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Arousal level classification of the aging adult from electro-dermal activity: From hardware development to software architecture

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ABSTRACT

The fast aging of the population around the world makes ambient intelligence-based assistive technologies essential for sustainable and efficient health-care systems. Aging adults who decide to live alone at home need constant monitoring to control their health status and quality of life. This work introduces a new wearable device that continuously monitors the emotional state of the elderly. Electro-dermal activity (EDA) is used to classify the aging adults into two groups: sleepiness and stressed. The results report a performance of more than 83% of accuracy by using exclusively time and magnitude features from EDA events.

1. Introduction

In Europe, the total population older than 65 is expected to increase from 22% by 2015 to 27.5% by 2050, while the population aged over 80 may grow more than 4% in the same period [1]. According to experts, this increasing trend has a deep impact on several aspects which will affect the quality of life of millions of people around the world [2]. Developing countries are presenting different actions aiming to palliate these effects, which include changes in pensions and social security systems, among others. From a technological point of view, it is imperative to take advantage of emerging assistive technologies together with ubiquitous and pervasive computing in order to increase the quality of life of aging people who decide to stay at home. Moreover, the innovation and development of assistive technologies might help in saving resources from medical services. In this regard, the last reports published by the World Health Organization show that cost reduction in health-care systems is one of the most promising challenges in the upcoming years [3].

In this sense, many researchers are focusing their efforts in developing novel assistive systems based in improving health-care through tele-medicine equipments, fitness devices and/or entertainment systems [4]. However, only a few efforts have been made towards monitoring and regulating the aging adult's arousal state, which is usually indicative of stress or mental illness. In fact, these are fundamental aspects in the self-perception of well-being [5]. In addition, the lack of human–machine interfaces in interpreting the patients' emotional states is a severe drawback [6].

Moreover, continuous monitoring of arousal levels in the aging adult is essential for understanding and managing personal well-being regarding mental state. Indeed, a number of physiological features have been widely used in the

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literature. The proposed features measure alterations of the central nervous system [7–9]. One of the physiological markers corresponds to the electro-dermal activity (EDA), as it is able to quantify changes in the sympathetic nervous system. Therefore, EDA has been tested in numerous works to assess the arousal level of the patients. Wearable sensors are most appropriate for continuously measuring the EDA signal from the patients, given their performance in providing detailed user-specific information. Moreover, these sensors are greatly valued due to their lightweight and wireless communication capacities with either a computer or other wearable sensors [4].

Furthermore, it is crucial to assemble a real time system to react upon the ongoing activity of the elderlies in order to regulate their arousal level. Such a system is formed by clusters of sensors and actuators capable of changing the environment. Consequently, this kind of system should be able to recognize different emotional contexts by using the continuous flow of information provided by a number of sensors such as wearable sensors (physiological measurements) and environmental sensors (temperature, humidity, and so on), among others. And, simultaneously, the system provides personalized services by adapting the reaction to the aging adults' needs. In this regard, Ambient Intelligence (AmI) has emerged as a promising approach to face this challenge. Indeed, AmI takes advantage of pervasive computing, sensor networks and Artificial Intelligence (AI) [10,11].

Taking into account the aforementioned considerations, the present work aims to develop a novel and unobtrusive wearable device capable of measuring the arousal level of the elderly at home in long term. The described wearable device and software architecture are part of an ongoing project dedicated to emotional regulation of the elderly. The main purpose of the system is to induce a calm state or to decrease the arousal level of an elderly who suffers from a high degree of activation. Indeed, it has been reported that older adults at home are prone to suffer from loneliness, which can lead to mental disorders like anxiety, stress and even major depression [12]. Consequently, some kind of actuation is required to change or regulate a high activation state. Nevertheless, the first step is to correctly detect and classify high arousal levels in a long term in elderlies. In this regard, very few works have reported EDA measurements in a long term [13,14]. However, to the best of our knowledge, this is the first work exclusively aimed to detect arousal variations in aging adults over time.

The remainder of the paper is organized as follows. Section 2 describes the related work. Sections 3 and 4 describe the hardware design and system architecture, respectively. In Section 5, the population under study and the signal processing algorithms that obtain the physiological markers to carry out the classification are described. In Section 6, the features are assessed for the sake of showing the classification efficiency of the model. Finally, the conclusions of this work are presented in Section 7.

2. Related work

In the last years, a number of theories have emerged attempting to define and classify emotional states. However, the most used emotion classification model is the two-dimensional scheme proposed by Russell [15]. The scheme assesses how pleasant or unpleasant a stimulus is (valence) and the excitement or calmness a stimulus produces (arousal). Nevertheless, some emotions related with a high arousal level like negative stress or fear have received an important attention, specially in elderlies who decide to live alone at their home [16]. Indeed, suffering from chronic stress or fear may lead to sustained state of hyper-arousal, provoking important mental disorders such as anxiety and depression [12]. Consequently, it is important to make use of assistive technologies to control or reduce the arousal level in the elderly as a preventive action. In other words, it would be interesting to deactivate the older adult and relax him/her in order to improve wellness. Traditionally, research on arousal has been carried out by studying physical and physiological aspects, including face expressions, speech recognition and physiological markers, among others.

2.1. Facial expression recognition

Systems based on facial expression recognition have received a great deal of attention in the past decades. Such systems are commonly based on geometrical features where important facial components such as mouth and eyes are characterized. One most common used system is the Facial Action Coding System (FACS), which offers a detailed decomposition of facial muscle movements into units. The movements are related to the contraction of a specific set of facial muscles, which produces the expression [17,18]. In this regard, facial recognition has been used to assess the anxiety level of subjects who are exposed to low and high arousal stressors [19]. Similarly, high and low self-rated anxious segments are coded using FACS, while subjects under study describe an anxious past events and answer stressful and not stressful questions [20]. The results show that more eye blinks and facial movements, involving elements of the fear expression, are produced in stressful events [20]. More recently, facial expression recognition has been tested utilizing hidden Markov models and facial animation parameters for discriminating between different arousal-related emotions such as fear and anger, among others [21]. In the same line, facial expression charts are estimated for each individual using high arousal stimuli to obtain temporal changes of stress using non-linear features and complex classifiers [22]. The authors report differences in facial expressions when influenced by stress among different subjects [22]. Finally, recent studies have used facial recognition to quantify stress and hyper-arousal situations in drivers [23].

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