Owens Luis - A Context-aware Multi-modal Smart Office Chair in an Ambient Environment

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***Abstract*—This paper introduces a smart office chair, Owens Luis, whose pronunciation has a meaning of "an encouraging chair (応援するイス)" in Japanese. For most of the people, office environments are the place where they spend the longest time while awake. To improve the quality of life (QoL) in the office, Owens Luis monitors an office worker's mental and physiological states such as sleepiness and concentration, and controls the working environment by multi-modal displays including a motion chair, a variable color-temperature LED light and a hypersonic directional speaker.**

***Keywords*-Context awareness; Multi-modal displays; Sleepiness recognition;**

I. Introduction

In an ambient environment, where in our definition ambient intelligence functions and watches people within, a variety of appropriate services are provided depending on the user and environmental contexts in a timely fashion. As an example, we study on an ambient office, where a variety of sensors are embedded to recognize individual workers' states and to improve the quality of life (QoL) in the office by controlling lighting, air conditions, BGM etc.

More specifically, we aim to develop a rest control system in an ambient office. In Japan, 60 to 80 percent of people are said to feel stressed physically and / or mentally at office. Especially many office workers at video display terminals (VDT) experience eye strain, back and neck aches, and nausea and can also develop serious long-term problems such as visceral diseases and insomnia. Government's guideline suggests to take 10 to 15 minutes of break per hour. However, it is often the case an office worker continues to work even when it is actually recommended to take a rest from a point of view of health or work efficiency. On the other hand, office workers often have to keep working to fulfill business requirements no matter how tired they are.

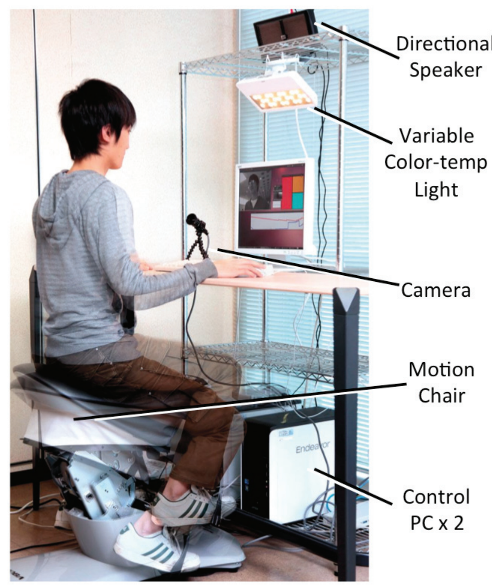

Figure 1. Configuration of Owens Luis (Courtesy of the Mainichi Newspapers Co., Ltd.)

In our ambient office, we aim to develop an intelligent office worker supporting mechanism, where a worker will be suggested to take a rest when necessary, and on the other hand, be encouraged to continue working when appropriate. As a first step, we prototyped a smart rest control system in a form of an office chair, named Owens Luis (Figure 1). Owens Luis monitors an office worker's mental and physiological states such as sleepiness and concentration, and controls the working environment by multi-modal displays including a motion chair, a variable color-temperature LED light and a hypersonic directional speaker.

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II. Related Work

Many studies have been reported on estimation of mental and physiological fatigue. Hoshino et al. report that the velocities of miosis and mydriasis are highly correlated with the degree of visual fatigue [1]. Shiomi et al. report that human fatigue can be measured by a chaotic voice analysis [2]. Zhang et al. report mental fatigue can be estimated by electroencephalogram (EEG) and heart rate variability (HRV) [3]. Many studies have also been done on estimating mental comfort and concentration levels. Yoshida discusses that α-wave frequency fluctuations are correlated with human's comfortable level [4]. Fujiwara et al. report that the quality of comfortableness can be measured by peripheral skin temperature, pulse and galvanic skin response (GSR) [5]. It has been reported that workers under a high illuminance environment exhibit better task performance [6]. Other reports indicate a low illuminate environment is effective for relaxing [7]. To our best knowledge, however, few attempts have been made to dynamically and adaptively control a working environment according to the worker's mental and / or physiological states.

III. Owens Luis

Figure 1 shows an overview of our smart chair, Owens Luis. Owens Luis estimates sleepiness and concentration of a office worker using a variety of sensing devices, and controls the working environment by multi-modal displays according to the estimated states. We plan to use a camera, an EEG sensor, a thermometer, an electrocardiogram (ECG) sensor, an accelerometer, a pressure sensor to develop a robust worker states estimation mechanism. As a first step, we implement a simple camera-based sleepiness and concentration estimation method.

