Physiological Sensing and Feature Extraction for Emotion Recognition by Exploiting Acupuncture Spots*

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Abstract. Previous emotion recognition systems have mainly focused on pattern classification, rather than utilizing sensing technologies or feature extraction methods. This paper introduces a method of physiological sensing and feature extraction for emotion recognition that is based on an oriental medicine approach. The specific points for affective sensing were experimentally determine, in which it was found that skin conductance measurements of the forearm region correlate well with acupuncture spots. Features are then extracted by the same way to interpret pulsation signals in diagnosis. We found that the proposed sensing and feature extraction method benefits the recognition of emotion with a neural network classifier.

1 Introduction

In order to realize a smart environment, an intelligent computer should be aware of user's context and situational information to offer personalized services. Over the last decade, many researchers have carried out studies on context awareness such as location, emotion, intention, etc. Among them, implicit contexts such as emotion and intention are essential for obtaining a user's feedback as whether the user is satisfied with the automatically triggered services or not.

One possible approach of emotion recognition is to analyze physiological signal. Picard et al. proposed a physiological feature extraction method that handles the daily variations of the features, and includes a linear classification method which projects numerous features into lower dimensions 1. Daniel Chen et al. measured the mental burden using an ECG (Electrocardiogram) signal and an EEG (Electroencephalogram) signal when the user was stressed and interfered with a certain strong stimuli 2. They categorized user's mental status with a decision table based on scientific background and evidence in combination with the two electronic signals.

However, in previous work 12, the features obtained from physiological signals were largely overlapped among other classes. Each class is a set of features further classified into emotion categories. The reason for the overlapped distribution among the distinct emotional classes might have occurred from physiological sensing

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condition such as sensing position, sensing posture or sensing intervals. In case of sensing position, electrodes for sensing skin conductance and PPG (Photoplesysmogrphy) sensor for monitoring the heart activity are placed on the second or third fingertip in previous work. Furthermore, the features were not verified for whether they were appropriate for emotion recognition or not.

In this paper, we propose a physiological sensing method for analyzing emotional status based on a traditional oriental medicine approach. Oriental medical science, especially the Yin and Yang and Five element theory, supports a clear mechanism between an individual's internal status and the external changes of his or her body. The meridian, or acupuncture theory represents the responsible reflection of inside or outside of a body against the stimuli 5. Based on this theory, we determine the forearm acupuncture spots which could be used for affective sensing by conducting an experiment for in which skin conductance measurements correlate well with expected skin conductance of the acupuncture spots. Our experiment was also designed to locate appropriate sensing positions for recognizing the changes in physiological signals by instigating a user with a sound stimulus. In feature extraction step, we deployed a diagnosis method of measuring pulsation and skin conductivity, which support multiple analyses in terms of depth, shape, strength or quality.

We established that the proposed sensing and feature extraction methods benefit the recognition of emotion with a neural network classifier. In addition, the proposed method reduces the number of physiological sensors and features as compared to multimodal technologies which use computer vision technologies and speech recognition technologies. This method supports multiple analyses through the proposed sensing method, as referenced by the detailed description of pulsation and skin humidity.

This paper is organized as follows. The proposed sensing and feature extraction method are described in section 2 and section 3, respectively. In section 4, we analyze and evaluate the experimental results. Finally we give the conclusion in section 5.

2 Physiological Sensing on Acupuncture Spots

2.1 Sensing Condition on Acupuncture Spots

Most physiological signals depend on an environmental factor since they usually are measured in a low frequency and are low in voltage and current. In addition, a human body is highly nonlinear and complex due to the fact that the signals of organs and tissues are combined together in the human body. To compensate for this, we apply a method for measurement, which has gage repeatability and reproducibility (Gage R&R) used for checking the consistency of measurements. In order to estimate Gage R&R measurement, we define both the evaluation factor and measurement factor. A measurement value is an index of meaningful factor from the sensing device. It is defined as the difference of conductivity between an acupuncture spot and a non-acupuncture spot.

$$M = \frac{\sum_{n=0}^{10}(C(n)_{acupoint} - C(n)_{nonacupoint})}{N} \tag{1}$$

where, $C(n)_i$ is the skin conductivity of n^{th} trial when i^{th} event is occurred. And N is the total number of tested data. An evaluation factor defined as a resolution is represented by repeatability and reproducibility for criticizing the output characteristic of the measurement system. The repeatability is determined to be the variance of measurement errors when we measure a physiological signal with the same device and the same experimenter.

We analyzed the process of physiological sensing as shown in Fig. 1. Process analysis objectively illustrates all feasible input variables which have a major influence on the output results in terms of measurement factor.

