NeuroPlace: Making Sense of a Place

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ABSTRACT

The ability to detect mental states, whether relaxation or stressed, would be useful in categorizing places according to their impact on our brains and many other domains. Newly available, affordable and 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 paper 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.

Categories and Subject Descriptors
C.3 **[Special-purpose and Application-based Systems]:** Real-time and embedded systems, H.5.m **[Information Interfaces and Presentation (e.g., HCI)]:** Miscellaneous, I.2.9 **[Robotics]:** Sensors, J.3 **[Life and Medical Sciences]:** Neuroscience, J.4 **[Social and Behavioral Sciences].**

General Terms
Experimentation, Documentation, Design, Human Factors.

Keywords

Mobile Sensing, EEG, Neurology, Pervasive Computing, Social and Behavioral Sciences**.**

1. INTRODUCTION
Nowadays, people seem to spend most of their time indoor working with various technologies. This may result in chronic stress and inability to relax. High stress levels need to be treated and managed using stress management techniques. Generally, people spend their times in quiet places to help them relax and cope with the hassle of modern busy life style.

Many studies have proved that spending time at relaxing places can relieve stress. For example, Stigsdotter [20] and Kohlleppel et al. [9] have shown that nature and gardens have a positive impact on stress. In addition, Korpela et al. [10] showed that a large number of people feel relaxed and their stress level decreases at places such as, cafe, library, and zoo. In this paper, 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 using brainwaves analysis.

Brain signals are electrical signals produced by the human brain, known as brainwaves. Measuring brainwaves is done using a non-invasive and inexpensive method known as electroencephalogram (EEG) [22]. Medical EEG sensors use a large number of electrodes to detect accurate data. However, NeuroVigil Inc. [14] has developed iBrain that can analyze brainwaves and map out data to diagnose medical conditions using a single electrode. Also, Emotiv [5] and NeuroSky [13] have developed EEG sensors available in the market and can be used for different brain-computer Interaction (BCI) applications.

So far, the application of BCI technology has focused mainly on four areas: communication, smart home control, assistive technology [11] , and gaming [15]. While the majority of effort continues into expanding and developing BCI methodology in the ways described above, increasing attention is now being directed towards investigating potential of BCI technology for outdoor applications.

Sensed mental states of subjects can give us valuable information on how people perceive places. The study has developed a mobile application that is compatible with off-the-shelf EEG headsets to collect brainwaves at different places. Alongside the EEG, we also correlate the brainwaves with environmental noise levels in order to analyze and process changes in patterns that exist in the surrounding places. Once we have collected and analyzed our data we aim at disseminating our results and findings in a form of a mobile applications, map or web interface. The idea of this framework is to give people the ability to choose the place(s) that relaxed them the most. The EEG sensor that will be used in this study, developed by NeuroSky is a dry sensor and requires no gel, no expertise to wear, and it consists of two electrodes to detect brainwaves.

2. RELATED WORK
EEG sensors have been used in a wide variety of applications. For example, Ashkan et al. [1] have developed an EEG-based brain-computer interface system for implicit emotional tagging of multimedia content. Also, Mostow et al. [12] have used EEG sensors on students to monitor cognitive processing and their mind state during learning. However, these EEG applications were based on indoor use scenarios, and hence EEG sensors used in non-mobile settings. SmartCap [19] have used a mobile EEG and developed a monitoring system that fits on the head to measure and monitor the car driver fatigue, which can help in reducing the occurrences of incidents. Outdoor environments require mobile technologies in order to facilitate data collection such as mobile phones.

Recent availability of low-cost wireless electroencephalography (EEG) headsets [5] [13]and programmable mobile phones capable

of running sophisticated data processing algorithms, gave us the ability to interface neural signals to phones to deliver new mobile computing paradigms.

However, there is a need for more work in developing a practical and robust brain-mobile phone interface not only capable of working in controlled laboratory settings but also out while the users on the move. Exploring the potential use of EEG in outdoor environment is part of our on-going research.

In this paper, we discuss our broader vision of a brain mobile phone interface and then present the initial design, implementation, and evaluation of the NeuroPlace system.

Our initial results look promising showing that modern mobile phones are capable of processing raw neural signals using an affordable and commercial EEG headset.

In what follows, we define what we mean by a place, present an overview of NeuroPlace architecture. We also discuss a number of design considerations that directed our initial implementation in another section.

3. OUR SENSE OF OUTDOOR PLACES

’Place’ is defined in geographic research as “space which people have made meaningful” [4]. Perhaps more importantly, places are reproduced through people’s imaginations, memories, emotions and feelings, both positive and negative, and by using different senses [18] [21]. Thrift [21] discusses place experiences during a walk in the countryside as compared to a walk in the city. The author illustrated how places are constructed through different senses and people’s bodies. Such impressions can construct place as welcoming and pleasant or hostile and aggressive.

By walking 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.

Walks have been used, for example, in studies exploring the relationship between people and urban environment [17] or the role of places for people’s well-being [2]. In order to make the walk tangible and recall it later voice recorder, photo or video camera are often used by researchers [3]. New research methods are needed for exploring people- place relations.

