Physiological signal sensing on acupoints for emotion recognition*

Ahyoung Choi and Woontack Woo

GIST U-VR Lab.
Gwangju 500-712, S.Korea
+82-(0)62-970-2226
{achoi, wwoo}@gist.ac.kr

ABSTRACT

Emotion recognition is one of the emerging technologies to support user adaptive services in the fields of context awareness. Previous work, however, have mainly focused on pattern classification rather than a sensing technology or a feature extraction method. In this paper, we describe a method of position based physiological sensing for analyzing a person's emotion based on an oriental medical approach. The proposed method uses two electrodes to sense the skin response at an acupoint, a specific body point used for treating a disease and a diagnosis in an oriental medicine. The sensing points are determined by the correlation coefficient between measurements and the expectation of acupoint in a forearm. In the evaluation of the proposed positions, we prove the tendency that the differences of minimum value and maximum value increase after stimuli in the proposed points. This work can be applied not only to emotion recognition system but also to attention and intention recognition system.

Keywords: Physiological signal sensing, Oriental medical science, Emotion recognition

1. INTRODUCTION

In a smart environment, an intelligent computer or machine should recognize human's situation to offer personalized services. Recently, researchers have studied on context awareness such as location, emotion, intention awareness. Especially, the implicit contexts like emotion and intention are essential to obtain a user's feedback when some services are triggered automatically. One possible approach of emotion analysis is to use physiological signal analysis. We can measure a physiological status with a simple sensing method just attaching electrodes or an infrared sensor on the body. Physiological signal continuously provides the feedback of a user`s inner state without interfering with the user's work.

Picard et al. proposed a new physiological feature extraction method to handle the daily variations of physiological features and found a linear pattern classification method after projecting numerous features into lower dimension. The proposed recognition result is up to 81 % for emotion recognition. They used four kinds of physiological signals, which were measured by an electrocardiogram, a galvanic skin response sensor, a respiration sensor and a skin temperature sensor [1]. Daniel Chen et al. measured a mental burden using an ECG and an EEG when the user was stressed and interfered with a certain strong stimuli [2].

However, the distribution of features obtained from physiological signals in previous work, is largely overlapped among other classes which are the set of features classified into emotion categories. In addition, features within same classes have large variances, resulting in low recognition accuracy. The reason is that previous psychological recognition technologies have mainly focused on a pattern classification rather than a sensing technology or a feature extraction method. In order to recognize emotion, previous researchers followed the general physiological sensing methodologies which were not verified whether the emotion can be sensed or not. In this regards, they place the physiological sensors in arbitrary points.

In this paper, we propose a physiological sensing method for analyzing a psychological status such as emotion based on an oriental medical approach. In the oriental medical science, a physiological disease results from the emotional status in terms of anger and sadness. Most of the oriental medical doctors believe the direct and close relationship between psychological status and physiological status. Our experiment was designed to find out appropriate sensing positions to recognize the changes in physiological signals by instigating a user with a sound stimulus. Two electrodes record an electric response on random points of a forearm, which is related to heart changes. We calculated the

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correlations between the measurements and the meridian map which was referenced by previous work. Sensing positions were determined by the intersections of the heart-related meridians and correlated column lines. We proved whether sensing position represented well the inner status of a user or not.

We enhance the emotion recognition accuracy since oriental medical science regarded the relation of a physiological change and a psychological change as one unified flow. In addition, we support the multiple analyses through proposed single sensing method. In this experiment, we just utilize the two electrodes to find out a user's inner status. Moreover, this position based physiological sensing method is useful to extend the other inner status such as intention and attention.

This paper is organized as follows. In section 2, we introduce an oriental medical science and a physiological sensing method. Experimental results and evaluation are given by section 3 and section 4 respectively. Finally we conclude in section 5.

2. PHYSIOLOGICAL SENSING METHOD

Emotion recognition consists of three stages: physiological signal sensing, feature extraction and pattern classification. Figure 1 illustrates each step. We focus on the position based physiological signal sensing method for emotion recognition. We assume that the physiological sensing is that proper sensing position reflecting the psychological changes is laid on acupoint or meridian based on the oriental medical science.

