Application of Vision Sensor to Communication Device for Person with Serious Disability

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Abstract: We developed a communication device for person with serious disability to use slight movement. This device is developed mainly for patients suffering from ALS or a cerebral infarction. They often have communication difficulty because of deterioration of muscle functions. A feature of this device is that slight movements of user's finger, eyes or lips can be detected by using a vision sensor. Due to the features of the vision sensor, it is quite easy even for person with serious disability to use a communication device. By the field test it is confirmed that the vision sensors have superior performances as an input device for communication device. Experiments to use an EMG (electromyography) sensor and a rotary sensor are also tested to compare the performances.

Keywords: Disability, Welfare device, Vision sensor, Assisting device

1. INTRODUCTION

Communication is important for everybody to live independent life. Suppose you are unable to communicate with others. It is clear that it becomes impossible to enjoy your life. Patients suffered from serious disabled often have communication difficulty because of deterioration of muscle functions. Therefore, communication devices are indispensable to support lives of serous disabled [1-3].

Nowadays we can use the commercialized computer systems in which the special word processor for the people with disability is incorporated. Persons with upper limb disability are often unable to operate commercialized keyboard and pointing device. Therefore, simplified input devices such as touch sensor and the push button are usually employed in the communication system for the disabled. However, in case that the physical situation of the patients becomes serious, using a touch sensor or pushing button turns to be difficult. In such case, specialized input devices are required instead of a touch sensor or push buttons.

In the previous paper we proposed two kinds of wearable sensors, one is an acceleration sensor and the other is a rotary sensor they are used to detect mechanical movement of head and eye-rids [4]. They were effective even for the slight movement of the person with disability. However, for more serious patient of ALS these wearable sensors are not satisfactory. An ALS patient could move his lips less that two-millimeter. We confirmed that the accuracy of wearable sensor is not enough and the wearable sensor always requires mechanical contact with the patient body. A technique to use vision sensor is effective to cope with these problems. In the previous paper the vision sensor was used to detect eye-ball movement [5]. Data detected by the vision sensor was used to operate communication device. But the proposed system didn't consider the slight body movement of the operator like serious ALS patients.

In this paper we are focused on the detection of slight movement of the finger, eye-rids or lips as well as eye-ball. For peoples with serious disability, slight movement of the finger, eye-rids or lips are important media to communicate with others. Vision sensors are effective to detect such slight movement with accuracy. It should be noticed that sophisticated image processing may enhance the ability of the persons with serious disability.

In Section 2, configuration of our proposed communication system to use vision sensor is explained. In section 3, vision sensor and its image processing technique to detect intentional body movement is explained. In section 4, field test of the communication device to use vision sensor is discussed. The result is discussed in comparison with a rotary sensor and a EMG sensor. Our input device to use vision sensor was applicable to serious patients in Nagasaki. This device is indispensable for him.

2. CONFIGURATION OF COMMUNICATION DEVICE

Proposed 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 circuit with programmable remote controller. A sensor part includes a rotary sensor and a vision sensor. The rotary sensor is used to detect the slight physical movement of the user. The output signal of the rotary sensor is processed by the one-chip CPU. In case the intentional movement is detected, one-chip CPU activates the click button on the mouse. By employing a compact rotary sensor, the input device can be wearable. An vision sensor is used to detect a slight movement of the user's body by image processing.

In case of an ALS patient in Nagasaki city, he wears a rotary sensor on his eyebrow where muscular movement is active. Another ALS patient in Nagasaki city uses a vision sensor to watch his lips where muscular movement is active. When they want to activate the communication software, they are requested to move his eyebrow or lips intentionally. Immediately after the movement is detected, the communication software in the computer responds. The communication software has a function to control a programmable remote controller and relay circuits those are connected to various home electric appliances. Using this function, the user can call a nurse at hospital by beeping alarm or the user can call a family member at home by using this system.