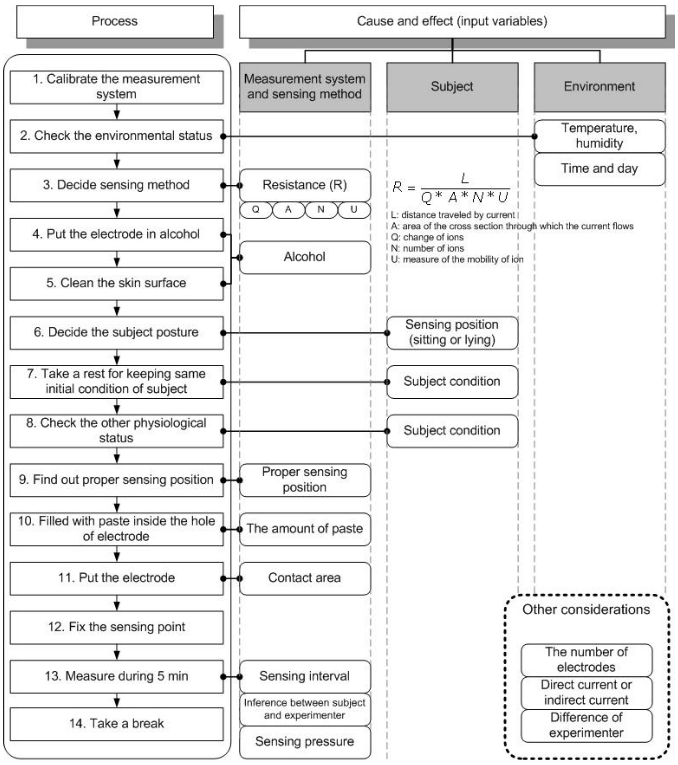


Fig. 1. Process analysis and possible input variables

We analyzed that disinfecting with alcohol, the posture of the subject such as lying or sitting had considerable influences in sensing. In addition, the sensing position like arms or fingers, the amount of paste, sensing pressure, electrical inference between the experimenter and the subject all have potential to affect the experimental results. In section 4, we evaluated whether measurement values had an influence on varying the sensing conditions or not.

2.2 Position Based Physiological Sensing Method

Among other conditions as mentioned in section 2.1, sensing position is one of the important conditions for affective sensing. From previous research, we know that meridians and acupuncture spots have a unique characteristic in that there is a lower resistance than any other point around acupuncture spot 4. Utilizing this, position based emotion recognition consists of four steps: sensing through the electrodes for analyzing skin resistance, preprocessing of noise filtering, computing the correlation of emotion labeled physiological signal and deciding the points responsible. The process is depicted in Fig. 2. The experiment is designed with the 7 by 24 matrix as shown in Fig. 3, covering two heart-related meridians.

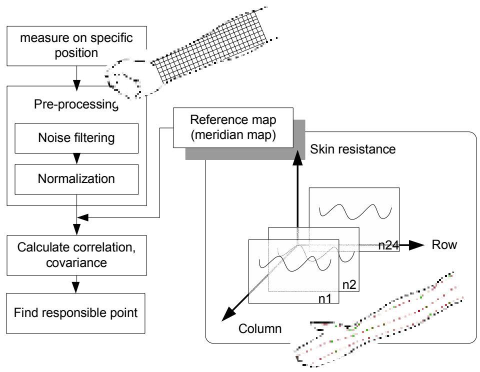
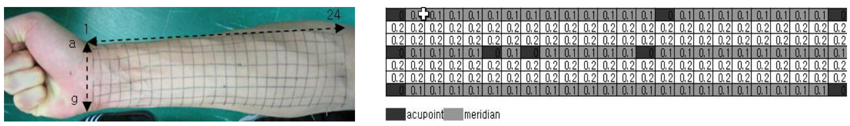


Fig. 2. Steps for finding proper sensing position



(a) **(b)**

Fig. 3. (a) 7 by 24 matrixes forearm matrix (b) reference map of meridian and acupuncture spots

We measure the resistance at random points of the forearm to find out the acupuncture spots by sensing the current. We check for either low resistance points or lines connecting the low resistance measurements. We select key sensing points by computing the correlation between the expectations of the reference map and the measurements from the same column line. Each element of matrix is filled with expectations based on acupuncture spots. We determine the sensing position to be the junction of two lines: the vertical lines are the highly correlated column lines from among 24 lines and horizontal lines are the two heart-related acupuncture spots.

