Study on Computer Input Device Using Head Movement for People with Disabilities

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Contents

Chapter 1 Introduction

1.1 Background of research

As humans we are free to exercise the right to survive. However, it is inevitable to encounter some diseases or accidents which may bright some inconveniences to our life and cause some disabilities of our body. Although the case with some people, they still struggle with their life and try their best to lead a life they are expecting. Great changes in science and technology improved our life quality dramatically, and people with disabilities can also have a comfortable life with the help of the desired assist devices.

Persons with disabilities are people who are forced to undergo substantial limitations in daily lives or social life for reasons [1] such as incurable disease or accidents. In recent years, due to the improvement of medical technology, many patients with various incurable diseases or with disabilities have been effectively treated. Even though some diseases get worse over time and cannot be completely cured, the patients can live a long time relying on advanced technology. *This has changed the life expectancy dramatically in twentieth century, and the average life expectancy has been extended by 20 years from 1950 with 66 years old, and it will be extended by 10 more years by 2050 year* [2].

Currently China has more than 160 million aging population and the number is increasing at a rate of nearly 8 million per year. The Chinese government's latest data shows that the average annual population growth rate of the first 10 years of the 21st century is 0.57%, lower than the annual growth rate of the last 10 years of previous century maintaining 1.07%. Therefore, China is entering into an aging society [3]. The growth curve of elderly population is shown in Figure 1-1 [4]. The rapid increase in the elder population brings increasingly prominent problems for the lives of the elder such as rehabilitation care, medical care, spiritual and cultural needs.

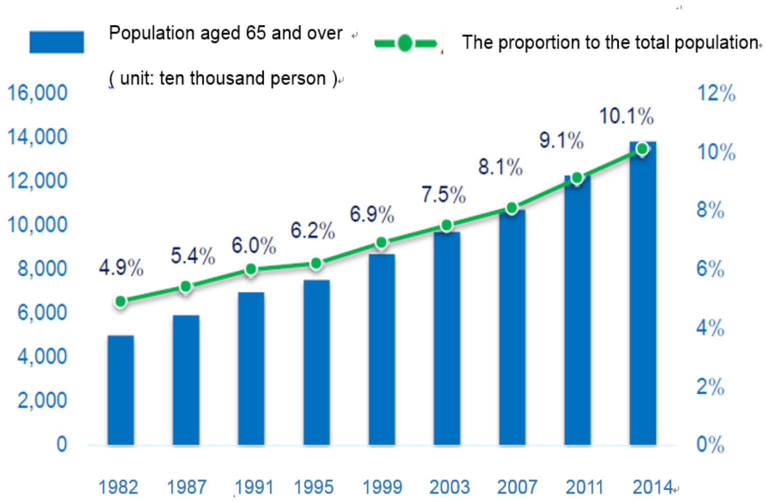


Figure 1- 1 Proportion of the elderly aging 65 or older to the total population in China [4]

Nowadays, Japan is not only a nation with the longest life expectancy, but also a developed country with the fastest aging population. *In Japan, the percentage of aged generation will grow from the current 17.4% (2000) to the 25% range in 2014, which means that the age group will comprise one-quarter of the population of Japan. It will reach 27.0% in 2017 shown in Figure 1- 2* [5].

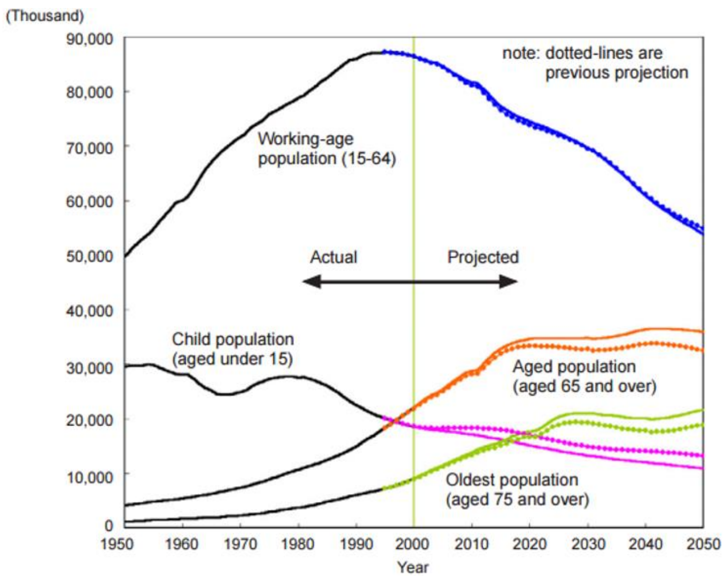


Figure 1- 2 Trends in the number of the major age composition, 1950-2050: Medium Variant [5]

At or below a threshold of 7% of a population being 65 or older, a country is considered to be "aging". After that, it is seen as "aged" until it goes beyond

14%; when more than 20% are 65, societies are often referred to as "super-aged". According to this definition, Japan became the first super-aged country with more than 20% of its citizens above the age of 65 in 2006 [6].This is also due to the fact that in recent years the birth rate has progressively reduced with the increase of the elderly. The number of people with disabilities with different ages is shown in Figure 1-3 [7].

Therefore, the situation has produced many problems in the aspects of the economy and medical fields, especially in the welfare and care field. In order to offer proper nursing cares for those in need to maintain their QOL(quality of lives) in the desired level, sufficient medical and care staffs are required. However, at hospitals and care houses only a small number of workers have to care too many people with disabilities. So the shortage of caregivers directly result in a labor with discomfort, fear and pain. Nowadays most of caregivers are suffering chronic low back pain, stiff neck muscle pain and so on. What is more, in the super-aged society, it is not desirable that the less powerful people such as the elderly and children are forced to work in the care situation. It is high time to consider measures that are immediately effective.

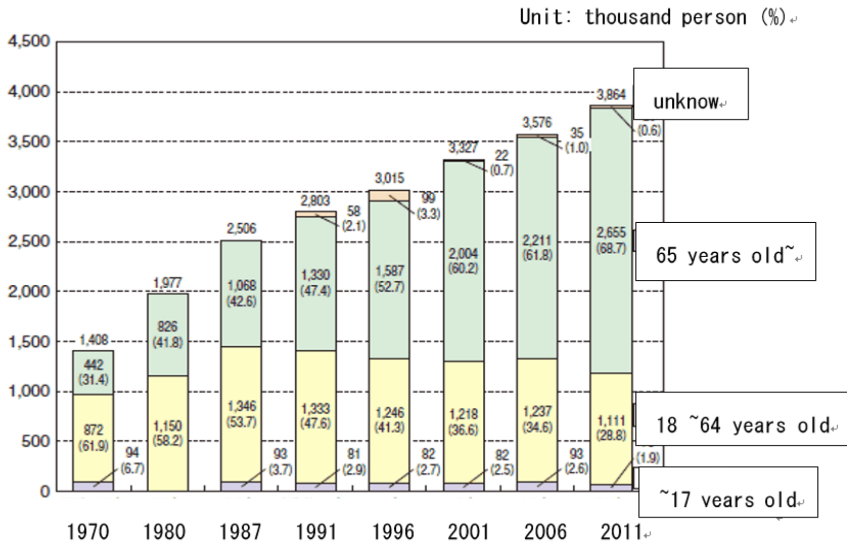


Figure 1- 3 Number of people with disabilities according to age hierarchy [7]

It is a major practical issue placed in front of us to take scientific and reasonable social policy actions to help people with various disabilities. Furthermore general volunteer activities are also actively carried out. It also corresponds to the social problem-solving. *In recent years, remarkable robot technology development of non-industrial fields has attracted public attention* *as an effective means to solve this problem* [8]. It is expected that robot working in non-industrial field can be applied to the services in offices and homes, social welfare, medical field, space development, and amusement to help people undertaking the agonizing works in extreme environments. Under the impetus of the high technology, medical robots and rehabilitation robots is also developing in a rapid speed.

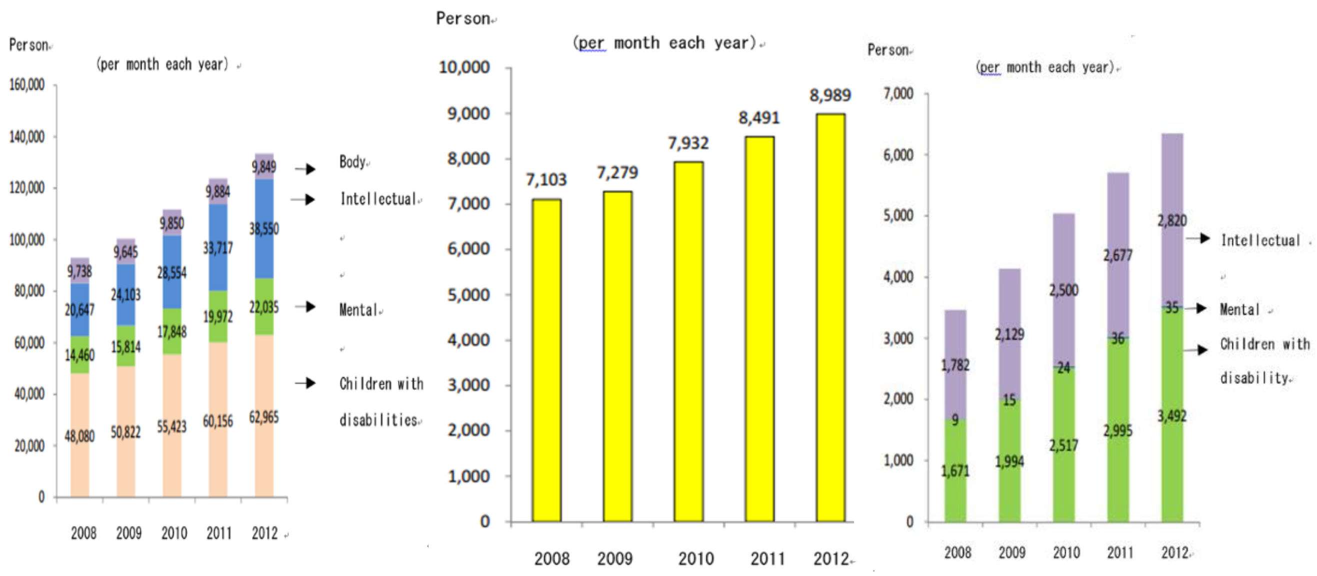
1.2 Current state of the patients with the severe disability

Most of the severe patients with disability are falling into bedridden state and suffering paralysis. Especially, there are many patients who have to sustain breathe by the artificial respirator. So it is necessary for the nurses and caregivers to care the patients continuously for 24 hours in order to cope with sudden emergencies such as excretion and aspiration of sudden sputum. Furthermore, it is necessary for the caregivers and nurses to master the health conditions of the patients, clean the artificial respirator or Gastric fistula and replace the tube. Therefore visiting nursing is also required.

