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Advanced GIS – Project Report

Sunburn Warning System

Contents

1 Introduction

Sunburn is an inflammation (burn) of the skin that develops in response to exposure to ultraviolet (UV) radiation from the *sun* or from *tanning beds* and *booths* that emit UV radiation.[1] While the radiation from tanning bed can be avoided by simply avoiding going for tanning, exposure to sunlight cannot be totally avoided unless one will not go out door through life time.

Figure 1: A picture of sunburned body[2]

Exposure to sunlight is on daily basis and depends on the duration of time people spend outside, individual skin types and other factors which are identified in this report. Simply spending too much time outdoor without proper protection and engaging in outdoor activities - such as beach relaxation, surfing, city walking, mountain climbing, outdoor water sports, and skiing - expose people to sunburn. Protections, that have been used over time, are wearing of sun glasses to protect the eyes and application of protection cream. But people do not generally prepare every day to apply protection since they do not know the intensity of the radiation.

Therefore, our project is to develop a warning system which will alert subscribers when their skin is going to be in danger with UV radiation from sunlight. Also, we suggest protection methods based on the exposure period. We are to use geospatial technology to create a service that is helpful in reducing the risk of sunburn effect. This involves using geoprocessing techniques to analyse data and event services to notify subscribers.

2 Motivation

The effect of sunburn is primarily on the skin but also on other parts of the body, for example it can cause damage to the eyes. The negative effects of sunburns are cumulative and can cause premature skin aging, skin cancer and eye damage.[3] Everybody is affected at different levels based on the skin type. Dark skins contain melanin which reflects UV radiation from the skin thereby reducing the effect. Skin types are classified into six classes with type 1 being white skin which is highly endangered and type 6 being dark skin that is less affected by UV radiation.[4] Although many people use sunscreens to protect their skin from UV radiation, it is not clear if UV radiation can cause other damaging effects, such as chronic diseases.[5]

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1 http://www.medterms.com/script/main/art.asp?articlekey=53395
2 http://www.nosunblock.com/photos/161-five-finger-sunburn
3 http://www.health.gov.au/internet/skincancer/publishing.nsf/Content/fact-uv
4 http://www.himaya.com/skin/skintypes.html
5 http://rpd.oxfordjournals.org/content/91/1-3/19.full.pdf

Since those effects are dangerous and not only short term, there is need to find a way to protect people from UV radiation by warning procedures that provide alert and also warning to the general public. Therefore, in order to control or caution people's exposure to UV radiation from sunlight, a Sunburn Warning System is necessary.

3 Usage Scenario

Users will be able to interact with the system through their smartphones. They will be able to create personalised settings which will be the input for the processing and conditions for alert. Based on those settings, the alert will be sent through email or SMS to the user in the morning or the evening. This will help users to protect themselves before going out in the morning.

Users will have to set their locations in two different categories; the home zone which is for daily activities and the vacation mode which deals with travels away from home country for vacation purposes. Note that these two categories may not capture in totality the time users will spend outdoor, it requires user to explicitly create the periods in which they will be outdoor. The home zone takes care of the everyday period to be spent outdoor, for example on the way to school or to the work. It allows multiple specifications of times to comprise the difference between working days and weekends. The vacation mode allows settings for date and time at a particular location that the user will be visiting for vacation period. How our application could look like, you can see here:

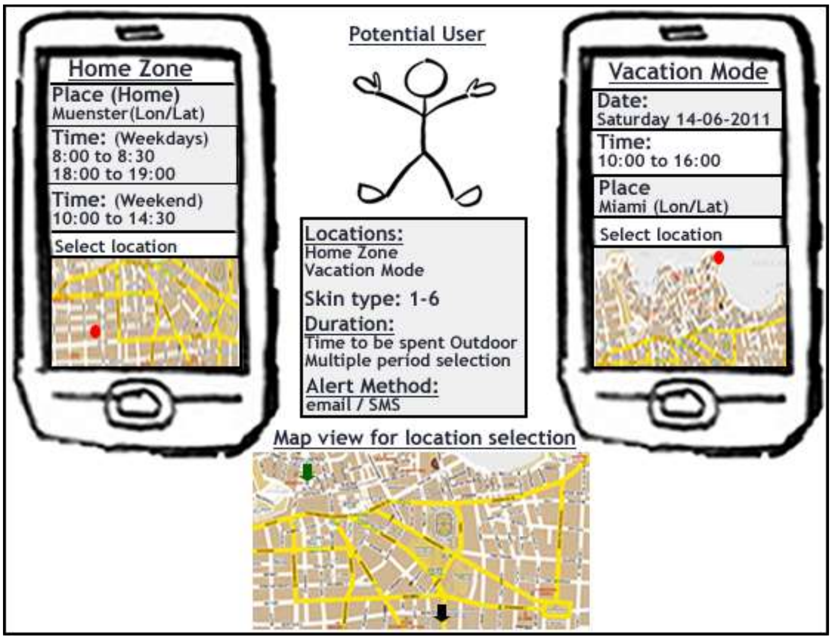

Figure 2: Sample client application for our warning system

To help users in selecting their location, a map view is suggested where users can click on their location or type in a place name. Another possibility for location settings is through the use of the internal GPS of the smartphone to get the coordinates of the home zone or the user's current position. The coordinates can then be used as input criteria for geoprocessing. Users will also be able to select from predefined skin types which they belong to and set the means through which they want to receive the alert: email, SMS or both. The personalized setting will form the profile of each user and users can change this profile at any time.

4 System Architecture

4.1 Component Description

1. Client Application: This application enables users to create a personalised profile which is sent to the server.
2. Web Notification Service (WNS): This service sends notifications or alerts, created from the SES, to each user.
3. User Registry: This web repository receives and stores all user profiles. Sensor Event Service criteria are created from this data. The user registry serves as input for processing the UV index for a specified location.
4. In situ Database: This data repository for other information is needed to refine the UV index. It will contain land and snow cover maps as well as a digital elevation model.
5. UV Data API: This is the API that serves UV index data which will provide the input for the processing service.
6. Sky Coverage API: This API includes information about sky coverage conditions, sunrise and sunset times for a further adjustment of the UV index.
7. Sensor Event Service (SES): Alerts are created in this component, based on the processed UV index and personalised parameters, and sent through the WNS to customers.
8. Web Geoprocessing Service (WPS): This is where most of the processing and refining of the UV index is done, based on parameters provided by other modules.

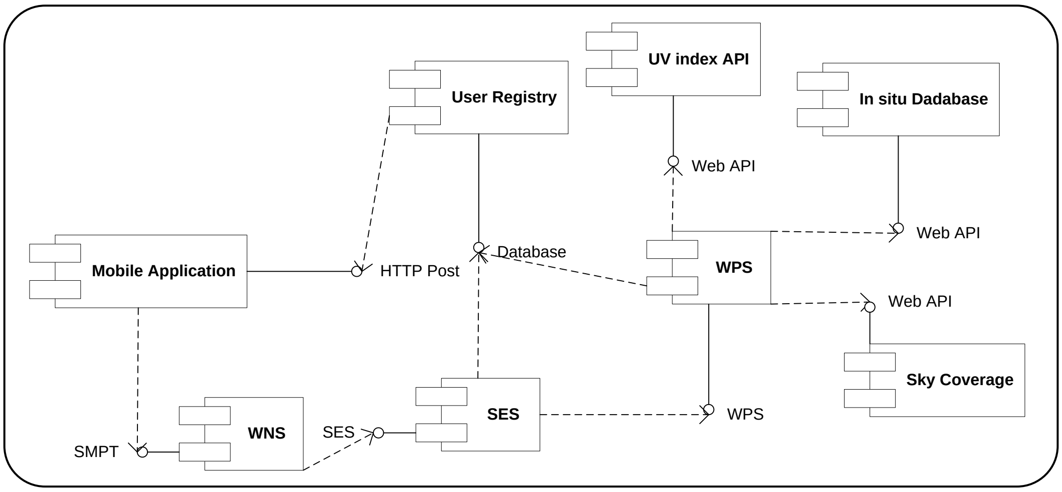

Figure 3: Component diagram of the planned architecture

4.2 Process Description

The WPS receives in situ data from the database and daily UV indices from an online service. Both are processed for a specific location, which is provided by the user registry. The output will be the modified UV index for the user's current position. The processed UV index is next sent to the Sensor Event Service for filtering.

The SES takes personalised settings from the user registry to create filter parameters. The duration, which a person is going to spend outside, will be used to filter the UV index and to check the exposure threat for individual subscriber. The skin type will then be taken to create the tolerance level of the user to the UV radiation. Lastly, an exposure report will be created which is sent to the user of the system, based on his or her specifications.

