Recognizing Emotional States Using Physiological Devices

Ali Mehmood Khan(✉) and Michael Lawo

TZi-Universität Bremen, Bremen, Germany
{akhan,mlawo}@tzi.de

Abstract. Emotional computing is a field of human computer interaction where a system has the ability to recognize emotions and react accordingly. Recognizing Emotional states is becoming a major part of a user's context for wearable computing applications. The system should be able to acquire the user's emotional states by using physiological sensors. We want to develop a personal emotional states recognition system that is practical, reliable, and can be used for health-care related applications. We propose to use the eHealth platform which is a ready-made, light weight, small and easy to use device for recognizing few Emotional states like Sad, Dislike, Joy, Stress, Normal, NoIdea, Positive and Negative using decision tree classifier. In this paper, we present an approach to build a system that exhibits this property and provides evidence based on data for 8 different emotional states collected from 24 different subjects. Our results indicate that the system has an accuracy rate of approximately 91 %. In our work, we used three physiological sensors (i.e. BVP, GSR and EMG) in order recognize Emotional states (i.e. Stress, joy/Happy, sad, normal/Neutral, dislike and no idea).

Keywords: Emotional states · Electromyogram · Blood volume pulse · Galvanic skin response · Skin temperature · International Affective Picture System · Machine learning classifier · User studies

1 Introduction

It is hard to express your own emotions; no one can accurately measure the degree of his/her emotional state. According to Darwin, "….the young and the old of widely different races, both with man and animals, express the same state of mind by the same movement" [16]. According to Paul Ekman, there are seven basic emotions which are fear, surprise, sad, dislike, disgrace, disgust and joy [14]. The concept behind emotional states (also known as affective computing) was first introduced by Rosalind Picard in 1995 [2]. Since then the affective computing group have produced novel and innovative projects in that domain [3]. Emotional states recognition has received attention in recent years and is able to support the health care industry. Emotions and physical health have a strong link in influencing the immune system too [15]. Due to untreated, chronic stress; occurrence of an emotional disorder is more than 50 % [6]. According to Richmond Hypnosis Center, due to stress; 110 million people die every year. That means, every 2 s, 7 people die [4]. According to American Psychological

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Association, in 2011 about 53 percent of Americans claimed stress as a reason behind personal health problems [5]. According to Dr. Alexander G. Justicz, in the 21st century, stress is a huge problem for men [9]. Stress affects our health negatively, causing headaches, stomach problems, sleep problems, and migraines. Stress can cause many mouth problems, the painful TMJ (temporomandibular joint) syndrome, and tooth loss [7]. "Stress has an immediate effect on your body. In the short term, that's not necessarily a bad thing, but chronic stress puts your health at risk" [8]. Long term and intense anger can be caused of mental health problems including depression, anxiety and self-harm. It can also be caused of "high blood pressure", "cold and flu", "coronary heart disease", "stroke", "cancer" and "gastro-intestinal problems" [13]. "If you have a destructive reaction to anger, you are more likely to have heart attacks" [12] whereas "an upward-spiral dynamic continually reinforces the tie between positive emotions and physical health" [17]. Although the negative effects of stress are known to people, they choose (deliberately or otherwise) to ignore it. They need to be forcefully notified, that they must shrug off negative emotions; either by sending them calls or some video clips/text messages/games [10]. According to number of studies, negative thinking or depression can adversely affect your health [19]. Probably automatic and personal applications can be very helpful if it can monitor one's emotional states and persuade people to come out of negative emotional states. According to William Atkinson; "*The best way to overcome undesirable or negative thoughts and feelings is to cultivate the positive ones*" [18]. Emotional recognition technology can tackle this problem as it is able to monitor an individual's emotional states. This kind of system can also send an alarming call to a person when he is in a negative emotional state for long time or notify the caregivers or family members. The system can also log an individual's emotional states for later analysis. In some cases, especially in heart diseases, emotional states are also required along with the physical activities and physiological information for doctors in order to examine their patient's conditions when he is away from the doctor's clinic [11]. We want to develop a system for recognizing emotional states using physiological sensors which should be able to identify a few emotional states like sad, dislike, joy, stress, normal, no-idea, positive and negative.