When the patients want to go out for a walk or a hospital visit, it is impossible for those with serious disability using the artificial respirator to move from bed to wheelchair by themselves. *Also, if any trouble occurs with the artificial respirator, two caregivers are required at least, so that one caregiver can cope with the situation manually while the other caregiver gets touch with the doctors or manufactures* [9]. In this way in the home care of persons with severe disabilities, it is necessary for 5-6 people to care one person. In case that if the family is living with the patient with severe disabilities, no doubt that this manpower of 5-6 people will become a heavy burden on the family.

Figure 1- 4 shows the number of different care users from 2008 year to 2012 year in Japan. *Figure 1- 4(a) shows that the average annual growth rate of home care users is 9.5% per month; Figure 1- 4(b) shows that the annual average increase rate of home care for severe patients is 6.1%; Figure 1- 4(c) shows that the annual average growth rate of outdoors assistance users is 16.5%* [10]. According to the data, care of people with severe disability causes heavy burden to their family members and caregivers.

In order to reduce the burden of care, there is no way other than to enable the patients with serious disabilities to sustain themselves as much as possible. The measures can be considered from two aspects, on one aspect, people with disabilities need to save their life when they are in danger; the other aspect is to enable patients to do the daily things through their intention directly with the help of some devices. It is expected that caregivers and the patients' family members will become relaxed and be free from the heavy caring burden. There has been many studies about helping the patients to be self-supporting until now. But the existing researches cannot cope with a variety of situations, so it is not desirable for reducing the caring burden and making the patients independent.



(a) Home care (b) Home care for severe patients (c) Outdoors assistance

Figure 1- 4 Number of users from 2008 year to 2012 year [10]

The first thing necessary for the patients with severe disability who cannot utter a word and move his body is to express their intentions correctly. It is an important element in human living to hear and understand others and communicate with others through expressing our thoughts. Even if a patient has a serious limb paralysis, it is possible for him to talk with others by utterance; if he or she has disability in the vocalization functions, such as the lung or voiceprint, the communication is also possible by writing.

In the cases of progressive incurable diseases, such as ALS (amyotrophic lateral sclerosis), Muscular dystrophy, MSA (multiple system atrophy) and SCI (spinal cord injury), the patients with severe symptoms cannot breathe spontaneously and lose the speaking ability the entire body in paralysis. The causes and symptoms of three diseases mentioned above are described as follows:

- ALS (amyotrophic lateral sclerosis)

Amyotrophic lateral sclerosis (ALS) is a rapidly progressive, invariably fatal neurological disease that attacks the nerve cells (neurons) responsible for controlling voluntary muscles (muscle action we are able to control, such as those in the arms, legs, and face). In ALS, both the upper motor neurons and the lower motor neurons degenerate or die, and stop sending messages to muscles [11].

ALS causes weakness with a wide range of disabilities. For example, if all muscles under voluntary control are affected, patients will lose their muscles strength and the ability to move their arms, legs, and body. However, ALS does not affect a person's ability to see, smell, taste, hear, or recognize touch. Patients usually maintain control of eye muscles and bladder and bowel functions [11].

An example of the ALS patient who is bedridden is shown in Figure 1-5 . He has sensing ability of hands and feet and can move his eyes and mouth but cannot move his body by himself. He is breathing with the help of an artificial respirator. Figure 1- 5 shows that the patient is using a computer input device by chewing his mouth to touch a touch sensor.

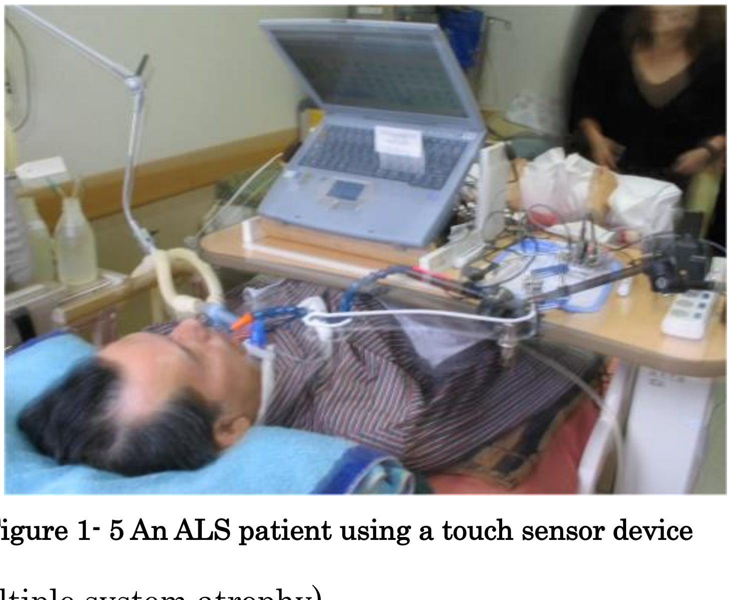


Figure 1- 5 An ALS patient using a touch sensor device

- MSA (multiple system atrophy)

Multiple system atrophy (MSA) is a progressive neurodegenerative disorder characterized by a combination of symptoms that affect both the *autonomic nervous system (the part of the nervous system that controls involuntary action such as blood pressure or digestion) and movement. Nerve cells in the brain and spinal cord is losing progressively. This directly brings about progressive loss of motor function such as slowness of movement, clumsiness or incoordination and impaired speech and eventual confinement to bed* [12].

An example of MSA patient is shown in Figure 1- 6 , who has lost the sensing ability from the neck to feet and also has difficulty with listening but can move his eyes and mouth. His body has to be turned every two hours in order to prevent the bedsore.

Figure 1- 6 MSA patient

- SCI (spinal cord injury)

Spinal cord is a bundle of nerves that runs down the middle of your back. It carries signals back and forth between our body and brain [13]. A spinal cord injury is caused by trauma which disrupts the signals. The spinal cord and nerve roots are damaged depending on the site of injury shown in Figure 1- 7. Therefore, the situations of patients with spinal cord injuries vary widely, from pain to paralysis to incontinence.

Spinal cord injuries can be complete or incomplete. With a complete *spinal cord injury, the cord can't send signals below the level of the injury. As a result, patients are paralyzed below the injury. With an incomplete injury, patients have some movement and sensation below the injury* [13].

An example of SCI patient is shown in Figure 1- 8. He is injured by a falling accident in the factory and damaged around his neck. Because of the damage, his limbs are paralyzed and all his intentional physical abilities are limited above his neck. He needs artificial aspirator and has communication difficulty since uttering voice is not possible. Figure 1- 8 shows that the patient is using a computer input device that employs an acceleration sensor to detect the head movement and pressure sensor to detect the muscle movement of the both sides of the forehead.

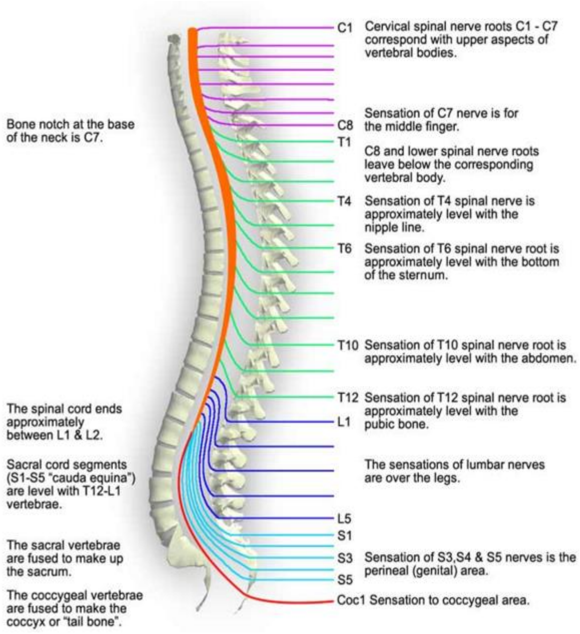


Figure 1- 7 Symptom and injuries of spinal cord [14]

Figure 1- 8 SCI patient

It is urgent to search a new means for the patients to communicate with others.

From the standpoint of care work, communication with the patients with disability is the foundation for implementing the care work, and it is also the indispensable element to sustain the quality of serious patients' life. Fortunately, there are a number of communication techniques established currently. Also, in the society communication device is commercially available. So it is possible to realize the function of expressing intention by utilizing them. Communication device is not simply a device for conversation for patients, but also a means for saving the patients' life to notify the caregivers when the patients are falling into emergency such as poor physical condition or when any sudden accident occurs to the assistive devices in use. Also the positioning is heavier in the Services and Supports for Persons with Disabilities Act, for that assistive devices can help improve the difficulties of daily life of patients, and support the self-reliance. *Which method is used and which kind of communication device is adopted depends on the overall judgment as to how much the devices fit with the hope, budget, medical condition and adaptive capacity of the people with disabilities* [15].

