Development of Estimation System for Concentrate Situation Using Acceleration Sensor

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Abstract. Recently, to discipline to increase powers of concentration is popular. One of the reason, it is difficult to concentrate something in these days because of a flood of information. However we discipline our concentration by using the how-to books and the portable games, we cannot evaluate the training effect on the practical life. In this paper, we propose an evaluation system for user's powers of concentration in which the method for the estimate user's sitting situation is utilized. This system is constructed by two kinds of method, one is the method which estimates the sitting situation and the other is the evaluation method for user's powers of concentration situation. These methods use user's motion that is obtained from the acceleration sensor that is fixed on the chair. And we prepare the three kinds of Graphical User Interface (GUI) which presents the concentration situation to the user.

Keywords: Powers of concentration, GUI, Sensory evaluation and Self-management.

1 Introduction

The modern society can be described as information society because of a flood of miscellaneous information. It is getting difficult to handle with these information obtained by Internet and e-mail as well as newspapers and televisions with full understanding. We have a difficulty to deliberate and concentrate something in our life environments. On the other hand, since the launch of game software aiming at brain activation, commonly known as 'Notore', which means brain training, various games to train brains, how-to books for improving our concentration are becoming popular among wide range of age groups. One of main factors of this phenomenon is attributed to middle-aged and senior people's demands for prevention of brain aging and wide-range age groups' desires for obtaining abilities to deal with a large number of information in a short time. Since these trainings are mostly performed by recitations and simple calculations, users can improve the ability as though they were playing some kind of games. Moreover the results of the trainings can be described as 'age of brain' so that they can easily check their abilities. This is one of the reasons that 'brain training' software are widely accepted among various age groups.

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However, even our thinking ability and concentration powers can be improved in such games and trainings, we cannot evaluate the effects in the practical life. Currently, the method using biosignals including breathing, heartbeat, and brain waves…etc. is proposed in order to measure person's powers of concentration [1]. For example, it is found that a brain wave called Frontal Midline theta is generated when solving a problem and concentrating on abstract thinking. Also it has been researched that transition of learner's skin potential level meets his interest in lectures. However, this sort of method put a heavy burden on a measured person as well as it is costly and time-consuming.

Therefore in this study, assuming the situation as if users are working with a computer, studying and doing some paper works in sitting situation, we propose an evaluation system for user's powers of concentration by processing information obtained by motion sensor fixed on a chair and presenting the concentration situation to the user. Along with development of the actual system, we also prepare the three kinds of Graphical User Interface (GUI) and perform the sensory evaluation experiments for the proposed system and the interface evaluation using these GUI.

2 Hardware Configuration of Estimation System in Sitting Situation

Hardware configuration of proposed system is showed as Fig. 1. The motion sensor sends acceleration data to Personal Computer (PC) through Bluetooth communication after measuring a movement of a chair. User's sitting or standing up situation and his power of concentration are estimated on PC according to the received data, and the estimation result is presented to the user.

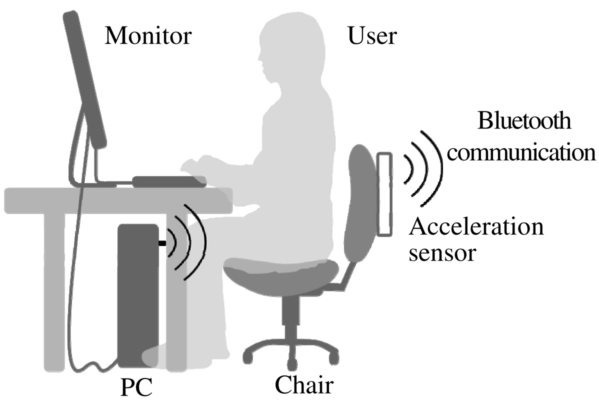


Fig. 1. System configuration

In the proposed system, the user's sitting situation on a revolving chair that is generally used in households and offices as shown in Fig. 2 is estimated. Since the revolving chair reflects the various users' movements, we can estimate the user's movements by measuring the acceleration of the movements and swings using the motion sensor.

We use a remote controller of Nintendo Wii games as the motion sensor. This remote controller uses Bluetooth for connecting to the main unit so that we can easily connect to PC. Since Wii game is available at a relatively low cost, it has already been popular among many households. Fig.2 shows that we fix the remote controller on the upper side of the backrest of the chair because the inclination of the backrest and the revolution of seating face appear prominently there and yet it doesn't disturb the user. The three dimensional motion sensor is installed near A button located around the center of the remote controller surface. Fig.2 also shows the coordinate axes with putting it lengthwise: X axis is horizontal direction, Y axis is vertical direction and Z axis is depth direction [2].

