Are Computers Capable of Understanding Our Emotional States?

Min Cheol Whang[1], Joa Sang Lim[1], Kang Ryoung Park[1], Youngjoo Cho[1], and Wolfram Boucsein[2]

[1] Sangmyung University, 7 Hongji-dong, Jongro-gu, Seoul, Korea
[2] University of Wuppertal, Max-Horkheimer-Str. 20, 42119 Wuppertal, Germany
{whang, ycho, jslim, parkgr, ycho}@smu.ac.kr, boucsein@uni-wuppertal.de

Abstract. As emotion provides an important clue for communication, the computer needs to be more sympathetic to users' commands in the context of their emotion. A challenging attempt has been made to develop an emotional computer, which reads such physiological signals as photoplethysmogram, electrodermal activity and skin temperature and analyzes them online with a rule base into human emotion. We adopted a two-dimensional emotion model and a number of empirical studies have been conducted to find out some valid physiological parameters and to map them with nine categories of human emotions. Some research challenges were found that need to be addressed until the emotional computer comes to the market.

Keywords: Emotion in HCI, Emotional computer, Psychophysiology, Emotional mouse.

1 Introduction

Research into human computer interaction (HCI) has concentrated in the past on cognitive issues such as effectiveness and efficiency, easy-to-understand menus, and appropriate temporal structures [1], [2]. While interacting with a computer, however, users experience emotion, which certainly affects HCI. Emotion has been often regarded as an important context from a communication point of view [3]. However, it's role has been less clarified in HCI [4]. Positive emotions often result in faster, simpler and more flexible information processing strategies, while negative ones may result in more systematic strategies but also slow down HCI substantially [5], [6]. Taking emotion into account as a key for a satisfying HCI, a number of studies addressed this problem recently [7], [8]. To recognize human emotion automatically, HCI studies rely on diverse measures such as facial expressions, spoken words, body gestures or physiological signals [9], [10]. These measures may be subject to various limitations such as environmental conditions (e.g. lighting, audio recording) or obtrusiveness. The present study aimed to continuously record the user's emotion during HCI by means of psychophysiological methods as unobtrusively as possible, perform an online analysis of the user's emotional state and respond appropriately to it.

D. Harris (Ed.): Engin. Psychol. and Cog. Ergonomics, HCII 2007, LNAI 4562, pp. 204 – 211, 2007.

2 Methods

2.1 Emotional Model

This study has adopted a two-dimensional model of emotion suggested by Larsen and Diener [11]. All emotions can be located on circumplex in the two-dimensional space made up from valence and arousal. Emotions are classified in each of the four quadrants made up by the two bipolar axes: pleasantness (P) vs. unpleasantness (U) and arousal (A) vs. relaxation (R). The four quadrants were named after the combinations of the axes (U-A, P-A, U-R and P-R) as shown in Fig. 1. In an earlier study, the present authors successfully probed the usability of the two-dimensional system for monitoring the basic emotional states by means of psychophysiological measures [12]. The four basic emotions were induced by different combinations of olfactory and auditory stimuli. Over the emotional treatment, recorded were electrocardiogram (ECG), electrodermal activity (EDA) and four channels of electroencephalographic activity (EEG) along with regularly measured subjective emotional states. Multivariate combinations of psychophysiological parameters figured out to be superior to any single measure in detecting the subject's emotional state.

2.2 Physiological Measures of Emotion

Any physiological approach to HCI would bring about obtrusiveness, which is the most evident for EEG. Thus, autonomic nervous system measures were selected for these needs. A measurement device called "emotional mouse" (see Fig. 2) was specially constructed for recording three measures that cover the most salient aspects of autonomic activity, i.e., electrodermal activity (EDA) as an indicator for pure sympathetic activity [13], skin temperature (SKT) for parasympathetic activity and photoplethysmogram (PPG) for arousal and orienting. EDA is a slowly changing signal and rising of its level means an increase of tension. SKT is also a slow signal, but rising means an increase in relaxation. PPG is a relatively fast signal with a peak about every 0.8 second, which is correlated with the heart beat. Thus, heart rate (HR) can be derived from PPG as an indicator for arousal vs. relaxation, and the modulation of the PPG volume amplitude provides a measure of orienting.