Based on the estimated parameters, Owens Luis's action is determined using an attractor selection model. An attractor selection model is a biologically inspired approach found in E. coli cells to self-adaptively react to changes of a nutrient in the environment [8]. It is used as an algorithm for flexible adjustment to various change of the environment. An attractor is a convergence point in a state space and corresponds to a stable point of a given system. The attractor selection chooses an attractor according to the suitability for a given environmental condition. In this way, our system is expected to control the working environment so that worker's states are improved in the end from an arbitrary initial states. As display devices, we plan to use a variable color temperature light, a directional speaker and an aroma generator in addition to a motion chair. In the prototype system, we use these devices except an aroma generator.

Owens Luis is configured to shake the worker up by horse-riding motion when he/she is sleepy, and to slightly and randomly change the inclination of the seat when the concentration level is low. Owens Luis also changes the lighting and BGM settings to cheer up or relax the worker according to the worker's states. In the following, sleepiness and concentration estimation, attractor selection, and multi-modal displays of the prototype system are described in order.

A. Sleepiness and Concentration Estimation from Camera

It is known that an average length of a blink is 100 to 150 milliseconds and it will become longer when drowsy [9]. Our prototype system estimates worker's sleepiness simply from blinking speed. Concentration levels are estimated from body motion, simply assuming a worker will move less when in concentration. A real-time face tracking library accFace (ATR-Promotions) is used to detect a worker's face. A blink is detected by thresholding intensity change within an eye region by comparing current and previous frames with template matching. A sleepiness level is sequentially increased or decreased based on the number of frames of a single blink. We also assume that a sleepiness level is continuously increased based on a time constant. Using this model, a low sleepiness level is kept as far as moderately fast blinks are observed within a certain time interval, whereas a high sleepiness is detected when a slow blink is observed or no blink is observed for a long period of time. In the prototype system, blink speed is detected at 50 to 70 frames per second by using an IEEE 1394b camera, Flea3 (Point Grey, 120Hz) and a control PC (Intel Core i7 870, 2.93GHz). On the other hand, a trajectory length of a center of the eye region on 2D image space in last 10 seconds is simply used to estimate the body motion level.

B. Attractor Selection from Estimated States

Attractor selection is employed for flexible adjustment to various changes of the environment, where each device is given state variables and its behaviors follows their values. State variables will dynamically change in real-time according to pre-defined functions and randomness levels.

In the prototype system, a motion chair can make three types of actions, forward tilt, backward tilt and horse-riding motion. The purpose of attractor selection is to determine an appropriate action to take based on the estimated states, to decrease the sleepiness level (or to increase brain activity a:0$\sim$1) and increase the concentration level (or to decrease body motion b:0$\sim$1). We introduce state variables for the motion chair, x and y (0$\sim$1). State variables x and y at time $t+1$ can be determined from all related variables at time t, by, for example, following equations. Horse-riding motion will then be selected more often when the brain activity level a is low, whereas forward or backward tilt will be selected more often when the body motion level b is high.

$$\begin{cases} x_{t+1} = x_t + a_t u(x,y) + \zeta_t \\ y_{t+1} = y_t + (1-b_t) v(x,y) + \eta_t \end{cases} \tag{1}$$

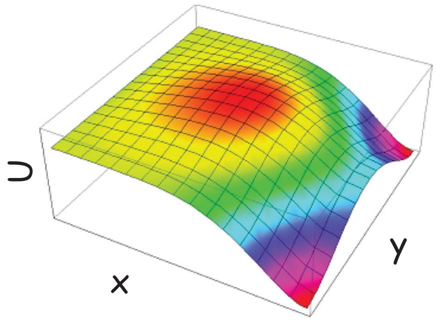

Figure 2. Potential energy field of state variables of the motion chair

Here, ζ and η are random variables and u and v are following deterministic functions.

$$\begin{cases} u(x,y) = x_t^5(1-x_t) \\ v(x,y) = x_t y_t (1-y_t)(y_t-0.5) \end{cases} \tag{2}$$

Figure 2 shows potential energy field (U) of each state determined by Eq.(2). The motion chair's state will move to one of the three attractors $(0, 0 \sim 1), (1, 1), (1, 0)$ when the randomness levels ζ and η are small, and it will jump between them when ζ and η are large. The attractors $(0, 0 \sim 1), (1, 1), (1, 0)$ correspond to the three actions; horse-riding motion, forward tilt and backward tilt, respectively, and a corresponding action command is sent to the motion chair at a certain probability. In this way, the motion chair will produce a monotonous action at a low probability when the worker is in good condition, and it will produce a variety of actions at a high probability when in bad condition.

