.065948,-118.454169
Total length of the segment was 180 ft.
Time of Day: Between 9am and 10am

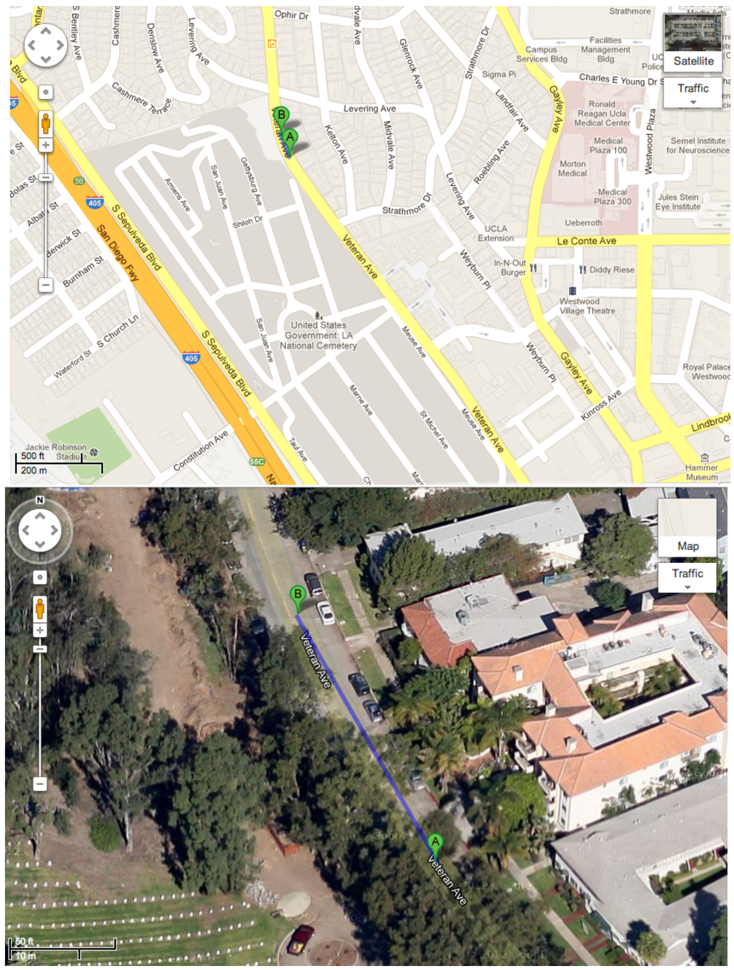

Figure 15: *Sample selected segment map view*

No of Readings	UVA Accuracy	UVB Accuracy
1	62.33563	90.8751
2	68.69139	95.34372
3	71.9053	96.88052
4	83.7723	96.1235
5	75.60744	95.95051
6	78.77724	97.39062
7	78.30137	97.96218

Table 2: *Accuracy table for bootstraping*

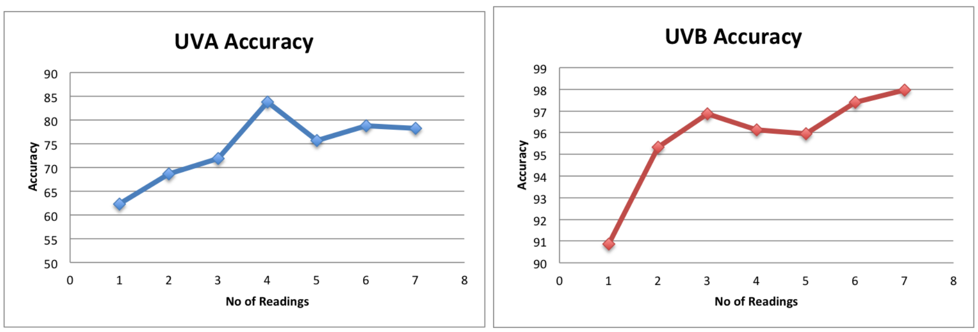

Figure 16: *Accuracy v/s No of Readings for UVB*

As observed from the table that UVA takes 4 samples to reach the accuracy of 75% and UVB take 2 readings to reach the accuracy of 95%.

