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Development Stress monitoring System based on Personal Digital Assistant (PDA)

Mi-hee Lee[1], Gyunghye Yang[2], Hyoung-Ki Lee[3], Seokwon Bang[4]
[1 2 3 4]Human Computer Interaction Laboratory, Samsung Advanced Institute of Technology

Abstract– **We have developed non-intrusive type stress monitorng system based on the PDA (Personal Digital Assistance). This system separated sensing part of the physiological signal and estimating part of the stress states. First, sensing part consists of four electrodes such as one PPG electrode, two EDA electrodes and one SKT electrode. Sensing part was able to measuring heart rate, skin temperature variation, and electrodermal activity, all of which can be acquired without discomfort from finger. Second, estimating part was developed and verified for physiological signal database that was obtained from multiple subjects by presenting stress stimuli that were elaborated to effectively induce stress. This system is a useful measure of human stress in portabel device as PDA and smart phone.**

Keywords – ***stress monitoring system, PDA, physiological signal, PPG, EDA, SKT***

I. INTRODUCTION

Stress (psychology), an unpleasant state of emotional and physiological arousal that people experience in situations that they perceive as dangerous or threatening to their well-being. The word stress means different things to different people. Some people define stress as events or situations that cause them to feel tension, pressure, or negative emotions such as anxiety and anger. Others view stress as the response to these situations. This response includes physiological changes—such as increased heart rate and muscle tension—as well as emotional and behavioral changes. However, most psychologists regard stress as a process involving a person's interpretation and response to a threatening event.

Self-management techniques, which enable individuals gain greater control of their mental and emotional stress and improve their sympathovagal balance, can significantly impact a wide variety of disease states in which autonomic imbalance plays a role. Ischemic heart disease, hypertension and diabetes are all prime targets for such interventions. Indeed, recent experimental evidence suggests that rehabilitation programs aimed at decreasing emotional distress and sympathetic arousal and improving mood can significantly reduce the long-term risk of cardiac mortality [1,2].

Recently, most people want to know their state of health, such as a stress state, anywhere and anytime. The Personal Digital Assistant (PDA) has the portable wireless apparatus and it has become widely popular. Further more, boundless application area is the advantage of PDA to use mobile-care devices. Either as a realization of a smartphone or as a personal digital assistant (PDA), the base station is representing your personal stress management. It is the user interface, used to configure the sensors applied, analyzing and visualizing the measure vital parameters, and is able to inform the stress reduce method whenever a critical vital parameter is captured.

The purpose of this study is a development of the PDA based stress measurement system using automatic nervous system physiological signal and yielding the algorithm to estimate a stress level.

II. Sources of Stress

The circumstances that cause stress are called stressors. Stressors vary in severity and duration. For example, the responsibility of caring for a sick parent may be an ongoing source of major stress, whereas getting stuck in a traffic jam may cause mild, short-term stress. Some events, such as the death of a loved one, are stressful for everyone. But in other situations, individuals may respond differently to the same event—what is a stressor for one person may not be stressful for another. For example, a student who is unprepared for a chemistry test and anticipates a bad grade may feel stress, whereas a classmate who studies in advance may feel confident of a good grade. For an event or situation to be a stressor for a particular individual, the person must appraise the situation as threatening and lack the coping resources to deal with it effectively.

Stressors can be classified into three general categories: catastrophic events, major life changes, and daily hassles. In addition, simply thinking about unpleasant past events or anticipating unpleasant future events can cause stress for many people[3].

III. The Stress Response

When a person appraises an event as stressful, the body undergoes a number of changes that heighten physiological and emotional arousal[4]. First, the sympathetic division of the autonomic nervous system is activated. The sympathetic division prepares the body for action by directing the adrenal glands to secrete the hormones epinephrine (adrenaline) and norepinephrine (noradrenaline). In response, the heart begins to beat more rapidly, muscle tension increases, blood pressure rises, and blood flow is diverted from the internal organs and skin to the brain and muscles. Breathing speeds up, the pupils dilate, and perspiration increases[5,6]. This reaction is sometimes called the fight-or-flight response because it energizes the body to either confront or flee from a threat.

