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Delivery of personal ultraviolet radiation information to smartphones

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Abstract. Smartphone technology is becoming a promising medium for delivering personalised ultraviolet (UV) radiation information to people. Different sources of UV data are discussed and current issues around the usage of wearable UV sensors are presented. UV data from these sources can be combined with the user's skin type profile to present metrics such as UV index, burn time, and cumulative dosage over the day as well as to alert the user of dangerous UV levels.

Introduction

Overexposure to UV radiation has long been linked to adverse effects on health, such as the development of non-melanoma skin cancers and skin aging [Armstrong and Kricker, 2001]. At the same time, underexposure has also been linked to problems arising from Vitamin D deficiency such as osteoporosis [Holick, 2006]. To manage personal risk, it is important for individuals to know the amount of UV they are exposed to and understand the effects on their body.

Currently, the majority of the public's knowledge surrounding UV comes from printed media, television advertising and forecasts reported by meteorological services [Gray and Beckman, 2010]. Although they provide safe tips applicable to those at highest risk, they do not cater for the varying skin types and outdoor habits in this multicultural society. There is also a lack of tools available to help people manage their exposure in a way where they can obtain their daily requirement of Vitamin D without increasing their risk of developing skin cancer.

The proliferation of smartphones and wearable computers over the recent years has opened up an entirely new channel for delivering UV information to the public. This information can be tailored to the individual and delivered in the form of alerts so they can better manage their UV exposure.

Acquiring UV data

In order to deliver useful information to the individual, we must predict or measure the UV levels they are exposed to. One way to do this is through ground UV models. Knowledge of the time, day, location and altitude can be used to accurately predict the clear sky UV intensity. The prediction could be further improved by combining it with ozone data from a satellite [Wang et al., 2000]. However, ground UV intensity is susceptible to spatial and temporal variations which could occur on cloudy days. This can be corrected to some extent using forecasted cloud effects, but is still prone to weather fluctuations. This is why most of the current apps available only display clear sky UV, giving the maximum UV the user could be exposed to at the time. In countries such as New Zealand and Australia where there is a combination of high UV values over summer and a high percentage of fair skinned individuals [McKenzie et al., 2014], it is better to overestimate the UV than to underestimate it for the prevention of sunburn. At the same time, this overestimation is less desirable for darker skin individuals during winter months.

Accounting for real-time cloud variations could be done through the installation of ground sensor stations. These stations consist of UV sensors and data logging equipment, which can distribute ground UV data to smartphones over the internet. They can provide very accurate measurements of ground UV especially if they are spectrometer based. However, these can be expensive to install and maintain and only cover a certain area.

Tracking personal exposure is important to personalise the recommendations displayed to the user. It can be done using the aforementioned data sources but will require constant manual input from the user to specify whether they are outside or inside. Having a sensor on the user can automate this. Over the recent years, several wearable UV sensors have been developed, some with a smartphone app component [Fahrni et al., 2011; GoodLux Technology, 2014; Netatmo, 2014]. These contain miniature UV-B responsive photodiodes and typically transmit this data to a smartphone using Bluetooth.

A prototype of a wearable sensor was constructed and usability studies were performed. The module, mounted on a wristband, contained an AlGaN photodiode, transimpedence amplifier, microcontroller and Bluetooth module (Figure 1). A corresponding app was developed to retrieve the data and present it in real time to the user.

Figure 1. Wristband mounted sensor (left) and smartphone app (right).

One issue was that most of the time, the sensor was not at the optimal angle towards the sun due to the constant movement of the subject. Even with cosine correction using a diffusive window in front of the sensor, there was still an angle dependence. These variations could be mitigated to some extent using algorithms to filter out the data. Placing the sensor on the shoulder or hat where it is more exposed to the sun can further improve the measurement.

A more fundamental issue which may prevent their widespread use is the reluctance for most people to wear a sensor solely for tracking UV. It is also likely that they will forget to wear it during crucial times if they do not regularly wear it. This problem, however, may be solved in the near future through the sudden growth in the wearable devices market. It is expected that at the end of 2014, the wearable device market will triple that of the previous year and it is expected to continue to grow by 78 % per year until 2018 [Llamas, 2014]. As main stream devices such as fitness trackers and smart-watches become more widely embraced, it is likely that there will also be a rise in personal sensors. This rise in awareness has been seen in the recent release of a new digital, ultra-low power UV sensor (Si1132, Silicon Labs, Austin, Texas) designed to be integrated to these devices. It is expected that a large number of smartphone and smart-watch manufacturers will be including these in their products to maintain a competitive edge. The major advantage of having these UV sensors integrated in devices that serve other purposes is that the individual will carry it with them more regularly and thus make it more useful.

Data display

Once UV exposure is measured, the next step is to display this information in a meaningful way back to the user. The goal of this is to educate the user about their personal risks in the current conditions and recommend a course of action.

The most common way of displaying UV intensity is through the internationally recognised UV Index. This number, which is weighted towards the biologically active side of the UV spectrum, can allow the user to decide when they need to apply sunscreen or seek shade. However, these recommendations do not take into account skin type, nor do they take into account the length of time someone has been exposed to UV.

Smartphones have the ability to capture personal information from the user to assist in displaying more personalised metrics. Users provide their skin type by selection, filling out a survey, or taking a photograph of their skin. They can also specify whether they are using sunscreen. Knowing this will allow the app to display their instantaneous burn time and vitamin D requirements.

Furthermore, cumulative UV dosage over the day could be tracked by knowing the duration for which the person is exposed to UV. This will allow the user to visualise their exposure over the day and seek appropriate protection to prevent themselves from exceeding the safe limit. In countries where there is low UV radiation throughout the year, the reverse problem may exist. In these countries, it may be more useful to use the UV dosage to track the amount of Vitamin D generated by the person. Knowing this will allow the individual to decide whether more sun exposure or supplements are required.

Alerts

People often forget to apply appropriate sun protection. The reapplication of sunscreen has been identified as a major issue [*Greenoak and Oakley*, 2013]. It is therefore important to have a way to remind the user. When the UV level is above a safe threshold, the user could be alerted to apply sunscreen, followed by a reminder to reapply. In this situation, the alert should only be displayed when the user is actually outside. Identifying this is straightforward when a personal sensor is used, but can be more challenging when the UV data is from a ground station or a model. One possible solution is to use the user location as a basis for making the decision of whether or not to alert the user. The end goal of this alert system is to further educate the user in an on-the-go basis and hopefully allow them to develop better habits in the sun.

Future work

Future studies will involve delivering personalised recommendations through a single app using aggregated data from modelled UV, ground sensor stations and personal trackers. Doing this will address some of the disadvantages of each measurement modality as well as keep it accessible for those who can obtain data from any one of those sources.

The design of how this data is presented will be of upmost importance in the success of the solution. Further work will be done in developing human friendly recommendations for the user, derived from the metrics discussed in the previous sections.

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