Segment 3 as seen in Fig. 17.
Start Point: 34.064022,-118.449589
End Point: 34.064489,-118.449965
Total length of the segment was 200 ft.
Time of Day: Between 9am and 10am

Figure 17: *Sample selected segment map view*

No of Readings	UVA Accuracy	UVB Accuracy
No of Readings	UVA Accuracy	UVB Accuracy
1	65.33298	90.0156
2	62.29749	88.62024
3	66.94044	95.30881
4	87.81089	95.66149
5	77.13757	97.265371
6	87.79633	96.34902
7	93.55506	97.49347

Table 3: *Accuracy table for bootstraping*

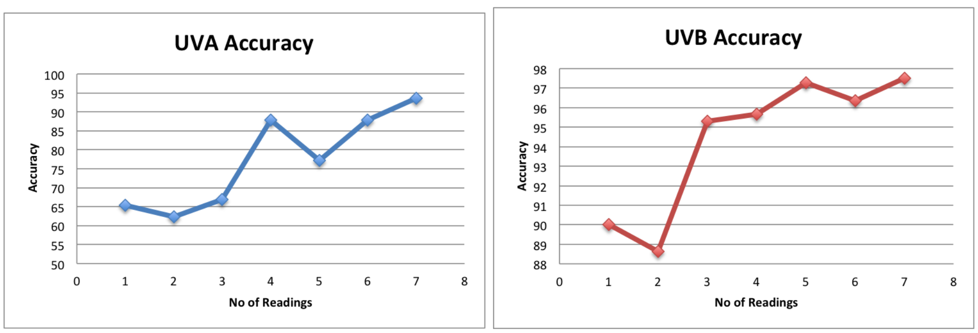

Figure 18: *Accuracy v/s No of Readings for UVB*

As observed from the table that UVA takes 6 samples to reach the accuracy of 75% and UVB take 3 readings to reach the accuracy of 95%.

Segment 4 as seen in Fig. 19.
Start Point: 34.059344,-118.448027
End Point: 34.058979,-118.448648
Total length of the segment was 233 ft.
Time of Day: Between 9am and 10am

