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Classification of the emotional stress and physical stress using signal magnification and canonical correlation analysis

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ABSTRACT

In affective computing, stress recognition mainly focuses on the relation of stress and photoelectric information. Researchers have used artificial intelligence to determine stress and computer identification channels. However, in applications such as health and security, Emotional stress (ES) information is usually to be alongside physical stress (PS) information, making it urgent to classify ES and PS. The thermal signals of ES and PS have yet to be classified, for which, signal amplification is offered. In this study, we propose a classification algorithm based on signal amplification and correlation analysis called Eulerian magnification-canonical correlation analysis. This signal amplification algorithm expands the signals of ES and PS in different frequency domains. Sparse coding and canonical correlation analysis then fuse the original signal and its amplified features. The extracted entropy features are used to train the correlation weight between ES and PS, which formulates stress classifications. The new classification method achieves an accuracy rate of 90%. This study can lead to a practical system for the noninvasive assessment of stress states for health or security applications.

1. Introduction

As an important physiological index, stress has attracted increasing concern. Stress has been defined in multiple ways from various perspectives [1]. One comprehensive definition of stress is that it is a biological response to a physiological or psychological stimulus [2]. The stress can be triggered by emotional stressor and physical stressor. A physical stressor has a direct effect on the body. This stressor could be the internal physical or physiological demands of the human body. An emotional stressor only causes stress by mere information that reaches the brain with no direct physical impact on the body. This information may place demands on either the cognitive (thought processes) or the emotional system in the brain. The influence of physical stress on human healthy and specific diseases (symptom) has been widely studied over the past decades [3–9]. Meanwhile, Emotional stress has been proven as one of the most significant causes of chronic health challenges. Several research studies have reported that cardiovascular events [10,11], endothelial function [12], immunological problems [13], mental health [14] and several diseases are related to emotional stress. Two distinctive stressors may affect health and specific diseases (symptom) in different ways. Accordingly, efficient classification of ES and PS is favorable to ascertain pathogenic characteristic and diagnostic approach. Moreover, classification information can be utilized to design the daily health plan for mental & physical health. Aside from its effects on health, its security features have been gradually valued by the industry. The individual ES and PS index can provide useful information (or one of the aspects) for preliminary screening and intent detection. Therefore, the classification of ES and PS is conducive to the industrial application of stress recognition. We initiated a basic research on whether one's physiological states, such as those induced by PS and ES, can be probed using electro-optics (EO) imaging technique at a stand-off distance. Our work classifies the EO characteristics of physiological responses arising from these two different kinds of stressors (physical and emotional stressors).

Emotion recognition, including stress detection (ES & PS), quantitative study, and sentiment classification, has been the focus of research over the past two decades. Numerous effective non-contact stress recognition methods have been proposed. In face of external threats, the sympathetic nervous system (SNS) of individuals triggers the known "fight or flight" response [15,16]. The SNS is one of three major components of the autonomic nervous system (ANS) along with the enteric and parasympathetic systems [17,18]. Previous studies have shown that, as one of the

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most important SNS responses, stress stimuli can induce a complex chemo-electronic analysis procedure (hypothalamic-pituitary-adrenal (HPA) axis) [19,20], and cortisol levels and heart rates (for ES) are typical stress markers. Furthermore, galvanic skin response (GSR) [21,23,38], electrocardiography (ECG) [24], fMRI [26] technologies, mobile sensing [22] and several machine vision methods [25,27] have been widely used in ES and PS recognition studies. However, some of these methods require the impossible information, that is, for participants to acquire coordination and contact data in public area. Thus, imaging-based stress recognition methods gradually received attention from the industry. Unlike non-contact methods, thermal imaging systems have the advantages of non-invasiveness, versatility, and reliability [28]. Human body temperature is very sensitive to physiological information [15,29]. Moreover, stress recognition methods emerged in an endless stream because of its non-contact characteristic. Pavlidis first observed the startling thermal signature and reported an instantaneous increase of blood demand in the periorbital region [30–33], Followed by the effective extraction and extensive research on the physiological parameters of the human body, such as sweating [34–35], blood flow velocity [36], heart rate [37,39], and breathing [33]. ES-sensitive facial muscles and regions (such as the supraorbital, cheek, and perinasal areas) are also extracted and studied [34,40–43,56]. Recent studies have employed Smartphone sensors to model ES and PS [22,45,46] detection, and this non-invasive method achieved encouraging experimental result. Except for information extraction through direct imaging, non-physiological data, such as occupation and personal experiences, are added as ES stress recognition components [48,49]. Blood perfusion variation caused by mood changes (such as pressure, fear, and joy) is studied using facial imprint information [50–55,57,58]. However, the study these variations is not associated with concrete emotions, which further challenges ES and PS recognition.