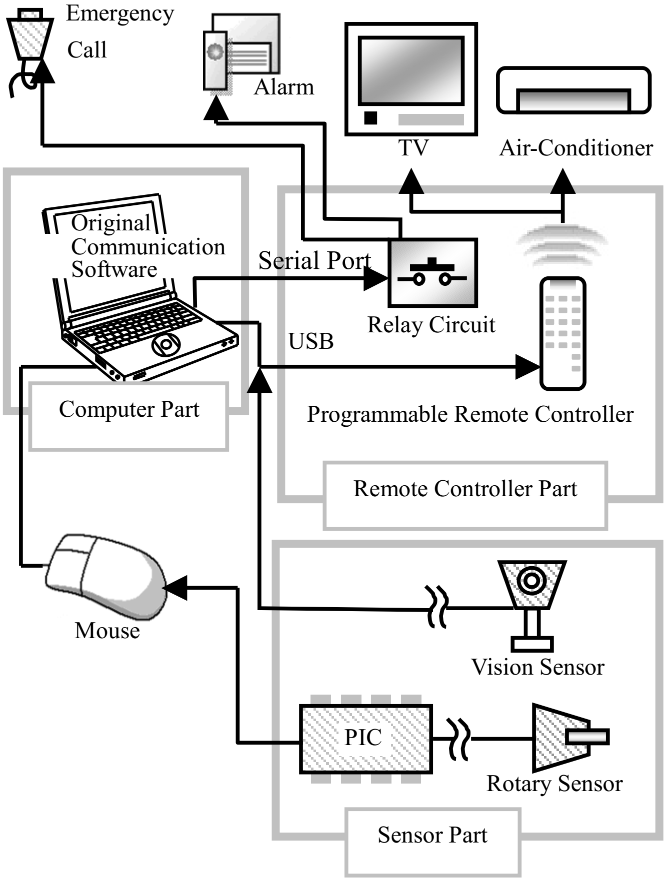


Fig. 1 Configuration of communication device

3. VISION SENSOR

In this communication device, an vision sensor is applied to detect user's slight body movement.

Many ALS patients use touch sensor as an input device of communication device. However, in the case that the possible physical movements of ALS patient is slight, e.g. lip movement less than two millimeters, is serious, the touch sensor is not practical and undesirable. A reason is that the setting a touch sensor for the serious ALS patients needs intensive attention about the position of the sensor. Even one-millimeter miss-arrangement makes the user unable to use the touch sensor. In addition, the focused part, like lips and eyebrow easily moves one or two millimeters by breathing and coughing. In order to cope with this problem, wearable sensors can be effective. In our input device to use rotary sensor, the main body of the rotary sensor is mounted on the user's forehead. The movement of the eyebrow is measured as a rotating angle of a rotating wheel mounted on the main body. Employing this technique, the sensor becomes robust to the head movement and the caregiver is free from intensive and cumbersome setting of the sensor.

The wearable sensor was effective to patients with serious disability. However, for more serious patient of ALS these wearable sensors are not satisfactory. For example, an ALS patients in Nagasaki city can move his lips less that two-millimeter. We confirmed that the accuracy of wearable sensor is not enough and the wearable sensor always requires mechanical contact with the patient body. In the followings a vision sensor technique is proposed to detect slight movement of the lips, eye-rids, fingers and eye-balls.

[Vision sensor]

An approach to detect slight body movement is to use a vision sensor. The vision sensor can measure slight movement of lips, eye-lid and purples. In order to extract intentional movement from the disturbing body movements under the hazardous lighting conditions, we introduced an robust and simple algorithm as follows. The vision sensor is mounted on the bed.