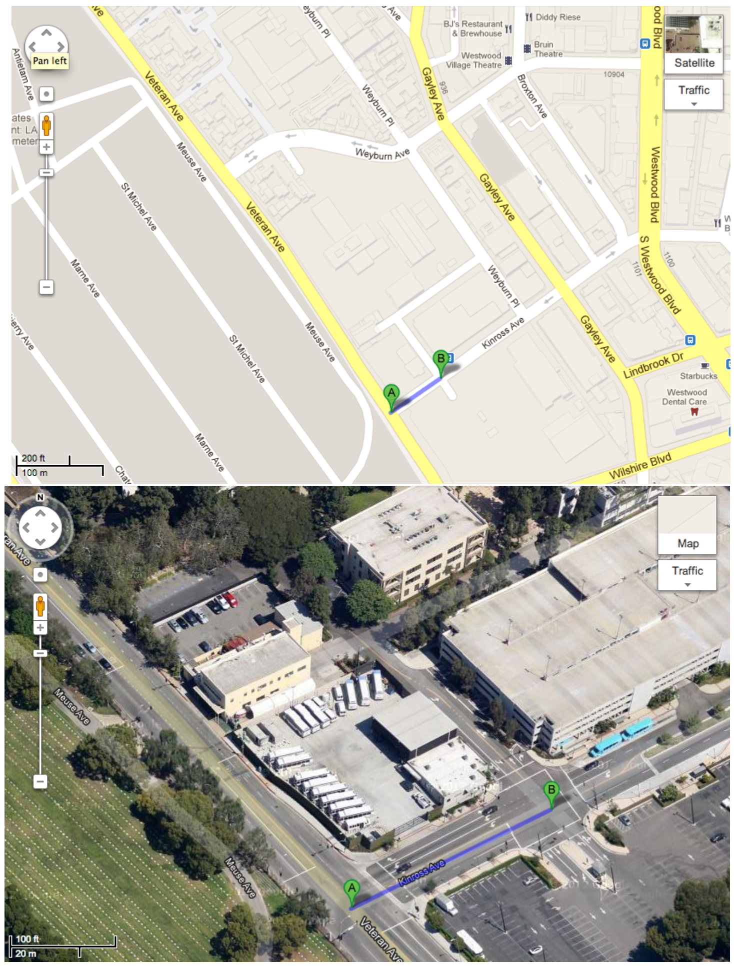

Figure 19: *Sample selected segment map view*

No of Readings	UVA Accuracy	UVB Accuracy
1	65.7383	91.02471
2	71.87201	91.05025
3	75.28261	93.0015
4	75.29943	94.89313
5	82.68207	95.38655
6	84.31634	96.13141
7	83.41866	96.61768

Table 4: *Accuracy table for bootstraping*

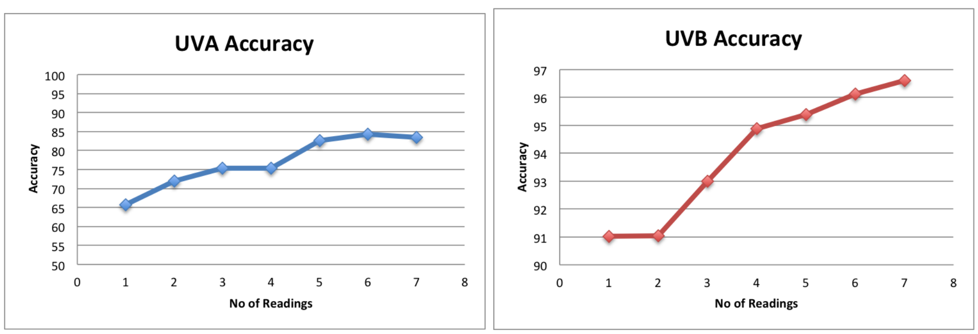

Figure 20: *Accuracy v/s No of Readings for UVB*

As observed from the table that UVA takes 3 samples to reach the accuracy of 75% and UVB take 4 readings to reach the accuracy of 95%.

Segment 5 as seen in Fig. 21.
Start Point: 34.061717,-118.448455
End Point: 34.062535,-118.449184
Total length of the segment was 480 ft.
Time of Day: Between 9am and 10am

Figure 21: *Sample selected segment map view*

No of Readings	UVA Accuracy	UVB Accuracy
1	69.59812	95.60988
2	78.61146	98.00997
3	87.20315	97.4513
4	90.96039	97.66619
5	92.75761	98.88199
6	88.489	98.63385
7	88.63886	98.75971

Table 5: *Accuracy table for bootstraping*

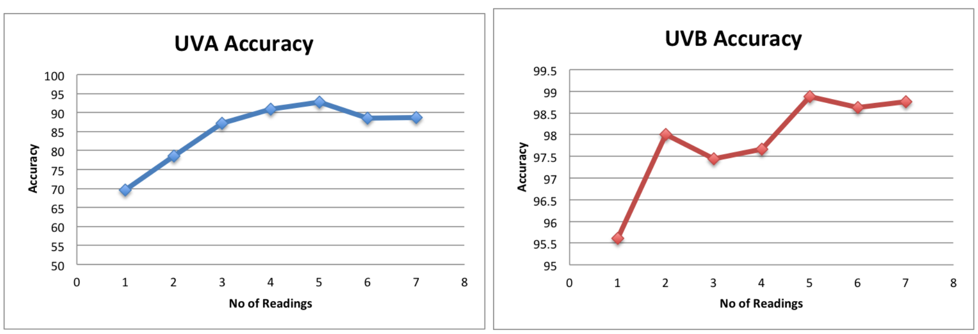

Figure 22: *Accuracy v/s No of Readings for UVB*

As observed from the table that UVA takes 2 samples to reach the accuracy of 75% and UVB take 1 readings to reach the accuracy of 95%.

