Communication device to use slight body movement for ALS patients

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Abstract: Communication device to use slight movement for serious disabled is proposed. This device is developed mainly for patients suffering from ALS or a cerebral infarction. They often have communication difficulty because of deterioration of muscular functions. Features of this device are that the device is wearable on the user's body and that it detects the movement of eyebrow. Because of these features, it is quite easy to install the sensor on the patient's body, not like the conventional sensors. Furthermore, an adaptive communication software is incorporated. A feature of this software is that the arrangement and size of the button and window on the display can be optimized depending on the user's physical ability. In the field test it is confirmed that the communication device developed in this study is successfully helped the people with disability for increasing their communication ability.

Keywords: Disabled, Welfare device, Communication, ALS

1. INTRODUCTION

These days, the increase of patients suffered from cerebral infarction is one of the notable social problems. Due to the development of medical technologies, many of them can be saved from the serious situations. Unfortunately some of them are disabled in the knee, hand or cerebral functions. Some patient of cerebral infarction can't communicate with the others because of acroparalysis. Communication is important for everybody to live independent life. If we are unable to communicate with others it becomes impossible to enjoy life with others. Of course, patients suffered from ALS (Amyotrophic Lateral Sclerosis) also have communication difficulty because of deterioration of muscle functions. Therefore, communication devices are indispensable to support their life.

As a communication device, computer systems incorporated with specialized word processing system are commercially available. The communication device usually includes the touch sensor and the push button as an input device. However, if the user's disability becomes serious, the user often cannot use the touch sensor or push button anymore. One reason is that the user is unable to move his body or finger until the touch sensor. A patient with communication problem is introduced as a typical example here. He is 78-year-old male who suffers from ALS for forty months. He needs an artificial respirator because of lack of muscular function. He lies on the bed all day long and is not able to utter any voice and move his body except his eyeball and eyebrows slightly. It can be readily understood that his disability is too serious to handle a touch sensor. To cope with such problem, vision sensors that detect patient's eye movement or blink have been developed [1,2,3,4]. However, it is rather difficult to distinguish patient's intentional movements from unintentional movements on the eyes.

In this paper, a communication device is proposed that is operated by the slight movements of his eyebrow. A feature of this device is that the sensor can be compactly wearable. Therefore, the device is available in any posture of the patient. This is an important aspect typically for the patient confined to bed. Two kinds of sensors are introduced to detect patient's slight eyebrow movements. One is an acceleration sensor and the other is a rotary sensor. The slight movement detected by these sensors is used as a command signal to operate communication software or electric devices such as TV, air conditioner and emergency call. The sensor is applicable other slight movements on his body as well as eyebrow.

An original communication software incorporated in our communication device is also proposed that is easily accessible by serious disabled. By using this software, user can edit a text, exchange e-mail, and operate home electric appliances with a simple on-off command signal. A feature of this software is the adaptability. The configuration of the screen such as size and location of buttons and texts can be readily rearranged. This is important typically for the disabled since the optimum screen configuration is different depending on their level and type of disability. The adaptability is strongly desired by the disabled who has progressive disability like ALS and muscular dystrophy.

Both the communication device and the communication software developed in this study are applied to ALS patients and cerebral infraction patients to help his communication with his family. And high applicability of the system is confirmed in the field test.

2. CONFIGURATION OF COMMUNICATION DEVICE USING SLIGHT BODY MOVEMENT

A communication device is composed of a computer part, a remote controller part and a sensor part as shown Fig.1.
The computer part includes a personal computer incorporated with original communication software. And a remote controller part includes relay circuits with programmable remote controller. A sensor part includes an acceleration sensor, a rotary sensor and two one-chip CPUs that detects a movement of user's body and click a button on the mouse. These two sensors are introduced due to the compactness that is required for the wearable device.
The user wears either an acceleration sensor or a rotary sensor on his body where muscular movement is active. When the us er wants to activate the communication software, he is request ed to move his eyebrow or the part of the sensor intentionally. Immediately after the movement is detected, One-chip CPU cl icks a button of the mouse. The computer operates the commu nication software, a programmable remote controller and relay circuits that are connected to various home electric appliance s. As an example, at home the user can call families by beepin g alarm or at hospital the user can call a nurse under an emerg ency situation by using this system.

