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Short Communication

Objective model assessment for short-term anxiety recognition from blood volume pulse signal

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ABSTRACT

Human emotional recognition using physiological signals is relatively recent. The interest to this field has been motivated by the robustness of physiological traits to avoid the artifacts created by human social masking. In this paper our attention is focus on two aims: the development of an anxiety recognition system using only one physiological signal "Blood volume pulse, BVP" and the creation of a reliable anxiety model using objective assessment. This assessment is done by using dynamics of selected features. The anxiety elicitation is based on exposure to virtual reality (EVR). The results of these investigations show that this assessment technique is effective for the construction of a reliable database and hence improves the recognition system rate.

1. Introduction

The handicap caused by social anxiety for many people in the world has drawn attention of scientists leading to the development of efficient strategies for reducing and/or treating it. Efficiency of cognitive behavioral therapy (CBT) in virtuo for treating this disease has been proved by several studies. Several anxiogenic scenes were developed according to different scenarios (performance scenario, scenario of privacy, scenario statement and observation scenario) [1–3]. Those scenes were used to make a comparative study with cognitive behavioral therapy in vivo, thus proving the reliability of CBT in virtuo. In these studies, the anxiety measure is done by using subjective methods such as self-assessment and different questionnaires (Liebowitz questionnaire, ATPSQ: Attitude towards Public Speaking Questionnaire and SUDS: Subjective units of discomfort) [2,4–6].

Controlling these therapies in a progressive manner using automatic anxiety recognition has many advantages. It helps in preserving the privacy and safety of the patient, assessing the progress of therapy through the means used in measures and allowing the therapist to be more attentive to patient behavior. Different anxiety levels can be resulting in several varieties of physiological reactions. An important aspect of this procedure is the selection of the effective and comfortable physiological signal for recognition system. It is essential to obtain a reliable database representing specific emotional states, to acquire a database in which the influence of emotional status is faithfully reflected, a set of protocols for emotional induction using exposition to virtual reality (EVR) was developed [7–9].

Finding a reliable indicator in order to ensure that the subject is in a particular emotional state is a tough task. In addition, all methods of emotional recognition compare a set of characteristics after measurements with a predefined template which is assumed universally [10]. The creation of these models is based on generated characteristics labeled by an artificial stimuli, self-assessment and questionnaires. Our challenge is to check the emotional state of the users using objective method. For that purpose, we investigate a novel method for database assessment using dynamics of relevant features to differentiate each affective state.

This paper shows the development of a short-term anxiety recognition system based only on blood volume pulse signal (BVP) using a reliable model. The advantage of this work is the use of only one sensor which contributes in reducing the time required for signal monitoring and minimizing gene users. The emotion stimulus is based on exposure to anxiogenic virtual environment. Our most challenge in performing this system is the assessment of the anxiety model created using objective method.

In the following sections, first we present, some previous works achieved on emotion recognition using physiological signals. Second, some information on the selected physiological signal is

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provided and different features which contributes in recognizing the emotional state are revealed. Third, the elaborated protocol and procedure are described in Section 4. Fourth, we present the different stages to implement the system: BVP acquisition, features selection, classification and the objective database assessment. Finally, the limitations and applications of the proposed approach are discussed in the last section.

2. Related work

Most of emotion recognition methods are focused on a methodology based on classification techniques and combination of several physiological signals to strengthen the recognition rate.

In 2004, Kim achieved a four emotional state recognition system "Sad, anger, stress and surprise" using multimodal stimuli (visual, audio and cognitive). This system used three physiological signals: electrocardiogram, electrodermal activity, and skin temperature. These physiological signals analyze gave 67.76% of rate recognition [11]. In 2005, a novel system have been designed and built to detecting stress during real-world driving tasks using physiological sensors (electromyography, electrocardiogram, electrodermal activity, respiration and video). The result was 97% from statistical and spectral analyze [12]. Kim [10] investigated other stimuli method "Music" and used other physiological signals "Electromyography, electrocardiogram skin conductance and respiration" to differentiate between different combination of arousal and valence level. The obtained overall accuracy was 95%. In our previous work [13], we developed a virtual reality exposure system (VRE) in order to induce anxiety to phobic people. Based on Picard features and SVM classification method we have obtained 76% of rate recognition using only blood volume pulse signal (BVP). These reported approaches used self-report of the subjects for validation.