Segment 6 as seen in Fig. 23.
Start Point: 34.06197,-118.447984
End Point: 34.062575,-118.448217
Total length of the segment was 226 ft.
Time of Day: Between 9am and 10am

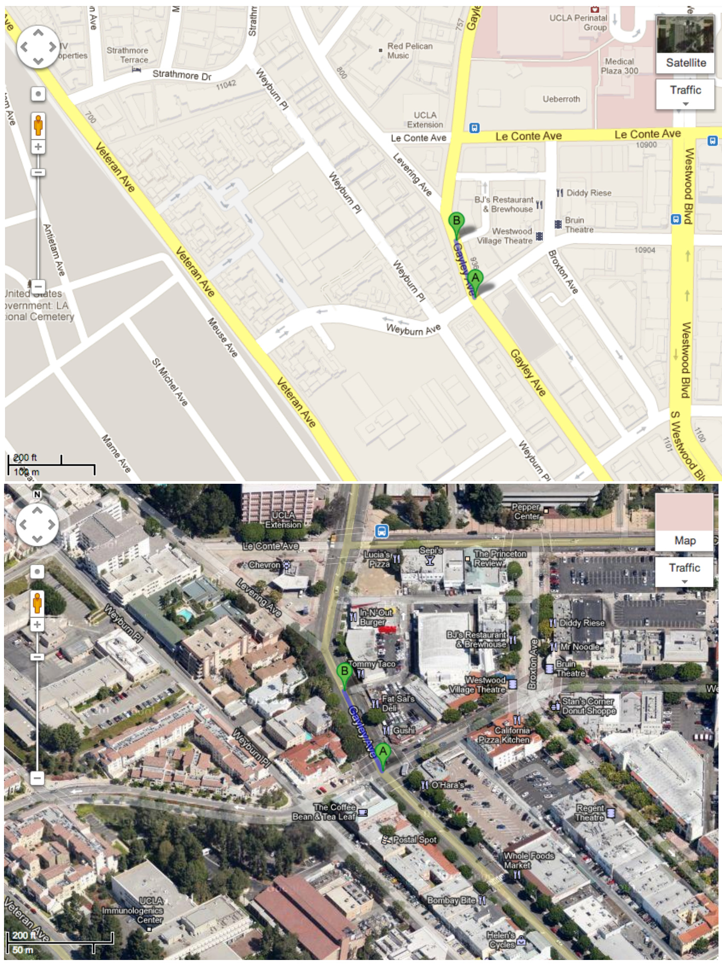

Figure 23: *Sample selected segment map view*

No of Readings	UVA Accuracy	UVB Accuracy
1	71.31901	92.55076
2	81.64635	94.07683
3	87.95883	97.4513
4	91.56362	96.77067
5	96.39601	98.60045
6	95.10367	97.80031
7	98.67633	98.67633

Table 6: *Accuracy table for bootstraping*

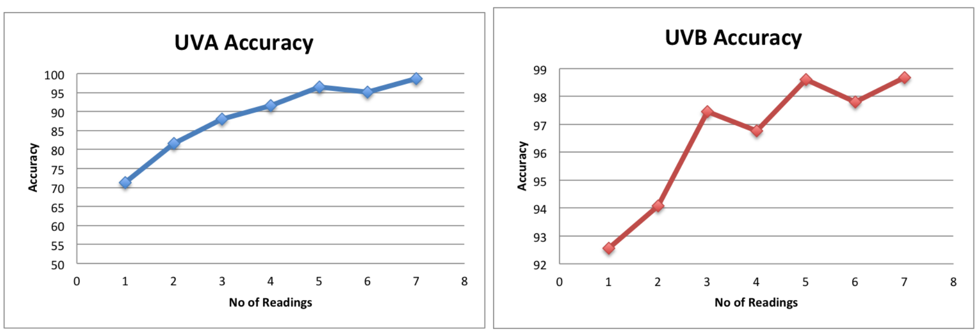

Figure 24: *Accuracy v/s No of Readings for UVB*

As observed from the table that UVA takes 2 samples to reach the accuracy of 75% and UVB take 3 readings to reach the accuracy of 95%.