Communication device is to help the patients with serious disability who have lost utterance function and been in limb paralysis to transmit their own intention to caregivers and family, call the caregivers when they are in danger. In the case of the patients who cannot move their hands or legs freely, the device can help them to operate the home appliances around them, such as TV, air conditioning, bed controller, etc. However, the purpose of the recent communication devices also includes the environmental controlling function based on the idea that these devices aim to realize the patients' requirements rather than to tell their own thoughts.

1.3 Problems of computer input devices

Although many computer input devices for the patients with disabilities have been developed, some problems still exist in daily life considering from the standpoint of the patients and caregivers. The disabilities of patients are various and the using range of existing self-support devices are limited. They have the following problems:

(a) Discomfort: Some input devices are categorized to wearable type, patients have to wear the devices such as bandage devices which is fixed on the head shown in Figure 1-9. The patient's eyebrow movement is measured by a rotary encoder which is attached on the tip of the wearing device for the mouse cursor click function. If the device is put in use in a short while, it is ok. However, for a longer usage, the patients will feel uncomfortable with the attachment.

Figure 1- 9 Wearable device used by SCI patient

(b) Barrier of nursing care task: Some devices belong to stand type devices. There are lots of many pieces of stand type equipment for caring the patients. These equipment often becomes a barrier for caring and nursing tasks around them shown in Figure 1- 10 . It should be noticed that these some assistance devices have many wires to connect input devices and controller. Since the wires are too many, this may bring a lot of inconvenience to the nurses in caring for the patients to a certain extent.

(a) A patient suffering cerebral stroke using a touch sensor device

(b) ALS patient using computer mouse by her hand

(c) ALS patient testing a touch sensor input device by head movement.

(d) ALS patient using a pressure sensor input device by moving his head

Figure 1- 10 Patients with stand type input devices

(c) Movability of the device: Most of the patients suffering incurable diseases are in bedridden status, so it is necessary to turn their bodies every two hours to prevent the occurrence of the bedsore, as shown in Figure 1- 11.

When the body position of the patient changes, the position of the device used by the patient has to be changed in accordance with the body position of the patient. This increases the workload of nurses.

Figure 1- 11 Patient whose body has to be turned every certain hours

1.4 Purposes of research

The purpose of this research is to develop computer input devices aimed to help the patients with disabilities to live a comfortable life and decrease the nursing burden of care givers. It should be noted that even if a device has many good functions, it cannot be utilized in the daily life of the patients if it brings about many inconveniences.

Ability to speak and hear is the most basic communication tool for humans. So it is urgent to develop the devices to help the patients who have lost the ability to speak. And the assistance devices for helping communication do get invented and developed one after another. However, the ideal devices are different according to the requirements of each patient.

When a device is put into use, it is better to consider the patient's emotion and life environment as well as whether it is easy for the nurses to care the patients or not. The devices developed so far still have some deficiencies in these aspects. As mentioned above as problem (a) in section 1.3, the wearing communication device is not unfavorable for the SCI (spinal cord injury) patients; the patients will feel uncomfortable when wearing the device for a long time to input the text;

Problem (b) listed in section1.3 is a common problem in medical care and home care. If the wires of the assisting devices around the patients can be reduced, it will be a great help to the caregivers. In view of the patients, it will create a cozy operating environment for them as well. Problem(c) listed in section 1.3 is also a no small problem which is vexing the caregivers.

Under the normal circumstances, the serious patients such as ALS (Amyotrophic lateral sclerosis) patients and MSA (multiple system atrophy) patients, cannot move their hands, feet and bodies by themselves. When the patient's body is turned by the caregivers, the communication device used by the patient may be a hindrance if the device is not smart enough and worn by the patient as shown in Figure 1- 12(a). In the other case as shown Figure 1- 12 (b), because the device is installed on one side of the patient's bed, the caregivers have to reposition the communication device every time the patient's body is turned to another side of his bed, which is rather annoying for the caregivers. If the device is smart enough and dose not require adjusting the position that will decrease the burden and increase the convenience for the caregivers to do the care work.

In order to solve these problems listed above, in this research, the purposes of this research are summarized as follows:

(a)Wearing device used by a patient   (b) Touch sensor device used by a patient

Figure 1- 12 Examples of the devices used by patients

- Development of pillow-type computer input device:

The proposed device is installed in the pillow in use. It employs four pressure sensors and one potentiometer to detect head movement signals of users. Four pressure sensors detect the signals when the user move his head leftward or rightward, and then the signals are applied to move the mouse cursor left or right. Potentiometer detects the signal when the user move his head upward or downward, and then the signal is applied to move the mouse cursor up or down. When the user stop moving his head for 5 seconds, the function of mouse cursor click occurs.

In the first half of this thesis a pillow-type computer input device is proposed. The proposed pillow- type computer input device has three merits compared with the devices fixed on the head of the patient.

As the first merit, the pillow-type computer input device is installed in the patient's pillow. For this reason, it is avoided that the loop wires are scattered everywhere, which will provide a cozy environment for the nurses and avoid perplexing the nurses.

As the second merit, the device breaks the traditional mode and avoids the head-fixed type which decreases the stress of the patients and allows more comfortable for the patient to use.

As the last merit, the device is suitable for a wide range of patients even if the symptoms of the diseases deteriorates. Its use not limited by the conditions of the patients as long as the patients retains little head movement.

- Development of face mount computer input device

The proposed device has a compact mask type, the user can wear it over the nose. It consists of two sensors: tri-axis acceleration sensor and touch sensor. When the device works, the acceleration sensor detects the head movement signals of users for performing the function of mouse cursor positioning. When the user swelling his chewing muscles, the touch sensor detects the signal for performing the mouse cursor click function.

In order to solve bedsore, the body of the patients in bed-ridden status has to be turned every two hours. However, the devices such as touch sensor device used by the patients currently have to be repositioned at the same time in order to be convenient for the patient to use. But this is an annoying task for the caregivers.

In order to liberate the nurses from the annoying task and help the patients to use the device easily, in this research, face mount computer input device is proposed.

The proposed device has two merits compared with the conventional devices such as the touch sensor device. On one hand, the device has small body, it is convenient for the nurses to care the patients and not disturb the caring work. On the other hand, the device is mounted on the face of the patient, which avoids adjusting the direction of the device every time the patient's body turns.

1.5 Overview of this thesis

In this thesis, there are five chapters.

In chapter 1, the research background and the purpose of research are mainly described. The purpose of the research is to propose efficient computer input devices considering the situation of the patient under bedridden state. The nursing condition around the bed should be free from obstacles and annoying wires. In addition, the device needs to be user-friendly that should be operable with remaining physical abilities without any skill.

In chapter 2, Input devices for the environmental control system are discussed. Although the types of computer input devices are various, they cannot meet the needs of all the patients because of the various body conditions of patients. A computer input device by using vision sensor is proposed. It consists of a camera and computer. The principle of the proposed device is based on image matching of the user' eyes. The Orientation Code Matching (OCM) algorithm is introduced in the experiment. In addition, an environmental input device to use tablet is introduced. The system could be compact and available under various nursing environment. Various input devices are operated by slight finger movement. The devices are comfortable, stable and wearable for patients to use.

In chapter 3, a pillow-type computer input device is developed. This device enables the user to move the computer cursor to the desired position on the screen keyboard by his nodding and shaking action of the slight head movement. A distinct feature of this input device is that all required sensors and control boards can be installed inside the pillow. Therefore, the environment around the bed can be free from cumbersome control boxes and wires. This feature is important typically in case the patient is in severe conditions. The patients are often surrounded by life supporting equipment including an artificial aspirator and a throat pump. An original algorithm is proposed which moves the computer cursor on the computer monitor with limited slight head movement of the user. The algorithm employed proportional mode and incremental mode. These modes are exchanged based on the amplitude of the head movement. In case that the amplitude is small enough, the proportional mode is activated. And in the other case, the incremental mode is activated. By incorporating these two modes, even the severe user with slight head movement succeeded to locate the computer cursor to the desired position on the monitor. The performance was evaluated by tracing test and tying test. Tests results revealed the applicability of the proposed pillow-type input device.

In chapter 4, a face mount computer input device is proposed. This device has a compact body and can be mounted on the user face around the nose. A feature of this device is that the sensor of the device is fixed stably on the face. Therefore, even the user's body is turned toward left or right in order to prevent bedsore, the input device is available without the care givers annoying adjusting task of the device. Due to the face mount feature of this input device, care givers could be free from annoying task in the daytime and in the night. On this input device, an acceleration and touch sensor are mounted to enable computer control and also emergency call. Tracing and typing test of the proposed face mount input device were conducted successfully.

In chapter 5, conclusions and future of this thesis are described. Firstly , conclusions are described, in this research, two kinds of computer input devices are developed as effective input devices of a communication system.

In the first part of the conclusion of Chapter 5, pillow-type computer input device is evaluated: the interface device is achieved in a compact pillow type body. A supporting and care devices around the bed often becomes barriers for the care and assist task for the patient. The proposed pillow type interface is designed not to disturb the care and assist tasks and can be used in a large range of the people with various disabilities.

In the second part of the conclusion of Chapter 5, face mount computer input device is summarized. The proposed face mount computer input device is a mask-type input device which employs acceleration sensor for the cursor positioning and the touch senor for the switching motion. By the fine machine work, the mask sticks to the face and nose surface. Input devices for patients under bed-ridden condition need special consideration. Directions of the patient are changed every two hours for the prevention of the bedsore. A feature of the device developed in this study is that the even under the body change for the prevention of bedsore the sensor need not to be re-adjusted.