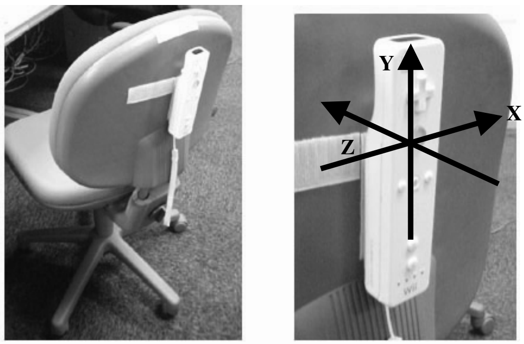


Fig. 2. Coordinate of 3-axis accelerometers

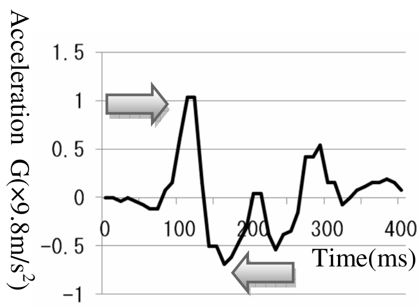
3 Software Configuration of Estimation System in Sitting Posture

3.1 Estimation of Time of Sitting and Leaving

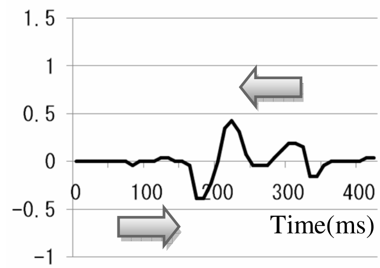
This proposed system estimates if the user is sitting down or standing up and user's powers of concentration in sitting situation.

At first we propose the method for estimating if the user is sitting down or standing up. There are the following two kinds of methods for estimating user's situation. The first one is a method for estimation by momentary change of acceleration at the time of sitting down and at the time of standing up. The second one is a method for estimation by the change of acceleration along with time. In the proposed system, we use these two methods to ensure the reliability.

Estimation by Momentary Change of Acceleration Speed. We sample the acceleration around 100Hz from Wii remote controller via Bluetooth. We instruct several subjects to sit down, work and stand up the chairs with the remote controller fixed on and perform the preparatory experiment to measure the acceleration of these movements. As a result, we find that the accelerations significantly change at the time of sitting down and standing up in the all axes directions. However, we also find that relatively greater acceleration is measured in X-axis and Z-axis at the time of sitting down. Therefore we estimate whether sitting down or standing up by Y-axis acceleration which shows less change. Moreover we focus on momentary change of acceleration at the time of sitting and standing up, respectively. Fig. 3 shows an example of transition of Y-axis acceleration at the time of sitting down and standing up. It shows that the acceleration shifts to a negative direction after shifting greatly to a positive direction. This occurs due to the rise of the seat front as a reaction when the subject is being seated and the seat front sinks down once. On contrary, the acceleration shifts to a positive direction when standing up after shifting greatly to a negative direction. This occurs due that the seat front sinks down as a reaction when the subject is standing up and the seat front rises, which means that the Y-axis acceleration shifts from a positive direction to a negative direction when sitting down and shifts from a negative direction to a positive direction when standing up. Moreover, these shifts of the acceleration such as positive to negative by sitting down and negative to positive by standing up occur within 50ms. Using these shift patterns of the acceleration, we estimate the subjects' sitting down and standing up situations.



(a) When sitting down



(b) When standing up

Fig. 3. Transition of the Y-axis acceleration by (a) sitting down and (b)standing up

Now we perform the preparatory experiment for setting the threshold value against the acceleration in order to distinguish the movements among sitting down, standing up and working in sitting situation. Among the nine subjects, maximum value of 0.27G is measured by two subjects and minimum value of -0.23G is measured by another subject. Therefore we set the threshold value of the acceleration to estimate sitting down and standing up as 0.3G in the positive direction and -0.3G in the negative direction.

We summarize the estimation method for sitting down and standing up using the momentary acceleration change. At first if more than 0.3G acceleration is measured, and if less than -0.3G is measured within 50ms during standing up, we estimate the subject is sitting down. Also if less than -0.3G acceleration is measured during sitting down and if more than 0.3G acceleration within 50ms is measured during sitting down, we estimate the subject is standing up.