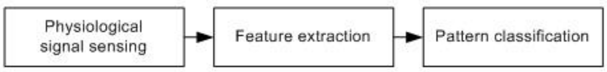
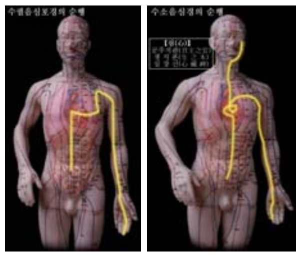


Figure 1. Steps for emotion recognition

2.1 The relation between a body and mental

In an oriental medical science, the human bodies were susceptible to a disease because of internal factors and external factors: internal factors are emotions, foods, and a physiological burden by overwork. External factors are atmospheric phenomena, temperature. There are direct and close relationship between psychological status and physiological status. The metal and a body mechanism are based on the Yin and Yang-Five Elements Theory [6]. Yin and Yang-Five Elements Theory categorizes the status of a human body into five states through metaphors - tree, fire, soil, metal and water by provision of nature. For example, a liver related meridian reflects stimulated signals and a stomach weakens when a person is getting angry. In this paper, we select the heart as an important organ to reveal a psychological status. The meridian and acupoint is a specific point for regulating and controlling each organ as well as representing the status indirectly [7]. Among the meridians, directly heart- related meridians are two: one is heart - meridian controlling the heart activity; the other is managing the pericardium, which has a role of advocating about a heart organ to help and facilitate the heart activity. Referenced by a classical book, 'The Yellow Emperor's Classic of Medicine' indicates that heart is a main and an essential part taking charge of controlling the flow of spirit and assisting other organs activities while the human is alive. Simpo meridian deals with heart oriented diseases. And the emotion of joy and gladness is revealed well in this position. Figure 2 shows the heart-related meridian. We try to find out proper sensing position on these heart-related meridians because it is closely related to emotional reaction.



(a) (b)

Figure 2. Heart - related meridian (a) Pericardium Meridian (b) Heart meridian [4]

2.2 Position based emotion recognition

We inherently inspire the previous work that meridian and acupoint have the characteristic of lower resistance rather than any other point around meridian [5]. Through the electrical characteristics of meridian, we find out the sensing positions which are related to the meridians. Then, we apply Yin and Yang-Five Elements Theory to emotion recognition methodology and we prove the relationship between meridians or acupoints and organic mechanism.

Position based emotion recognition consists of four steps: sensing through the electrodes for analyzing skin resistance, preprocessing of noise filtering, computing the correlation and deciding the responsible points. The steps to find physiological sensing positions on meridians and around acupoints are depicted in Figure 3.

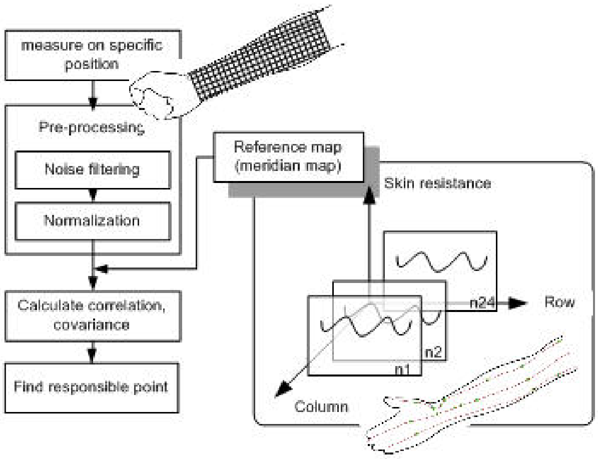


Figure 3. Steps for finding proper sensing position

Skin conductance is measured from the two electrodes, one is placed on a specific position along the right forearm and the other is placed on a left finer tip with the paste for reducing the contact resistances. The principle of skin conductance is to check the energy of an electro dermal activity while a cell membrane is polarized by an instantaneous or a spark stimulus as well as by a sweat perspired. Namely, the high conductance may be generated by diverse effects internally or externally after occurring dynamic activities and tensions respectively. Therefore, this sensing method shoud be considered static situation for discrimination of the internal and external signals.

For that purpose of our research, the experiment is designed as follows: At first, we measure the resistance on random points of the arm to find out the meridians or the acupoints in current sensing situations. In the arm, we can utilize the two heart-related meridians and we can do the experiment comfortably. We draw the 7 by 24 matrix covering the heart-related meridians. Then, we check the low resistance points or lines connecting the low resistance measurements. We select remarkable sensing points by computing the correlation between expectations of reference map and measurements of same column line. We design the reference map, 7 by 24 matrixes. Each column and row is filled with expectations based on meridian and experimental results by referencing the previous work [6]. We determine the sensing position as the junction of two lines: vertical lines are the highly correlated column lines among 24 lines and horizontal lines are two heart-related meridians. Finally, we evaluate the position with a simple stimulus which expects to bring the emotional feelings. Position selection in this study differs from those typically explored.