3 Feature Extraction for Emotion Recognition

Pulse diagnosis is one of the primary diagnostic methods used in oriental medical acupuncture and herbal medicine. Each emotion has a close relationship between the organism and the inner status as referenced by Yin and Yang and five element theories 56. Joy is revealed directly in the heart when the blood circulation is dynamic. Each meridian is inherently followed by the reflection of the status of each organ, and any variance creates a different meaning according to the position and the characteristic of the signal. Depth, frequency, quality or shape, width, strength, length, and rhythm of the pulsation are key characteristics found in diagnosis, providing information which is then used to treat a wide range of disease conditions.

Depth information is extracted by categorizing the sensing position along with pressure into floating pulsation and deep pulsation. We calculate this with two basic variables of period and intensity. Floating pulsation can be measured when the signal has a low intensity and high speed. Deep pulsation is only detectable in the case of high intensity and low speed pulsation. Therefore, the measurement factor is computed by the ratio of speed and intensity of the pulsation.

$$D_i = \frac{I_{norm}}{T_i} \tag{2}$$

where, D_i implies the depth information in i^{th} segment pulsation, and I_{norm} is normalized intensity, T_i means the i^{th} period of the pulsation. Frequency of pulsation is interpreted by the speed of the pulsation. Each pulsation has one peak and one point of inflection. The reverse number of the difference value between the peaks is interpreted as the frequency at a segment of the pulsation. The average frequency during one minute is the heartbeat of the subject. R_i is the relative time when the peak is occurred.

$$F_i = \frac{1}{R_{i+1} - R_i} \tag{3}$$

Strength indicates the intensity or amplitude of the pulsation. Full strength means that the pulsation is wide and strong. Empty strength shows a wide but not strong pulsation. However, the amplitude of pulsation varies with environmental changes and the sensing pressure. Therefore, we use a normalized value to determine the status of pulsation. Rhythm is defined as the regularity of the pulsation. If the variation of the period (RR interval) is large and unstable with rapid speed, we determine the pulsation to be hurried. If the rhythm is rapid and is accompanied with irregularly in the peak to peak interval, we can anticipate that the heart agitated by heat.

$$I_i = \frac{1}{N-1}(R_i R_{i+1} - \overline{RR}) \tag{4}$$

Where, $\overline{RR}$ is an average one minute period in pulsation and N is the total number of peaks in one minute. Quality and shape mean the status such as roughness, smoothness, thickness, and thinness. We define the quality and shape with the standard deviation and time difference between peak point and 50% of the falling point. Skin conductance is one of the diagnosis parameters used in an oriental medical science. In this section, we found the specific sensing points and measured the average of skin conductance. In the case of skin conductance, a lot of difficulties are presented practically. A reciprocal of the resistance must be measured due to the small amount of current. Therefore, we employed a normalized skin conductance value and transition value.

4 Experimental Results and Analysis

We conducted experiments to determine the effective factor prominent under one variable condition which restricted other conditions. We took ten measurements of the conductivity of seven acupuncture spots while varying the sensing conditions such as infection of the skin surface by using alcohol. By exploiting MINITAB simulation tool, we applied the two-sample T analysis method to find out whether the alcohol affects the measurement value or not. Eventually, the difference in conductivity between an acupuncture spot and non-acupuncture spot was found to be dependent on the following conditions; sensing position, sensing pressure, inference between subject and experimenter, experimenter, and sensing interval. We set the experimental condition according to the previous results. As a result, the Gage R&R is 25.33% when control variables are considered and 62.32 % without considering control variables, as shown in Table 1. If the Gage R&R is more than 30%, the system is not accepted as a valid measurement system due to low resolution and large variation 3. This result demonstrated that acupuncture spot sensing should be considered especially carefully with respect to sensing pressure, sensing position, interference from other subjects, and sensing interval, than to other conditions.

Table 1. Total gage R&R result

Source	*StdDev(sd)*	*Study var*
Total Gage R&R	*0.565*	*25.33*
Repeatability	*0.270*	*12.15*
Reproducibility	*0.495*	*22.22*
Variation	*2.23*	*100*

We set one electrode on the arbitrary point of a 7 by 24 matrix on with 1cm square the right forearm. The other is placed on the left fingertip which is used as the ground point. To collect the system-independent signals, we used two kinds of sensing devices, MP-35 and EAV, with different backgrounds. The data was gathered over a period of 10 days from a single male subject who was 25 years old.