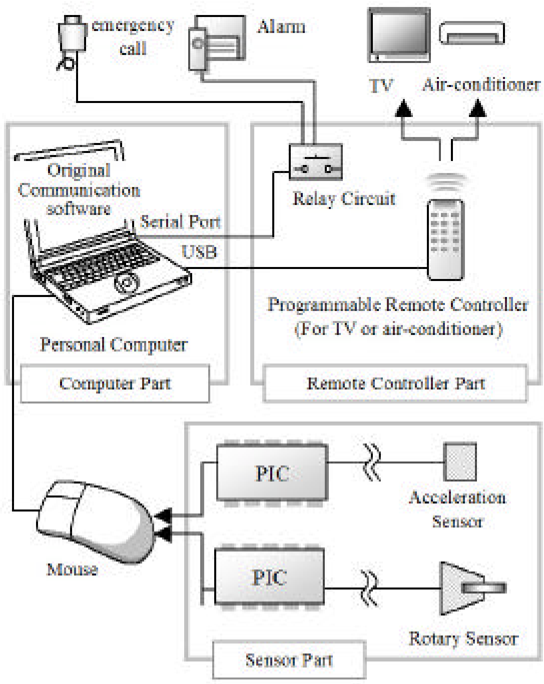


Fig.1. Configuration of communication device

3. SENSORS TO DETECT SLIGHT BODY MOVEMENT

In this communication device, two kinds of wearable sensors, an acceleration sensor and a rotary sensor, are applied to detect user's body movement. The user can choose one of these sensors according to his physical ability.

By using these wearable sensors, the caregiver does not need special intention about the position of the sensor like the case of a touch sensor. In case of the touch sensor, the sensor must be exactly located in a right position so that the user can easily touch the sensor. If the sensor is too near to the user's body, the sensor often emits wrong control signals. If the sensor is too far, the user is unable to touch the sensor. In the case of the serious disabled, the range of body motion is quite limited. Therefore, it requires an intensive attention to locate the sensor in the proper position and direction. In addition, the sensor position needs to be adjusted every time when the patient changes his body position on the bed. However, by wearing the compact acceleration sensor or rotary sensor on the body, such intensive attentions are not required.

(1) Acceleration sensor

An compact acceleration sensor (produced at ANALOG DEVICES Co.Ltd. :ADXL202E) is employed. The acceleration data detected at the user's body in two dimensions are transmitted to one-chip CPU as PWM signals. A one-chip CPU converts the PWM signals to numerical data. Based on the numerical data, the click action on a button of the mouse is decided. Considering that the acceleration signal is affected by the gravitational acceleration, the click action is executed when the absolute value of gravitational acceleration excesses a pre-specified threshold as shown at the point (a) in Fig.2. It is important to note that once the user moves his body toward one direction, the user's body tends to return to the original position as shown at the point (b) in Fig.2. To cope with this problem, a time interval to ignore the movement in opposite direction is set after the first excess of the threshold.

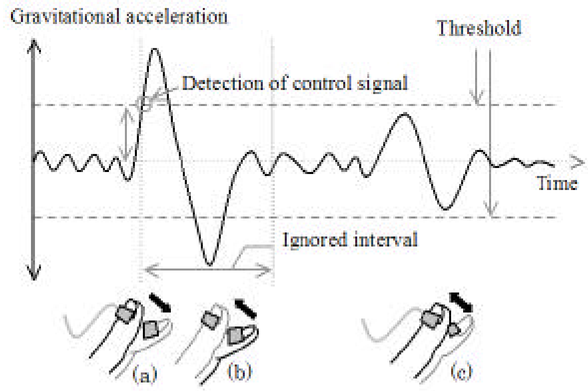


Fig.2. Generation of command signal

(2) Rotary sensor

A compact original rotary sensor is introduced to measure a slight movement of eyebrow. The slight movement of the eyebrow is converted to rotation using a small wheel (diameter is 15mm) as shown in Fig.3. The main body of the rotary sensor is set at the upper part of the operator's forehead. The wheel is fixed around the eyebrow. The rotary sensor can measure the rotating angle with the resolution of five degree using the optical sensor that is commercially available at conventional rotary encoders. The rotation of the wheel caused by the movement of the eyebrow can be measured. This data is transmitted to the one-chip CPU and a click action on the button of the mouse is activated based on the same algorithm with the acceleration sensor. A typical output signal of the rotary sensor is demonstrated in Fig.4, where the value of clockwise rotation excesses the threshold value.