In this paper, we use two kinds of approaches to compute correlation between the expectations of a map and measurements. At fist, we match the result based on the meridian map. Secondly we analyze based on the expected waves of acupoints. meridian is line and acupoint is a point on meridian. Both express the similar characteristic of low resistance. However, acupoints are tended to reveal more prominent property than the meridians.

3. EXPERIMENTS

3.1 Experimental setup

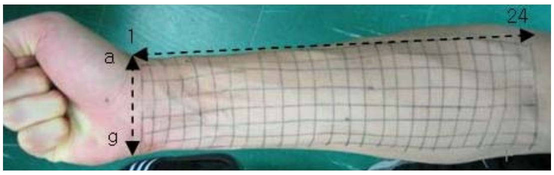
We set the electrodes on a random point of the arm in order to measure the an skin resistance. One electrode is on the arbitrary point of 7 by 24 metrics in the right site of arm including 1cm square. The other is placed on left site of a finer tip which performed as the a ground point. Skin resistance sensor, SS3LA, and processor, MP-35,was manufactured by the BIOPAC company [8]. We utilize the two kinds of devices, MP-35 and EAV, with the different backgrounds to collect the system-independent signals. MP-35 inherently developed for western medical science and designed by the researcher in the field of the biomedical engineering. EAV developed by Voll in 1953 for the purpose of diagnosis and disease treatments of meridians and acupoints founded on oriental medical science. The MP-35 measures the skin resistance but EAV measures the skin current when the stimuli are applied. In order to compare the result, we corrected each measurement. Both voltage ranges are under two microvolt. The sensing situation and utilized devices are illustrated in Figure 4.

(a) (b) (c)

Figure 4 Experimental setting (a) Sensing situation (b)EAV (c) MP-35

Considering the transmission of nerve substances when we applied some pressures to measure the skin conductance, we rubbed the sensing point against hands during one minute. Another consideration is minimizing interference between an experimenter and an examinee. We isolate each other with a towel placed on sensing table. The sensing interval of each measurement took at least one minute to minimize the previous residual stimuli. Motion artifacts were discarded since our experimental setup is static.

The data was gathered from a single subject during 10 days. The subject is male and 25 years old. The subject was seated and required not to move. Before the experiment, the subject took a rest during ten minutes for discarding other situational effects. Then, we measured sequentially the point laid on the second finger tip on the 7 by 24 matrix. Each measurement lasted one minutes; the whole time took around two hours long. Sensing direction is from the wrist to the elbow and from the outside to the inside, a to g, 1 to 24 as depicted by Fiture 5.



Fiture 5. Regular matrix on the arm

The map of the meridians and the acupoints which simulated by expected value based on the characteristics of the meridian and the acupoint is depicted in Figure 6.

0	[illegible]	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0	0.1	0.1	0.1	0.1	0	0.1	0	0.1	0.1	0.1	0.1	0.1	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0

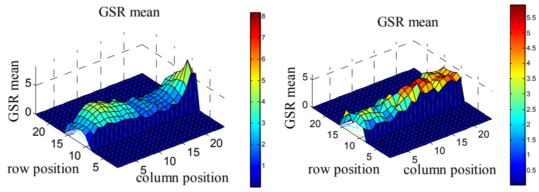
acupoint meridian

Figure 6. Map of meridian and acupoint

It describes how each point and each acupoint are mapped in 7 by 24 matrixes. We got an advice of acupoints on the square matrixes from the oriental medical doctor. The recommended acupoint was indicated by 0 which means low resistance in the range of 0 to 1. The heart meridian and Pericardium Meridian correspond to column vector d and g respectively.

3.2 Experimental result and analysis

The measurement of each point on the forearm is distributed from minimum 0.8 micro-ohms to maximum 4.5 micro-ohms, average varies from 1.3 micro-ohms to 3 micro-ohms. The geometrical distribution of average skin response is shown in Figure 7. The average skin resistance values increases along with the surface of the forearm. The value of the elbow is higher than that of wrist entirely. In statistically, about 92 % of the collected data set in the side line represents the low resistance which is similar characteristics of meridians or acupoints. However, the middle line of among three meridians is not discovered visually. Therefore, we could not conclude the substance of meridian with skin resistances under our experimental settings.



(a) (b)

Figure 7. Average skin resistance in different days (a) Data type 1 (b) Data type 2

We compute the correlation coefficient of same vertical line in pairs of gathered data to check the day dependence factor. The correlations between different data sets are shown in Figure 8. The number of reliable data is shown in Figure 9.