Also, the future of the communication input device for the disabled is discussed. The purpose of the communication device is to improve the life quality of people with serious disabilities. Although some people are suffering the serious diseases or disabilities, they have clear consciousness as the healthy people, and they have the right to take part in the social activities. In order to help these people to better adapt to the life and realize their life value, the future task of the computer input device not only focus on the word processing, but also support intellectual, creative activities and social participation as the goal.

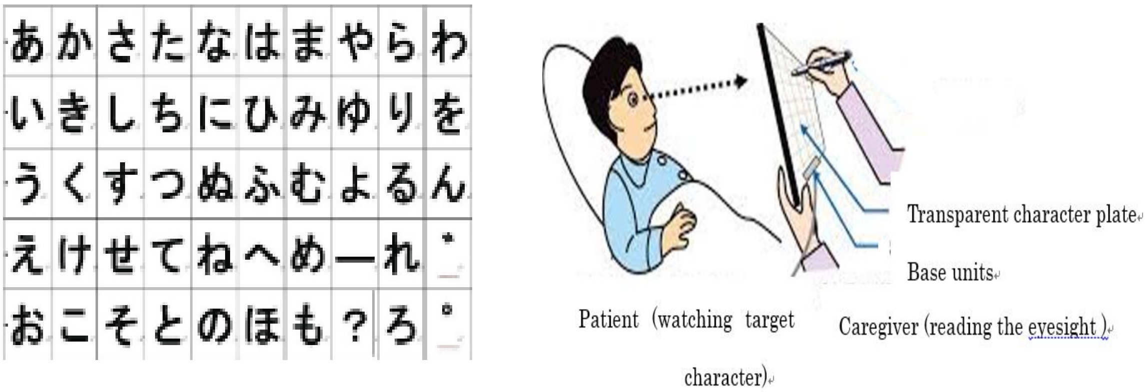
Chapter 2　Input device using body movement

2.1　Introduction input devices using body movement

Body movement mainly includes head movement, finger movement, hand movement, leg movement, feet movement, toe movement and so on. Patients with disabilities in paralysis conditions are have lost some types of body movement listed above. This leads to that they cannot be independent in their daily life. So many kinds of input devices using body movement for patients came into being in the society. In order to realize the function of input, considering that patients with disabilities have some limited body movement for example head movement , finger movement , foot toe movement or eye movement, these input devices employ some sensors such as touch sensor, pressure sensor, push button, rotary encoder and so on to detect of patients. Several kinds of input devices are introduced below.

- Transparent character plate

Figure 2- 1 shows a classic technique to read the intention of persons with disabilities with the help of character plates on which there are 50 characters . The plate is used as follows: the caregivers hold up the plate to the patients, and then the patients look at the plate, the caregivers watch the eyes of the patients and move the plate at the same time until the eyesight of the patients is matched. If the eyesight is matched between the caregiver and the patient, the caregiver reads the character and check it. The caregivers understand what the patients want to express through choosing one character by one character by pointing the rows and columns in sequence with a finger shown in Figure 2- 1(b).



(a) Transparent character plate (b) Using method of character plate

Figure 2- 1 Overall system of transparent character plate

- Scanning input board called "Let's chat"

Figure 2- 2 shows a scanning input method the principle of which is that when the cursor moves on the computer screen automatically where there are 50 characters or numbers or function keys displayed, the patients with disabilities can push the remote switch connected to the body of the input board to select the desired character which is on the places to which the cursor moves. The communication device by scanning input method comprise input switch, a dedicated equipment and accessories such as an alarm. Figure 2- 2 shows an communication device called "Let's chat" [16] developed by Japanese Panasonic Co. Ltd by which the users can write a text, print the text, display. *It is possible to save and read out the texts up to 62, at the same time, it has been installed remote control functions of TV and calling buzzer function* [16].

Figure 2- 2 Let's chat

- Communication device to use a computer

There is also other communication devices especially developed for the computers in the market instead. The familiar examples are shown in deficiencies called “Denn No Shinn” [17] shown in Figure 2- 4 developed by Japanese Hitachi KE system and “Hearty ladder” [18] shown in Figure 2- 3 which is a free software for anyone. It is possible for the patients to watch TV and DVD provided to the computers and search the internet to send mails rather than just write passages and call the caregivers with the help of “Denn No Shinn” and “Hearty Ladder”.

Figure 2- 4 Denn No Shinn [17]

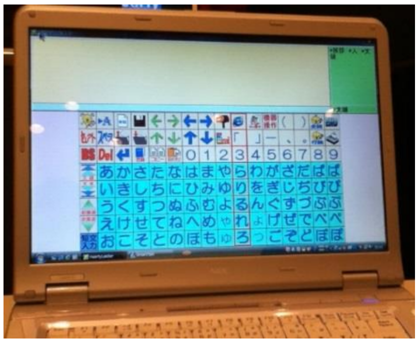


Figure 2- 3 Hearty ladder [18]

In addition, the communication device by the scanning method is also expanded the operating range through many kinds of sensors and switches considering the status of different serious patients. However, the symptoms of people with disabilities are diverse, the auxiliary devices commercially cannot be corresponding to all kinds of patients, in this case, there are some volunteers to develop some assisting devices for inputting in accordance with the individual symptoms. In the case of the incurable disease ALS, progression of the disease is fast, it is necessary to change the input device in a short period.

- Push button switch and Bending switch

A simple one is contact push switch which can be available to transmit the signal if pushed by human’ hands or feet. There are many kinds shown in Figure 2- 5 [19], Figure 2- 5(a) shows a kind of push button switch, while (b) shows another type switch called bending switch [20].

(a) Push button switch (b) Bending switch

Figure 2- 5 Contact input type switch [19] [20]

- Capacitance touch sensor switch

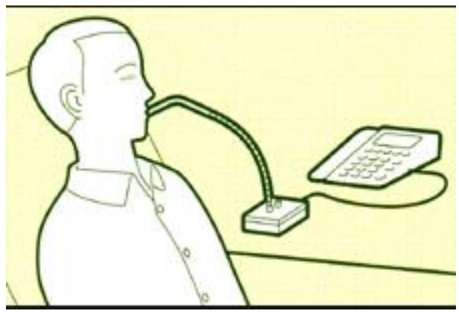
Another input switch employs the touch sensor shown in Figure 2- 6. The principle of the touch sensor is based on the fact that capacitance of the electrode will increase when the user touch the tip of the sensor.

Figure 2- 6 shows a method applied to the daily life. It is mainly fixed in the bed, the tip of touch sensor is close to the body of people with disabilities. If the patients touch the tip, it will generate an "ON" signal, and if the patients leave the tip, it will generate an "OFF" signal.

Figure 2- 6 Patient using a capacitance touch sensor

- Breath switch

The principle of breathe switch is as follows: a tube is connected to the breathe type switch shown in Figure 2- 7 [21]. And inside the sensor body a compact pressure sensor is mounted. When the user blows to the tube shown in Figure 2- 7 (b), the switch will generate "ON" signals which is detected by the control system. Figure 2- 7(a) shows a breathe type switch developed by Tokki technology research industry Co.Ltd.



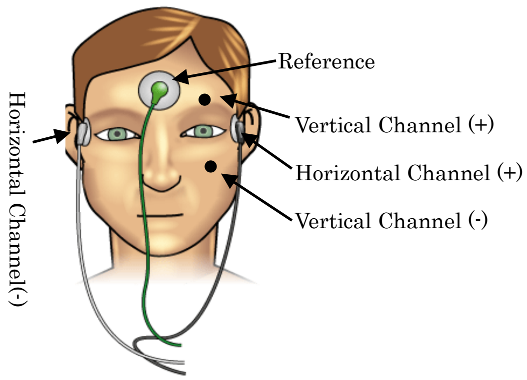
(a)Breath type switch (b) An example for using the switch

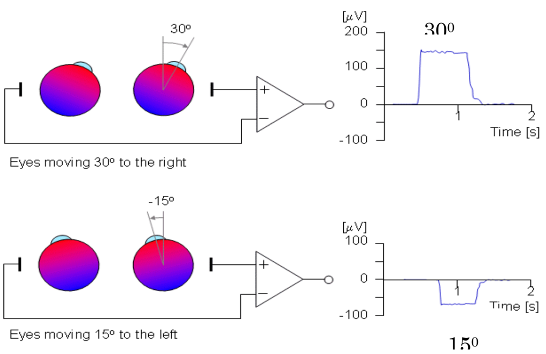
Figure 2- 7 Breath type switch [21]

- Input switch using EOG signals

Electrooculography (EOG/E.O.G.) is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye [22]. The principle of electrooculogram is described as follows: when people gaze towards left, a negative-trending change in the recorded potential difference occurs near the outer canthus of the left eye; when people gaze towards right, a positive-trending change in the recorded potential difference occurs near the inner canthus of the left eye.

The eyes can be described as a fixed dipole with positive pole at the cornea and negative pole at the retina shown in Figure 2- 8 (a) [23]. *The magnitude of this corneoretinal potential is in the range 0.4-1.0 mV. It is not generated by excitable tissue but, rather, is attributed to the higher metabolic rate in the retina. This potential difference and the rotation of the eye are the basis for a signal measured at a pair of periorbital surface electrodes.* The signal is known as the electro-oculogram, (EOG) shown in Figure 2- 8 (b) [24].





(a) Electrode placement (b) Signal corresponding to angle of eye rotation

Figure 2- 8 Electro-oculogram (EOG) signal generated by horizontal movement of eyes [23] [24]

Figure 2- 9 shows that a patient is using an input switch using EOG (electrooculography) signals [25]. The principle of this device is a technique that records the eye movements, by measuring the changes on electrical dipole present on the eye (cornea positively charge and retina negatively charge). During eye movements this dipole position changes. And then electrodes are placed on the skin area close to the eyes these electrical changes can be measured and also the eye movement can be detected. So patients suffering full limbs paralysis can operate the computer with the help of this device only by their eyes movement.