2.3 General Outline of the Algorithm

Built into the computer was an emotion processor to measure and analyze physiological signals continuously recorded from the users. Sensors, which were designed to be wearable and comfortable with a minimal burden from their attachment, were used for recording. The signals were amplified, filtered, and digitized by a data acquisition system designed as small and light as possible. Automatic noise detection and removal should be performed according to pre-defined specific algorithms. The pre-treated signals were processed to extract appropriate physiological parameters that were qualitatively normalized based on a defined state of emotional neutrality. These normalized data were referred to a special algorithm or rule base for evaluating the user's current emotional state. Both measured and processed data were stored in the database, which can potentially upgrade the algorithm or rule base. Since the subjective report played a central role in determining the qualitative aspects of any emotion, it was necessary to confirm the emotion evaluated by recording the user's subjective emotional state during a data acquisition phase and save it together with the physiological measures in the database. These confirmed data were used to upgrade the database for the algorithm and/or the rule base. Furthermore, the system was trained for an evaluation of an individual user during a learning process. An emotion indicator was used to present the user's emotion on the screen. In case of a negative emotion being detected, the program initiated a service of helping the user to have a more positive emotion.

2.4 Neutral Band for Reference

Computer users stay comfortable without any noticeable changes in their emotion with respect to arousal and valence during most of the time. Thus, the four quadrants defined by two-dimensional model as outlined in 2.1 are not sufficient for explaining a region for the neutral state of emotion. However, such a region of neutral emotion is needed as a reference state, from which the non-neutral emotions should be defined. Therefore, the emotional model was refined by adding a neutral band to the original emotions as shown in the left panel of Fig.1.

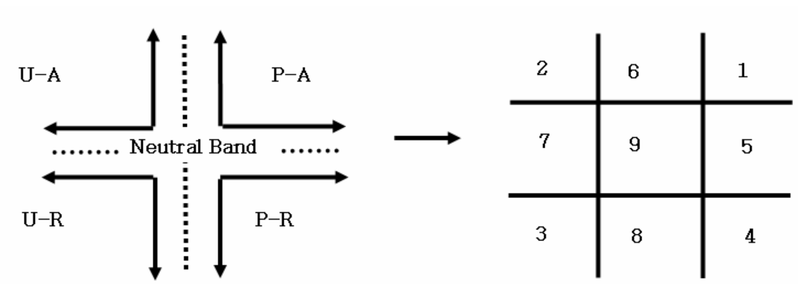

Fig. 1. Neutral Band of Emotion

Taking such a neutral band into account for the boundary among each pair of the quadrants and having an additional neutral-neutral field in the center increases the number of emotions from 4 to 9, as can be seen in the right panel of Fig. 1.

The neutral band was defined separately for each physiological measure. Because the sensitivity of the measures may vary over different persons, neutral bands were defined separately for each individual. A relatively narrow neutral band corresponds to high sensitivity but low accuracy of determining the emotion, and vice versa. During the system's adaptation process, subjective assessments of emotion were used to automatically adjust the neutral bands wider or narrower. Therefore, the neutral band was different in the physiological signals within a user and among users at the same time.

