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# Wearable Systems for Service based on Physiological Signals

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*Abstract*— **Many researches for useful status information on humans have been done using the bio-signals. The bio-signal acquisition systems can be used to connect a user and a ubiquitous computing environment. The ubiquitous computing environment has to give various services anywhere, anytime. Consequently, ubiquitous computing requires new technology, such as a new user interface, dynamic service mechanism based on context and mobility support, which is different from technology used in desktop environment. To do this, we developed a wearable system, which can sense physiological data, determine emotional status and execute service based on the emotion. In this paper, we described wearable systems for personalized service based on physiological signals. The wearable system is composed of three subsystems, the physiological data sensing subsystem, the human status awareness subsystem and the service management subsystem. The physiological data sensing subsystem senses PPG, GSR and SKT signals from the data glove and sends the data to a wearable system using Bluetooth. The human status awareness subsystem in the wearable system receives the data from bio-sensors and determines emotional status using nonlinear mapping and rule-base. After determining emotion, the service management subsystem activates proper service automatically, and the service management subsystem can provide personalized service for users based on acquired bio-signals. Also, we presented various feature extraction using bio-signals such as PPG, GSR, SKT considering mobility, and emotion recognition of human status for the ubiquitous computing service.**

## I. INTRODUCTION

Many researches for useful status information on human have been done using bio-signals. The bio-signal systems can be used to connect a user and a ubiquitous computing environment. The ubiquitous computing environment has to give various services anywhere, anytime. So, ubiquitous computing requires new technology, such as a new user interface, dynamic service mechanism based on context and mobility support, which is different from technology used in desktop environment. To do this, we developed a wearable system, which can sense physiological data, determine emotional status and execute service based on the emotion.

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In this paper, we described wearable systems for personalized service based on physiological signals. The wearable system is composed of three subsystems, physiological data sensing system, the human status awareness system and the service management subsystem. The physiological data sensing system senses PPG, GSR and SKT signals from the data glove and sends the data to wearable system using Bluetooth serial profile. The human status awareness subsystem in wearable system receives the data from bio-sensors and determines emotional status using nonlinear mapping and rule-base. After determining emotion, the service management system activates proper service automatically, and the service management subsystem can provide personalized service for users based on acquired bio-signals. Also, we presented various feature extraction using bio-signals such as PPG, GSR, SKT considering mobility, and emotion recognition of human status for the ubiquitous computing service. In section 2, we describe bio-signals. In section 3, we describe feature extraction. The human status/emotion recognition is shown in section 4, and the experimental results, and implementation are described in section 5.

## II. PHYSIOLOGICAL-SIGNALS FOR HUMAN STATUS

Human emotion changing is related to the sympathetic nervous and parasympathetic nervous system. Therefore we have to get bio-signals that related the sympathetic nervous and parasympathetic nervous system. And we have to consider that mobility and wearing convenience.

Photoplethysmography(PPG), galvanic skin Response(GS R) signal, and Skin temperature(SKT) are useful bio-signal with respect to simple measurement such as sensors in contact with fingers, and wearable convenience. We describe bio-signals and feature extraction.

### *A. PPG –Physiological signal*

PPG signal is the elecro-optic technique of measuring the cardiovascular pulse wave found throughout the human body. Pulse waves are caused by the periodic pulsations of blood volume and are measured by the changing optical absorption which this induces. Infra-red light is used since it is relatively well-absorbed in the blood and weakly absorbed in tissue. Blood volume changes are therefore observed with reasonable contrast. We can get blood volume and HRV(Heart Rate Variability) using PPG signal. Analysis of

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HRV provides an effective way to investigate the different activities of the autonomic nervous system.[1]

### B. *GSR - Physiological signal*

The galvanic skin response is a simple, useful, and reproducible electrophysiological technique to investigate sympathetic nervous system function.[2]

GSR is a measured value of conductance or resistance obtained by using two electrodes. GSR provide useful data for human status analysis.