Figure 2- 9 Patient using input device by EOG signal

Although many kinds of assisting devices for patients with disabilities appear in the society, they cannot meet the needs of all patients in the welfare and caring field. Considering from the viewpoint of device, on one hand, it is difficult for some assisting devices to be widespread in use because of the high price; On the other hand, the application ability varies according to different patients. The disease of some patients are progressive such as ALS disease, the device is just only available for a period, so it is necessary to change the device from time to time.

Two types of input devices using body movement will be introduced in the next section.

2.2 Computer input device by using vision sensor

2.2.1 Configuration of the computer input device

With the development of information technology in our society, we can expect that computer systems to a larger extent will be embedded into our environment. These environments will impose needs for new types of human-computer-interaction, with interfaces that are natural and easy to use. In particular, the ability to interact with computerized equipment without need for special external equipment is attractive in view of patients with the disabilities.

Today, the keyboard, the mouse and the remote control are used as the main interfaces for transferring information and commands to computerized equipment. In some applications involving three-dimensional information, such as visualization, computer games and control of robots, other interfaces based on trackballs, joysticks and datagloves are being used. In our daily life, however, we humans use our vision and hearing as main sources of information about our environment. Therefore, one may ask to what extent it would be possible to develop computerized equipment able to communicate with humans in a similar way, by understanding visual or auditive input [26]. Next a computer input device by vision sensor will be introduced.

Figure 2- 11 shows a perceptual interfaces for human computer interaction based on visual input captured by vision systems replacing traditional interfaces based on keyboards, mouses, remote controls, data gloves or speech. The system consists of a computer connected to one video camera with telephoto lens, which can measure target's displacements correctly [27]. The video images of a target on a face, such lips and eyeballs, captured by the camera and streamed into the computer with a maximum sampling rate of 60 frames per second. The advantage of this device is that it can be fixed in a location distant from the patient.

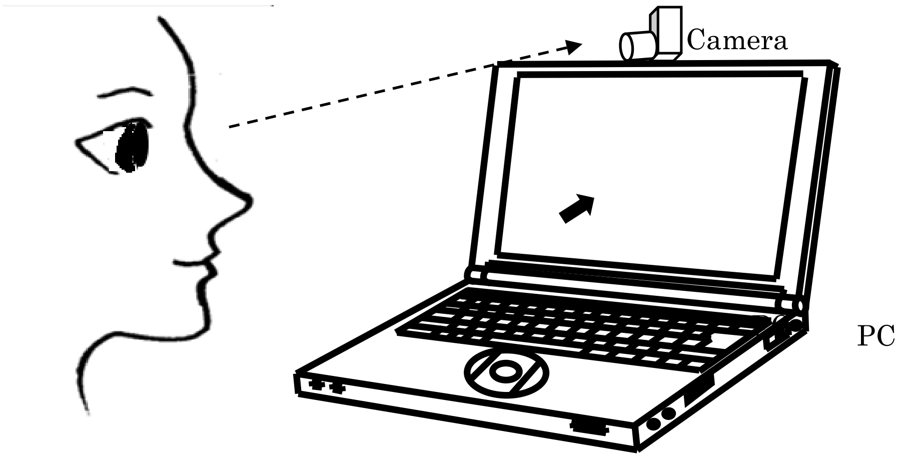


Figure 2- 10 Vision based interface [27]

Because the input device aims to help these serious disabilities communicate with others, a convenient tracking of head or face movement by video camera provides an accurate measurement of changing facial features. The robustness of the system is rather important for the patients with serious disabilities. In designing the system, orientation code matching (OCM) algorithm is introduced. A feature of the algorithm is that accuracy of the template matching can be increased even under the hazardous conditions.

In this study, the vision-based interface system consists of one web video camera connected to a desktop computer, which can measure target's displacements correctly. Eyeballs is the target video images captured by a camera which is digitized into 640 × 480 pixel images in 8 bit scales and streamed into the computer with a maximum sampling rate of 60 frames per second shown in Figure 2- 11. According to position of user's eyes in the image this interface system could be used as computer input device for the serious cord injury people where the cursor is positioned with conventional image processing such as template matching.

Suppose face image in Figure 2- 11 is captured by the vision sensor and image 1 in Figure 2- 12 is an image pattern prepared in advance. Since the similarity between these two images is insufficient, tracking accuracy of the eye position may become unreliable and/or fail [28]. In order to overcome this problem, multiple pattern images are captured under various head movement conditions. And then compare the captured image with the pre-prepared multiple pattern images sequentially to select the best matching image. Suppose the captured image is well matched with image 5 in Figure 2- 12 , the next captured image needs only to be compared with the neighboring pattern images 1, 2 and 3. In order to increase the system speed as well as accuracy, the number of potential matching images in this template matching technique must be kept to a minimum. It is noticed that the eye's winking actions are clearer to be detected than other eye actions in Figure 2- 12 , so it can be designed to activate the switching of the mouse click button. By increasing the number of image patterns, the performance of the face tracking and eye's winking detection can be improved in regard to accuracy, the Orientation Code Matching (OCM) algorithm is introduced in this study which will be described in the following section.

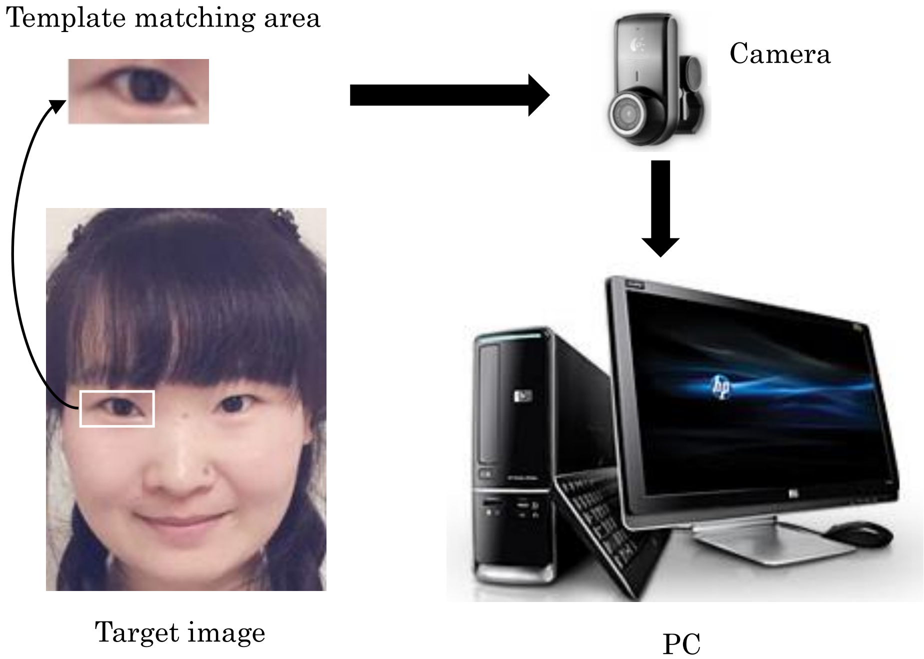


Figure 2- 11 Vision based interface

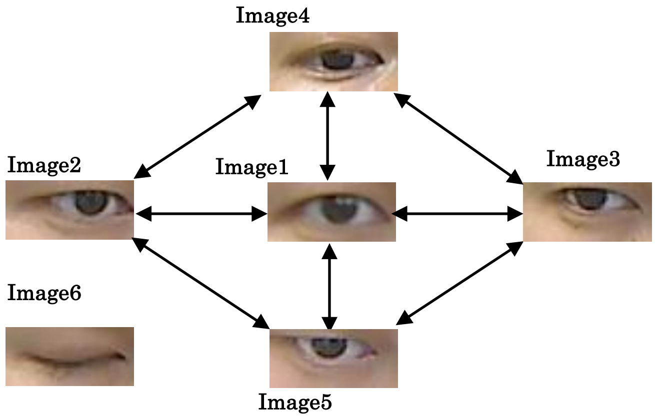


Figure 2- 12 Multiple pattern images

2.2.2 Pattern matching method to employ OCM algorithm

As a pattern matching method called NCC(Normalized Correlation Coefficient algorithm) is mostly used [29] . The OCM algorithm is based on the matching of the gradient information. It has the advantage of being robust to abnormal brightness variations such as highlighting or shadowing background over the conventional pattern matching methods. Rather than gray levels, the OCM algorithm computes using orientation codes directly around each pixel. A recent study by the project team has shown that the matching can be made robust by using only differences or tendencies of adjacent pixel brightness values rather than their actual values [30], based on this, the OCM algorithm was proposed and formulated [31] ~ [32].

Different from the Normalized Correlation Coefficient algorithm, orientation code representations in the OCM algorithm for an object image from the captured images and the template are constructed from the corresponding gray images such that each pixel represents an orientation code that is obtained by quantizing the orientation angle at the corresponding pixel position in the gray image. The orientation angle refers to the steepest ascent orientation evaluated from the neighboring pixels, and measured with respect to the horizontal axis.

Assumed that $K(x, y)$ represents an analog image, so we can obtain that $\nabla K_x = \frac{\dot{K}}{\dot{x}}$ is horizontal derivative; $\nabla K_y = \frac{\dot{K}}{\dot{y}}$ is the vertical derivative of the analog image. For the discrete version of the image, it is evaluated around a pixel positio (m, n) , then the orientation code is obtained by quantizing

$\theta_{(m,n)} = \tan^{-1}(\nabla K_x/\nabla K_y)$ into $N(= 2\pi/\Delta_\theta)$ levels with a constant width Δ_θ $(=\frac{\pi}{8})$. Since the value range of tan^{-1} function is $\left[\frac{-\pi}{2}, \frac{\pi}{2}\right]$, the practical orientation is determined after checking signs of the derivatives, and so the orientation range angle θ is made to be $\left[0, 2\pi\right]$. For precise detection of template instances, this width $\Delta\theta$should be fixed upon as an adequate value. This should be considered in relation to the inherent amount of information and possible spatial resolution.