We computed the correlation coefficient of same vertical line in pairs of gathered data in order to check the day dependence factor. When we set the threshold coefficients as 0.3, 0.4, and 0.5, the correlated data was found to be 70%, 64%, and 60%, respectively. We determined the threshold of the correlation coefficient to be 0.4 since the number of neglected column vectors was the same as with a 0.5 threshold value. Additionally, when the coefficient was 0.4, we could not use 6, 7, 16, and 17th columns due to a day dependency factor.

The results of correlation between expected values and actual measurements are illustrated in Fig. 4. From these result, we analyzed the measurements from certain positions which exhibited patterns similar to acupuncture spots. In this experiment, six lines, column 1, 6, 8, 14, 15, and 24, were extracted from the acupuncture spot map which included black marked points. Each line was analyzed with an acupuncture spot wave up to two adjunct lines. We found out that column 1 was the outstanding point resulting in an averaging 6.3 correlation coefficient among 78 % of the data. In addition, 4, 6, 7, 15, 17, and 22 revealed useful correlation coefficients in 53 % of the data. We selected the column 1, 4, 15, 20, and 22 as significant points in recognizing a user's internal status. However, the 6, 7, and 17 columns were not reliable to use, due to day dependency.

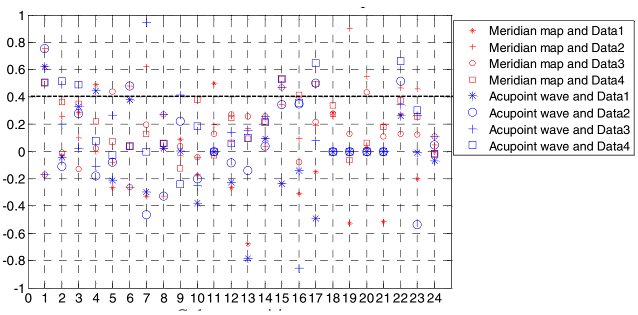


Fig. 4. Correlation between measurements and expectations

For emotion induction, we stimulated the user to a set emotional status with multimodal media like music and image, which were predefined according to the user preference. We used two kinds of stimuli, i.e. positive and negative as a medium to evoke the certain emotion. We adopted the basic five-emotion model followed by Yin and Yang and Five elements theory. The emotional status was divided into the emotional bases of joy, anger, grief, sadness, thoughtfulness, fear, and fright. However, 'sadness' and 'grief' were combined together for sensing. Additionally, the 'fright' basis is not applicable to express the emotion status in daily life. Eventually, for the purpose of this study, we assume the basic emotions to be an individual's common status, joy, anger, and sadness. After gathering the raw signals, we calculated the features based on the proposed method. Then, the feature projection analysis (PCA) was employed to check the reliable three dimensional features. We selected the higher priority features such as rhythm, strength, and quality or shape in Case A, and its linear combination in Case B. In order to figure out whether the selected features were useful or not, neural network classifier were applied for classification of the result, as shown in Table 2.

The ratio of correct recognition rate was comparable with that of previous results. One advantages of the proposed feature set is actually a smaller number of features. In case of four emotion categories, we found that smaller feature set can replace the result of a larger number of feature set while maintaining a comparable recognition rate. It means that, a small number of features, using a PCA based on oriental medical science, can be used efficiently and effectively.

Table 2. Results of classification according to the features (a) irregularity, GSR transition, speed (b) linear combination of 3 features using PCA (c) irregularity, norm GSR, GSR transition

input	*output*	*Hidden node*	*Momen-tum*	*Learning rate*	*Learning error*	*Test error*
3	*4*	*10*	*0.2*	*0.5*	*53%*	*32.50%*
		12	*0.2*	*0.5*	*48%*	*32.50%*
			(a)			
3	*4*	*10*	*0.2*	*0.5*	*62%*	*40.50%*
		12	*0.2*	*0.5*	*52%*	*37.50%*
			(b)			
3	*4*	*10*	*0.2*	*0.5*	*48%*	*36.00%*
		12	*0.2*	*0.5*	*42%*	*25.50%*
			(c)			

5 Conclusion and Future Work

We have proposed a physiological sensing and emotion recognition based on oriental medical science. In physiological sensing, we found that acupuncture spots are more responsible for measuring stimuli than acupuncture spot and random points combined. For feature extraction, the present version uses only a portion of the data recorded from PPG sensor and GSR sensor. We analyzed various ways clinically used for diagnosis in oriental medical science. As a result, we discovered the feasibility that a small number of features can replace the complex and multimodal features currently used. Finally, we concluded the proposed sensing methodology and feature extraction is noteworthy for emotion recognition since the recognition rate was 74.5% under four emotional statuses. Future work includes applying multiple user databases and combining with several user contexts such as time of day and location of person, in order to help determine emotional status.

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