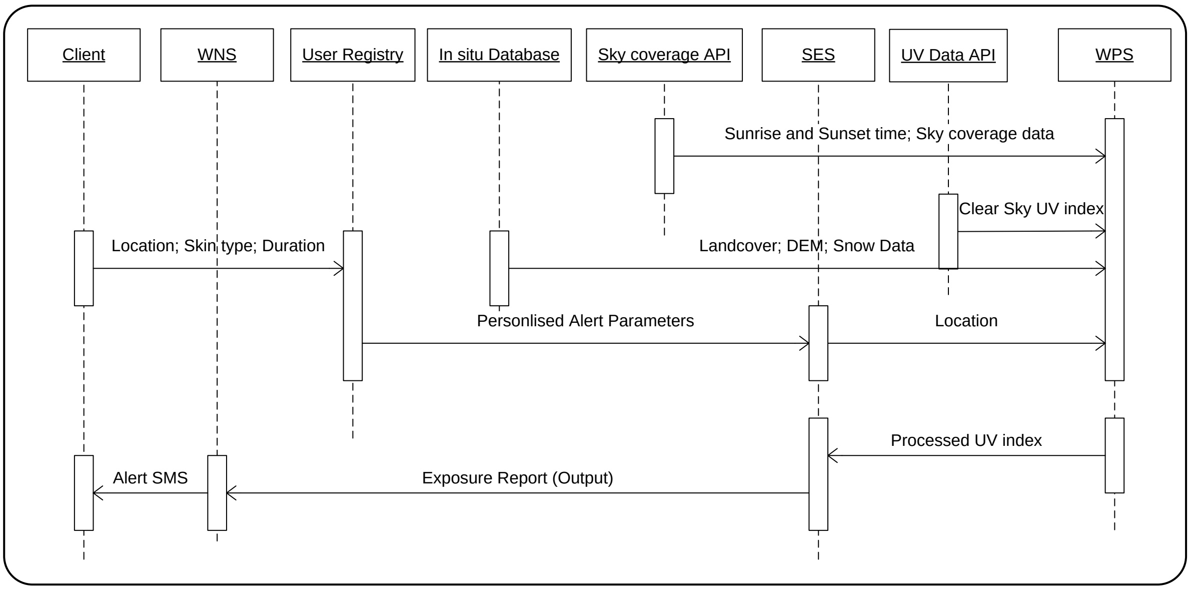

Figure 4: Sequence diagram of the intended process flow

5 Processing Steps

In the following, we concentrate in detail on the processing needed to be done by the SES and WPS. First in this chain, the UV index has to be retrieved for the user's location. Next, modifications like height, sky coverage and ground reflection are taken into account. The diurnal change of the UV index has also to be included. After that, the estimated UV-intensity can be compared with maximum exposure intensity for the user, so finally we are able to recommend a sunburn lotion and send an alert if necessary. In all steps, we mention different data sources and explain calculations based on this data.

5.1 Input parameters

To get the processing started, the SES requires the following inputs by the user:

- Location: Latitude and longitude of the user's position (could be at home or at vacation)
- Skin type: Selection of predefined skin types 1-6
- Exposure Duration: Schedule on daily basis for the period to be spent outside

Only when all three parameters are provided, the system will be able to give a realistic approximation of the danger of getting a sunburn.

5.2 UV index retrieval

The UV index is a measure for the intensity of UV radiation for the public.[6] Depending on your skin type, you can deduce from the UV index how much time you can stay in the sun without getting sunburned. The UV index is calculated on the base of the amount of ozone in the atmosphere and the

[6] http://tinyurl.com/UV index-defined

solar zenith angle. The less atmospheric ozone and the smaller the angle between the zenith and the direction to the sun, the higher is the UV index.[7] The solar zenith angle changes with latitude (equator – poles), season (summer – winter) and time of the day (day - night).

TEMIS, a Tropospheric Emission Monitoring Internet Service by ESA, offers daily maps and forecasts for the UV index at a specified location.[8] This allows us to retrieve the UV index for the user's current position at the forthcoming day. As an example, we queried the UV index in Münster by entering its latitude and longitude.[9] The resulting table is shown in figure 5. Later on, these values can be parsed from the source code of website (see Appendix 1).

Date	*UV index*
7 Feb 2011	0.9
8 Feb 2011	0.8
9 Feb 2011	1.0
10 Feb 2011	1.0
11 Feb 2011	0.9

Figure 5: Exemplary "clear-sky" UV index values from TEMIS website[7]

These values are averaged at a spatial resolution of 0.5 x 0.5 degrees (around 50 x 50 km). There is a 2% uncertainty for values above 1.0, and a less than 0.1 point difference for values below 1.0. TEMIS calculates the UV index for local solar noon (when the sun appears the highest in the sky), clear-sky conditions and in the absence of snow.[10]

5.3 UV index adjustments

To get more realistic values, we examine in the following three subchapters possibilities to modify the UV index.

5.3.1 Height

The first factor which influences the UV index is height. One might have the common saying in mind that the sun is more intense in the mountains. The scientific background behind this is that the atmosphere gets thinner with higher altitudes, and absorbs less UV, so more UV radiation can pass. ESA[11] predicts a 5% increase of the UV index by one kilometre height. Since the original values for the UV index are given at sea level[12], we need additional information about the approximate height of the user. This data can be retrieved for example by a global digital elevation model, like GTOPO30[13].