More creative and interactive methods based on ubiquitous technologies are able to reveal the respondent’s whole body and senses in generating knowledge and communicating a place. In so doing, they reveal emotions triggered by direct contact with the object or event is a particular event. Especially methods that can be used ‘in the field’ enabled research participants to communicate place by using their senses (olfactory, tactile, auditory, and visual).

In this paper we define a place as an outdoor space that can be visited by people such as gardens, shops and cafes.

4. NEUROPLACE ARCHITECTURE

Mobile phones are commonly used as sensors in outdoor environments [7]. Our study uses mobile phones as a mean of collecting and recording brainwaves data. The mobile phone and the EEG headset are married to acquire EEG signals. After that, the EEG data are correlated with environmental noise to filter any noise from the signal. Data of one place collected are now ready for offline analysis using different statistical models. Also, in order to categorize places to be adapted to users’ needs, we will apply classification functions. 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 will be considered for predicting the outcome of a categorical (a variable that can take on a limited number of categories) dependent variable based on one or more predictor variables (see Figure 1).

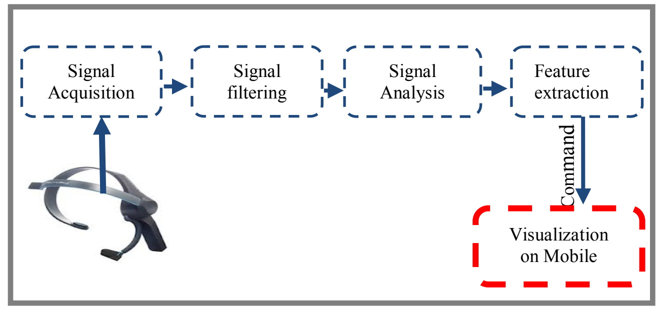

Figure 1. NeuroPlace system components

A mobile application for Android-devices is developed to collect EEG, environmental noise and location data, the application was installed on Samsung Galaxy S2 Smartphone. The application connects to the EEG headset via wireless connection. The mobile application gives us the ability to move and take the experiments to outdoor places. Figure 2 shows NeuroPlace running in real-time while displaying data for attention, meditation levels, noise levels as well as the values for different frequency bands and saves them into log files. The subjects wear the EEG headset and run the mobile application while going to different outdoor places. These data are recorded in the mobile memory for offline analysis.

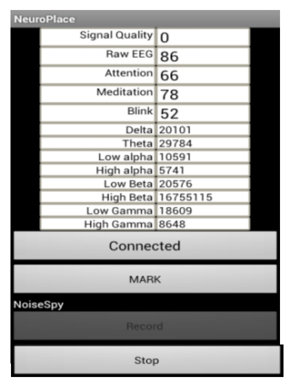

Figure 2. NeuroPlace Application

This study uses Mindwave Mobile EEG headset developed by Neurosky. The participant wears the headset and run the mobile application before reaching a place and when the participant arrives at a specific place, she will mark that place aid us in identifying EEG data for that particular place. The EEG headset allows us to record a number of EEG data such as raw EEG, different frequency bands, and two mental states (attention, meditation). Neurosky headset calculates 8 different types of brain waves. These eight frequency bands are in the following order: delta (0.5 - 2.75Hz), theta (3.5 -6.75Hz), low-alpha (7.5 - 9.25Hz), high-alpha (10 - 11.75Hz), low-beta (13 - 16.75Hz), high-beta (18 - 29.75Hz), low-gamma (31 - 39.75Hz), and mid-gamma (41 - 49.75Hz). These values have no units and therefore have a relative meaning.

Neurosky provides attention and meditation mean levels ranging from 0 to 100, see Figure 3. Those values are determined by

proprietary algorithms where values between 40 and 60 are considered neutral or baseline. Values between 80 to 100 refer to strongly elevated meditation/relaxation levels. Similarly, values between 20 and 40 mean slightly lowered levels, and between 1 and 20 indicate strongly lowered levels. And finally, zero value means the signal is subject to noise. Based on these levels, our places are classified into different categories such as relaxing or stressful place.

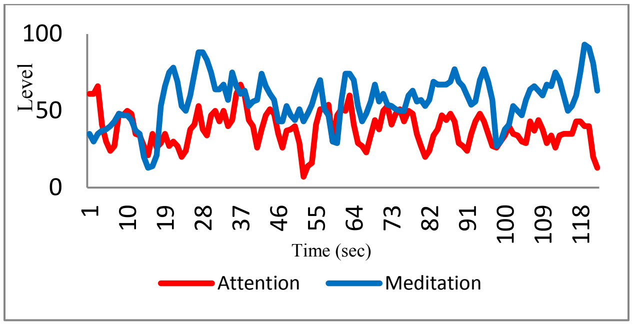

Figure 3. Attention and meditation mental states features provided by Neurosky

The data from EEG, NoiseSpy [6] and GPS are correlated and time stamped in one data raw. Noise can detect some abnormal environmental distractions which might affect user perception of a place.