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Another part of the stress response involves the hypothalamus and the pituitary gland, parts of the brain that are important in regulating hormones and many other bodily functions. In times of stress, the hypothalamus directs the pituitary gland to secrete adrenocorticotropic hormone. This hormone, in turn, stimulates the outer layer, or cortex, of the adrenal glands to release glucocorticoids, primarily the stress hormone cortisol (see Hydrocortisone). Cortisol helps the body access fats and carbohydrates to fuel the fight-or-flight response.

Canadian scientist Hans Selye was one of the first people to study the stress response. As a medical student, Selye noticed that patients with quite different illnesses shared many of the same symptoms, such as muscle weakness, weight loss, and apathy. Selye believed these symptoms might be part of a general response by the body to stress. In the 1930s Selye studied the reactions of laboratory rats to a variety of physical stressors, such as heat, cold, poisons, strenuous exercise, and electric shock. He found that the different stressors all produced a similar response: enlargement of the adrenal glands, shrinkage of the thymus gland (a gland involved in the immune response), and bleeding stomach ulcers[7,8].

Selye proposed a three-stage model of the stress response, which he termed the general adaptation syndrome. The three stages in Selye's model are alarm, resistance, and exhaustion. The alarm stage is a generalized state of arousal during the body's initial response to the stressor. In the resistance stage, the body adapts to the stressor and continues to resist it with a high level of physiological arousal. When the stress persists for a long time, and the body is chronically overactive, resistance fails and the body moves to the exhaustion stage. In this stage, the body is vulnerable to disease and even death[9].

There have been many questionnaires, catecholeamins analysis[10], physiological signal analysis to analyze human sensibility condition through out the years, and especially researches in physiological signal analysis have been actively increasing. The purpose of our research is quantitative analysis of sensitivity with synthesis of physiological. To do the experiment heart rate, skin temperature and skin conductance are used to evaluate human stress stages.

IV . Stress-Specific Physiological Signal Database

High-quality database of physiological signals is vital for the stress recognition algorithm development. Influence of the change in activity of the nervous system due to the stress status should be apparently reflected in the physiological change. There are some difficulties for this task. It is not easy at all to judge whether a specific stress state is properly induced or not. Even if it is properly induced, it is expected that a large amount of variation among individuals is present. It is also not clear whether the phenomenological change of the features of the physiological signals is from the stress status change or other factors.

Some signals such as electroencephalogram (EEG), respiration, and facial electromyogram (EMG) cannot be adopted, because attachment of electrodes on the scalp or face seems not to be tolerable for practical use. The target signals are skin temperate variation (SKT), electrodermal activity (EDA), and heart rate that can be derived from electrocardiogram (ECG) or photoplethysmogram (PPG). The sensors for these signals can be eventually implemented as a compact module that can be wearable without much discomfort. All the selected target signals reflect the activity of the autonomous nervous system (ANS).

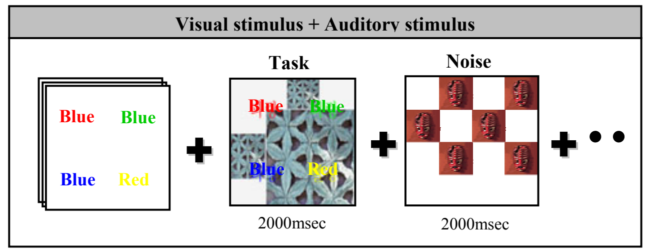

Fig. 1: Illustration of an example of the stress induction protocols.

One of the major roles of the ANS is to maintain internal equilibrium of body[11,12]. It is connected to smooth muscles, secretion glands of internal organs, cardiac muscles. It is divided into sympathetic nervous system (SNS) and parasympathetic nervous system (PNS). These two branches operate in antagonistic fashion to maintain homeostasis. Change of emotional status has a great effect on the activity of the ANS [13]. Increase of heart rate and blood pressure, and enlargement of the pupil diameter under fearful situation are well known examples.

To acquire database of physiological signals in which the influence of state of stress is faithfully reflected, we used a set of elaborate procedures for the stress induction. Fig. 1 illustrates stress induce task. The system was tested to 80 healthy persons and achieved a template of a stress progress. We have selected the 'stroop color-naming task' method to evaluate the stress. It consists of visual stimulus using the high chromatic yellow illumination and auditory stimulus using 70dB nose. This method has following advantages.
1) Possible to perform without physical movement.
2) Increase mental load by distracted visual stimulus.
3) Can stimulate tension in a relatively short period.
4) Has small individual variation of stress.
5) Easy to clarify the state of stress in variation of time.

