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Reaction time and physiological signals for stress recognition

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ABSTRACT

This paper investigates the potential of stress recognition using the data from heterogeneous sources. Not only physiological signals but also reaction time (RT) is used to recognize different stress states. To acquire the data related to the stress of an individual, we design the experiments with two different stressors: visual stressor (Stroop test) and auditory stressor. During the experiments, the subjects perform RT task. Three physiological signals, Electrodermal activity (EDA), Electrocardiography (ECG) and Electromyography (EMG) as well as RTs are recorded. We develop the classifier based on the Support Vector Machines (SVM) for the stress recognition given the physiological signals and RT respectively. An overall good recognition performance of the SVM classifier is obtained. Besides, we present the strategy of recognition using the decision fusion. The recognition is thus achieved by fusing the classification results of physiological signals and RT with the voting method and a further improvement of recognition accuracy is observed. Results indicate that RT is efficient for stress recognition and the fusion of physiological signals and RT can bring in a more satisfied recognition performance.

1. Introduction

In modern society, the stress of an individual has been found to be a common problem. In 2007, the research indicated that the stress was the second most common work-related health problem in the European Union [1]. Continuous stress can lead to various mental and physical problems [2] and especially for the people who always face emergency situations (e.g., fireman): it may alter their actions and put them in danger. Therefore, it is meaningful to provide the assessment of the stress of an individual. Based on this idea, we proposed the Psypocket project which is aimed at making a portable system able to analyze accurately the emotional state of an individual based on physiological, psychological and behavioral modifications. It should then offer solutions for feedback to regulate this state. The system adopts the data from heterogeneous sources, such as physiological signal, cognitive reaction and behavioral reaction, for stress recognition. In this paper, we present the feasibility and the interest of stress recognition from heterogeneous data, specially physiological and behavioral signals, which is the essential part of the research of this project.

Traditionally, to assess the individual affective state, people are asked to fill in the standardized questionnaire (e.g., Perceived Stress Questionnaire [3]) which helps to quantify the stress. In 2001, Picard et al. [4] proposed that the ability to recognize emotion should be an important part of machine intelligence and developed a machine's ability to recognize human affective state given the physiological signals, which opens a new gate to assess the individual affective state. After that, the researchers began to investigate the potential of physiological signals for stress recognition. Rani et al. [5] presented online stress detection by monitoring the heart rate variability (HRV) of a human. They chose playing video games to generate mental stress and fuzzy logic for stress detection. Picard and Healey [6] collected and analyzed physiological signals during real world driving tasks to determine a driver's relative stress level. Their proposed methods based on linear discriminant function distinguished three levels of driver stress with high accuracy. Based on these discussions, several stress recognition systems were proposed. Fletcher et al. presented the system iCalm [7]. Using a wearable sensor and network architecture, the iCalm could provide the long-term monitoring of autonomic nervous system by recording the Electrocardiography (ECG) and Electrodermal activity (EDA). Jung et al. [8] presented a mobile system using the IP-based wireless sensor networks. By analyzing the HRV in time and frequency domains, the system estimated if the patient was under the normal or stressed state. Mohino-Herranz et al. [9] proposed a system to assess the subject's stress through the analysis of ECG and thoracic electrical bioimpedance (TEB) signals. The physiological signals were recorded using customized non-invasive wearable instrumentation and the assessment processing was implemented in the Android-based smartphone.

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As can be seen, these existing systems just adopt the physiological signals for stress recognition. However, it should be mentioned that the physiological signals are not the only source of data to quantify the reactions of an individual. Intuitively, we can observe that personal reaction time (RT) may differ when an individual deals with various situations. Bolmont et al. [10] presented that the climbers' mood states may change when they are exposed to high altitude and their performance in RT differs as well. Noteboom et al. [11] studied the effect of anxiety and stressor intensity on arousal and motor performance during a pinch task. They found that cognitive arousal tended to increase with stressor intensity. Coombes et al. [12] investigated how anxiety alters the balance between attentional control systems to impact performance of a goal-directed motor task. They found that high anxiety was associated with slower RTs. The results of these researches give us the idea that not only physiological signals, but also RT is possible to be adopted to recognize if an individual is under stress state. However the existing systems pay little attention to use RT for stress recognition.

Besides, in the previously mentioned systems [7–9], only one stressor was used to elicit the stress and thus the presented recognition performance was only related to this stressor. However, in reality, there exists various stressors [13]. Since Psypocket system aims to be used in the real life, it is designed to provide good recognition performance when facing different stressors.

Based on these ideas, the objective of this paper is to show the interests of stress recognition using physiological signals as well as RT. We designed the experiments using two kinds of stressors (visual and auditory) on two different panels of subjects.

The rest of the paper is organized as follows: Section 2 describes our experiments and Section 3 explains our methodology of stress recognition. The results of recognition are presented in Section 4 and discussed in Section 5.