The orientation code of each pixel is defined by the following equations:

$$V_{(m,n)} = \begin{cases} \left[\frac{\theta_{(m,n)}}{\Delta_\theta}\right] & |\nabla K_x| + |\nabla K_y| > Л \\ N = \frac{2\pi}{\Delta_\theta} & |\nabla K_x| + |\nabla K_y| \leq Л \end{cases}$$

Where $Л$is a threshold level for neglecting the low contrast pixels. N is a large value as a code assigned for practical orientation.

A dissimilarity measured based on the definition of orientation codes is designed to evaluate the deference between any two images of the same size. The best match is determined object image $K$from the same scene. Which is defined as following equation:

$$\mathrm{E} = \frac{1}{F} \sum_{K_{(a,b)}} e(G_{K_{(a,b)}}(m,n), G_T(m,n))$$

where $G_{K_{(a,b)}}$ and G_T are the orientation code images of the sub image and the template respectively, $F$is the size of the template, (a, b) shows the position of the sub image in the scene, and $\mathrm{e}(G_{K_{(a,b)}}(m,n), G_T(m,n))$ is the error function based on an absolute difference criterion

$$\mathrm{e}(p,q) = \begin{cases} \min\{|p-q|, N-|p-q|\} & if\ \ p \neq N \bigcap b \neq N \\ \frac{N}{4} & if\ \ p \neq N \bigcap b = N \\ 0 & otherwise \end{cases}$$

When a comparison is performed between a pixel having an orientation code evaluation by the $\tan^{-1}$ function and the one whose code was set to N due to low contrast neighborhood, the error cannot be computed by finding the difference. In order to avoid such an inconsistent comparison, we need to assign a reasonable value to the error function corresponding to such pixels. The assigned value should be such that it does not bias the dissimilarity evaluation for the sub image. For such cases, we assigned the value of $\frac{N}{4}$ to error function. This is the error value which is expected when these two pixels have no relation between each other. A large value for N is helpful for discriminating such an incompatible comparison.

Since the orientation code are cyclic in nature, the absolute difference is not used directly for computing the error function, rather the minimum distance between the two codes is determined. For example, in Figure 2, the code 0 is only a unit difference away from the code 15, whereas their simple difference yields 15. Such evaluation makes the matching stable against minor pose variations of the object, regardless of the direction of the movement. As a consequence of this cyclic property of orientation codes, the maximum distance between any two codes is never more than $\frac{N}{2}$

Finally, the similarity ratio s is derived as follows:

$$c = \frac{E}{\frac{N}{2}} \quad (0 \leq c \leq 1)$$

$$l = 1 - c \quad (0 \leq l \leq 1)$$

where c is discrimination ratio obtained by dividing the average absolute difference E by the maximum of absolute difference $\frac{N}{2}$. l is the similarity ratio. To find the best matched point, at which the similarity reaches the maximum value, the template image must be compared with the entire target frame pixel by pixel. This is obviously time consuming. In order to drastically reduce the computational time, a ROI window is defined based on the currently best-matched point, and the OCM processing is carried out only within this limited window.

2.2.4 Experiments

In order to evaluate the effectiveness and stability of the proposed algorithm (OCM), a vision input device was tested employing current algorithm NCC and proposed algorithm OCM. In the experiment six pattern images of the eye were used as shown in Figure 2- 12 . By using this template matching technique, switching action could be achieved as well as positioning of the computer cursor on the computer display. Furthermore, image 6 in Figure 2- 12 was captured at the instant of closing the eyeball, which was correlated to the left button on the computer mouse. Then the user could operate the computer by head movement and eye winking actions.

OCM algorithm compares captured image and template image focusing on the trend of orientation extracted at every pixel. In order to convince the robust feature of OCM algorithm, the trajectory tracking test of the mouse along the pre-specified rectangle by using NCC and OCM algorithm was conducted. The mouse cursor was moved to follow a rectangle (512*384 pixels) starting at the left-lower corner and rotating counter clockwise. Both of them could work in the normalize situation environment. However, in Figure 2- 13 and Figure 2- 14, show other experiments where the user tilted his neck rightward with thirty degrees at the right-lower corner of the rectangle. The NCC algorithm could not track the rectangle as shown in Figure 2- 13. The NCC algorithm could not detect the position of the mouse correctly. And around the right upper corner of the rectangle the tracking task was aborted. Although, the OCM algorithm succeeded to trace the rectangle even under the condition that the user tilted his head thirty degrees during the tracking task.

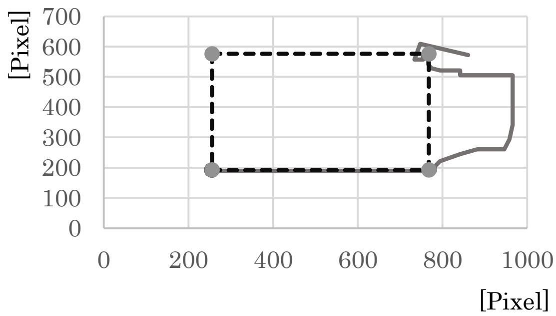


Figure 2- 13 Trajectory of mouse cursor by NCC algorithm with inclination

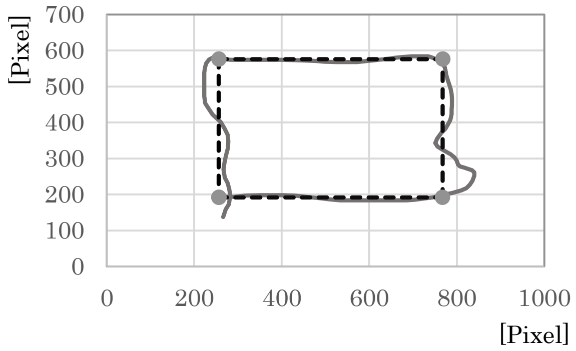


Figure 2- 14 Trajectory of mouse cursor by OCM algorithm with inclination

2.2.5 Summary about image sensor

For serious patient with spinal cord injury, vision-based interface used as an environment control system is proposed. The input device detects the movement of the mouth or eyes. The displacement data of the eye's movement is used to locate the computer cursor. The eye winking action is used to click the computer mouse. Important features to the vision input device are accuracy and robustness by the introduction of multiple pattern images. Furthermore, for fit the multiple pattern methods, two kinds of algorithms were compared. One algorithm is a conventional tracking algorithm (NCC) and the other algorithm is an advanced algorithm (OCM). By the experiments it was convinced that the second algorithm is robust with regard to variation in brightness including the presence of highlights and shadows and also existence of the obscuring objects.

While the NCC algorithm method to use multiple pattern images was efficient, the OCM algorithm method proved to have significant potential for wider application in regard to assisting long term health care for patients with spinal injuries. A computer controlled environment system using the proposed input devices is possible for a serious spinal cord injury patient. The patient's quality of life is now significantly improvement, his activities include his ability to freely communicate with friends and control home electric appliances.

2.3 Environmental input device to use tablet

An environmental input device by using tablet serve as a visual interface for the ALS patient. ALS disease is a degenerative disease which affects the patients muscular activity in feet's and hands, leading to a bed ridden status. The loss of independency affects their will to live. In order to assist their daily lives and give them more independency, the input device is equipped with the function of handling the home appliances and make telephone calls shown in Figure 2- 15. The system uses a tablet as a visual human interface so that the patient can select the desired appliance by selecting the corresponding item on the tablet screen. Based on the remaining patient's abilities this input device can detect slight finger movement. The tablet is connected to two controllers via Bluetooth. The first one is an input controller, which receives the signal from the input device. The second one is an infrared controller for the home appliances such as Room-light, TV, Air-conditioner and so on. And the infrared controller includes an original bed remote controller. Additionally the tablet is connected to the telephone network, so the patient can make phone calls to his relatives or the hospital. The user is supposed to operate the tablet by using his slight finger movements.

