emoBAN: Improving Quality of Life via Psychophysiological Mobile Computing (Position Paper)

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Abstract
Our daily affective states are a key element in the analysis of our quality of life (QoL). Yet, to date a reliable and accurate solution for an affect analysis in our daily environments does not exist. This paper draws a research path towards a development of a Body Area Network (*emoBAN*) that enables long-term monitoring and analysis of affective states, as well as provision of appropriate feedback via adaptive interfaces. emoBAN can be realized with the use of unobtrusive psychophysiological measurement sensors (e.g., heart rate, respiration), supported by mobile-device based self-reports to investigate a range of affects we exhibit in our natural daily life environments. The acquired data can be automatically mined for patterns and correlated with different contexts, such that QoL could be quantified and areas of personal improvement pointed out. With the use of emoBAN, we can gain a deeper understanding of our personal experiences and resulting behaviors. The system has the potential to be exploited in many application domains and contribute to defining new research questions in disciplines ranging from behavioral to applied sciences.

Keywords
Quality of Life, user experience, psychophysiological signals, affective computing, mobile computing

ACM Classification Keywords
H.5.2. User Interfaces – Input devices and strategies; B.4.2 Input/Output Devices – Channels and controllers; K.6.4. System Management - Quality Assurance

Introduction
Quality of Life (QoL) is an important high-level goal we work towards in our day-to-day experiences. However, when asked to evaluate our QoL, we tend to choose a socially desirable response or we consider only our most recent experiences [1]. Research indicates that our affective states, their duration and intensity are a

key element in the analysis of our overall, long-term QoL [1, 2]. Yet, to date, a reliable technology for continuous analysis of affects in our natural, daily life environments ('anywhere-anytime'), does not exist. "What is always speaking silently is the body" [2]; our affects influence the psychophysiology of our body, which is not subject to cognitive processing and social masking. Given that sensors measuring psychophysiological signals and the research on analysis of those signals for affect recognition are available at an increasing rate, we propose a research path building upon this knowledge towards a development of a Body Area Network for affect monitoring and control, called *emoBAN*. emoBAN is a set of minimally obtrusive sensors and actuators worn on a person's body (or available in the person's environment) that continuously and in real-time monitor this person's affective state, based on which, appropriate feedback can be provided. With the use of emoBAN, we can gain a deeper understanding of our behavior, quantify our QoL and point out areas for personal improvement.

In this paper we present the state of the art for emoBAN development, and then we list emerging questions and enumerate details of research challenges and issues to be tackled before emoBAN can be deployed successfully. We also indicate its potential to be exploited in many application domains.

Related Work

There exist proposals of BAN systems measuring a wearer'spsychophysiological signals like heart rate (HR), electrodermal activity (EDA), respiration (RR), electromyogram (EMG), skin temperature and electroencephalogram (EEG), but these systems are intended for use in healthcare [3] or for affect recognition and modeling only. For the latter use, the BANs are then used in controlled environments for a limited time span, in which specific affects are evoked in a subject and data is manually annotated for the ground truth. This approach has been used to model stress responses in drivers [4], and to model valence/arousal responses in users of well- and ill-designed interfaces [5]. Others have gathered BAN data to model states of fear and sadness induced by selected movies [6], and proposed to measure user emotions, based on which one could deploy a recommendation system for mobile services [7]. To our best knowledge, none of the proposed systems is intended for continuous, real-time affect monitoring and control for user self-reflection upon personal experiences and improvement of certain behaviors.

Research Questions

The research questions for our research are:

- Can we quantify human QoL in relation to his affective states? What are those states and how do we define them?
- Is there a baseline of a human affective state?
- Can we reliably recognize and analyze the above-defined affective states while person is mobile in natural daily life environments? What sensing modalities are of interest? What mechanisms can we employ to gather the ground truth data?
- With what software and hardware technologies can sensor data be reliably acquired and processed? Does the system require local (*i.e.*, mobile) or distributed processing technologies?
- What actuator (feedback) modalities are of interest for a control of person's affective state? With what software and hardware technologies can feedback be optimally provided while a person is mobile in natural

daily life environments?
- How can feedback be provided via adaptive user interfaces such that it does not hinder a person's actions for a given task, but, instead, optimizes this person's experience?

emoBAN Research Issues and Challenges

There are a number of research issues and challenges to be tackled before we can successfully deploy emoBAN. Those relate to the functional (*i.e.*, affect monitoring and control) and non-functional system requirements, as well as the system validation.