Segment 7 as seen in Fig. 25.
Start Point: 34.064308,-118.451878
End Point: 34.064259,-118.451419
Total length of the segment was 180 ft.
Time of Day: Between 9am and 10am

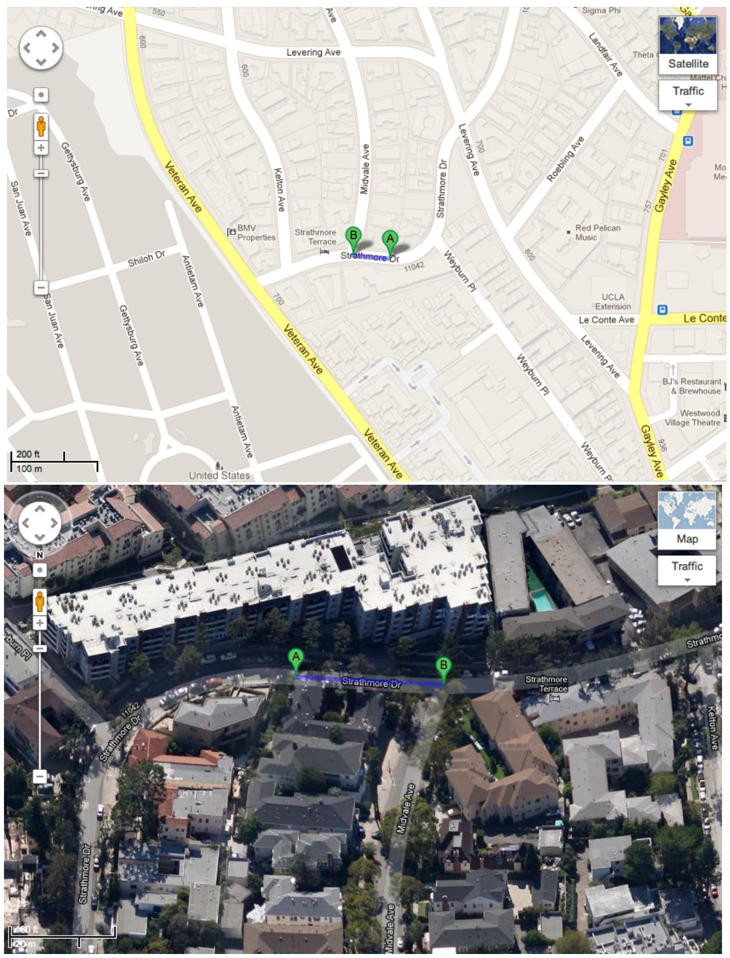

Figure 25: *Sample selected segment map view*

No of Readings	UVA Accuracy	UVB Accuracy
1	65.80804	94.09919
2	72.6942	92.74988
3	78.4838	94.06129
4	85.92444	95.666
5	89.87737	96.45172
6	92.88613	96.82911
7	91.17483	97.67854

Table 7: *Accuracy table for bootstraping*

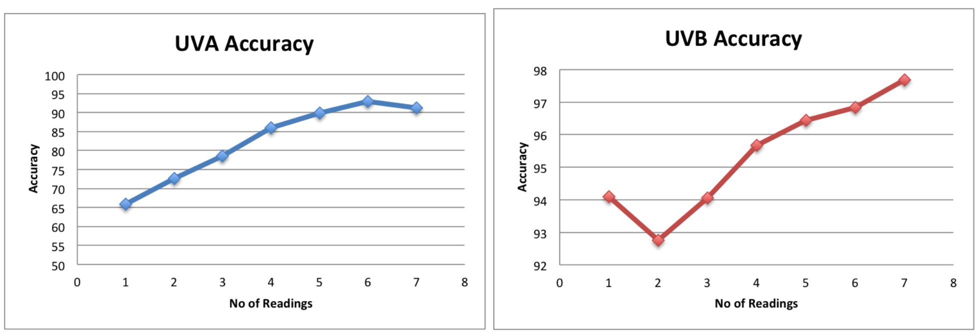

Figure 26: *Accuracy v/s No of Readings for UVB*

As observed from the table that UVA takes 3 samples to reach the accuracy of 75% and UVB take 4 readings to reach the accuracy of 95%.