Signal acquisition was done using the MP100 system of the BIOPAC system (Santa Babara, CA). Appropriate amplification and bandpass filtering was performed. One session of experiments took approximately 10 minutes. First 2 minutes corresponds to the baseline measurement and obtained without any negative emotional stimulus. The

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subjects were requested to be as relaxed as possible during this period.

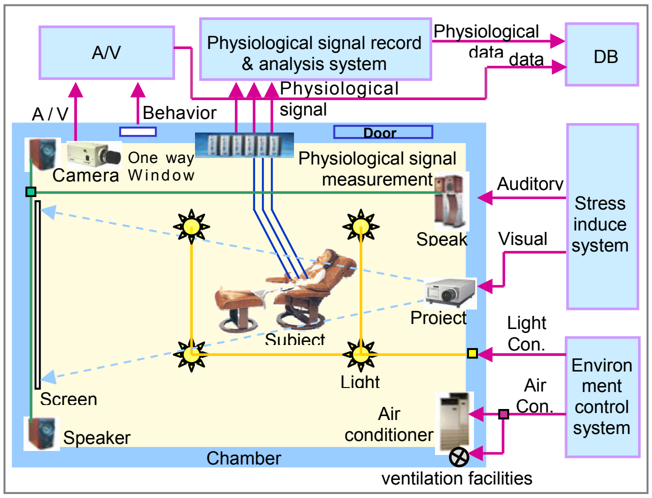

Fig. 2: Illustration of the stress induction system.

V. Signal Processing for Stress Detection

Power spectrum analysis is done on the IBI calculated from the ECG signal. From the plot, the range of frequencies corresponding to parasympathetic and sympathetic activity can be seen for a person. Frequency domain features representing subband powers (Low frequency (LF): 0.03-0.15 Hz, High frequency (HF): 0.15-0.4 Hz) are extracted. Simple time domain features SDNN and Heart Rate, are also used. For the Heart Rate calculation, outliers whose value belong to the 40<HR<150 are excluded.

EDA(Electrodermal Activity) are contained in its level(mean) and the distinctive short waveform indicated by arrows in Figure 3. This is usually called skin conductance response (SCR), measures of skin conductance (SC) can be interpreted as mainly reflecting changes in sweating activity and a high correlation between bursts of sympathetic nerve activity[14]. Although frequency domain analysis of the time-varying SKT (Skin Temperature) has been reported[15], here we simply used slop value.

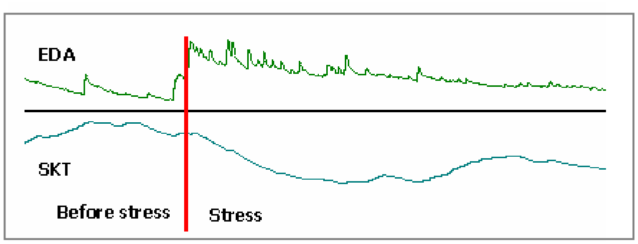

Fig. 3: A typical waveform of the EDA and SKT before stress vs. under stress stimulation.

Figure 4 shows the outlining the steps involved in the stress recognition algorithm. First, setup stress-specific physilogogical signal database, and 3 distinct features of physiological signals were extracted manually as shown in Fig 4(a)(b). Labeling of the data points according to the values of the 3 features was performed. After the feature vectors are extracted, they are given to the pattern classifier. It is clear that those features represent the difference between baseline states and stimulated states as shown in Fig 4(c). Scatter plots show that stimulated/baseline states can be classified easily - feasible with simple linear classifier. Stress reccogniton algorithm relation between (3 features) and (the stress label) were modeled by 3 universal approximators.