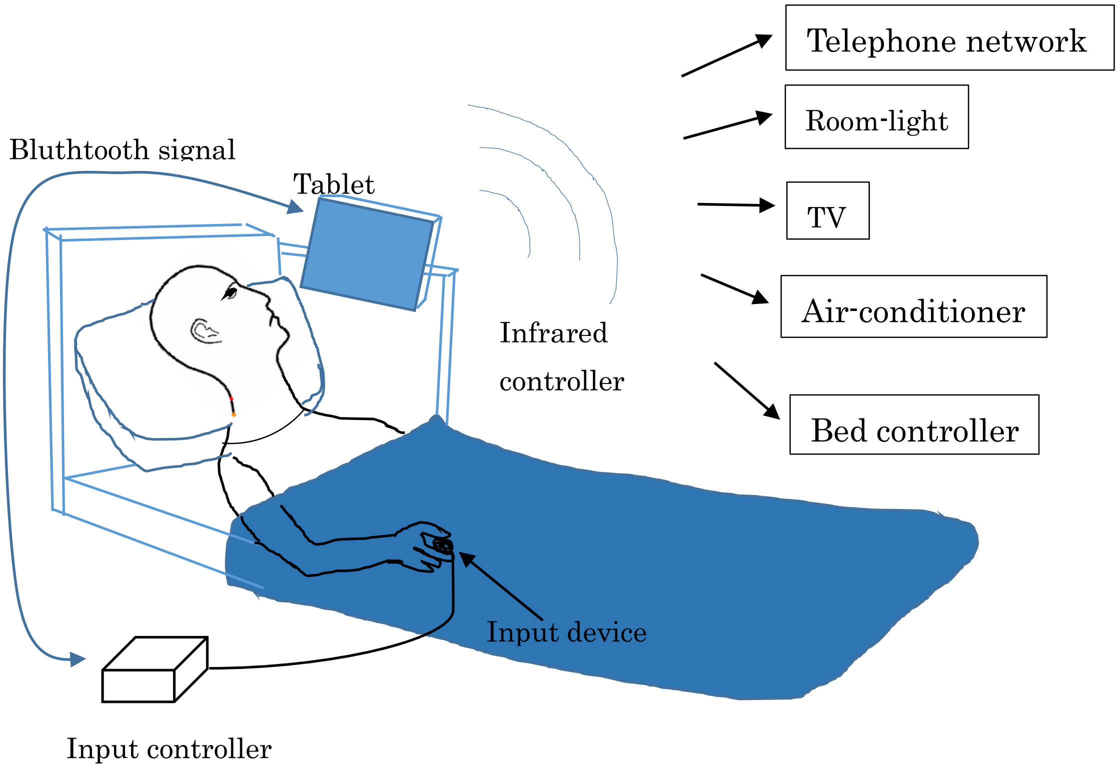


Figure 2- 15　Configuration with wireless network

2.3.1 Controller to use tablet with wireless network

There are main menu and sub-menu listed on the screen of the tablet shown in Figure 2- 16 , the patient selects the desired menu or sub menu through an input device. Depending on the selected menu or sub menu the patient can make phone calls through the Wi-fi internet to relatives or hospital; or control the home appliances that have functions controlled by infrared signal. In addition to the home appliances, the tilt angle and height of the bed can be changed by the infrared controller. According to the ability of patients, the input device connecting to the tablet varies, such as pressure sensor, touch sensor.

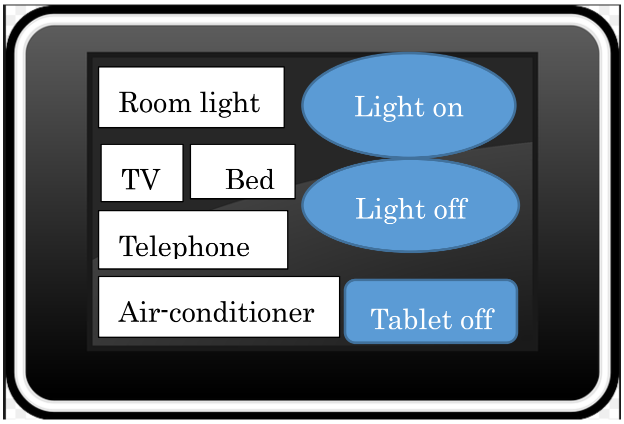


Figure 2- 16 Application screen of the tablet

2.3.2 Input device with wireless communication

In this research, the slight finger movement is detected as effective input signals. The controller obtain the signal from input device and send the data to tablet through Bluetooth. Considering the stable and reliable switching by the user and easy setup for the care-givers, as input device, there are many types are designed such as sheet type, box type and grip type,. Pressure sensors, touch switch, mouse switch and push button are taken into account in the experiment. The patients can choose the best type input device according to their ability of moving fingers.

The feature of sheet type input device is easy for the patients to use, it detects the finger movement of patients by a sheet type pressure sensor. And patients need not to wear the device. It is available for the serious patients who just have a little finger movement.

In the front side of the box type input device, a pressure sensor or touch sensor is installed. The patients just put his hands on the box type input device to push or touch the sensor.

The grip type input device is an easy wearable type, it employs pressure sensor or touch sensor to receive the signals of finger movement. It is suitable for the patients who can grip his hands a little harder.

2.4 Conclusion

Input devices for the environmental control system are discussed. And also the wireless controller to use tablet is proposed. Conclusions of this chapter is summarized as follows:

(1) In section 2.1, body movement is the essential movement for humans, while the patients suffering incurable diseases or accident, they have limited body movement. Many computer input devices by using body movement existing in the society are introduced. Although the types of computer input devices are various, they cannot meet the needs of all the patients because of the various body conditions of patients.

(2) In section 2.2, a computer input device by using vision sensor is proposed. It consists of a camera and computer. The principle of the proposed device is based on image matching of the user' eyes. In this experiment, the Orientation Code Matching (OCM) algorithm is introduced. The computer receives the patient's eye image captured by the camera, and it is applied to activate the switching of the mouse click button. The experiment result using NCC algorithm is compared with the experiment results using OCM algorithm, and the OCM algorithm is more accurate than the NCC algorithm revealed from the result graphs. Even if the patients have serious condition, the proposed device is available to use.

(3) In section 2.3, an environmental input device to use tablet is introduced. A computer controlled environment system using the proposed input devices is possible for a serious spinal cord injury patient. The patient's quality of life is now significantly improving, his activities include his ability to freely communicate with friends and control home electric appliances.

The system could be compact and available under various nursing environment. Various input devices operated by slight finger movement. The devices proposed in this paper are designed to be comfortable, stable and wearable. Applicability of the tablet system and the input devices were evaluated by ALS patients.

Chapter 3 Pillow-type computer input device

3.1 Introduction

Due to the introduction of advanced robotic and sensing technology in some welfare cases, even serious patient also can be live self-independently with the help of various care and assist devices. However, there still remains difficult situations since the environmental and also physical conditions around the patient are too various. In order to deal with these various patients, various care and assist devices are required.

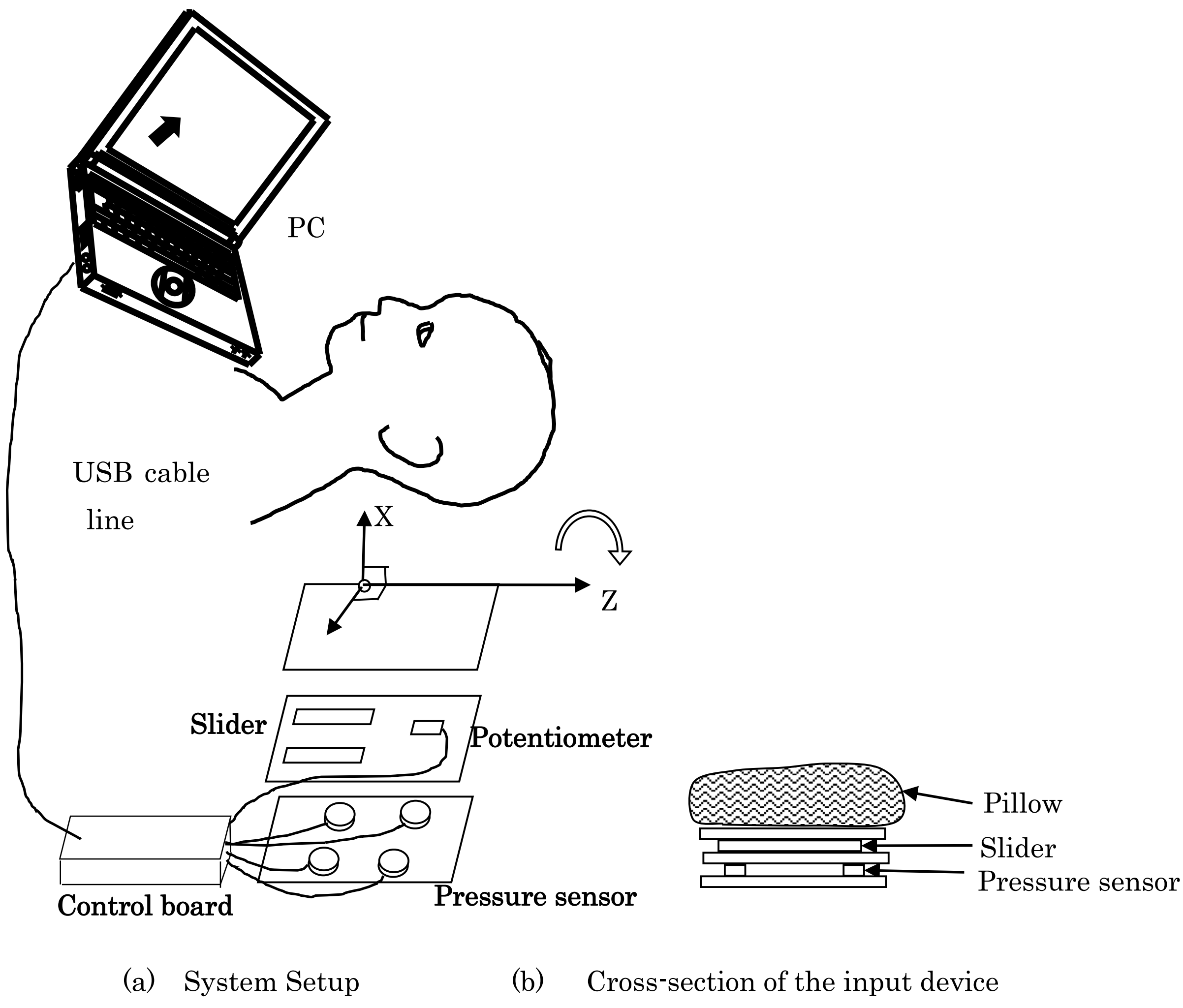
A pillow type interface device is proposed in this thesis . Since the interface device is achieved in a compact pillow type body, interference of the interface device to the care environment can be neglected. By using this device, the patients can move the computer cursor on the computer to the desired position two-dimensionally by the slight movement of the user's head. While patients are on the bed, the pillow gives us various vital information like body temperature, pulse beat, snoring sound and so on. These vital signals are often used for medical treatments and prevention of diseases. An interface device to have a pillow type-body was already proposed, where the pillow was composed of four air bags. Head movements of the user were estimated by the pressure variation arising on the four air bags. Advantage of the proposed pillow type-interface is that you can use your lovely pillow as the interface which every day you use. Another feature is the introduction of the four pressure sensors and two sliders. Four pressure sensors enable to measure the degree of the shaking action of the head. Sliders enable to measure the degree of the nodding action of the head. In addition, the slider made the nodding action easier by reducing the friction force between the head and the pillow.