2.5 Rule Base for Emotion Determination

To minimize any individual differences in physiological readings, a neutral band was employed as a reference as discussed earlier. Given this, the percent variation of incoming physiological signals from the defined neural band was calculated as shown in Equation 1.

$$E = (C-N)/N \tag{1}$$

E is expressed in percent and equals the increase or decrease of each signal from the neutral state (N) to the current state (C). These normalized values of the physiological signals were used to set the rule base which used to determine emotions. The rule base used three different entries for signal changes: an increase (+E) or decrease (-E) from the neutral band, or a zero value (0) in case of no deviation from the neutral band. Given these three entries (+E, -E, and 0) and three physiological measures (PPG, EDA, and SKT) resulted in 27 different patterns. Six combinations were eliminated because they showed an opposite direction for physiological reasons. The all-zero case was considered as a reference and therefore also eliminated, so that 20 different combinations of physiological changes remained for setting up the rule base. As a consequence, different patterns may result in the same emotion.

Besides individual differences in the neutral band, there are also individual differences to be taken into account for the rule base. For example, a 5% increase of SKT, a 10% decrease of EDA and a 15% increase of PPT from the neutral band may indicate relaxation in one person, while 20% increase of SKT, a 5% decrease of EDA and a 10% increase of PPT may indicate relaxation in another person. Therefore, the values of the expression E were individualized for all nine emotions. The personal set of rule base was automatically updated by using the subjectively reported emotion.

2.6 Subjective Confirmation of Emotion

The physiological signals do not fully account for the variation in the emotional states of individual users and thus, subjective confirmation of the emotion is required. In addition to the psychophysiological measures of emotion, subjective ratings of perceived arousal and valence were obtained in regular intervals. A pop-up window was presented, asking the subject to click on one of three buttons, representing relaxation, neutral arousal and high arousal state. Thereafter, another window asked for unpleasant, neutral or pleasant feelings. To form a stable data base for each individual, a subjective evaluation was performed every two minutes during the initial stage of emotion evaluation. If the incoming physiological signals were not in accordance with the subjectively reported emotion, the rule base was adjusted. After having reached a stable data base, the distances between subjective evaluations increased to five minutes or more.

2.7 Hardware and Software Development

To obtain the least noisy physiological readings of PPG, EDA and SKT, an emotional mouse was carefully designed to establish a firm contact between the bio-sensors and human palm. Ten design factors were taken into consideration during product development. The width (9-10 cm) and the length (18-19cm) of the emotional mouse were determined in reference to Korean anthropometric data of twenty year-aged in 1992.

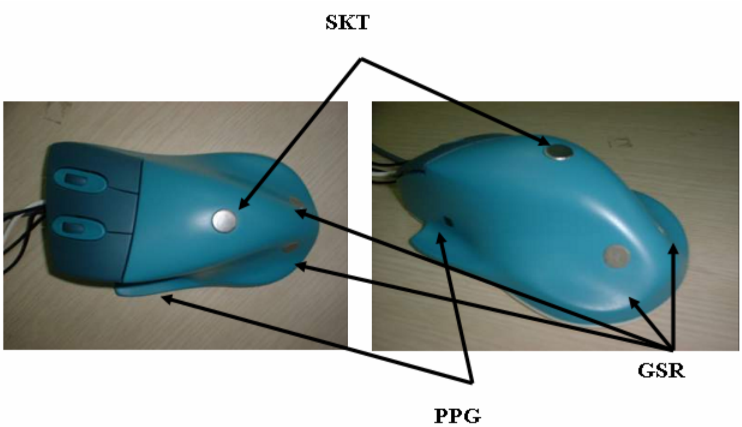

Fig. 2. Emotional Mouse

Fig. 2 shows the sensor location in the emotional mouse. It uses three curvatures that reflect the natural form of the hand; the thenar-hypothenar curvature for EDA (Fig. 27, [13]), the curvature of the inner palm for SKT, and a special thumb holder for the PPG, preventing the thumb from moving up- and downward.