Estimation Using the Acceleration Changes with Time Course. The acceleration measured at the time of sitting down and standing up varies with each individual. Sometimes it is difficult to estimate if the acceleration occurred by sitting down and standing up or movements generated during sitting down. According to the maximum and minimum value of Y-axis acceleration when sitting down and standing up, the acceleration of one subject shows less change when sitting down; at 0.11G and -0.19G. If the acceleration is more than 0.1G and less than 0.3G, and if it is less than -0.1G and more than -0.3G when sitting down and standing up, the estimation will be inaccurate simply by using the momentary acceleration. Therefore, we also use the estimation method using the power spectrum sequentially obtained by sampling the acceleration in a certain period of time.

At first we seek the power spectrum by executing Fourier transform of 256 pcs sample data among about 2.5s acceleration in the three axes. The frequency component 0.01Hz being regarded as noise is eliminated. We can find that the power spectrum is barely measured in the all frequency domains when absence but is measured in many frequency domains during sitting. Then we add up the value of power spectrum except the spectrum at 0.01Hz frequency. We will judge between absence and sitting by sum of the power spectrum obtained as above.

Fig. 4 shows the transition of sum of 3-axis acceleration power spectrum when absence, sitting, and working by using the acceleration data obtained by preparatory experiment

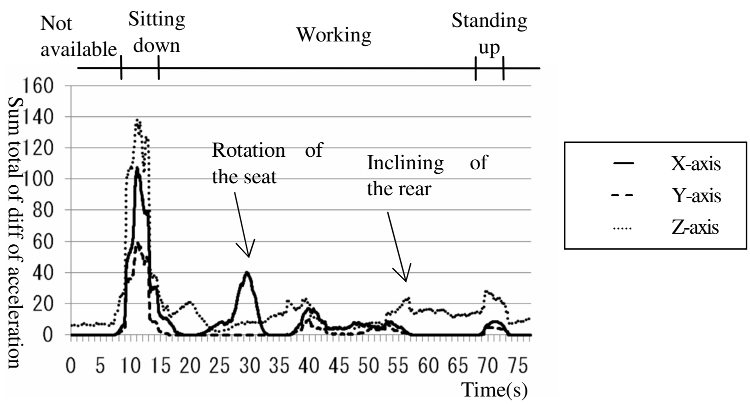


Fig. 4. Transition of sum of 3-axis acceleration power spectrum

Comparing between absence and working in Fig.4, we find that the sum of Y axis accelerations power spectrum does not change very much comparing to that of other axes. On the other hand, the sum of X and Z axis acceleration power spectrum changes greatly depending on the user's motion. For example, the sum of X axis acceleration power spectrum increases by the user's motion like rotating the seat front and the sum of Z axis acceleration power spectrum increases by the user's motion like inclining the backrest of the seat.

We summarize the estimation method for sitting down and standing up using the power spectrum. In case more than -0.3 G and less than -0.1G acceleration is measured when absence and the sum of power spectrum exceeds 50 afterwards, we estimate for "sitting down", otherwise we estimate for "absence". On contrary, in case more than -0.3G and within -0.1G acceleration, or more than 0.1G and under 0.3G acceleration are measured and the sum of power spectrum is between 5s and 10s, we estimate for "standing up", otherwise we estimate for "working".

3.2 Relationship of Sitting Situation and Power Spectrum

Experiment Objective. Generally, it is considered that a person's motion strongly tends to lessen when concentrating. That is, when concentrating, it is highly possible that the sum of X-axis and Z-axis acceleration power spectrum obtained by the motion sensor fixed on the chair (hereinafter called the sum of the acceleration power spectrum) become smaller. We perform the preparatory experiments in order to examine this assumption. In the experiments the subjects are instructed to type on the computer for quantitative evaluation for concentration.

Experiment・Evaluation Method. In this experiment we examine the relationship between the sum of the acceleration power spectrum and the typing speed per unit of time while three subjects engage in typing on the computer for 30 minutes. The subjects are instructed to sit down the chair for 30 minutes and engage in either typing or taking a rest. Except the first 1 minute and last 1minute in each of 30-minutes data, we divide the remaining 28-minutes data into 1 minute to find the cross-correlation functions.

Evaluation result. The transition of the sum of power spectrum and typing speed, and the examples of the cross-correlation function is as shown in Fig.5. According to Fig. 5 (a), we find that the sum of power spectrum increases when the typing speed becomes 0, when taking a rest. Also Fig.5 (b) shows the fact that approximately -0.7 negative correlation is obtained due to the result as mentioned above. Fig.5(c) shows the decrease of the sum of power spectrum when increasing the typing speed. Fig.5 (d) shows that approximately -0.7 negative correlation is obtained likewise.