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[7] http://www.UV index.ch/images/Leitfaden_COST-713.pdf (p.6)
[8] http://www.temis.nl/uvradiation/UVindex.html
[9] http://www.temis.nl/uvradiation/nrt/uvindex.php?lon=7.63&lat=51.96
[10] http://www.temis.nl/uvradiation/nrt/uvresol.html
[11] http://www.esa.int/export/esaCP/ASE2UZ9KOYC_Protecting_0.html
[12] http://dermatology.cdlib.org/DOJvol6num1/original/sunscreens/kinney.html
[13] http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30_info

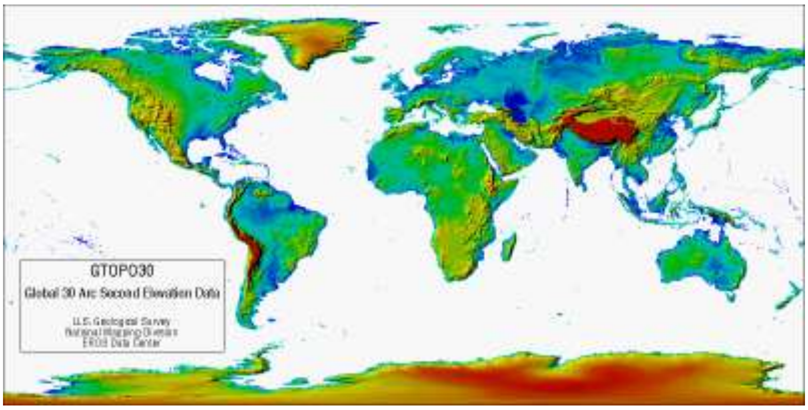

Figure 6: Map of the global elevation model GTOPO30[14]

As we have the user's location as an input parameter, we can find the corresponding height value on the DEM. Since we do not know how the user moves in space during a day, which could go along with a change in altitude (e.g. when he is skiing in the mountains), we think the spatial resolution - here one kilometre - is ok for our purposes. One could even think to take a coarser resolution by averaging height values in a certain radius. As an alternative to a DEM, the height value of a GPS device could be used.

5.3.2 Sky coverage

As the term clear-sky UV index implies, current sky coverage conditions are not included in its calculation. Therefore, weather phenomena - like clouds or fog - need to be considered, which would lead to a reduction of the UV index. Nevertheless, even at overcast conditions, there is a risk of getting a sunburn. The U.S. Environmental Protection Agency suggests the following adjustments of the UV index concerning sky coverage: "Clear skies allow virtually 100% of UV to pass through, scattered clouds transmit 89%, broken clouds transmit 73%, and overcast skies transmit 31%."[15]

Next, we have to find out how the weather will be like at a given location during a day. Yahoo[16] and Google[17] offer web services for this purpose. Here, we use Yahoo's RSS feed exemplarily. For this, we first need to translate the latitude and longitude of the user's position into Yahoo's "Where on Earth Identifier" (WOEID). This can simply be done by using Geomojo's reverse geocoder.[18] Provided with the WOEID, we can now request Yahoo's weather API what we did here for Münster.[19] The result is an RSS feed which contains current as well as forecasted conditions (see Appendix 2). Each of these weather conditions can be identified by a code and description.[4] Based on the percentages mentioned above, we assigned each condition an individual factor (see Appendix 3), which can be yielded into our calculations.

5.3.3 Ground Reflection

Another important factor, which affects the UV index, is the reflection of UV rays by the surface. Each material on the ground reflects UV light differently. Kinney et al. propose the following percentages for a further adjustment the UV index:

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[14] http://www.src.com/datasets/Images/image_gtopo30_global_map.gif
[15] http://www.epa.gov/sunwise/uvicalc.html
[16] http://developer.yahoo.com/weather/
[17] e.g. http://www.google.com/ig/api?weather=Muenster
[18] http://geomojo.org/?p=38
[19] e.g. http://weather.yahooapis.com/forecastrss?w=24515397&u=c

Surface	% Reflection (additional energy)
Water	5% to 7%
Grass	2.5% to 3%
Sand	20% to 30%
Snow and Ice	80% to 90%

Figure 7: Ground reflection factors for UV radiation[10]

In the table, you see clearly that snowy and icy surfaces increase the UV index the most. That is why we need to investigate whether the user is in such an area or not. For the northern hemisphere, ESA delivers daily and freely-available snow level data.[20] With the help of this data, we can retrieve a fraction of the snow cover for the user's position at a grid resolution of 0.01 × 0.01 degrees.[21] This fraction, we can multiply with the percentage for snow and ice from the table above.