- Multilayer perceptron (MLP)
- Generalized regression neural network (GRNN)
-Adaptive network based fuzzy inference system (ANFIS)

VI. SYSTEM

The developed system consists of measurement module cradle type) and software module for a diagnosis. The measurement module was based on PDA-cradle-type device and connected with PDA using RS-232C serial communication protocol. The developed system consists of four electrodes such as one PPG electrode, two EDA electrodes and one SKT electrode for physiologycal signal measurement. The PPG provides an effective heart rate (measuring heart beats that generate identifiable forward-flow), useful for circulatory consideration though less useful for strict electrophysiologic consideration. For instance, the PPG signal may reveal heart rate variability, provided ectopic heart beats, which corrupt the association with autonomic tone, can be excluded. In this paper we adopted reflectance type PPG sensor because it makes the device compact. Two EDA sensors and one SKT sensor made from Ag/AgCl skin electrode and thermistor. Central to the PDA-cradle-type device design is the importance of easy grip and noninvasive reliable sensor attachment.

Software module was built with eMbedded visual C++3.0 (Microsoft^{TM}) and PDA type was iPAQ H3600(Compaq^{TM}) and MITs400(SAMSUNG elec.). This system is doing stress measure, stress analysis, stress history management, stress imforamation offer service as shown figure 6.

VII. RESULT

Overall system was tested for stress-specific physiological signal database that was constructed from the procedure described in section IV. No special preprocessing by visual inspection was performed to eliminate severely contaminated segments from the raw signals described in section V. Data from the half of subjects were used for the training, and data from the rest were used for the test.

Classification performance was quantified as ratio of correctly classified data points (correct classification ratio, CCR). We obtained CCR was 98.33 % for the training set, and 96.67 % for the test set, for classification of two statuses – stress, unstress.

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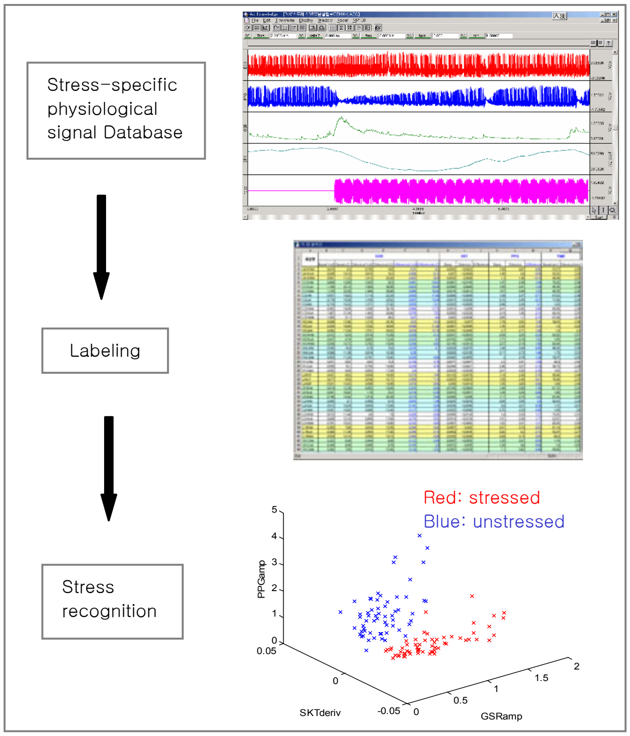

Fig. 4: Illustration of the stress recognition algorithm development process.

Fig. 5: Arrange of the electrodes and measurement method.

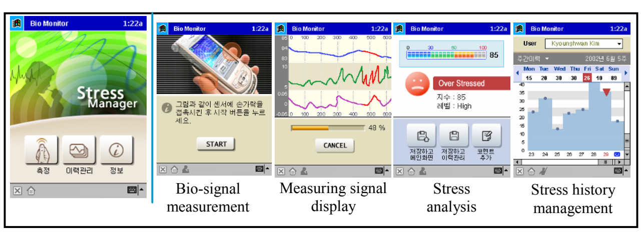

Fig. 6: Illustration of the stress monitoring service

VIII. CONCLUSION AND FUTURE WORK

We have presented a novel technique in this paper for PDA based stress measurement system using automatic nervous system physiological signal such as HR, EDA amplitude and SKT slop. This has been used as an index for stress detection. This porcedure however has some limitations. Gathering accurate physiological data pertaing to specific emotional states, simulating stress environment for eliciting adequate response, day variability and subject variability are few of them.

Future work will focus on overcoming these limitations and integrating this stress detection technique with a smart phone or intelligent robot system that takes adequate measures after implicitly detecting stress in a human working in the same environment.

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