### C. *SKT – Physiological signal*

Skin temperature depends on complex relations between blood perfusion in the skin layers and heat exchange with the environment and the central warmer regions by the skin. Variation in blood flow of the hand during exercises has been shown. The initial phase of exercise was related to a reduction of the skin blood flow, which increased with continued work. [3][4]

## III. FEATURE EXTRACTION OF PHYSIOLOGICAL SIGNALS

- PPG Normalized Mean: the value of normalized mean of the PPG signal. The normalized equation is shown in equation(3-1) and the normalized mean can be obtained by using equation(3-2).

$$\overline{P} = \frac{P - \min(\breve{P})}{\max(\breve{P}) - \min(\breve{P})} \tag{3-1}$$

$$\overline{\mu}_P = \frac{1}{N}\sum_{1}^{N} \overline{P}_N \tag{3-2}$$

- PPG Normalized Variance: the value of normalized variance of the PPG signal.

$$\overline{\sigma}^2 = \frac{1}{N-1}\sum_{1}^{N} (\overline{P}_N - \overline{\mu}_P)^2 \tag{3-3}$$

- PPG Heart Rate Mean: the value of heart rate mean using PPG signal analysis. Heart rate can be obtained by using equation(3-4), (3-5). Where $T_{Peak}$ is the peak time of the PPG signal. And, $T_S$ is the sampling time.

$$Interval\ (k) = (T_{Peak}\ (k) - T_{Peak}\ (k-1)) \times T_S \tag{3-4}$$

$$HRV\ (i) = \frac{1}{Interval\ (k)} \times 60 \tag{3-5}$$

- PPG Heart Rate Variance: the value of heart rate variance using PPG signal analysis.
- PPG Low Frequency Power / Total Power: the ratio of low frequency power / total power using heart rate variability power spectrum analysis.
- PPG High Frequency Power/Total Power: the ratio of high frequency power / total power using the heart rate variability power spectrum analysis.

To obtain physiology information using PPG, we should choose an effective method to extract heart rate signal from PPG. In other words, we must detect the peak accurately. We adopt an adaptive threshold and a differential method.

The Procedure is explained as follows:

1. Put window on measured 3 cycle PPG data every captured time.
2. Calculate maximum value, mean value using windowing PPG data.
3. Adaptive threshold can be obtained by using equation(3-6). Where, $P_{w-Max}$ is a maximum value of the windowing PPG signal and, $P_{w-Mean}$ is the mean value.

$$Threshold = (P_{w-Max} - P_{w-Mean}) \times 0.7 + P_{w-Mean} \tag{3-6}$$

4. If PPG signal is larger than the threshold, we calculate moving average of PPG signal for smoothing.
5. To detect peak, we can obtain the peak time that gradient is changed from positive to negative

The low frequency(LF) variations in heart rate(0.01-0.08Hz) are influenced by both sympathetic and parasympathetic activity, while the high frequency(HF) variations(0.15-0.5 Hz) are almost due to parasympathetic activity.[5][6]

A low frequency heart rate variability peak is at 0.04-0.15 Hz, related to reflexes and represents sympathetic and parasympathetic activity, and a high frequency peak is at 0.15-0.4 Hz, related to respiration and represents parasympathetic activity. Stress can be inferred by using HRV analysis of the ratio LF component, HF component or sympathetic and parasympathetic activity.

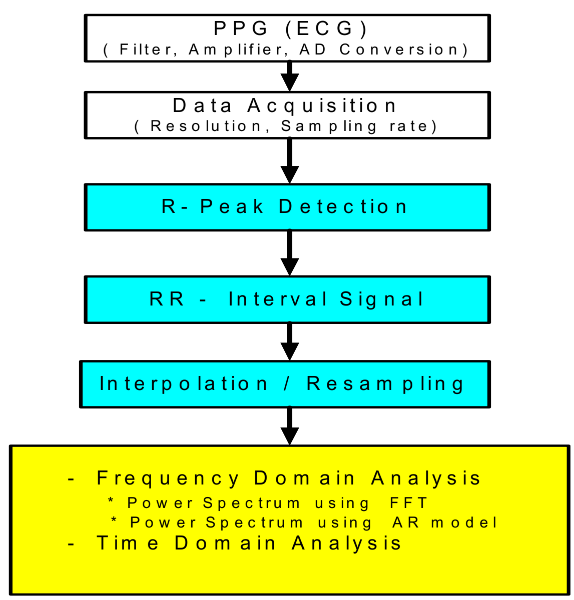


Fig. 1. The flow chart for HRV Analysis from PPG signal.