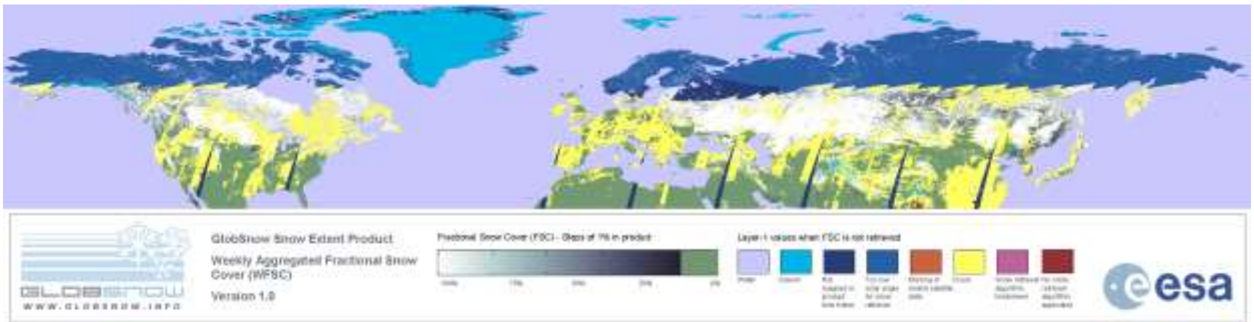

Figure 8: Example of ESA's weekly aggregated fractional snow cover[22]

For ground, which is not or just partially covered with snow, we have to consider a land cover map. Once more, ESA provides such a map which is freely-accessible to the public.[23] The map has a spatial resolution of 300m and covers the whole earth. The map can either be downloaded from ESA's official website[24] or alternatively here[25]. Similarly to the weather data, we next gave each land category a factor based on the table above (see Appendix 4). Together with the snow fraction, we can now reasonably estimate how the surface around the user's location influences the UV index.

5.4 Diurnal change of the UV index

Due to the rotation of the earth around its axis, the solar zenith angle changes over day. This in turn has an effect on the UV index. At solar noon the UV index has its largest value, whereas at night the UV index can be assumed to be zero. Measurements[26] and official illustrations[27] let assume that the UV index can be described as a Gaussian function[28] or as a sine function[29]. During our research, we did not find any

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[20] http://www.globsnow.info/index.php?page=Data
[21] http://www.globsnow.info/se/GlobSnow_SE_product_readme_v1.0.e_draft.pdf
[22] http://www.globsnow.info/se/nrt/2011/WFSC_ql/
[23] http://www.esa.int/esaEO/SEMXB7TTGOF_index_0.html
[24] http://ionia1.esrin.esa.int/
[25] http://geoserver.isciences.com:8080/geonetwork/srv/en/metadata.show?id=228
[26] http://tinyurl.com/diurnal-UV index-measurements
[27] http://www.bom.gov.au/nsw/uv/sydney.shtml
[28] http://en.wikipedia.org/wiki/Gaussian_function
[29] http://en.wikipedia.org/wiki/Sine

scientific articles discussing that topic. So, we chose here exemplary the Gaussian function which is defined by this equation:

$$f(x) = a * e^{-\frac{(x-b)^2}{2c^2}}$$

Parameter 'a' adjusts the height of the curve. In our case, it will be the beforehand modified UV index value at solar noon, explained in chapter 5.3. Parameter 'b' in the Gaussian function influences the centre of the curve. We set b as the time of solar noon, which we approximate by taking the mean value of the sunshine duration: *time of sunrise + (time of sunset – time of sunrise) / 2*. Lastly, parameter 'c' characterizes the width of the curve. Analogue to the normal distribution, we can follow the 3σ rule[30] and define c as *((time of sunset – time of sunrise) / 2) / 3*. The required times for sunrise and sunset are provided by one of Geonames' web services[31]. The result of an exemplary query[32] for Münster's WGS 84 coordinates can be found in Appendix 5.

For a better illustration of the calculation, we would like to introduce the following example:
The sun rises at 8:00 in the morning and sets at 18:00 in the evening. That makes a sunshine duration of 10h, so solar noon (= b) would be at 13:00. 'c' is sunshine duration divided by 6, which results in 1.67. Parameter 'a' is the UV index at solar noon, let's say 2. Now, we insert the three parameters into the Gaussian function and display it in Wolfram Alpha[33] with the following command:

*plot 2*e^(-(x - 13)^2/(2*1.67^2)) from x = 0 to 24*

This results in a curve with the desired properties:

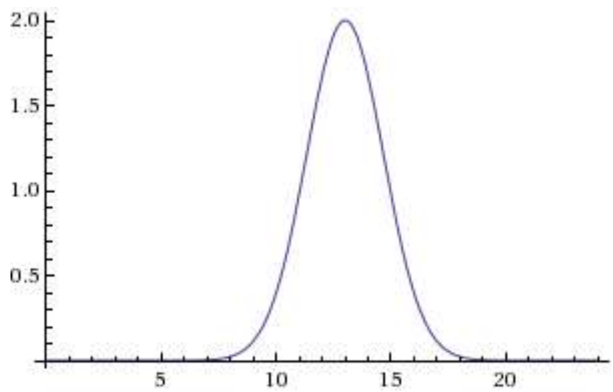

Figure 9: Exemplary diurnal change of the UV index

Next, we need to know when user will be exposed to the sun. This information we find in the user's customised profile. To continue with our example, we assume the user is on vacation and will be outside from 10:00 to 16:00. We use the time interval to calculate the area below the graph. This can be achieved by integrating the Gaussian function, which can also be done in WolframAlpha[25]:

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[30] Sachs &Hedderich (2006): Angewandte Statistik (12. Auflage). p. 197
[31] http://www.geonames.org/export/web-services.html#Timezone
[32] http://api.geonames.org/timezone?lat=51.96&lng=7.63&username=demo
[33] http://www.wolframalpha.com/

*integrate 2*e^(-(x - 13)^2/(2*1.67^2)) from 10 to 16*

The result of this query is circa 7.7657. The unit of the result would be something like UV index hours, meaning it would be the same as staying out 7.7657 hours at a *constant* UV index of 1. To convert it into minutes, we have to multiply the result by 60, what makes about 466 UV index minutes.

After that, skin types come into play. As discussed earlier, there are distinguished six different skin types in literature. For each of them, you can calculate how much time you can spend in the sun, without being endangered to get sunburn. On a sun protection website[34], we found the following values:

Figure 10: Maximum exposure times for different skin types

Let's imagine our user has very light skin (= skin type 1). That implies, he could stay outside a maximum of 67 minutes at UV index 1. With the help of WolframAlpha[25], this can also be shown as a function:

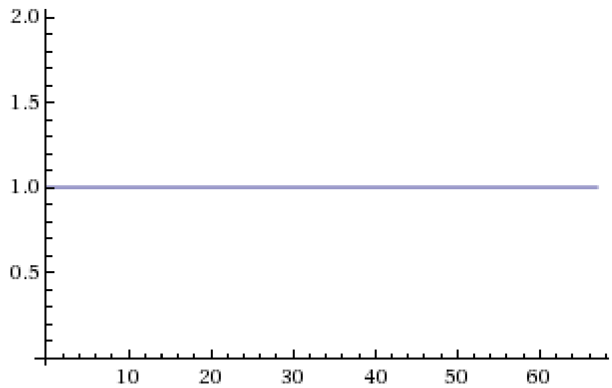

Figure 11: Exemplary exposure at a constant UV index value

Because it is a rectangle, the area calculation is pretty easy, namely 1 * 67 = 67 UV index minutes. You should see by this little excursus, that the maximum exposure times (given in figure 10) can be directly converted into UV index minutes.

Finally, we can make a comparison between estimated and maximum exposure. In our example, the user should definitely be warned, because the estimated exposure (= 466 UVI min) exceeds the maximum exposure (= 67 UVI min) by the factor around 7. This underlies the assumption that the absorption of UV radiation by human skin is cumulative.

[34] http://www.himaya.com/solar/avoidsunburn.html

5.5 Output

We can distinguish two possible outputs of our system:

a\ When the estimated exposure is smaller than the maximum exposure, a notification has to be sent to the user that he is not endangered to get a sunburn.

b\ When the estimated exposure is higher or equal than the maximum exposure, an alert is triggered which shall warn the user about the danger of getting a sunburn on this day.

Additionally in the second case, it will be calculated how many times the maximum exposure is exceeded by the estimated exposure. Based on this factor, a sunburn lotion can be recommended. The factor of a sunscreen indicates how many times longer you can stay in the sun, without getting burnt. The condition for this is that the lotion has to be applied correctly. When the factor is bigger than 30, it would be not sensible anymore to use a sunburn lotion.[35] Under this circumstance, it should be recommended either to wear convenient clothing or even better to avoid the sun. Furthermore, a hint should be given to protect your eyes by wearing sunglasses.

6 Implementation

The processing chain, mentioned in the previous chapter, could be set up on 52˚North's SES[36] and WPS[37]. 52˚North WPS is an open source implementation based on Java programming language. It has a robust library, several extensions (e.g. GRASS) and supports OGC WPS specifications. It also supports multiple data formats which are involved in our process flow, and it will be easy to integrate with the SES service. Results from the processing can be stored as simple web accessible resources with an URL, which is also useful in combination with an SES. The SES follows the OASIS WS-N standard, which is helpful for notifying the subscribed user. The in situ database needs to handle spatial data, so PostGIS would be a good candidate for this, which is also under open source license. To round it up, the operating system for the mobile application could be Google's Android. Reasons for this decision are stated in the following chapter.