In 2010, Maaoui [14] used International Affective Picture System (IAPS) to induce different apprehension levels. The result of the statistical analyzing of the blood volume pulse, electromyography, skin conductance, respiration and skin temperature was 84.3%. More recently, Katsis [15] developed an advanced monitoring system which optimally classifies subjects' levels of apprehension. He used International affective picture System (IAPS) for stimulation and SAM (Self-Assessment Manikin) for validation. The used physiological signals were blood volume pulse (BVP), heart rate, skin conductance (SKC) and respiration. The result of the statistical analyze was 84.3% accuracy using self-reports of the subjects (questionnaires) for validation. The analyzing of four physiological signals (skin temperature (SKT), photoplethysmography (PPG), electrodermal activity (EDA) and an electrocardiogram (ECG)) to recognize seven emotional states (happiness, sadness, anger, fear, disgust, surprise and stress) gave 70% using SAM (Self-Assessment Manikin) for validation. The used elicitation method was audio–visual film clips captured from movies, documentaries and TV shows [16].

The reported approaches achieved good accuracy rates for emotion recognition, which are validated by subjective methods. However, these recognition rates are strongly dependent on the stimuli, users, used sensors and the application context. These approaches can be used in clinical environment if the elicitation method is changed and oriented for the psychological diseases.

In view of clinical application, therefore we need to limit the discomfort caused by the number of sensor. For that, we propose the use of a single physiological signal "Blood volume pulse signal, BVP" because it is a more practical measure for accessing cardiac features than the electrocardiography (ECG) sensor [17]. Generally, the ECG is measured by using electrodes which need a firm skin contact, whereas the BVP is measured by using a photoplethysmograph. Hence, using the BVP signal has some advantages such as robustness against motion artifacts during recording process and stable baseline in the signal flow [10].

3. Blood volume pulse and emotion

The BVP signal is valuable in its own right, not merely as a convenient measure of heart rate variability (HRV). This subsection explores its potential benefits for emotion recognition.

The BVP signal is an indication of blood flow through the human body. With every beat, the heart pushes a volume of blood through the body's arteries and veins, causing a wave which travels from the heart to the peripheral regions of the body (arms and legs) and eventually returns to the heart [18]. The shape of BVP envelope indicates the relative constriction of the blood vessel (Fig. 1). This vasoconstriction is controlled by the sympathetic division of the autonomic nervous system (ANS) and is a defensive reaction. It increases in response to pain, hunger, fear, rage and decreases in response to quiet relaxation [19]. Heart rate (HR) refers to the frequency of the heart muscle contractions of myocardium. The heart rate reflects emotional activity. Generally, it has been used to differentiate between positive and negative emotions. HR variability refers to the oscillation of the interval between consecutive heartbeats. It has been used as an indication of mental effort and stress in adults. In high-stress environments such as dispatch and air-traffic control, it is known to be a useful measure [17]. Lower heart rate is generally associated with a relaxed state or a state of experiencing pleasant stimuli while HR accelerations occur in response to exercise, emotional states, loud noises, sexual arousal and mental effort [20].

The aim of this work is the short-term recognition of the anxiety which is defined as a psychological and physiological state characterized by somatic, emotional, cognitive and behavioral components. It is a fear considered normal reaction to a stressful situation but becomes pathological when there is no real danger [21]. The following table shows several features which can be computed in various analysis domains, including statistics in time series, frequency domain, geometric analysis and their changes depending on the emotional state. We tried to determine which features are most relevant to recognize anxious state from the BVP signal (Table 1).

There may exist features within the listed features which have no bearing on the differentiation of emotion types inherently. Such these features can ultimately reduce the performance of classifiers constructed from a limited number of training samples. Steps followed to select most relevant and performant of the mentioned features to achieve the recognition system are explained in the next section.

4. Methodology

One key research problem in the Affective Computing area is the mapping between affective states and physiological states. A well-established methodology for an emotion recognition system is primordial. It consists of several steps: subject's selection, emotions induction, data acquisition and processing. All these steps aim to establish the correlation between a set of data and the internal state.

4.1. Subjects selection

Twenty-two French-speaking users recruited through universities, completed the experiment (14 males and eight females) from 23 to 26 years. Each user completed Liebowitz social anxiety scale (LSAS) [30] which gives a rate of anxiety and avoidance relative to social situations (Table 2). We have selected those with a slightly and moderate level of anxiety, the result was 20 users.