5. EVALUATION

Evaluating systems that involve physiological and wearable devices require to follow rigorous and yet stepwise process in particular those related to EEG. The case of the envisaged NeuroPlace system domain is no exception. In fact, bad test design might lead to false positive results particularly when users are instructed to manipulate the user interface while trying to concentrate. Thus, two basic assurances are needed before proceeding: to have a robust system that delivers adequately the functional requirements; to provide a usable design that offers a good user experience. Furthermore on the latter, final users can hardly be used. In fact, patients can only asses the technology at the final stages of evaluation.

The system functionality has been evaluated using basic user experiences. 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 etc, see Figure 4 for the map where the experiment took place. 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 corrupt data using R project, a software environment for statistical computing and graphics.

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 and identify features. For each of the segments, feature were extracted and classes generated accordingly.

In this work we have adapted Neurosky mean meditation, however in futrue work we are planning to implemnt our own relaxation and stress classification functions.

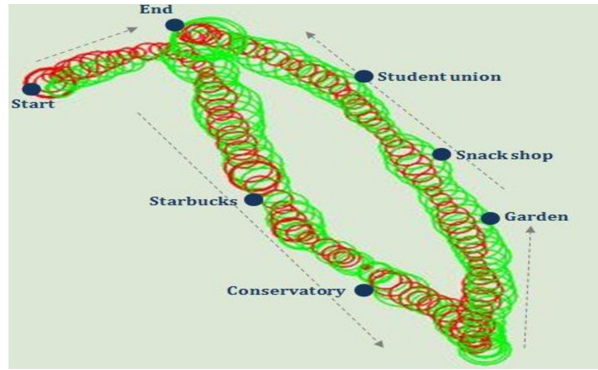

Figure 4. Map of places visited

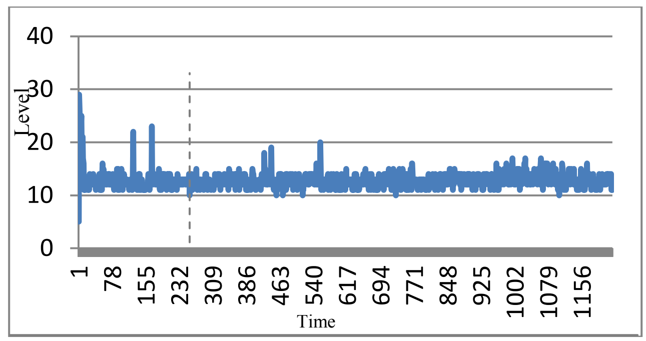

Figure 5. Campus garden environmental noise levels

Figure 3 shows an averaged mental states levels of participants at the campus garden, where it is clear that the majority of the participants perceived the garden as a relaxing place. In addition, when we look at the environmental noise level at the garden in Figure 5, we notice 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.

Box Plot in Figure6 is showing the Mean values of meditation from all participants at each place respectively. Places such as garden, and Starbucks have a mean meditation level of almost 80. However, conservatory, snack shop, and student union have a mean meditation value of 60 or less, which is considered as neutral and therefore these places cannot be classified as relaxing places. Whereas places that have a meditation level of 70 or higher can be classified as relaxing places. In this experiment, data were collected while environmental noise was low and therefore the EEG headset recordings were not affected by noise.

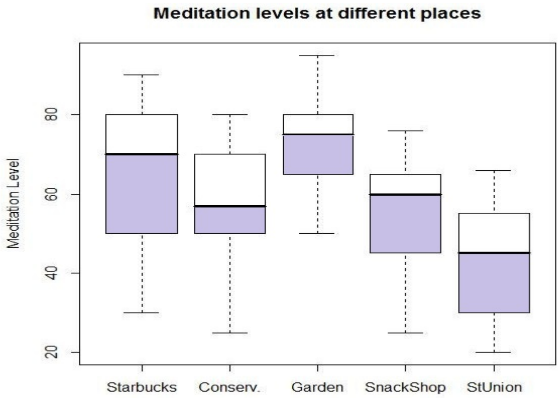

Figure 6. Meditation Levels at different places

6. CONCUSION AND FUTURE WORK

Every human perceives outdoor space differently. Some places are seen to be hectic and stressful, others as especially relaxing and pleasant. This perception is subjective and emotions are mapped in the brain as a reflection of the physical map. Sensing this mind map can be achieved by using portable EEG sensors then interpreting EEG signals to detect patterns of mental state.

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, that is, when the user is experiencing peaceful brain waves or not when visiting a particular place. The EEG signals associated with the place stimuli are analyzed and could be used to distinguish the place type, which in turn could be exploited in classification. NeuroPlace opens up new opportunities and challenges in pervasive computing and mobile sensing.

Our long term research goals are to influence brainwaves by guiding people to relaxing environments that suits their needs and to provide simple relax stimulation based on place stimuli. However our immediate objective in this project is to study the changes in the participants' brainwaves before and after reaching a specific place. The EEG signals for the place stimuli will be subjected to various feature extraction methods and temporal manipulations. We are also planning to disseminate our results and findings in a form of a mobile applications, map or web interface.

7. ACKNOWLEDGMENTS

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