2. Experiment

To acquire the physiological signals related to the stress, we proposed two different experiments. The experimental protocol is aimed at eliciting different stress states of the participating subject at the pre-determined period. The first experiment used a visual stressor (Stroop test) to elicit the stress. The Stroop test [14] asks the subject to name the font color of the word when the color and the meaning of the words differ (e.g., the word "yellow" printed in green ink instead of yellow ink). This test has been used as an effective physiological stressor for stress recognition by many authors like Hainaut and Bolmont [15]. The second experiment used an auditory stressor (acoustic induction) to elicit the stress. Music is found to be effective to arouse positive and negative emotion in the research of Kim and André [16]. They observed the physiological changes in music listening. This gave us the idea that acoustic induction could be a stress stimulus in the controlled laboratory environment. The details of these two experiments are explained in the following paragraphs. Twenty-two students (ages between twenty to twenty-two years old) from University of Lorraine participated in our experiments and they were divided into two groups. The first group of ten male students participated in the experiment of visual stressor and the second group of twelve female students participated in the experiment of auditory stressor.

An experimental platform was designed for data acquisition. A screen was placed in front of the subject for the Stroop test and a joystick was placed between them. The joystick can be manipulated by the subject to point in four directions and a button is equipped on the top of the joystick. Two LEDs were put below the screen for RT test. The BIOPAC^{TM} System, consisted of the physiological sensors and amplifiers, was used to record the physiological signals. Three

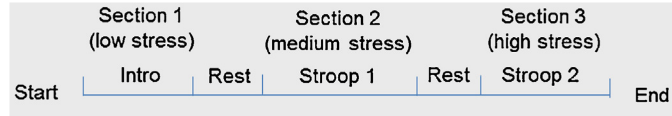

Fig. 1. Schedule of the visual stressor experiment.

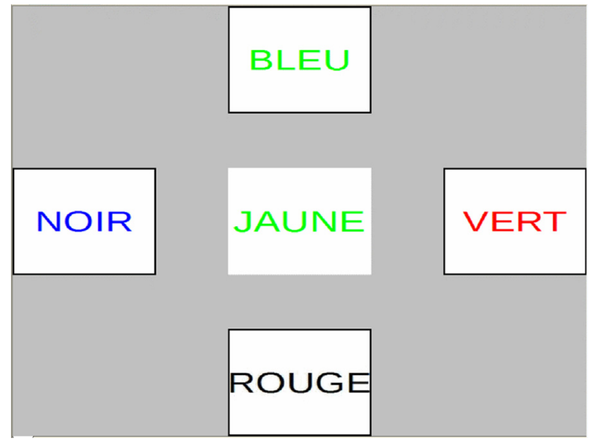

Fig. 2. Illustration of Stroop trial.

physiological sensors were used: EDA, ECG and Electromyography (EMG). The electrodes of the EDA sensor were attached to the index and middle finger of the left hand and the three-lead ECG signal was recorded with the ECG sensor on the chest. The EMG sensor was placed on the trapezius muscle (shoulder). The BIOPAC^{TM} System collected all three physiological signals and digitized these signals at a common sampling rate of 2000 Hz. During the experiment, the subject sat in the chair, wore a headset and held the joystick.

The experiment of visual stressor consists of three sections (Fig. 1). It begins with Section 1 composed of 100 consecutive RT trials. In one RT trial, when the LEDs (originally turned off) are lighted up, the subject should press the button on the top of the joystick to respond. The RT, which is the time interval between the moment when LEDs are lighted up and the moment that the subject clicks the button, is calculated and recorded. Section 2 and Section 3 are the sections for Stroop test and each section is consisted of 300 consecutive Stroop trials. We designed a computer-based interacting environment for the Stroop test. In one Stroop trial, a graphic user interface is shown on the screen. A word is written in the center of the interface with four buttons surrounding it (Fig. 2). The word is the name of a color in French and the buttons are also labeled with different colors' names in French. The subject should choose the button with the label that matched the font color of that word. The choice of the button is realized by using the joystick. When the joystick is manipulated to point in one direction, its corresponding button is chosen. For example, when the joystick is pushed to point forward, the button above the word is chosen. If the answer is not right, the subject will hear a buzz in the headset. Moreover, if the subject does not respond in 2.5 seconds, the screen will change to the next trial automatically. The Stroop trials of Section 2 are the trials without interference, which means that the word is printed in the color denoted by its name (e.g., word "jaune" (yellow) printed in yellow ink). The Stroop trials of Section 3 are the trials with interference, where the word is printed in the color not denoted by its name (e.g., word "jaune" printed in green ink instead of yellow ink). Besides, RT trials appear randomly in Section 2 and Section 3. In this way, there exist 100 RT trials in Section 2 and 100 RT trials in Section 3. The duration of Section 1 is 4 min. Section 2 lasts for 9 min and Section 3 lasts for 13 min. The duration of Section 3 is longer than that of Section 2 since the Stroop trial with interference is much