A System for Automatic Detection of Momentary Stress in Naturalistic Settings

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Abstract. Prolonged exposure to stressful environments can lead to serious health problems. Therefore, measuring stress in daily life situations through non-invasive procedures has become a significant research challenge. In this paper, we describe a system for the automatic detection of momentary stress from behavioral and physiological measures collected through wearable sensors. The system's architecture consists of two key components: a) a mobile acquisition module; b) an analysis and decision module. The mobile acquisition module is a smartphone application coupled with a newly developed sensor platform (Personal Biomonitoring System, PBS). The PBS acquires behavioral (motion activity, posture) and physiological (hearth rate) variables, performs low-level, real-time signal preprocessing, and wirelessly communicates with the smartphone application, which in turn connects to a remote server for further signal processing and storage. The decision module is realized on a knowledge basis, using neural network and fuzzy logic algorithms able to combine as input the physiological and behavioral features extracted by the PBS and to classify the level of stress, after previous knowledge acquired during a training phase. The training is based on labeling of physiological and behavioral data through self-reports of stress collected via the smartphone application. After training, the smartphone application can be configured to poll the stress analysis report at fixed time steps or at the request of the user. Preliminary testing of the system is ongoing.

Keywords.psychological stress, physiological monitoring, wearable sensors, knowledge models, decision support system

Introduction

Mobile phone usage has already been harnessed in health care generally, but in thelast few years the use of mobile devices has being explored also in the mental health field [1]. An emerging area of research is the use of mobile devices, in particular smartphones, as support tools for the treatment of anxiety disorders [2; 3] and stress management [4; 5]. Taken together, results of these pioneering studies support the use

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the final, defuzzification step, the linguistic variables are converted to continuous values (real outputs of the system) [11]. We developed membership functions and fuzzy rules for each relevant parameter, including heart rate, LF/HF and motion activity (Figure 1). The fuzzified features extracted are the inputof the classifier, a Kohonen's self-organizing artificial neural networkbased on unsupervised learning [12]. Data processing in the decision module consists of a *training phase* and a *test phase*. In the training phase, the self-organizing map is trained to adapt itself to classify the input features. The training set includes features extracted from sensors and self-reported stress levels. With the support of a learning algorithm, synapticweights of networks are modified, in order to force the output to minimize the error with the presented example (in this case, self-reported levels of stress). In the *test phase*, the fuzzified features are given as an input to thenetwork.When the neural network is adequately trained, it is able to classify the given input in order to present a consequent output value (the inferred stress level).When the decision module infers a new stress level value, this is uploaded to the remote database.
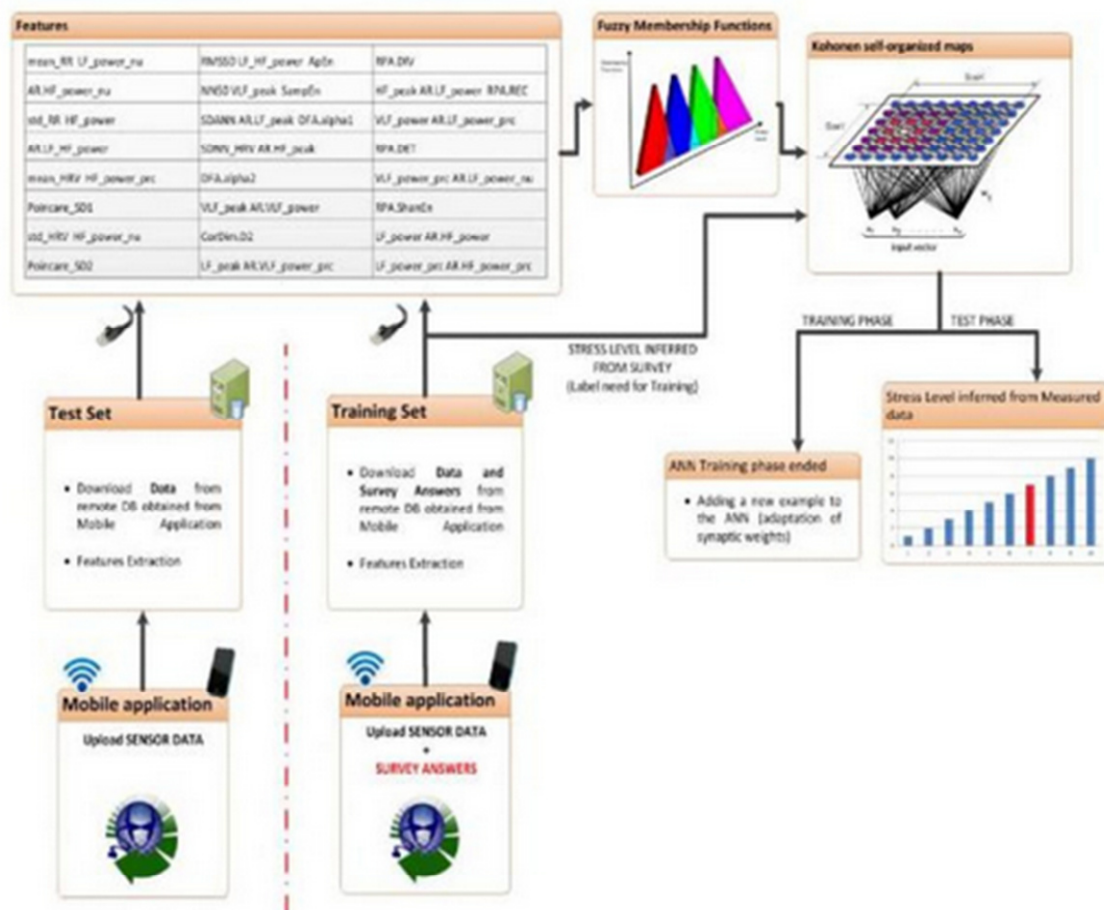