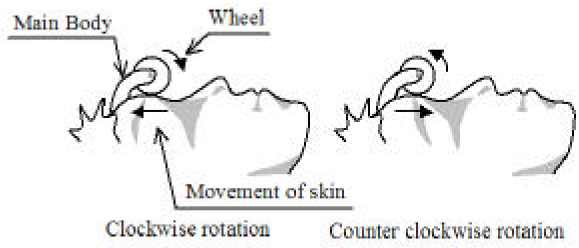


Fig.3. Rotation of wheel due to movement of skin

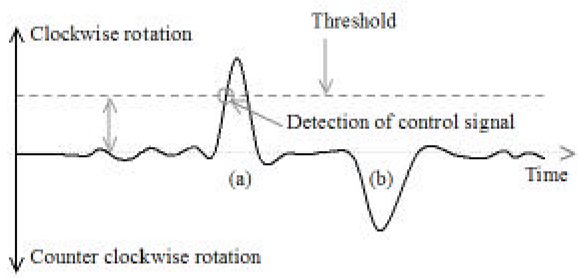


Fig.4. Detection of control signal

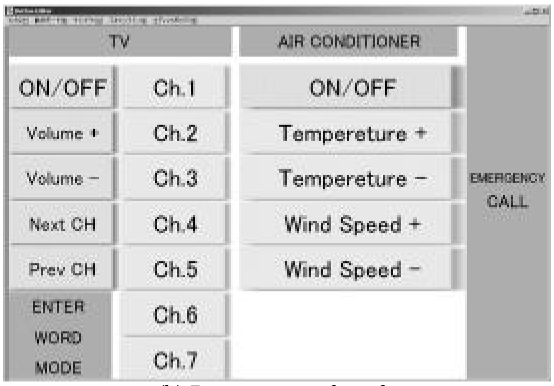
4. ADAPTIVE COMMUNICATION SOFTWARE TO VARIOUS DISABILITIES

Original communication software is developed to make the communication device adaptive to various disability conditions of users. A feature of this software is that the button arrangement in the computer screen can be easily changed based on the user's physical ability. This function is really important especially for patients with progressive disability such as ASL patients and muscular dystrophy patients because their physical ability is unstable and rapidly changes.

This software can be operated in two modes. One is the word processor mode, the other is remote control mode. In the word processing mode, the user can write texts and communicate with others. In the remote control mode, the user can operate home electric appliance such as TV and air conditioner through a programmable remote controller that is commercially available. Also emergency call can be activated through a relay circuit.

Screen images in these two modes are shown in Fig.5.

(a) Word processing mode



(b) Remote control mode

Fig.5. Screen image of adaptive communication device

The operator can select a variety of functions in these screens. In order to select one function allocated to each button on the screen, the user is requested to activate button of the mouse twice in this software. The procedure to select one function on the screen is as explained follows. Suppose word processing mode is selected. Fig.5(a) shows the screen image at the starting stage. First, a vertical line appears and goes across the computer screen from the left side to rightward. The user can stop the vertical line by the slight moving of the eyebrow. Once he stop the vertical line, a horizontal line starts going across the screen from the top to downward. The user can stop the horizontal line as same as the vertical line. Once he stop the horizontal line, the button at the cross section of these two lines is selected and the character or text allocated onto the button is printed on the screen.

In the remote control mode as shown in Fig.5(b), functions of the home electric alliances are allocated to buttons.

A distinguished feature of our communication software is that the images of these screens can be readily edited. For some user, the size of each button should be bigger. For other user, the number of the buttons needs to be less than ten. There may be various requests by the user depending on their physical situations. T he proposed communication software can meet these requests. Editing of these screens can be executed easily by mouse operation by a caregiver. Another input screen of word processing mode is shown in Fig.6 that is designed for serious disabled.

Fig.6. Simple word processing mode

5. FIELD TESTS

The applicability of the device is evaluated through the field tests. The developed communication device is applied to two patients. One is an ALS patient and the other is a cerebral infarct patient, both are confined to bed at home.