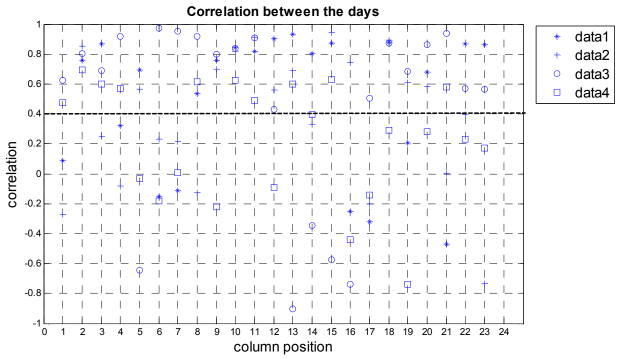


Figure 8. Correlation between data sets

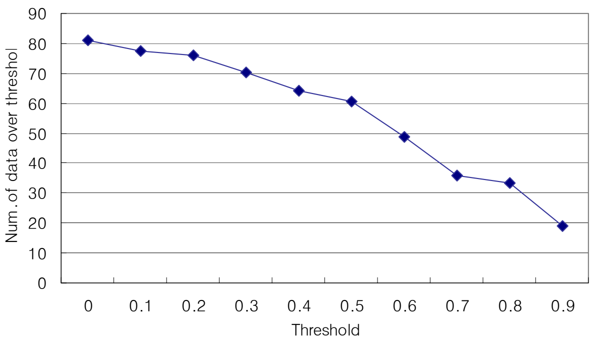


Figure 9. Rate of reliable data sets

The average correlation coefficient every column line is 0.4. When we set the threshold coefficients are 0.3, 0.4 0.5, and 0.6, the correlated data was revealed the 70%, 64%, 60%, 48 % respectively. The percentage of reliable data is saturated around 0.4. We determined the threshold of correlation coefficient as 0.4 since the number of neglected column vector is same with 0.3 thresholds. When the coefficient is 0.4, we could not use 6, 7, 16, and 17nd columns due to day dependency factor.

The result of correlation between expected values and measurements is illustrated in Figure 10. Small red markers indicate the first analysis which calculates the correlation coefficient with map of meridian. Large blue markers indicate the second analysis which computes the correlation using the expected waveform of acupoints. We accept the values only above 0.4.

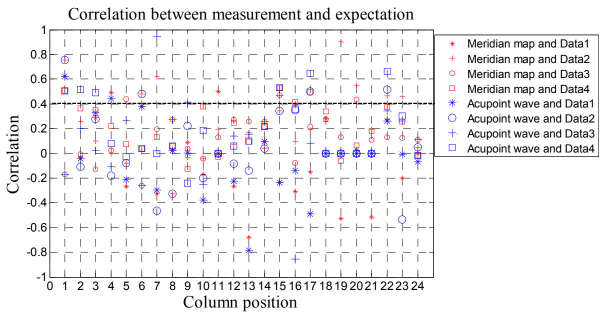


Figure 10. Correlation between measurements and expectations

From this result, we analyzed the measurements in certain positions which show the similar patterns to a meridian and an acupoint. Our first comparison was done between a meridian and a measurement computed with meridian map shown in Figure 6. As a result, we find out that about 4 % up to 12.5 % of data was correlated with reference map. However, it showed little relationship considering the 24 analysis lines entirely. Hence, we could not attest to the linear relation between meridian and low impedance line.

We took another approach and evaluated to get the reliability of experimental results since the results of first analysis had unreliable rates about 4% through 12 %. We tried to compare the acupoints rather than meridians. Acupoints are defined as prominent point against the stimuli and it can be shifted along the meridian. In this experiment, six lines, column 1, 6, 8, 14, 15, 24 in Figure 6, extracted from the meridian map including black marked points. Each line was analyzed with an acupoint waves up to adjunct two lines. The meaningful points increase twice as much as first analysis. In consequence, we find out that the low resistance in skin surface is more related to acupoints rather than meridians. Column 1 is outstanding point resulting in average 6.3 correlation coefficient among 78 % data and 4, 6, 7, 15, 17, 22 is revealed useful correlation coefficient in 53 % data. However, the data of 6, 7, 16, 17nd column lines are not reliable to use. Therefore, this study selects the column 1, 4, 15, 20, 22 as significant point to recognize a user internal status except the 6, 7, 17 columns.

Figure 11 reveals the comparison between the measurement of EAV and the measurement of MP-35 device.