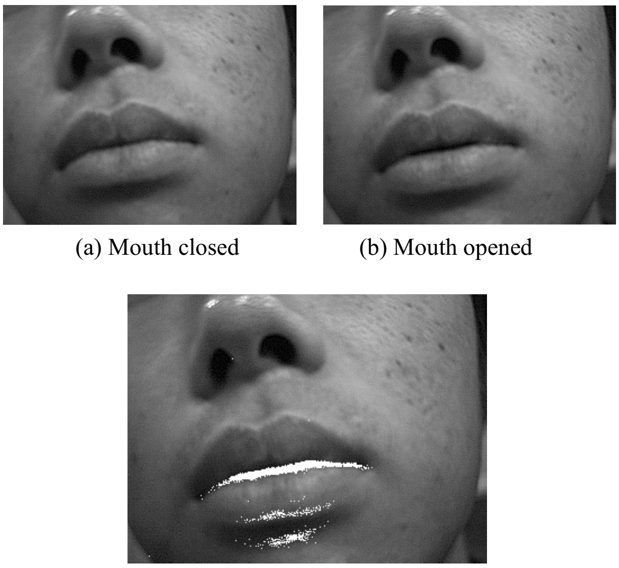
1) Repeat to capture the image of the focused position such as lips, eye-lid or chin with a specified time interval (0.1 sec).

2) Obtain the difference between the first image and the third image. (two times interval)

3) From the every subtracted image, calculate the total number of pixels that have different intensity more than pre-specified level.

4) Obtain the time-sequence of the above number determines the movement is intentional or not.

Using this technique intentional movement of the slight body movement can be detected. A benefit of this technique is that reliable and robust detection can be achieved. Furthermore, the technique is applicable not only to lips, but also to every moveable part on the body.



(a) Mouth closed (b) Mouth opened

(c) Image difference (white area)

Fig. 2 Sample of image processing

In the Fig.2, a typical example of slight lips movement (about 1.5 millimeters) are shown. In Fig.2(c), subtracted image is shown where pixels, which have different intensity, are high lightened.

In Fig.3 time-sequence of the number of the pixels that have different intensity is shown.

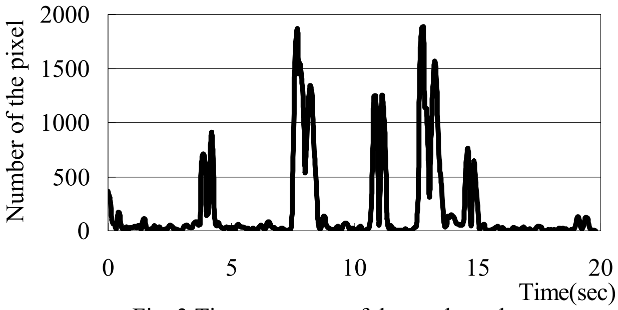


Fig. 3 Time-sequence of the total number of the different pixel

In Fig.3 the examinee opened his mouth five times. As you notice, two peaks at every opening action of the mouth could be detected. Considering these features of time sequence, intentional body movements can be extracted.

4. FIELD TEST AND DISCUSSIONS

4.1 Test of vision sensor

Vision sensor is applied to a serious ALS patient in Nagasaki Pref. The applicability of the device is evaluated through his satisfaction.

We applied vision sensor to an ALS patient as shown fig.4. He used touch sensors as an input device of communication device for about half years. He wrote a letter, switched on the TV and controlled air-conditioner by the movement of his lips. But his physical ability became worse. And even using the touch sensor became difficult for him. All he can move is eyelids and lips. The possible movement of lips is less than two millimeters. Therefore, a vision sensor explained in section 3 is applied to detect slight movements of his lips.

As shown in Fig.4, the vision sensor is settled to detect his lips. He succeeded operate the communication device by the slight movement of his lips. He has used the communication device for more than three months.