Functional Requirements

Affect monitoring: emoBAN needs to support continuous, unobtrusive real-time reliable affect monitoring. The research challenge is to leverage existing knowledge [4-6] towards recognizing a set of common human affects, *e.g.*, happiness, anger, surprise, or a 'neutral' state, in a user's natural daily life environments. emoBAN should link the affects with user context (*e.g.*, unhappy while shopping) and gather a ground truth (qualitative) data via, *e.g.*, a user's ecological momentary assessment (EMA) [8]. EMA can be event-contingent (*i.e.*, upon context or affect change) or interval-contingent (*i.e.*, every 15 minutes). A research issue lies in the reliable correlation of quantitative psychophysiological data with qualitative user self-report data. Another challenge lies in processing of the acquired affect data with data mining/machine learning methods, *e.g.*, neural networks or support vector machines.
Affect control: emoBAN needs to implement a function for a continuous, real-time affect control via adaptive user interfaces. The research challenge is to design a set of actuator systems in emoBAN (and/or in the user's environment), which positively influence the user's affect. The feedback functionality can include *e.g.*, an 'e-coach' for breathing or muscle relaxation techniques, change of music, ambient light/temperature, activation of a robot or even communication with significant other(s).

Non-Functional Requirements

emoBAN requires *continuous, real-time and reliable* functioning. These requirements are challenged by the fact that a) affective signals are temporally indirect, *i.e.*, there is often a lag between a cause (*e.g.*, context change) and psychophysiological change; b) sensors are unreliable: their reading is influenced by placement, movement artifacts, bodily position, ambient light, temperature/humidity conditions; c) there are individual differences in affects and their psychophysiological responses for each human; d) there are no established methodologies on how to reliably capture psychophysiological data: how many channels (*e.g.*, ECG), at what sampling frequency and signal resolution.
emoBAN usability is influenced by system wearability and (cognitive and physical) obtrusiveness of sensors and actuators, as well as the frequency and length of EMA. Moreover, the following non-functional requirements are research challenges: a) system security and data privacy; b) safety; c) system scalability with the number of attached sensors and actuators and number of recognized affects; d) monetary cost of use; e) battery lifetime; and f) user's mobility support, including 'anywhere-anytime' emoBAN availability.

Validation Challenges

emoBAN validation entails the following research

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challenges and issues: a) selection of a theoretical framework used for defining affective states of interest (emotions vs. feelings vs. moods [9]); b) validation that the gathered data accurately represents a given affect; c) validation of reliability and accuracy of emoBAN for a range of different affects; d) validation of reliability and accuracy of emoBAN for a range of different affects in different context the user is in.

Application Domains

Domains that can potentially exploit highly-personalized, affect- and context-aware services provided based on the operational emoBAN include, *e.g.*, a) mental healthcare including psychotherapy and life coaching; b) stress management; c) affective mobile multimedia; d) advertising; e) affective learning and tutoring. Results acquired with the emoBAN can be further explored in, *e.g.*, enhanced AI and robotics.

Conclusive Remarks and Outlook

emoBAN enables an analysis of our day-to-day affective states, through which we can gain a deeper understanding of our personal experiences, behaviors and overall quality of life (QoL). Therefore, it has a true potential to facilitate an improvement of our personal excellence and QoL and a potential of being employed in many application domains, but only if the research challenges and issues, pointed out in this paper, are tackled. Towards this goal, the research on emoBAN is necessarily interdisciplinary, involving scientists from computer science (HCI, affective computing, machine learning, wireless sensor/actuator networks), sociology, psychology, neuroscience and possibly other disciplines. We anticipate that the research on emoBAN enables answering the predefined questions in different disciplines involved in this research, as well as it will raise new, interesting and important research questions, which might not even be thought of today.

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