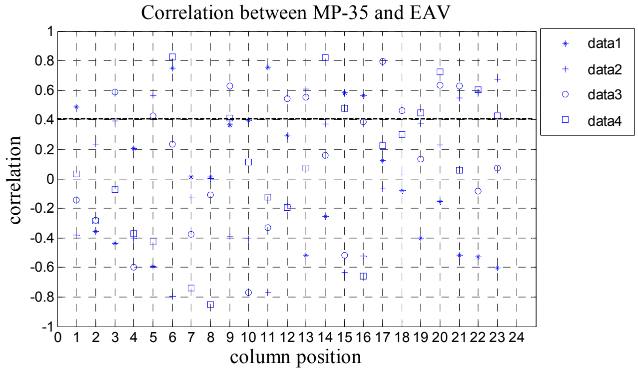
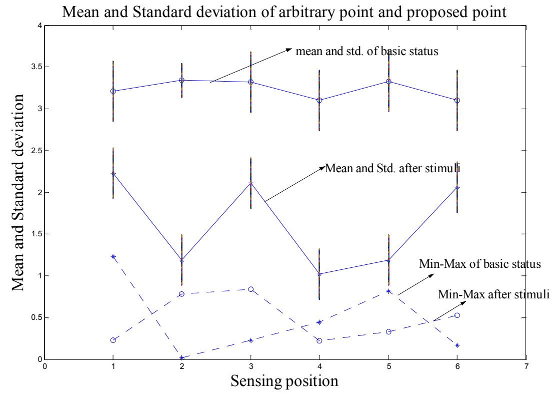


Figure 11. Comparision between devices

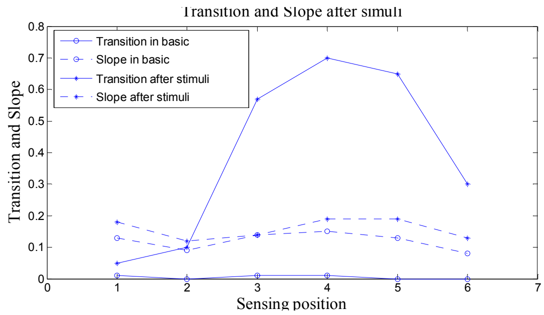
EAV measure the skin current from 0 to 100. Average measurement is laid on at least 27 to at most 72. Before analyzing, the values from EAV made reciprocal number and are normalized. Entirely 62 % of data indicated meaningful and 20 lines among 24 lines revealed useful.In this result, we conclude that the acupoints are more responsive under our experimental set up. Eventually we found the new map of physiological sensing position which is the intersection the 1, 4, 15, 20, 22nd columns and heart related meridians. In addition, these were not relied on sensing devices.

4. EVALUATION

In this section, we examine the reliability of proposed sensing position with a rough stimulus which doesn't involve the variable definition of emotion. We gave a sound stimulus irregularly to the examinee. The stimuli had high frequency and more than 60dB to arouse the uncomfortable situation. The features what we used was mean of skin resistance, standard deviation, maximum and minimum value, transition and 1st derivation. Transition indicates the difference between maximum value when the stimuli is occurred and saturated minimum value. And 1st derivative is decrease rate per second. The electrode is placed on the intersection of meridians, Simkyung and Simpokyung, and column 1, 7, 15, 19, 22 in regular order. The result is shown in Figure 12. 1st sensing position is the result of random points and the others are the result of acupoints.



(a)



(b)

Figure 12. Mesurement of arbitrary and proposed point

(a) Mean and standard deviation (b) Transition and slope

The difference of basic and a stimuli situation in arbitrary points is 0.98 micro-ohms, but the one of acupoints is larger from 1.04 micro-ohms to 2.36 micro-ohms than the former. And the range of data shown in minimum value and maximum value is also increased at most 0.4 micro ohms in basic status and decreased at most 1.65 micro ohms at distinctly. The transition increased entirely. Therefore, we can find out the tendency that the difference of minimum value and maximum value increased after stimuli in the proposed point. In addition, transition value after the stimuli showed notable changes in the proposed points. The slight variances was revealed in the proposed positions with respect to mean value, difference between basic status and stimulated status

5. CONCLUSION AND FUTURE WORK

In this paper, we propose the position based physiological sensing method for emotion recognition. We assume that the acupoints are a responsive point and represent low impedance. We found that acupoint is more affected on the stimuli than meridian and random points. Eventually, specific points should be used with physiological sensing method for emotion recognition. We determined the physiological sensing position of the intersection the heart related meridians and correlated column lines as a sensing position. In evaluation section, we found out slight variance between acupoints and arbitrary points with respect to mean value, difference between basic status and stimulated status and transition. Finally, we conclude this acupoint sensing is a significant to consider the emotion recognition with physiological signal. In addition, the comparison between EAV and MP-35 shows the feasibility of building independent emotion recognition system without considering inputted data. This work can be applied and extended to emotion, attention and intention recognition system to enhance the accuracy rate.

6. ACKNOWLEDGEMENT

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