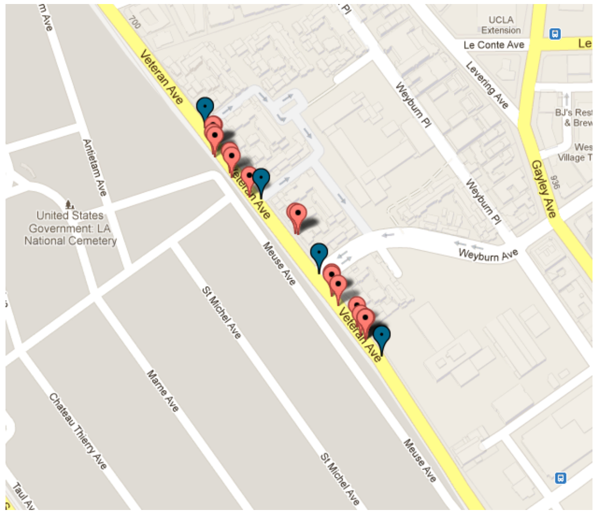

Figure 27: *Segment with less readings than minimum required*

After repeating this experiment for many different segments, observation was made that in the worst case, 6 points on a segment are necessary to get accuracy above 75% for UVA and 4 points on a segment are necessary to get accuracy above 95% for UVB. In average case, 4 points on a segment are necessary to get accuracy above 75% for UVA and 3 points on a segment are necessary to get accuracy above 95% for UVB.

3.4.3 Devising a method to handle segments with less number of samples than minimum required

There may be some segments, which may not have the minimum number of readings that is necessary to assert the UV values like the segment in the Figure 27. The problem of some segments not having desired number of readings is countered in the way mentioned below. In that case, a weighted average of the readings from the neighboring segments is taken. The weight is in terms of how far the segment is from the segment, which is currently under consideration and also, the number of readings that the current segment has. The immediately neighboring segments have a weight of 0.5, the weight is decreased by 0.1 as segments farther from the segment under consideration is taken into account for calculating the UV values. This method was selected since segments, which are near the segment under consideration, have a high correlation of readings with the segment. The window of neighboring segments is expanded till the desired number of readings for the segment is achieved.

For instance, if the segments in Figure 27 is considered. The segements end points are marked by blue colored markers and the red color markers indicate readings at those points. As observed in the figure, the number of readings are less than the minimum number of readings required. So, a weighted average of the neighboring segments is taken. Since both the segments are immediate neighbors, weight would eventually be proportional to the number of readings in each segment as there would be more confidence in considering readings from the segment that has more readings as compared to considering the segments with less number of readings.

3.5 Web Service Developement

Web Service was developed to provide API to the developers to make use of the common platform and develop navigation applications based in UV data. The Web Service developed is similar to the Google Maps Web Service [8] with extra information about the UV levels along the route. A choice was to be made whether to display the output in XML format or JSON. Finally, the output was in JSON format since its easier to read. Its also less decoding effort to programmers as compared to XML output. The inputs to the web service are source latitude, source longitude, destination latitude, destination longitude and UV criteria. UV criteria is whether route with minimum UVA or minimum UVB or an average of UVA and UVB is required. A part of sample output from the webservice is in Fig 28


```
{
 - routes: {
       summary: "Levering Ave and Gayley Ave",
       duration: 771,
       distance: 1139,
     + end_location: {…},
     - uv: {
           uva: 308.41723104774513,
           uvb: 407.407619088424
       },
     - start_location: {
           lng: -118.45299,
           lat: 34.06643
       },
     - steps: [
         - {
               summary: "Head <b>east</b> on <b>Levering Ave</b> toward <b>Midvale Ave</b>",
               duration: 433,
               distance: 654,
             - end_location: {
                   lng: -118.44834,
                   lat: 34.06287
               },
             - uv: {
                   uva: 296.0839627880453,
                   uvb: 439.918251969142
               },
             - start_location: {
                   lng: -118.45299,
                   lat: 34.06643
               }
           },
         + {…},
         + {…}
       ],
       polylines: "er|nEdj~qUBmJJg@Tk@|EwAxAm@hAq@pAiAlE}ErDgA|E_E|BkBl@hAjA`CXj@"
   }
}
```


Figure 28: *Sample Web Service Output*

3.6 Navigation Web Application

A Web Application is built in order to consume the web service built. The purpose of the web application is to serve as a basis for developers to use the system and build applications on top of it. The web application shown in Fig **??** is built using the web service and google maps javascript API to render the maps on the web page. Similarly other desktop and mobile applications can also be built. When entered the source and destination latitude and longitude and selecting the UV criteria, the application will suggest the most optimum route based upon the selected criteria as showin in Fig 30.