Figure 1. Architecture of the decision module: Artificial Neural Networks and Fuzzified Inputs, in training and test phases.

1.3. Visualization of stress levels

When the training of the artificial neural network is completed, the mobile applicationgoes in "stress monitoring mode" andcan be configured to poll the stress levels reportfrom the remote database at fixed time intervals, or at user's request.The

Stressometer and *StressTracker* components of the mobile application provide the user with graphic representations reflecting the measured stress. The *Stressometer* (Figure 2a) displays the current stress level of the user, which can be either a recent accurate estimate acquired from the central decision module, or an HRV-based approximation from the lightweight mobile decision module. Apart from the instantaneous values, the user can check the history of stress-level variations during the monitoring period. This information is visualized by the *StressTracker* (Figure 2b), which shows the number of detected stressful events over the course of last day, week, or month.
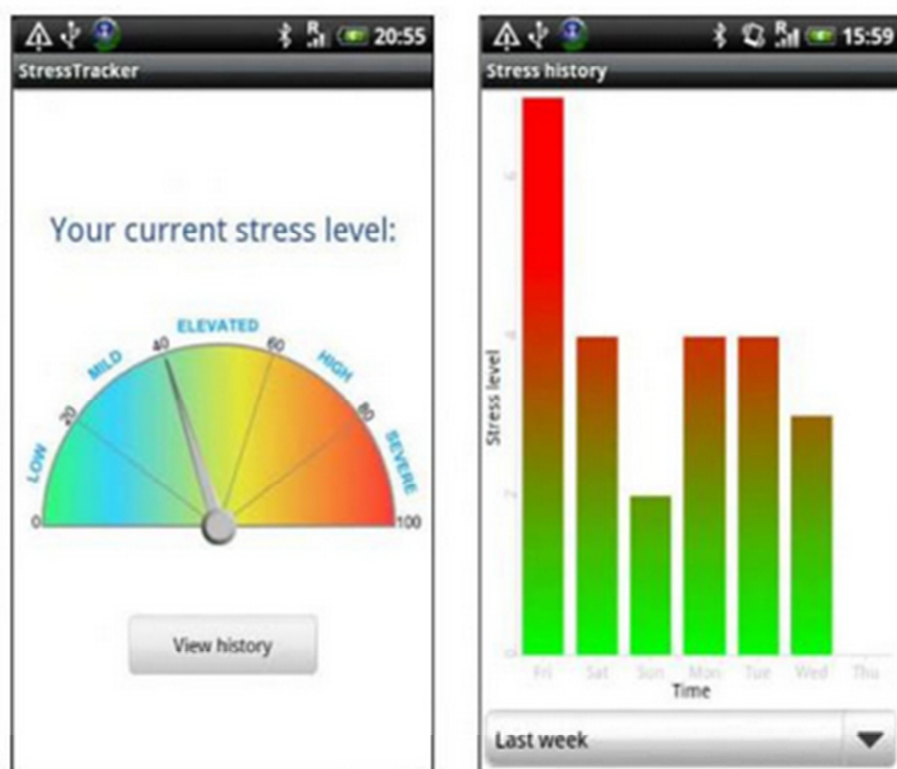

Figure 2a. The *Stressometer* (left) and **2b.** *StressTracker* (right) components of the mobile application.

2. Results

The system is currently being tested for validation in a pilot study involving healthy volunteers.

3. Conclusions

We present apervasive architecture for automaticdetection of stress levels with a minimal discomfort for the user. Differently from the state-of-the-art, our system is suitable for prolonged stress monitoring during daily activities. The innovative contribution of the proposed solution relies on the processing approach, able to automatically identify stress conditions of the user from the combination of psychological, physiological and behavioural information collected in ecological contexts.

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