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Categorizing Outdoor Places Using EEG Signals

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Abstract. The ability to detect mental states, whether relaxed or stressed, would be useful in categorizing places according to their impact on our brains and many other domains. Newly available, affordable, dry-electrode devices make electroencephalography headsets (EEG) feasible to use outside the lab, for example in open spaces and shopping malls. The purpose of this pervasive experimental manipulation is to analyze brain signals in order to label outdoor places according to how users perceive them with a focus on relaxing and stressful mental states. That is, when the user is experiencing tranquil brain waves or not when visiting a particular place. This work demonstrates the potential of exploiting the temporal structure of EEG signals in making sense of outdoor places. The EEG signals induced by the place stimuli are analyzed and exploited to distinguish what we refer to as a place signature.

Keywords: Mobile Sensing, EEG, Neurology, Pervasive Computing, Social and Behavioral Sciences

1. Introduction

People usually get attached to a place by developing an emotional bond between them and the place. [Cresswell, 2004] has defined the place in geographic research as "space which people have made meaningful". Perhaps more importantly, places are reproduced through people's imaginations, memories, emotions and feelings, both positive and negative, and by using different senses [Relph, 1976; Thrift, 2009]. By walking in a place, we can navigate our way and make sense of our surroundings. We look for things that stand out because they are different from their surrounds, or because they have a shape or form or structure that we believe we could recognize again. Sense of smell could lead us to tempting coffee aroma in nearby cafe. Noisy playgrounds and high pollution omitted from traffic could deter us from visiting the same place again [Al-Barrak and Kanjo, 2013].

Many studies have shown that some places can affect our minds and make us feel more relaxed. For example [Stigsdotter, 2004] and [Kohlleppel et al., 2002] have shown that nature and gardens have a positive impact on stress. In addition, cafés, libraries, zoos were proved to reduce stress levels in many people [Korpela et al., 2001]. Therefore, to explore the relationship between people and places, we need to use novel and creative methods. Ubiquitous technologies are able to reveal the respondent's whole body and senses in generating knowledge and communicating a place.

In this work, we present a novel method for categorizing places based on the current mental state sensed at an outdoor place to guide people to relaxing places. By measuring brainwaves using off-the-shelf EEG headsets, we can detect different mental states. Sensed mental states of subjects can give us valuable information on how people perceive places. In addition, we have correlated the brainwaves with environmental noise levels in order to analyze and process changes in patterns that exist in the surrounding places.

2. Material and Methods

A mobile application for Android devices has been developed to collect EEG, environmental noise and location data. The application connects to NeuroSky EEG headset via wireless connection. Data produced by the headset such as attention, meditation levels, and values for different frequency bands as well as the GPS data and environmental noise levels are saved into log files. The mobile application gives us the ability to move and take the experiments to outdoor places.

Twenty female students participated in the evaluation. We deployed 4 android mobile phones and 4 Mindwave EEG sensor models, daily, for one hour each around our campus. Each user has repeated the test three times which has given us 60 different data sets to analyze. Each user had to walk along the path of 5 distinguished places such as Starbucks, the conservatory, garden, snack shop and student Union. The noise meter and GPS application were installed in the phone and its readings were time stamped along with the various EEG frequency bands, eye blink, attention and meditation levels. A post-experiment interview revealed that the participants were comfortable with the system. All collected data, were subject to inspection and analysis to remove any corrupted data using R project.

After the process of noise removal, further processing of the data was carried out to chop the samples into small time periods to extract segments that are known to contain the stimuli. For each of the segments, feature were extracted and classes generated accordingly. In order to categorize places to be adapted to users' needs, we must use classifiers. Classification of signal segments into a given number of classes using segments features can be achieved by various statistical and probabilistical methods. Bayesian classifier or Logistic regression are considered for predicting the category.

3. Results

Our initial results look promising showing that modern mobile phones are capable of processing neural signals using an affordable and commercial EEG headset. In this work we have adapted Neurosky mean meditation, but plan to use our own relaxation and stress classification functions.

Mental states of participants at the Campus garden have shown that the majority of the participants perceived the garden as a relaxing place. In addition, when we analyzed the environmental noise levels at the garden, we noticed that the environmental noise was high just before reaching the garden. However, the noise levels were low when the participant reached the garden since our garden is a quite place and therefore the mental states are not affected by the noise in this case. Some places such as cafés can be classified as relaxing places but they hold high levels of environmental noise and therefore need further analysis to detect the correct mental state of the participant.

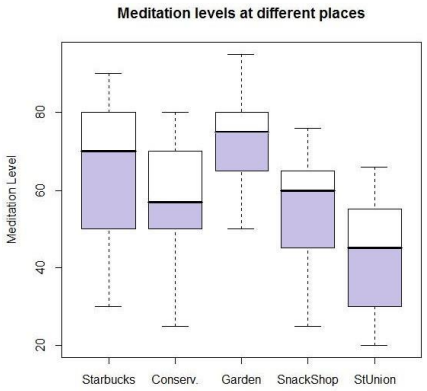

Figure 1. *Meditation levels.*

Fig. 1 shows the places visited by the participants and the different meditation levels perceived by them. Places such as Garden and Starbucks have a high level of meditation which mean that people felt more relaxed in these places, where as student union have the lowest meditation levels among the others

4. Discussion

The mental states sensed at those places are a rich source of information and could be used in understanding the people-place relationship. It is also possible to understand how places affect people since different mental activity can be detected before and at the place. In this work we explored the properties and temporal structure of the EEG signal with the aim to classify outdoor places according to the current mental states with a focus on relaxation/meditation, that is, when the user is experiencing tranquil brain waves or not when visiting a particular place. EEG signals associated with the place stimuli are analyzed and could be used to distinguish the place type.

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