7 Existing Applications

Since it was likely, that we were not the first ones having the idea of a sunburn warning system, we had a look around in the mobile sector and in the web, searching for similar applications:

In the internet, we found an UV information service for Europe, supported by ESA, which combines two different services called *UV-Check* and *MEDSUN*.[38] Unfortunately, it is not working at the moment. But according to its description, similar considerations are made concerning input parameters and the influencing factors of the UV index. Besides that, several weather stations deliver forecasted UV index values, e.g. the German Weather Service (DWD).[4]

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[35] http://www.esa.int/export/esaCP/ASE2UZ9KOYC_Protecting_0.html
[36] http://52north.org/communities/sensorweb/ses/0.0.1/index.html
[37] http://52north.org/maven/project-sites/wps/52n-wps-webapp/
[38] http://www.gse-promote.org/

In Apple's Appstore, we discovered two applications matching our topic. The first one, called *MySunCheck*[39], is kept quite simple. Here, location, skin type, exposure duration, and sky coverage have to be selected manually by the user. As a result, a sunburn protection factor is recommended. The second one, called *Sun Alert*[40], is a bit more sophisticated. In addition to the first app, a more detailed time profile, the current environment, and the already applied sunburn lotion can be chosen. Compared to our system, both applications do not include the automatic modification of the UV index.

In Android's Market, we could not find any corresponding apps. That is a good opportunity for developing our sunburn warning system here. Also, the fees for uploading apps to the market are lower than in other operating systems.

8 Summary

In this report, we have outlined the negative effects of UV radiation to human health and what a sunburn warning system could do in order to inform the public in advance. We sketched a sample application how the user could interact with such a system, which inputs he has to provide and which outputs he can expect. Next, we described the general architecture of our sunburn warning system and how the data has to be processed in detail. Lastly, we mentioned software which could be used to implement our system and we had a look on already existing applications to that topic.

[39] http://itunes.apple.com/de/app/mysuncheck/id364601341?mt=8
[40] http://itunes.apple.com/de/app/sun-alert/id324267089?mt=8

APPENDIX

A1 Source code excerpt of TEMIS “clear-sky” UV index website:

```
<tr>
    <td align=left ><i> <br>  Date</i></td>
    <td align=right><i>UV <br>  index</i></td>
    <td align=right><i>ozone <br>column</i></td>
</tr>
<tr>
    <td align=right nowrap>  7 Feb 2011</td>
    <td align=right nowrap>0.9</td>
    <td align=right nowrap>   327.7 DU </td>
</tr>
```

A2 Example of Yahoo’s RSS weather feed:

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>
<rss version="2.0" xmlns:yweather="http://xml.weather.yahoo.com/ns/rss/1.0"
xmlns:geo="http://www.w3.org/2003/01/geo/wgs84_pos#">
<channel>
<title>Yahoo! Weather - Muenster, DE</title>
<link>http://us.rd.yahoo.com/dailynews/rss/weather/Muenster__DE/*http://weather.yahoo.com/forecast/G
MXX0088_c.html</link>
<description>Yahoo! Weather for Muenster, DE</description>
<language>en-us</language>
<lastBuildDate>Mon, 07 Feb 2011 7:19 pm CET</lastBuildDate>
<ttl>60</ttl>
<yweather:location city="Muenster" region="NW"   country="Germany"/>
<yweather:units temperature="C" distance="km" pressure="mb" speed="km/h"/>
<yweather:wind chill="12"   direction="230"   speed="27.36" />
<yweather:atmosphere humidity="51"  visibility="9.99"  pressure="982.05"  rising="0" />
<yweather:astronomy sunrise="8:00 am"   sunset="5:26 pm"/>
<image>
<title>Yahoo! Weather</title>
<width>142</width>
<height>18</height>
<link>http://weather.yahoo.com</link>
<url>http://l.yimg.com/a/i/brand/purplelogo//uh/us/news-wea.gif</url>
</image>
<item>
<title>Conditions for Muenster, DE at 7:19 pm CET</title>
<geo:lat>51.96</geo:lat>
<geo:long>7.63</geo:long>
<link>http://us.rd.yahoo.com/dailynews/rss/weather/Muenster__DE/*http://weather.yahoo.com/forecast/G
MXX0088_c.html</link>
<pubDate>Mon, 07 Feb 2011 7:19 pm CET</pubDate>
<yweather:condition  text="Mostly Cloudy"  code="27"  temp="12"  date="Mon, 07 Feb 2011 7:19 pm
CET" />
<description><![CDATA[
<imgsrc="http://l.yimg.com/a/i/us/we/52/27.gif"/><br />
<b>Current Conditions:</b><br />
Mostly Cloudy, 12 C<BR />
<BR /><b>Forecast:</b><BR />
Mon - Cloudy. High: 8 Low: 5<br />
Tue - Mostly Sunny. High: 7 Low: -2<br />
<br />
<a
href="http://us.rd.yahoo.com/dailynews/rss/weather/Muenster__DE/*http://weather.yahoo.com/forecast/G
MXX0088_c.html">Full Forecast at Yahoo! Weather</a><BR/><BR/>
(provided by <a href="http://www.weather.com" >The Weather Channel</a>)<br/>
]]></description>
```

<yweather:forecast day="Mon" date="7 Feb 2011" low="5" high="8" text="Cloudy" code="26" />
<yweather:forecast day="Tue" date="8 Feb 2011" low="-2" high="7" text="Mostly Sunny" code="34" />
<guidisPermaLink="false">GMXX0088_2011_02_07_19_19_CET</guid>
</item>
</channel>
</rss>
<!-- api1.weather.ch1.yahoo.com compressed/chunked Mon Feb 7 11:07:30 PST 2011 -->

A3 Yahoo's weather codes and descriptions complemented with our UV index factors:

Code	Description	Factor
0	tornado	0.3
1	tropical storm	0.3
2	hurricane	0.3
3	severe thunderstorms	0.3
4	thunderstorms	0.3
5	mixed rain and snow	0.3
6	mixed rain and sleet	0.3
7	mixed snow and sleet	0.3
8	freezing drizzle	0.3
9	drizzle	0.3
10	freezing rain	0.3
11	showers	0.3
12	showers	0.3
13	snow flurries	0.3
14	light snow showers	0.3
15	blowing snow	0.3
16	snow	0.3
17	hail	0.3
18	sleet	0.3
19	dust	0.5
20	foggy	0.5
21	haze	0.5
22	smoky	0.5
23	blustery	0.5
24	windy	0.5
25	cold	1
26	cloudy	0.3
27	mostly cloudy (night)	0
28	mostly cloudy (day)	0.7
29	partly cloudy (night)	0
30	partly cloudy (day)	0.9
31	clear (night)	0
32	sunny	1
33	fair (night)	0
34	fair (day)	0.95
35	mixed rain and hail	0.3
36	hot	1
37	isolated thunderstorms	0.5
38	scattered thunderstorms	0.5
39	scattered thunderstorms	0.5
40	scattered showers	0.5
41	heavy snow	0.3
42	scattered snow showers	0.5
43	heavy snow	0.3
44	partly cloudy	0.9
45	thundershowers	0.5
46	snow showers	0.5
47	isolated thundershowers	0.5
3200	Not available	1

A4 ESA's land cover values and categories supplemented with our UV index factors:

Value	Globcover legend (level 1)	Factor
11	Post-flooding or irrigated croplands	0.06
14	Rainfedcroplands	0.06
20	Mosaic Cropland (50-70%) / Vegetation (grassland, shrubland, forest) (20-50%)	0.03
30	Mosaic Vegetation (grassland, shrubland, forest) (50-70%) / Cropland (20-50%)	0.03
40	Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m)	0.03
50	Closed (>40%) broadleaved deciduous forest (>5m)	0.03
60	Open (15-40%) broadleaved deciduous forest (>5m)	0.03
70	Closed (>40%) needleleaved evergreen forest (>5m)	0.03
90	Open (15-40%) needleleaved deciduous or evergreen forest (>5m)	0.03
100	Closed to open (>15%) mixed broadleaved and needleleaved forest (>5m)	0.03
110	Mosaic Forest/Shrubland (50-70%) / Grassland (20-50%)	0.03
120	Mosaic Grassland (50-70%) / Forest/Shrubland (20-50%)	0.03
130	Closed to open (>15%) shrubland (<5m)	0.03
140	Closed to open (>15%) grassland	0.03
150	Sparse (>15%) vegetation (woody vegetation, shrubs, grassland)	0.15
160	Closed (>40%) broadleaved forest regularly flooded - Fresh water	0.05
170	Closed (>40%) broadleaved semi-deciduous and/or evergreen forest regularly flooded - Saline water	0.05
180	Closed to open (>15%) vegetation (grassland, shrubland, woody vegetation) on regularly flooded or waterlogged soil - Fresh, brackish or saline water	0.05
190	Artificial surfaces and associated areas (urban areas >50%)	0.25
200	Bare areas	0.25
210	Water bodies	0.03
220	Permanent snow and ice	0.85

A5 Sample output of Geonames' timezone web service:


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<geonames>
    <timezone>
        <countryCode>DE</countryCode>
        <countryName>Germany</countryName>
        <lat>51.96</lat>
        <lng>7.63</lng>
        <timezoneId>Europe/Berlin</timezoneId>
        <dstOffset>2.0</dstOffset>
        <gmtOffset>1.0</gmtOffset>
        <rawOffset>1.0</rawOffset>
        <time>2011-02-17 21:33</time>
        <sunrise>2011-02-17 07:41</sunrise>
        <sunset>2011-02-17 17:46</sunset>
    </timezone>
</geonames>
```