The flow chart for HRV Analysis from PPG signals is shown in figure 1. Table 1 shows the bio-signals and extracted features. We extracted various features using physiological signals.

TABLE 1. BIO-SIGNALS AND FEATURES

| Bio Signals | Features |
|---|---|
| | Normalized Mean |
| | Normalized Variance |
| PPG | Heart Rate |
| | Heart Rate Variability |
| GSR | Low Frequency Component(HRV) |
| | High Frequency Component(HRV) |
| SKT | Power Spectrum |
| | Slope |
| | Min/Max |

## IV. EMOTION / HUMAN STATUS RECOGNITION

Table 2 shows that the emotions for human status classification using bio-signals.[7] We obtained the physiological signal data from our wearable sensing system. The data duration is 3 minutes for analysis.

### A. *Nonlinear mapping based on neural net*

TABLE 2. EMOTIONS

| Emotion | Arousal | Valance |
|---|---|---|
| No Emotion | low | Neutral |
| Anger | Very high | Very negative |
| Hate | Low | Negative |
| Grief | High | Negative |
| Platonic Love | Low | Positive |
| Romantic Love | Very high | Positive |
| Joy | Medium high | Positive |
| Reverence | Very low | neutral |

For emotion classification, we used following classifier in Equation (4-1).

$$\hat{y}(k) = f(I, W) \tag{4-1}$$

Where, $I$ is input pattern vectors, $\hat{y}(k)$ is outputs of classifier. $W$ are weights layers. f is neural-network nonlinear function. The error function is shown in Equation(4-2). This describes as feature pattern vectors and output of classifier.

$$E = \frac{1}{2}\sum_{n=1}^{m}(y_n(k) - \hat{y}_n(k))^2 = \frac{1}{2}\sum_{n=1}^{m} e_n(k) \tag{4-2}$$

$$W(k+1) = W(k) + [\eta](-\frac{\partial E}{\partial W}) \tag{4-3}$$

The learning rule of weights is shown Equation(4-3). Where, $\eta$ is learning rate.

### B. *Classification based on rule base*

The other approach for human status is the rule based method. Table 3 shows that human status for classification using bio-signal.

TABLE 3. HUMAN STATUS

| Human Status Awareness | | | | |
|---|---|---|---|---|
| Stress | Relax | None | Excite | Tired |

## V. EXPERIMENTAL RESULTS AND IMPLEMENTATION

Physiological signal sensing system is composed of a sensor, an analog filter, an amplifier, an A/D converter, and wireless communication module. The wearable physiological sensing system has not to be affected by user movements and easy to wear. To meet the goal of the system, PPG, GSR, and SKT sensors are selected. These signals can be detected in a hand.

These signals which are detected in the left hand is sent to the Wearable Personal Station(WPS) using bluetooth. WPS receives the signals and extracts the features, which are used to derive emotional status.

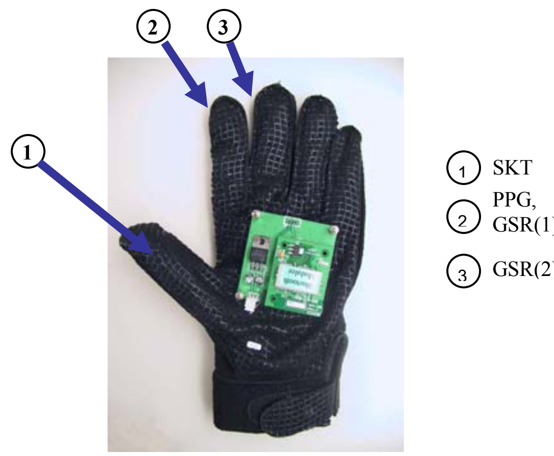


Fig . 2. The wearable physiological signal sensing system.