A customized integrated circuit board connecting the emotional mouse and the PC was constructed for acquiring, filtering, amplifying, and AD converting PPG, EDA and SKT signals. It communicated with the PC via RS 232. Since data recording and processing lead to an excessive consumption of CPU, causing the computer to operate slowly, client-server architecture was employed. The client PC had only the functions of recording physiological signals and indicating the results of the emotion evaluation. The server performed the emotion analysis and its evaluation, and also the updating of both the rule base and the data base. The information of the subjective emotional state was sent to the server together with the physiological signals. The server set and updated the neutral emotion band and the rule base, using new qualitative physiological data. The actual emotion was determined and sent to the PC for display. In addition, the PC indicated the results of emotion evaluation by a pop-up emotion indicator, consisting of bars graphs, verbal explanations and a schematic face icon (Fig. 3).

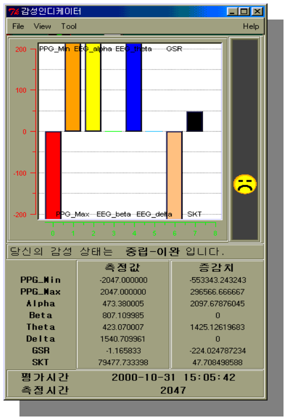

Fig. 3. Pop-up emotion indicator

For the icon, the mouth angles can be down, neutral or up, combined with three different orientations of the eyebrows, resulting in nine different icons that represent the different emotions. The user can decide to see additional detailed information, given in numbers that represent results of physiological measures. The icon stays on the screen continuously until being updated.

The subjective confirmation was used to identify the current emotion. It was correlated with the incoming physiological data and also continuously used to re-evaluate the neutral emotion. During on-line processing, the data base was continuously developed and updated. It consisted of the stored physiological parameters together with the E values for the 9 emotions. This data accumulation provides a continuously improving emotion evaluation that also takes personal characteristics into consideration.

2.8 Negative Emotion Recovery Service

The negative emotion may certainly be the state where the users do not want to stay on. Thus, the emotion computer should be capable of providing a service to mitigate negative emotion, once it is detected. This service was elicited by detecting the unpleasant emotions 2 and 3 (see Fig. 1). First, a pop-up window was presented, asking the subject to confirm the acceptance of this service. If accepted, the subject's favorite multimedia data base was provided, offering his/her favorite music, video clips and the possibility to get rid of the negative emotion via playing a short video game. For this, the multimedia preference of the user was determined prior to using the emotional computer system.

2.9 Empirical System Verification

The emotional computer has been empirically verified as to the consistency between qualitative emotion as assessed by the emotional computer and subjective reports of emotion. Five voluntary subjects took part in the experiment. The subjects rated their emotions 100 times for three days. Results showed 70-90% identification of the subjective emotion by the psychophysiological evaluation. The results will be presented in detail elsewhere. In general, the assessment was more accurate for arousal than for valence.

3 Discussion

During the past, research has focused mainly on technical aspects of user interfaces such as the customization of graphical interfaces and the design and behavior of interface objects [1]. More recently, there has been a growing interest in the principle of user-centered design in user interfaces, including not only users' cognition but also their emotion into computing environment [4] [14]. Thus, the time has come to challenge the behavioral issues of emotion in the context of HCI. Most pertinent questions will be: "what influences does human emotion have on the performance of computer tasks?" and "what aids should be provided to let users stay with their comfortable feelings?"

The first aim of the present study was to propose a theoretical framework for an emotional computer. It consisted of three functional components of (1) physiological measurement, (2) emotion recognition and (3) adaptive feedback. Based on these principles, we successfully developed an emotional computer with the aid of a specially-designed mouse for sensing the user's autonomic responses. As physiological signals, PPG, EDA, and SKT were recorded and forwarded to a server for data processing. The bio-signals collected were then analyzed to recognize the user's emotional state. The evaluation of emotion was individualized according to updating the neutral band and the rule base by means of subjective confirmation. The emotional computer was designed to provide a multimedia service in case of negative emotion to make it positive. An empirical verification with five student subjects showed 70-90% accuracy in identifying the subjective emotional state. Given the amount of data collected, these results are encouraging compared to the accuracy of the earlier study [12].