(1) Test for ALS patient

In the first test, the communication device is applied to an ALS patient as shown in Fig.6. He lies on the bed all day long and is unable to utter voice and to move his body. He can only move his eyes and eyebrow slightly. First, an acceleration sensor is applied to detect his intentional signals from his eyebrow movements. The acceleration sensor is attached on one of his eyebrow by using a tape. The signal can be detected by tuning up the sensitivity of the acceleration sensor although his eyebrow movement is feeble. The acceleration sensor successfully detected the slight movement of the eyebrow. However, once the sensitivity of the senor is increased, the sensor detects improper signals. One typical signal is recognized when caregiver’s touch the patient ’s bed. Slight movements of the bed easily caused improper signals. A rotary sensor is also applied to detect his eyebrow movements as shown in Fig.7. By using the rotary sensor, his eyebrow movement is clearly detected. Also it is found out that the data obtained from the rotary sensor is quite robust against the bed movements and also other disturbance from the surrounding environment. One output signal of the rotary sensor is shown in Fig.8. The system has been working without any trouble for about three months.

Fig.7. ALS patient with communication device

Fig.8. Rotary sensor on eyebrow

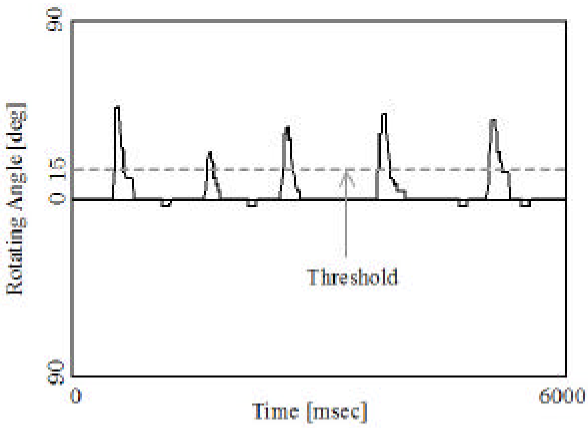


Fig.9. Rotation angle from rotary sensor

(2) Test for cerebral infarct patient

In the second test, the communication device is applied to the cerebral infarct patient as shown in Fig.9. He has been in bed for about fifteen years. He is unable to utter voice. He can move his head upward and downward slightly. An acceleration sensor is installed on his forehead to detect his head movements as intentional signals as shown in Fig.10. After adjustments of button configuration and control parameters such as threshold value and gain of sensitivity, his intentional movement can be clearly detected by using the acceleration sensor as shown in Fig.11. As a result, he successfully operated the word processing software and communicates with his family through the communication device. It is confirmed that he feels comfortable to operate the communication device through his message generated by the device.

Fig.10. User with communication device

Fig.11. Acceleration sensor on forehead

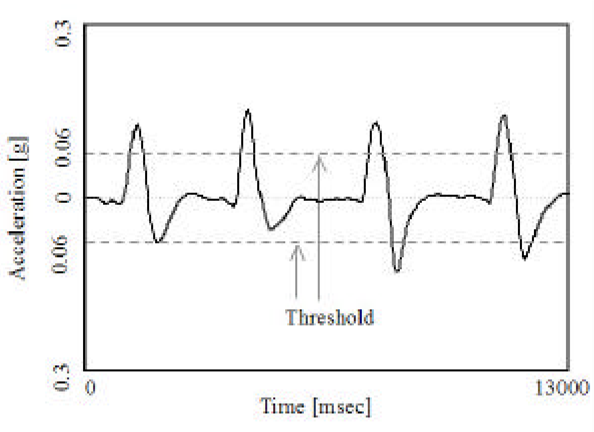


Fig.12. Acceleration data of forehead

6. SUMMERY AND CONCLUSIONS

A communication device that can be operated by operator's slight body movements is proposed. Different from the conventional device, the proposed device uses wearable an acceleration sensor or a rotary sensor to detect operator's intentional signal from operator's body. Acceleration sensor is easily applicable to detect movement of any part of operator's body but the data is often disturbed from the external disturbance such as vibration of the operator's bed. While the rotary sensor can robustly detect the operator's body movement but the location of the sensor for its installation is limited. These two sensors are selected depending on the circumstances and disability of each user.

Original communication software is incorporated in the communication device. A feature of the software is adaptability that the visual interface can be arranged depending on the level and type of the disability is developed.

The communication device is applied to two patients who suffer from cerebral infarct patient and ALS respectively. Through the tests, the performance of the communication device is evaluated. A patient suffering from ALS successfully used a rotary sensor to operate the communication device. A patient suffering from cerebral infarct also used an acceleration sensor successfully. Both patients successfully could communicate through text massage with their families and operate electric devices by themselves by using the communication device. Applicability of the device proposed in this study for two serious disabled people to extend their communication ability is confirmed through the operation tests by the two patients.

We are now applying this communication device to two ALS patients. The results are also successfully.

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