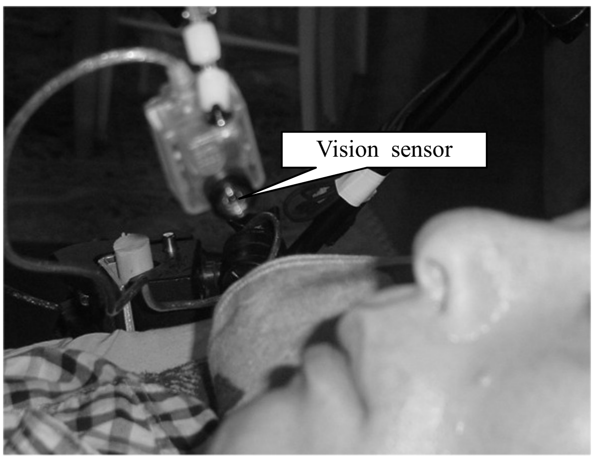


Fig. 4 ALS patient with vision sensor

4.2 Comparison with rotary sensor

We already proposed a rotary sensor to detects a slight movement of the body [5]. A wheel is attached to the target skin. And a compact rotary sensor as shown in Fig.5 can measure the rotation of the wheel. It should be noticed that the rotary sensor could be realized in a compact body. Therefore, the sensor system can be wearable on the patient's body. A benefit of the compact wearable sensor is that disturbing body movement can be neglected and reliable input signal can be obtained. A typical output signal of the rotary sensor is demonstrated in Fig.6, where the angle of clockwise rotation excesses the threshold value. In Fig.7, an ALS patient to wear rotary sensor is shown. The rotary sensor is used to detect his eyebrow movements

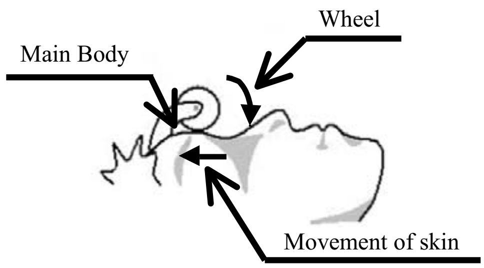


Fig. 5 Rotation of wheel due to movement of skin

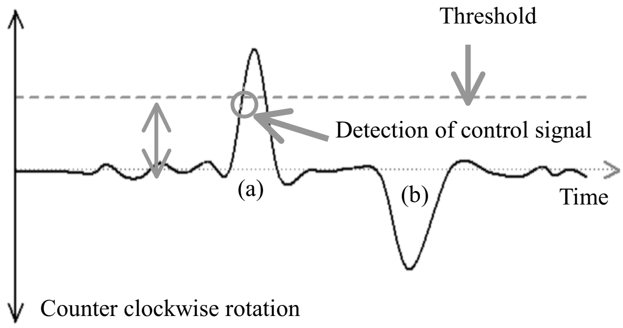


Fig. 6 Detection of rotation signal

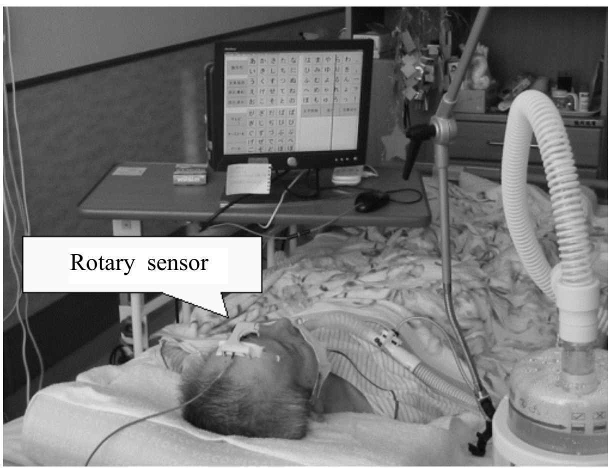


Fig. 7 ALS patient with rotary sensor

The vision sensor shown in Fig.4 is settled to the bed of the patient and is not wearable. Therefore, the unintentional movement of head and bed affects the output signal of the vision sensor. However, the feature of the time-sequence curve shown in Fig.3 enables us to reject unintentional movement from the intentional one by the computer programming technique. This means that the vision sensor proposed here is robust to unintentional body movement, and also hazardous lighting condition.

An advantage of vision sensor over rotary sensor is that the vision sensor has higher accuracy. In Fig2, only 1.5milimeters movement of the lips could be clearly extracted. Even 0.3 millimeters can be estimated as extractable.

Another advantage of vision sensor over rotary sensor is that the vision sensor is possible to measure without any contact with patient's body and skin.