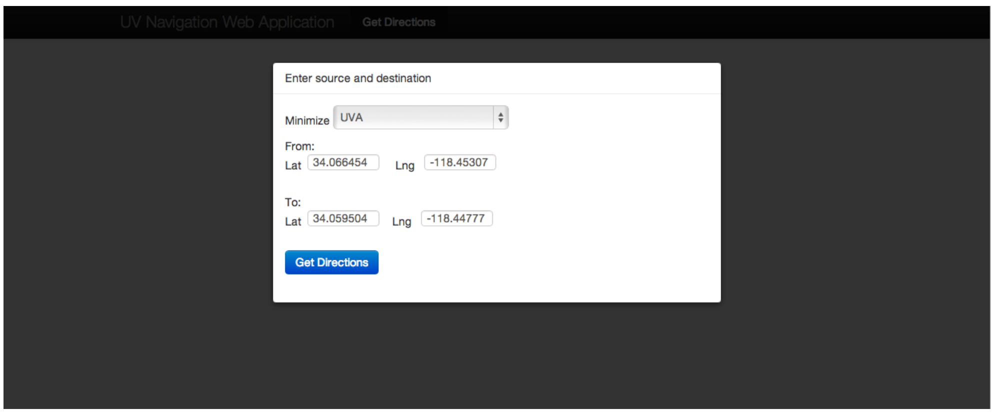

Figure 29: *a. UV Navigation Web Application*

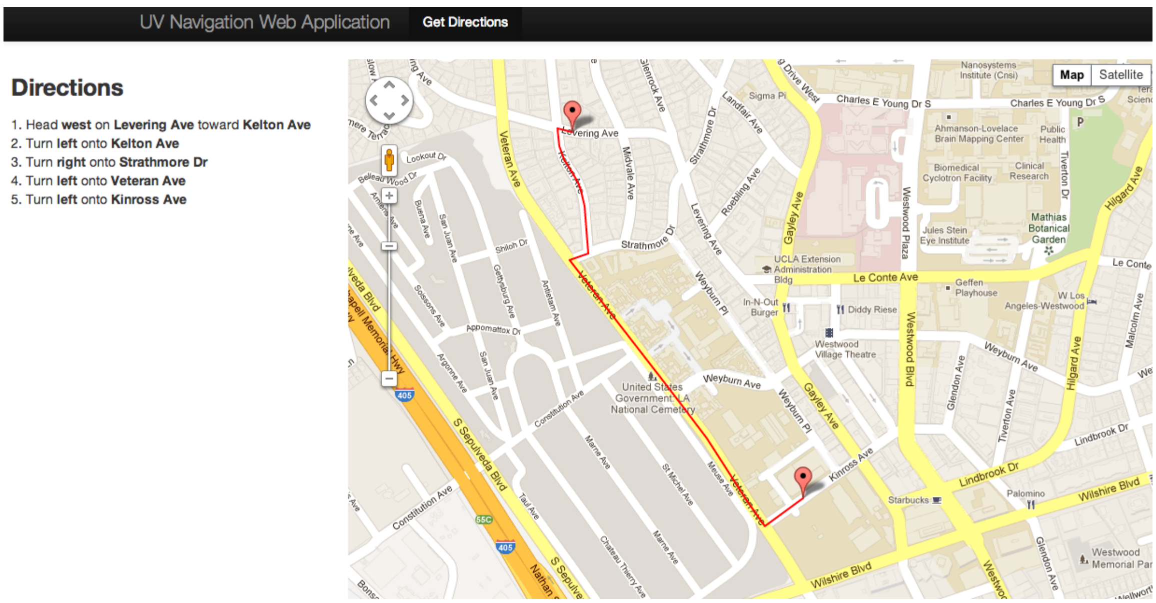

Figure 30: *b. UV Navigation Web Application*

4 Experiment

Taking the results from the data analysis that was done, experiments were performed to verify whether the desired accuracy was achieved. As per the observations from the data analysis,in the worst case, 6 points on a segment are necessary to get accuracy above 75% for UVA and 4 points on a segment are necessary to get accuracy above 95% for UVB. In average case, 4 points on a segment are necessary to get accuracy above 75% for UVA and 3 points on a segment are necessary to get accuracy above 95% for UVB. The best possible approach to test the analysis was to randomly take the number of sample points actually necessary and check whether the desired accuracy is achieved. To remove the randomness from the process, sample number of points were taken around 100 times and their accuracy was calculated. This accuracy was verified with the desired accuracy.

Listing 2: R Code for verifying accuracy

```
route <- read.csv("route.txt", header=TRUE , sep=",")
sampleSet = 4 # for worst case scenario
uvb = route$uvb # get UVB values
uvbAccuracy <- vector()
for(i in 1:100){
  uvbSample = sample(uvb,sampleSet)
  trueMean = mean(route5$uvb)
  sampleMean = mean(uvbSample)
  t = abs(100-abs((trueMean-sampleMean)/ sampleMean
     *100))
  uvbAccuracy[i]=t
  }
```

Again, some segments were selected. Accuracy was determined by considering the worst case as well as average case scenario. The results were as follows for different segments of the road.

Segment 1 as seen in Fig. 13.
Average Case Accuraccy
UVA: 75.93203
UVB: 96.50077
Worst Case Accuracy
UVA: 79.50551

UVB: 96.74856

Segment 2 as seen in Fig. 15.
Average Case Accuraccy
UVA: 74.38072
UVB: 96.12223
Worst Case Accuracy
UVA: 81.07674
UVB: 96.06205

Segment 3 as seen in Fig. 17.
Average Case Accuraccy
UVA: 81.29109
UVB: 95.44681
Worst Case Accuracy