In relation to the theoretical framework provided, a number of research issues can be raised. Firstly, the adaptive nature of emotional computers assumes their actions in good tune with the subjective emotion of users. Such adaptability is to a great extent trusted to the signal processors of emotional computers. Thus, research should be made to determine under what conditions mathematical models perform robustly (e.g., neural networks [9]). Secondly, the apparatus to be attached to the human body should be kept to a minimum size and be unobtrusive to users. The device may include some sensors and transmission systems required to measure and transfer the physiological data, which can be quite obtrusive to users [10]. Lastly, user interfaces should also be designed to provide appropriate action to alleviate the uncomfortable feeling of a user that may occur in the course of HCI [8]. It should be noted that too much care of unstable emotion may lead to irritation. Thus, in addition to constant monitoring of physiological emotion, the subjective and behavioral state of the user's emotion should be registered to keep track of the appropriateness of the adaptive behavior of user interfaces. The distinctive feature of an emotional computer is its adaptiveness of user interfaces, which plays a role in differentiating it from ordinary computers. The development of adaptive user interfaces is far from simple and requires interdisciplinary efforts. First of all, we need to know what provokes uneasy feelings of users and their effect of emotion on computer work [15]. The emotional computer will be continuously developed for next version which is wireless, mobile and portable, for future applications in ubiquitous computing environments.

References

1. Shneiderman, B.: Designing the User Interface: Strategies for Effective Human-Computer Interaction, 3rd edn. Addison Wesley, Menlo Park, CA (1998)
2. Boucsein, W.: The use of psychophysiology for evaluating stress-strain processes in human-computer interaction. In: Boucsein, W., Backs, R.W. (eds.) Engineering Psychophysiology: Issues and Applications, pp. 289–309. Lawrence Erlbaum Associates, Mahwah, NJ (2000)
3. Oatley, K.: Emotion. The Psychologist, 285–288 (1998)
4. Hudlicka, E.: To feel or not to feel: The role of affect in human-computer interaction. International Journal of Human-Computer Studies 59(1-2), 1–32 (2003)
5. Norman, D.: Emotional Design: Why We Love (Or Hate) Everyday Things. Basic Books, New York (2004)
6. Forgas, J.P.: Network theories and beyond. In: Dalgleish, T., Power, M. (eds.) Handbook of Cognition and Emotion, pp. 591–612. John Wiley & Sons, Chichester (1999)
7. Picard, R.W., Klein, J.: Computers that recognise and respond to user emotion: theoretical and practical implications. Interacting with Computers 14(2), 141–169 (2002)
8. Partala, T., Surakka, V.: The effects of affective interventions in human-computer interaction. Interacting with Computers 16(2), 295–309 (2004)
9. Fragopanagos, N., Taylor, J.G.: Emotion recognition in human-computer interaction. Neural Networks 18(4), 389–405 (2005)
10. Haag, A., Goronzy, S., Schaich, P., Williams, J.: Emotion recognition using bio-sensors: First steps towards an automatic system, in Affective Dialogue Systems. In: Proceedings. 2004, pp. 36–48. pringer-Verlag, Berlin (2004)
11. Larsen, R.J., Diener, E.: Promises and problems with the circumplex model of emotion. In: Clark, M. (ed.) Review of personality and social psychology, vol. 13, pp. 25–59. Sage, Newbury Park, CA (1992)
12. Whang, M.C., Lim, J.S., Boucsein, W.: Preparing computers for affective communication: A psychophysiological concept and preliminary results. Human Factors 45(4), 623–634 (2003)
13. Boucsein, W.: Electrodermal Activity. Plenum Press, New York (1992)
14. Picard, R.W.: Toward computers that recognize and respond to user emotion. Ibm Systems Journal 39(3-4), 705–719 (2000)
15. Scheirer, J., Fernandez, R., Klein, J., Picard, R.W.: Frustrating the user on purpose: a step toward building an affective computer. Interacting with Computers 14(2), 93–118 (2002)