C. Multi-modal Displays Controlled by Attractor Selection

The prototype system has three types of output devices, a motion chair, a variable color-temperature LED light, and a hypersonic directional speaker (see Figure 1). A horse-riding fitness equipment EU-JA50 (Panasonic) is used as a motion chair, which is connected to a control PC via a USB-GPIO interface module. By signaling the USB-GPIO output pins from the control PC based on the action determined by attractor selection, an appropriate button press is emulated and a corresponding action (such as 'forward tilt') is activated on the motion chair.

A high-power LED light iW Blast Powercore (Colorkinetics Japan) is used, which outputs 1,777 lm with variable color-temperature ranging from 2700K to 6500K. In the prototype system, we simply assign the brain activity level a and the body motion level b linearly to brightness and color-temperature, respectively. Brightness will be high when the brain activity level a is low. Color-temperature will be high when the body motion level b is high.

A hypersonic directional speaker H450 (HSS Japan) is used, which has a diffusion angle of 3 degrees. In the prototype system, we simply switch between a few types of music files (e.g. soft classic and hard rock) according to the brain activity level a.

IV. Observation and Discussion

Figure 3 shows an example sequence of sleepiness and concentration estimation in action. In each screen-shot, state variables of the motion chair are shown in the upper left, and the brain activity level a and the body motion level b are shown in the bottom in real-time. In Figure 3(a), the worker is in good condition with high a and low b. So the motion chair will rarely be activated. The worker starts body-sway to the left or right, then b became high and the seat was slightly tilted backward (Figure 3(b)). Then the worker made slow blinks a few times and a was decreased (Figure 3(c)). Finally the motion chair started swinging as shown in Figure 3(d).

One of the authors used Owens Luis during its own development process for a total of around 20 hours for more than three days. As a result, it was found that Owens Luis can be used for normal desktop activities such as touch typing without a problem despite its motion. It was found that the estimation method works fine when the thresholding parameters are well tuned. However, it was also confirmed that its accuracy and robustness need to be improved.

Owens Luis has been demonstrated at several university and academic events and more than a hundred people tried the system (see Figure 4). Due to lack of parameter tuning to individual visitors, estimation accuracy was not very good. However, most comments are positive and encouraging such as "cool idea," "I want to use it in my office." We also had many comments on the fitness function of the motion chair such as "you will be healthier if you are shaken not only when sleepy," and "how fantastic I can lose my weight while working."

V. Conclusion

A smart office chair, Owens Luis has been introduced. To improve the quality of life (QoL) in the office, Owens Luis monitors an office worker's mental and physiological states such as sleepiness and concentration, and controls the working environment by multi-modal displays including a motion chair, a variable color temperature LED light and a hypersonic directional speaker. In future, we will improve worker state estimation methods and conduct a long-term experiment in a practical working environment.

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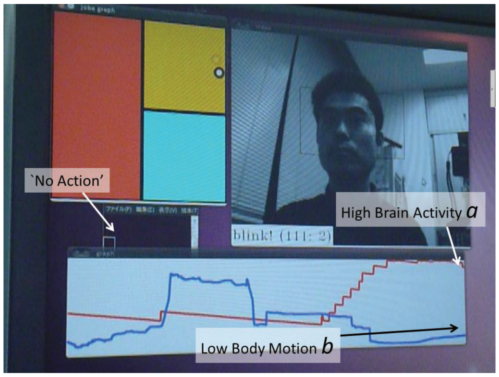

(a) High brain activity a and low body motion b

(b) The seat was tilted backward after b became high

(c) The brain activity a is decreasing due to slow blinks

(d) Finally the chair started swinging

Figure 3. Sleepiness and concentration estimation from camera

Figure 4. Four sets of Owens Luis at an in-house demonstration

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