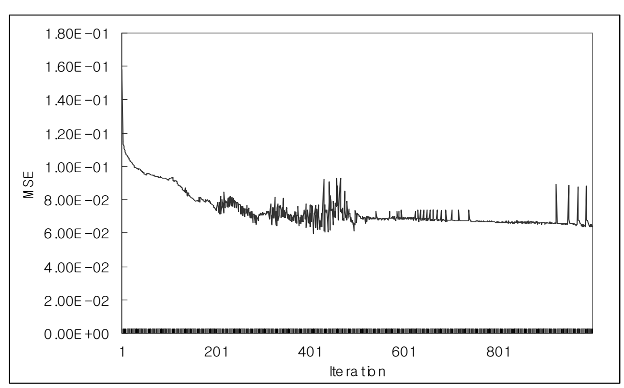


Fig. 3. MSE (Mean Square Error).

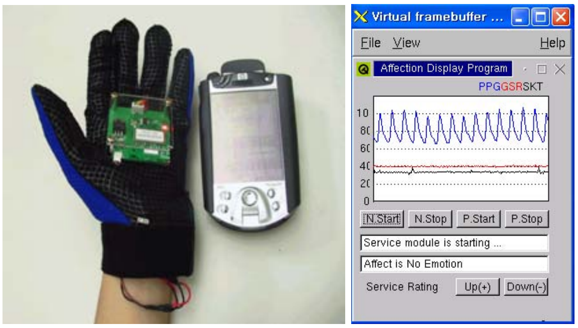


Fig. 4. The Physiological signal sensing system and user interface of human status aware system.

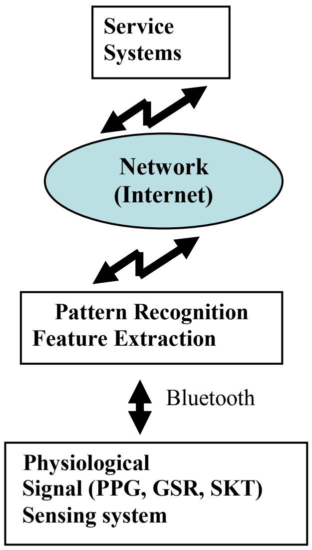


Fig. 5. The service flow of wearable systems for personalized service based on physiological signals.

Figure 2 shows the physiological signal sensing system. The input handling routine senses PPG, GSR, and SKT signals. The PPG sensor senses blood pulse wave. The SKT sensor senses skin temperature. The GSR used to detect electronic skin conductance. Using an A/D converter, these signals are converted to digital signals. Raw data is saved in memory temporarily for later use. The communication routine sends digitized signal to WPS. WPS receives the data and give them to the feature extraction routine. The feature extraction routine extracts feature from digitized signals. From Bio-signals(PPG, GSR, SKT), mean, variance, R-R interval, heart rate mean, heart rate variance, slope, min/max, and the power spectrum value are extracted. These extracted parameters are delivered to the human status aware system. For pattern learning, the learning rate of classifier is 0.005 till 500 step and 0.001 till 1000 step. The Fig. 3 shows MSE(Mean Square Error) of classifier leaning. The max value of classifier output is classified emotion. We got that the average classification rate is 80%. But the physiological signals are dependent on each human. So, this result is based on our obtained physiological signal data. The figure 4 shows the physiological signal sensing system and the user interface of the human status aware system. This system is composed of sensors, a micro processor, Bluetooth module and battery. The users can see the signal graph and status by using this graphic user interface of human status aware system. The service flow of wearable systems for personalized service based on physiological signals is shown in figure 5. The features and emotion are provided service systems for personalized service.

## VI. CONCLUSION

We developed a wearable system, which can sense physiological data, determine emotional status and execute service based on the emotion. In this paper, we described wearable systems for personalized service based on physiological signals. The wearable system is composed of three subsystems, the physiological data sensing system, the human status awareness system and the service management subsystem. The physiological data sensing system senses PPG, GSR and SKT signals from the data glove and sends the data to the wearable system using a Bluetooth serial profile. The human status aware subsystem in the wearable system receives the data from bio-sensors and determines an emotional status using nonlinear mapping and rule-base. After determining the emotion, the service management system activates proper service automatically. And the service management subsystem can provide personalized service for users based on acquired bio-signals. Also, we presented various feature extraction using bio-signal such as PPG, GSR, SKT considering mobility, and emotion recognition of human status for ubiquitous computing service. Our developed system is a prototype system. So, we will research accessory-type system for low power consumption, and small size.

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