4.3 Comparison with EMG sensor

EMG (electromyography) sensor is well known as a powerful tool to detect activity of the muscles. Therefore, EMG sensor is a possible sensor as an input device of the communication device. We introduced an EMG sensor developed at Otto Bock Corp. (Product No. 13E125=60 and 13E129=G300) to our communication device. The EMG sensor was tested to detect eyebrow movement as shown in Fig.8. The EMG signal detected is shown in Fig.9. During test the examinee moved his eyebrow three times. It was confirmed that the apparent eyebrow movement could be readily detected. However, in order to detect the slight movement of the eyebrow, mounting the EMG sensor onto the forehead needs special attention and also electrical hardware requires sophisticated knwoledges.

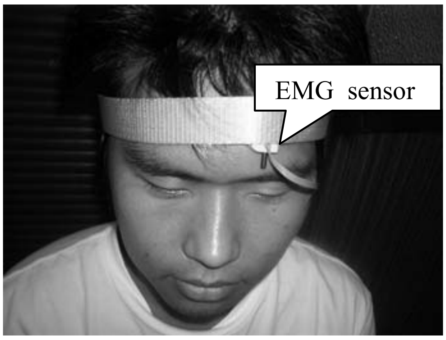


Fig. 8 Examinee with EMG sensor

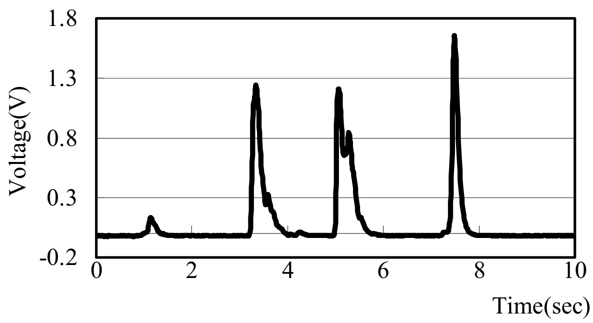


Fig. 9 Time-sequence of detected EMG signal

5. CONCLUSION

A vision sensor is proposed as an effective input tool of a communication device, that can be operated by operator's slight body movements. A feature of the vision sensor is that slight body movement of the operator can be detected with accuracy and without contact with body.

Different from the conventional device like a touch sensor and a rotary sensor, proposed vision sensor can detect operator's intentional movement with enough sensitivity and robustness.

The communication device is applied to a ALS patient. Through the tests, the performance of the communication device is evaluated. The patients successfully could communicate through text message with their families and operate electric devices by themselves by using the communication device.

In this paper we focused at the simple and robust algorithm to detect body movement. But the vision sensor has high potential to satisfy various requirements. The vision sensor is applicable to detect eyeball posture and apply the data to operate the communication device. Already such systems were reported for general purpose to assist persons with disability.

It is required to develop user-friendly communication device to use vision sensor for the person with more serious disability.

REFERENCES

[1] T. Ochiai, T. Ishimatsu, Computer Input device for handicapped using vision sensor, in Proc.3rd Int. symposium on artificial life and robotics Vol.2, pp.634-637, 1997.

[2] T. Ochiai, T. Ishimatsu, Computer Input device for handicapped using vision sensor, in Proc.3rd Int. symposium on artificial life and robotics Vol.2, pp.634-637, 1997.

[3] Osamu Takami, Takakazu Ishimatsu, and Takashi Shimomochi, Development of the environmental control system by using eyeball movements, Proceeding of the Asian Control Conference, pp.715-718, July 27-30, 1994.

[4] Yoshio Fukuda, Motohiro Tanaka, Shunji Moromugi and Takakazu Ishimatsu, A Communication device for disabled slight movement capabilities, International Journal of HWRS, vol.4, No.4, December, pp.7-12, 2003.

[5] Osamu Takami, Kazuaki Morimoto, Tsumoru Ochiai, and Takakazu Ishimatsu, Computer Interface to use head and eyeball movement for handicapped people, 1995 IEEE International Conference of System, Man and Cybernetics, Vancouver, Canada, October 22-25, 1995.