The average and standard deviation of the minimum of cross-correlation function of the three subjects are as shown in Fig.6. The average of over -0.4 negative correlation function can be seen in Fig.6. Thus we understand that the strong negative cross-correlation exist in the sum of the power spectrum of user's motion and the typing speed per unit of time. Also, the validity of estimation that the subjects are concentrating when the sum of the power spectrum become smaller is clarified.

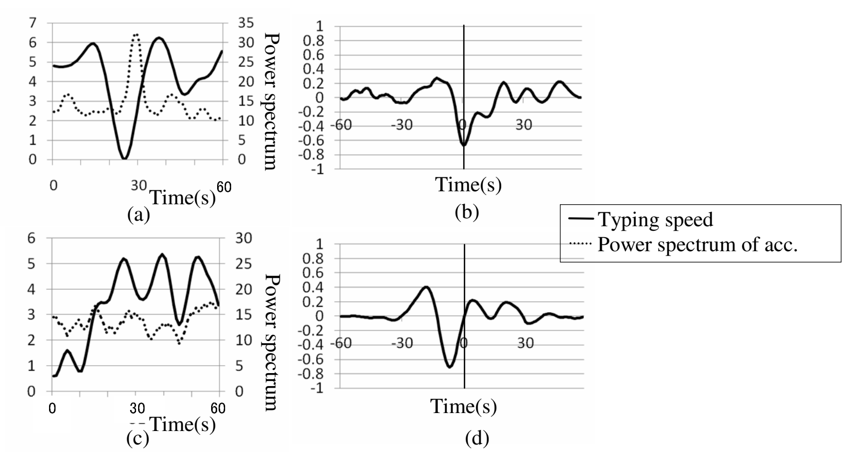


Fig. 5. Cross-correlation functions (b),(d) between power spectrum of user's motion and typing speed(a),(c)

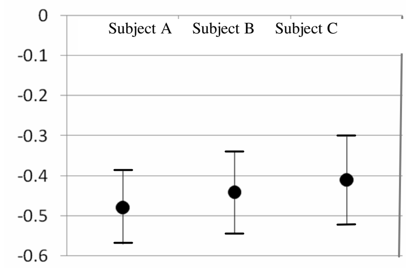
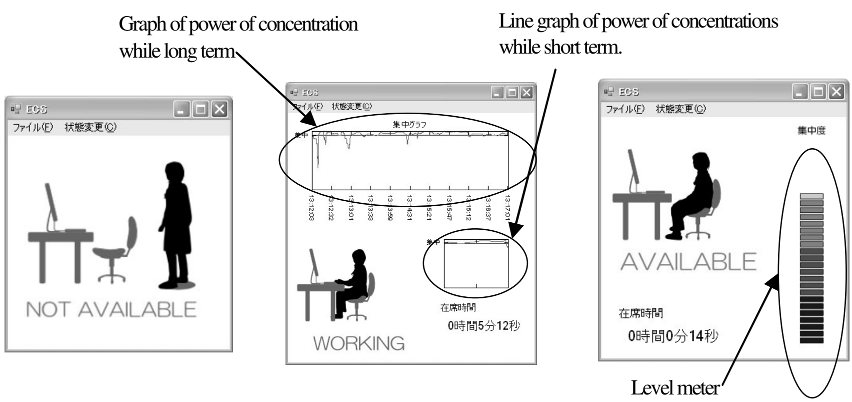


Fig. 6. Average and standard deviation of the minimum of cross-correlation function

3.3 Interface Set-Up

Recently, cars installed instantaneous fuel consumption meters are popular in the market. Drivers are likely to loosen gas pedals because of this meter by knowing his situation at the moment and by reviewing his own behavior. That is also the aim of this proposed system. The situations of users who are sitting are described with avatar so that the users can monitor their own situation objectively. The four types of avatars are prepared: "NOT AVAILABLE","AVAILABE", "WORKING", "PLAYING" and two patterns such as "male"(upper) and "female"(lower) are created. If the system is used as a self-management tool, it becomes important not only to present the user's situation whether concentrating or not concentrating, but also to present the powers of the concentration. Therefore, as well as displaying the avatar, we create a line graph that present the powers of concentration in the long term and three patterns of GUI using a level meter to describe momentary powers of concentration. Fig.7 (a) shows the GUI displaying the avatar only. In the Fig. 7 (b), GUI that presents transition of the powers of the concentration is added to the avatar. As we assume that the less the sum of the power spectrum decreases, the more the degree of the concentration increases, we set the upper limit of the sum of the power spectrum at 500. Then we reduce the sum of the power spectrum from 500 so that the line goes up when the



(a) GUI (avatar only) (b) GUI (with line graph) (c) GUI (with level meter)

Fig. 7. Graphical User Interface

degree of the concentration becomes high. The graph in the lower right of GUI presents the powers of the concentration in the previous 30s. Also the graph in the upper side of GUI presents the powers of the concentration for a last few minutes for users to check the record. In Fig. 7 (c), the level meter which displays the momentary change of the powers of concentration nonlinearly is added. Even if the sum of the power spectrum is small when concentrating, up down of the scale of the meter is visually confirmed by decreasing the sum per one scale.