2 Related Work

Recognizing emotional states by using automated systems have increased in recent years. Researchers developed systems for recognizing emotional states using speech [23–25], facial expressions [26–28] and physiological devices [20–22, 29, 30]. In this research, we want to recognize different emotional states using body worn physiological devices (EMG, BVP, GSR and temperature). Researchers used physiological devices in order to recognize for different emotional states like sad [20–22, 30], joy/happy [20–22, 30, 31], normal/neutral [21, 30, 31], negative [29] etc. However, the aforementioned researches have used different physiological devices in their work. For example; some researchers recognized emotional states using EEG, GSR and pulse sensor and they recognized joy, anger, sad, fear and relax. Audio and visual clips were used as a stimulus for eliciting the emotions [20]. Some researchers recognized

emotional states using ECG and they recognized Happiness, Sad, Fear, Surprise, Disgust, and Neutral. Audio and visual clips were used as a stimulus for eliciting the emotions [21]. Some researchers recognized emotional states using ECG, EMG, skin conductance, respiration sensor and they recognized Joy, anger, Sadness and Pleasure. Music songs were used as a stimulus for eliciting the emotions [22]. In another case, researchers gathered the data from the "blood volume pulse", "electromyogram", "respiration" and the "skin conductance sensor". They conducted 20 experiments in 20 consecutive days, testing around 25 min per day on each individual. They figured out neutral, anger, hate, grief, love, romantic, joy and reverence emotion states from the data. They got 81 % classification accuracy among the eight states [31]. Different techniques can be used as a stimulus for eliciting the emotions i.e. pictures, video clips, audio clips, games etc. In our work, we used International Affective Picture System (IAPS) for stimulation. IAPS is widely used in experiments studying emotion and attention. The International Affective Picture System (IAPS) provides normative emotional stimuli for emotion and attention under experimental investigations. The target is to produce a large set of emotionally-evocative, standardized, color photographs, inter nationally-accessible that includes contents under semantic categories [32]. Above mentioned researchers used different parts of body but in our research we used only left arm for the sensor placement.

3 Hypothesis

The physiological data measured by wearable devices (EMG, blood volume pulse, and skin conductance sensor) indicate which emotion state (Sad, Dislike, Joy, Stress, Normal, NoIdea, positive, Negative) the person is in using machine learning classifier (J48 and IBK).

4 Experimental Methodology

We developed following systems for the user study.

4.1 eHealth Platform and Application

We used eHealth platform [1] in order to recognize emotional states (Fig. 1) and connected Raspberry Pi [41] to eHealth platform (Fig. 2).

The eHealth sensor comes with few sensors like 2D Accelerometer sensor, Blood pressure sensor (Breathing), Pulse and oxygen in blood sensor, body temperature sensor, airflow sensor, Electrocardiogram sensor (ECG), Electromyography sensor (EMG) and Galvanic skin response sensor. We used Galvanic skin response sensor, body temperature sensor, Electromyography sensor (EMG) and we used another blood volume pulse sensor [40]. We connected 'GSR, 'EMG' and 'BVP' to the board. We wrote a piece of code which reads the values from the aforementioned sensors and writes it to a network port.

Fig. 1. eHealth platform

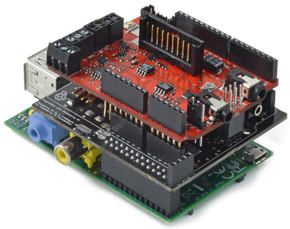

Fig. 2. Raspberri pi with eHealth platform

4.2 IAPS and Its Application (Application Stimulus)

We got an access to IAPS [32] images and these images are already used by several researchers for emotional computing [33–39]. We implemented an application in C#. net that shows participants' IAPS images in a sequence in order to change participants' emotional states and also states the starting and ending time for each IAPS image during experiments. After showing participants five different images from each group, our application used to ask participants about their current emotional state by using the Likert scale (as shown in below figure) approach. We chose 100 IAPS images from different categories and presented it in following order.