UVA: 87.52028
UVB: 95.89465

Segment 4 as seen in Fig. 19.
Average Case Accuraccy
UVA: 88.40942
UVB: 95.25212
Worst Case Accuracy
UVA: 91.58414
UVB: 95.81699

Segment 5 as seen in Fig. 21.
Average Case Accuraccy
UVA: 83.29114
UVB: 97.71054
Worst Case Accuracy
UVA: 88.49399
UVB: 98.27896

Segment 6 as seen in Fig. 23.
Average Case Accuraccy
UVA: 92.15421
UVB: 96.50476

Worst Case Accuracy
UVA: 95.55486
UVB: 97.02755

Segment 7 as seen in Fig. 25.
Average Case Accuraccy
UVA: 89.63042
UVB: 94.82353
Worst Case Accuracy
UVA: 91.7044
UVB: 96.18621

From the obersvation of all the readings, it could be inferred that if 6 samples to estimate UVA and 4 to estimate UVB are taken, then the accuracy remains above the thresholds that are required.

5 Future Work

The work can be extened to do analysis on different paths. That way, the current number of samples of can be reaffirmed. Since the accuracy of UVA is aimed to be 75%, a more accurate UVA sensor could be used and a higer UVA accuracy could be aimed for. UV sensors could be interfaced directly with the android device which could facilitate more flexibilty to gather data. After that is achieved, more users could be encouraged to gather UV data. In this way, crowd sourcing could be used to populate the database eventually helping uses navigate more routes.

6 Conclusion

It could be concluded that in the worst case, 6 points on a segment are necessary to get accuracy above 75% for UVA and 4 points on a segment are necessary to get accuracy above 95% for UVB. In average case, 4 points on a segment are necessary to get accuracy above 75% for UVA and 3 points on a segment are necessary to get accuracy above 95% for UVB. The number of points on a segment is not dependend on the length of the segment since the length of the segments are generally small. A web service was developed to estimate UV levels on a path and route the user through the path having the minimum UV value.

References

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