4 System Sensory Evaluation Experiment

4.1 Experiment Objective

We examine the usefulness and usability of the proposed system and understandably of the powers of concentration presented in three types of GUI. To be more specific, we confirm the operation capability of the estimation system for powers of concentration and perform the sensory evaluation experiments for aforementioned three types of GUI.

4.2 Experiment Conditions Methods

In the experiment, ten subjects (five males and five females in their twenties) are instructed to sit down the chairs with Wii remote controller fixed on, and to engage in typing on computers which the proposed system are running (Fig.8). They are asked to type letters printed on papers in word processing program for five minutes. The GUI is displayed in the upper left of the screen so that it will not disturb their works and the subjects can check it during the works.

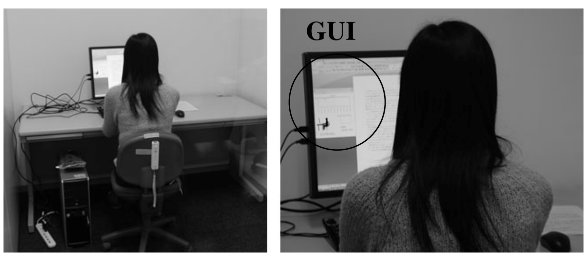


Fig. 8. Experimental scene

The experiments are conducted under the four kinds of conditions as follows: (1) without the proposed system, (2) with GUI using only avatar, (3) with GUI using avatar and line graph, and (4) with GUI having avatar and level meter. Taking into account of the order effect, the order of the experiment conditions changes every subject. After the experiment, we give the subjects evaluation questionnaires by five grades.

4.3 Result of Experiment

The average and standard deviation obtained by scoring the answers of questionnaire on understandability of the powers of concentration and the interface is shown in

Fig.9. These results show that comparing to when having no system and having GUI using avatar only; the subjects finds easier to understand their degree of the concentration when having GUI with the line graph and level meter. Also we conduct a sign test for all combinations in all questionnaires. About the understandability of the powers of the concentration, significant differences at 5% significant level are seen among the combination between having no system and having the line graph, and between having no system and having the level meter. This result also shows that GUI using the line graph and level meter is easier to understand the powers of concentration than having no system.

4.4 Discussion

The GUI with the line graphs and the one with level meters were preferred alike as mentioned previously. The subjects who prefer the line graphs evaluated the ability to check the archival record and the others who prefer the level meter evaluated the ability to understand the powers of concentration. However, some said that they were preoccupied by the system and couldn't concentrate. So the system which users can choose their favorite GUI and save the archival record to look back the day is desirable.

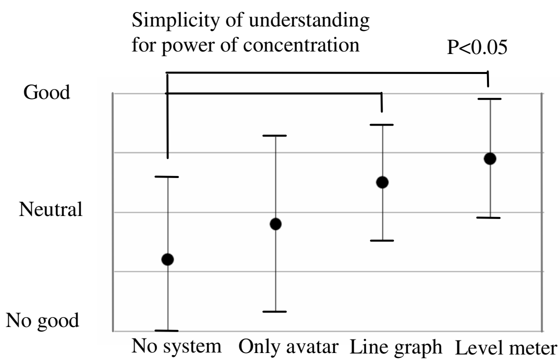


Fig. 9. Result of questionnaire

5 Conclusion

This study aims that users conduct self-management by presenting their situations while they are using the systems. We develop the systems which estimate user's powers of the concentration and sitting down and standing up situation, and also present the powers of concentrations using interface to the users. We conduct further experiments on the sensory evaluation to evaluate the operation effectiveness of the systems and interface. As a result, interface using the line graphs which presents the transition of the long-term powers of concentration and interface using the level meter which presents transition of the momentary powers of concentration are preferred equally by the users.

The proposed system is developed in order to review users' own behaviors by understanding their own situations. Although we consider that this system enables to facilitate the concentration, long hours of concentration turns out to be stress and have a bad influence on mental and health. Therefore, we think it is possible to build up the system to facilitate taking appropriate rests during long hours of concentration.

We will validate its effectiveness in the long-term experiments along with improvement of the existing system and interface.

References

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