The direct association of facial imprint signals with stress has shown no progress, although we successfully extracted weak facial signals for this purpose [59]. Owing to the lack of major breakthrough research on the classification of ES and PS, this paper directs the frontier of industrializing stress recognition by focusing on the establishment of a set of non-contact imaging-based classifications for ES and PS.

Apart from speech emotion recognition [60–65] and physiological signal-based emotion classification methods [66–69], imaging-based emotion classification has been studied for a long time. Current emotion classification methods have mainly focused on facial expression recognition [70]. Furthermore, emotional behavior has been widely studied [71–74], particularly in terms of intent [75–78]. The effort to study emotional visual scene, facial expression signal and emotional meta-features provide effective method to monitor emotional behavior [79–81]. The use of two-dimensional (including videos) [82–86] and three-dimensional imaging [87–90] for emotion recognition is still evolving. Facial expressions cannot clearly distinguish ES from PS, which makes these expressions easy to disguise [15,44,47]. To separate the two, information on the two kinds of stress on human faces should first be explored. Sparse coding [91–94], blind source signal analysis, and correlation analysis [95–98] have drawn attention to image classification and data mining. Meanwhile, a novel signal amplification method called Eulerian magnification (EM) provides a powerful extraction of hidden signals [39]. The empirical mode decomposition (EMD) algorithm has been used to extract classification information; however, this algorithm has achieved minimal progress because of the lack of profound analysis on hidden signal extraction [99].

To overcome the aforementioned difficulties, we propose a thermal imaging-based classification method for ES and PS called Eulerian magnification-canonical correlation analysis (EM-CCA). This algorithm can effectively decompose the thermal signals of PS and ES through signal amplification and image fusion, thereby providing reliable stress classification. This paper is structured as follows: Section 1 introduces the study, Section 2 presents the main framework of the method, whereas the experimental results and analysis are demonstrated in Section 3. Sections 4 and 5 present the discussions and conclusions, respectively.

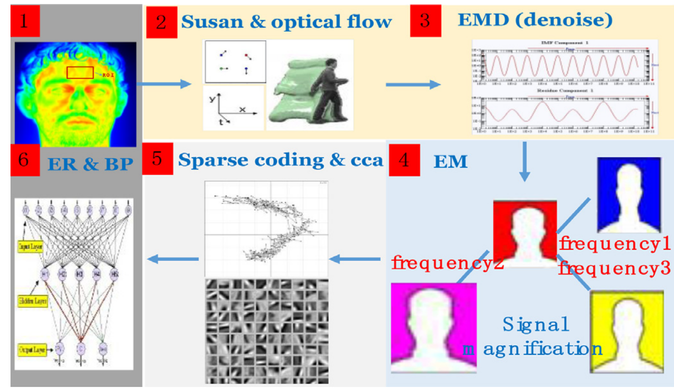

Fig. 1. Flowchart of the algorithm.

2. Methodology

The well-known temperature variation under ES and PS does not have structural differences. One temperature cannot distinguish between the two kinds of stress. Moreover, temperature variation and stress markers cannot be directly connected [28,100]. The temperature difference and its frequency spectrum are determined by complicated emotional and physiological factors. The partial discrimination of human emotional states through pattern differences, such as heart rates, is difficult [22,24,69]. Furthermore, the data collected by non-contact means has no background information, which leads us to further decompose thermal signals to acquire necessary information. In this study, we propose the EM-CCA algorithm to decompose and reconstruct the classification information we require.

This algorithm uses entropy feature as target for ES and PS classification. The algorithm has two parts. First, the signal is amplified by the EM algorithm to enhance the psychological signal. Second, the image fusion method is employed to extract the entropy feature for further classification. The methodology is structured as follows: 2.1 provides signal amplification using EM algorithm. Before amplification, Corner point detection and optical flow method are employed to eliminate the effect of the participants' tremble. Empirical model decomposition algorithm is used to remove noise from the image information. Section 2.2 shows the entropy features acquired from single thermal signals. After obtaining the amplified signals, image fusion, based on sparse coding and canonical correlation analysis (CCA) is used to obtain the entropy features for stress classification. Rényi entropy (ER) is used as the classification criterion. The resulting ER (for three intervals) becomes a parameter and an input into a back propagation (BP) neural network model for training. Fig. 1 presents the flowchart of the entire algorithm.

2.1. Feature extraction and amplification calculation of ES and PS signals

The Eulerian magnification (EM) algorithm is employed to amplify stress signals in order to extract the feature model of thermal signals. These psychological signals are hidden in the image signals; however, they are weak and require sorting from