1. Sad (5 images) Questionnaire Dislike (5 images) Questionnaire Joy (5 images Questionnaire Stress (5 images) Questionnaire
2. Dislike (5 images) Questionnaire Joy (5 images Questionnaire Stress (5 images) Questionnaire Sad (5 images) Questionnaire
3. Joy (5 images Questionnaire Stress (5 images) Questionnaire Sad (5 images) Questionnaire Dislike (5 images) Questionnaire
4. Stress (5 images) Questionnaire Sad (5 images) Questionnaire Dislike (5 images) Questionnaire Joy (5 images Questionnaire
5. Stress (5 images) Questionnaire Joy (5 images Questionnaire Dislike (5 images) Questionnaire Sad (5 images) Questionnaire

The images were shown as a slide show with a timer of 5 s for each image. For the questionnaire we used radio buttons and participants had to choose one emotional state, the application also stores the participants' personal information i.e. age, gender, height and weight. Participants were asked to wear sensors on their left arms, palms and fingers (Fig. 3). They were also required to perform the experiments twice; the first experiment was useful in getting the participants to familiarize themselves with the setup, while the second attempt was actually used for analyzing their data.

Fig. 3. Participant is wearing sensors

5 Results and Analysis

We recruited 26 participants (21 males, 5 females) for our experiment setup; two of them could not complete the experiments so we ended up with 24 participants (19 males, 5 females). The range of participants' age was from 20 to 44 (mean 26.17, SD 5.14) and ranged in BMI (body mass index) from 18.7 to 26.6 (mean 21.44, SD 2.17). Participants were required to conduct the experiment twice and on different days. They were asked to choose one of the following 'Emotional states' during experiments:

Normal, Sad, Dislike, Joy, Stress and No-Idea

We received values from three sensors i.e. EMG, GSR and BVP where sample rate was around 650 Hz. Our experimental setup was able to change participants' emotional states. Only four of the participants chose all of the given emotional states. This was due to the fact that it was hard for the participants to distinguish between sad, dislike and stress. Also being asked to distinguish between joy and normal during experiments was not a straightforward task. That also explains why some emotional states were ignored by participants. "*As everyone knows, emotions seem to be interrelated in various but systematic ways: Excitement and depression seem to be opposites; excitement and surprise seem to be more similar to one another; and excitement and joy seem to be highly similar, often indistinguishable*" [43]. Therefore, we generated another dataset from our experimental data; we categorized emotional states into two collections:

- Positive {Joy, Normal}
- Negative {Sad, Dislike. Stress}; 'No-Idea' is excluded

Now, we have the following types of datasets:

- Type1: It contains {Normal, Sad, Dislike, Joy, Stress and No-Idea}
- Type2: It contains {Positive and Negative}

Due to the fact that it was a huge dataset, it was not possible for WEKA [44] application to process the data of all 24 participants together. Therefore, we chose small portions of data randomly pertaining to each emotional from each participant. We got two types of data i.e. "Two-Class" and "Six-class". We applied J48 and IBK classifiers with 10-fold cross validation.

Our results show that J48 and IBK classifiers were able to classify the instances with the accuracies of 97.7584 % and 95.4684 % respectively for 'Two-Class'. J48 and IBK classifiers were also able to classify the instances with the accuracies of 96.5014 % and 91.9333 % respectively for 'Six-Class' (Tables 1 and 2).

Table 1. Confusion Matrices; Two class

	a	b
J48	394817	20401
	9917	927355
IBK	384330	30888
	30402	906870

a = Positive;
b = Negative

Table 2. Confusion Matrices; Six class

	a	b	c	d	e	f
J48	239926	4133	2313	1455	588	273
	3780	419739	4174	3533	1861	617
	2279	5123	268858	2955	683	320
	1543	4199	2577	245845	484	232
	606	2128	842	572	130597	255
	309	704	433	341	251	62123
IBK	227624	8887	5627	3826	1982	742
	9218	400731	10389	7895	4142	1329
	5882	11613	254002	5741	2222	758
	4024	8568	5841	233997	1748	702
	1613	3800	1989	1513	125707	378
	753	1241	789	670	395	60313

a = Sad; b = Dislike; c = Joy; d = Stress; e = Normal;
f = NoIdea

6 Conclusion and Future Work

Our system was able to recognize the aforementioned emotional states by using physiological devices and J48 (decision tree) and IBK classifiers with high accuracies. Results have shown that few physiological devices are enough for recognizing required emotional states ('Sad', 'Dislike', 'Joy', 'Stress', 'Normal', 'No-Idea', 'Positive' and 'Negative'). This prototype is only a "proof of concept" and our results show that our approach can identify the above mentioned emotional states independent of BMI (body mass index) and age group. The physiological sensor has to be fixed properly on the participants' skin in order to predict their emotional states successfully. We will conduct more user studies where we will use physiological data and facial expressions for recognizing these emotional states.

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