In order to enhance the operability of the input device, an original algorithm was developed. A feature of the algorithm is that the movement of the cursor in the near range is conducted in proportion to the slight head movement and the positioning in the wide area is specified by the stronger head movement as well.

3.2 Proposed pillow-type computer input device

The configuration of the pillow-type input device is shown in Figure 3- 1. The input device manipulates the computer cursor on the display by the head movement. The head movements can be categorized into two kinds of movements. One is the head shaking action, where the head is moved around the neck side by side. The other head movement is head nodding action, where the face is moved upward and downward.

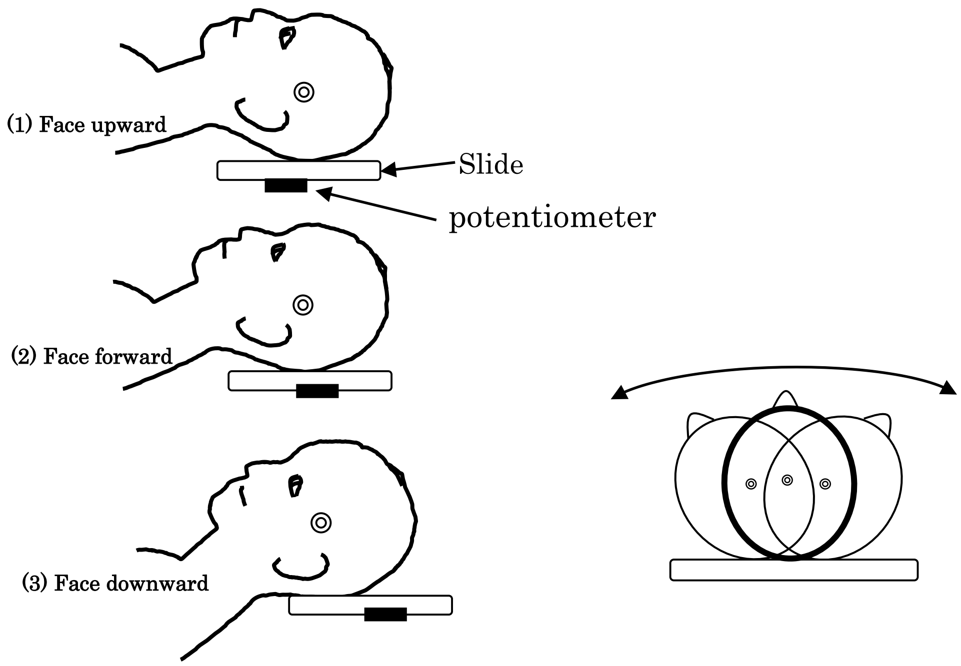
Sensing devices of the proposed input device are mounted under the pillow to obtain the information about the head shaking movement and the nodding movement. The device is composed of three-plates as shown in Figure 3- 1(a). Four pressure sensors are mounted between the bottom and middle plates. Two mechanical sliders are mounted on the middle plate. These sliders allow the top plate move horizontally toward the head or foot direction. Horizontal movement of the top plate is measured by a potentiometer .



(a) System Setup (b) Cross-section of the input device

Figure 3- 1 Overview of the system structure

The cross-sectional view of pillow and the input device is shown in Figure 3- 1(b). Four pressure sensors are used to measure the two-dimensional position of the gravity center of the head. It can be readily recognized that head shaking actions move the gravity center on the pillow side by side as shown in Figure 3- 2 (b). But, the nodding actions move the gravity center based on the complex mechanisms of head and body movements. Figure 3- 2 (a) shows while the user moves his face upward or downward, the movement of horizontal position of the gravity center of the head is negligible. Figure 3- 2(b) shows that while the user move his head leftward or rightward, the movement of the gravity center of the head is remarkable. In the experiments relationship between the nodding movement and the movement of the horizontal position of the gravity center of the head was obtained. In some case the center of the gravity moved downward by the upward nodding action. In other cases the center of the gravity moved down-ward by the down-ward nodding action. This can be estimated since the nodding action changes the posture of the head and changes the position of the center of the gravity slightly. Therefore, a sensor called potentiometer is employed to measure the sliding distance of the plates instead of pressure sensors when the user move his head upward or downward. The working principle is described as follows: when the user looks up, the slider will be moved to the left side, and the resistor of potentiometer connected to the slider will become bigger; when the user looks down, the slider will be moved to the right side, and the resistor of potentiometer will become smaller. Considering that nodding action moves the top plate remarkably, the horizontal movement of the mouse cursor is related by the four pressure sensors and the vertical movement of the mouse cursor is related to the top place movement.



(a) Nodding action and gravity center (b) Shaking of Head

Figure 3- 2 Gravity center of the head in different state

In this study, the controlling system of circuit board employs microchip cpu called (Dspic30f4012) developed by Microchip Technology Co.Ltd, which receives the analog signal from the four pressure sensors of the proposed pillow-type computer input device, and then convert the analog signals into digital signals and then transmit the digitals to the computer by FT232RL USB serial conversion module developed by Strawberry Linux Co.Ltd [33].

The circuit system is shown in Figure 3- 3. In this study, four pressure sensors called FSR402 shown in Figure 3- 4 are employed. The sensing range of force is 0.1~100N. The circuit board of the controlling board is shown in Figure 3- 5.

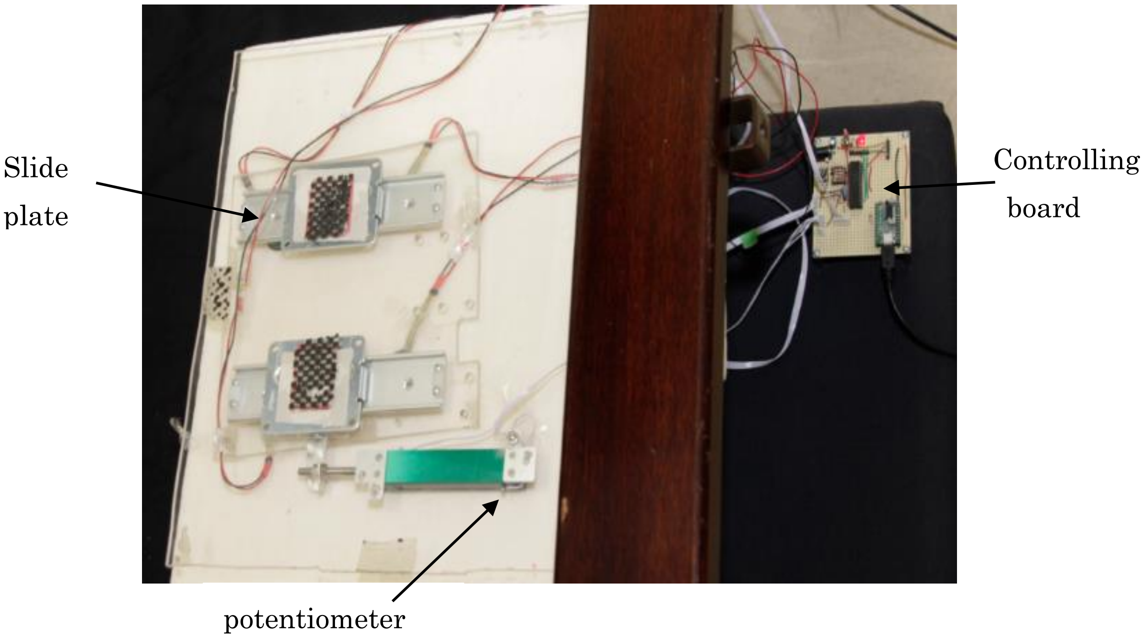


Figure 3- 3 Overview of pillow-type computer input device

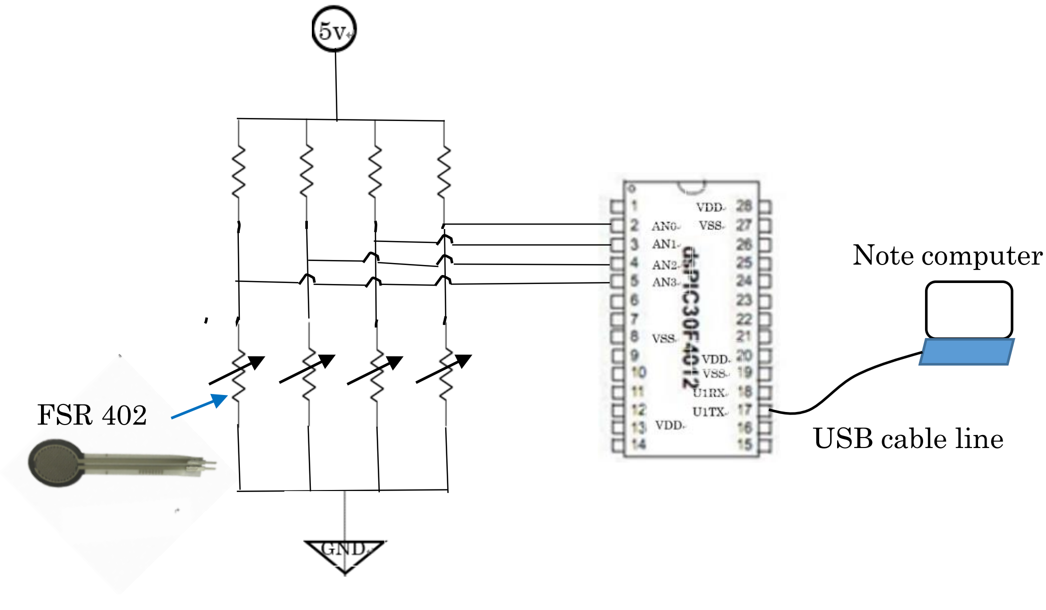


Figure 3- 4 Circuit diagram of controlling system

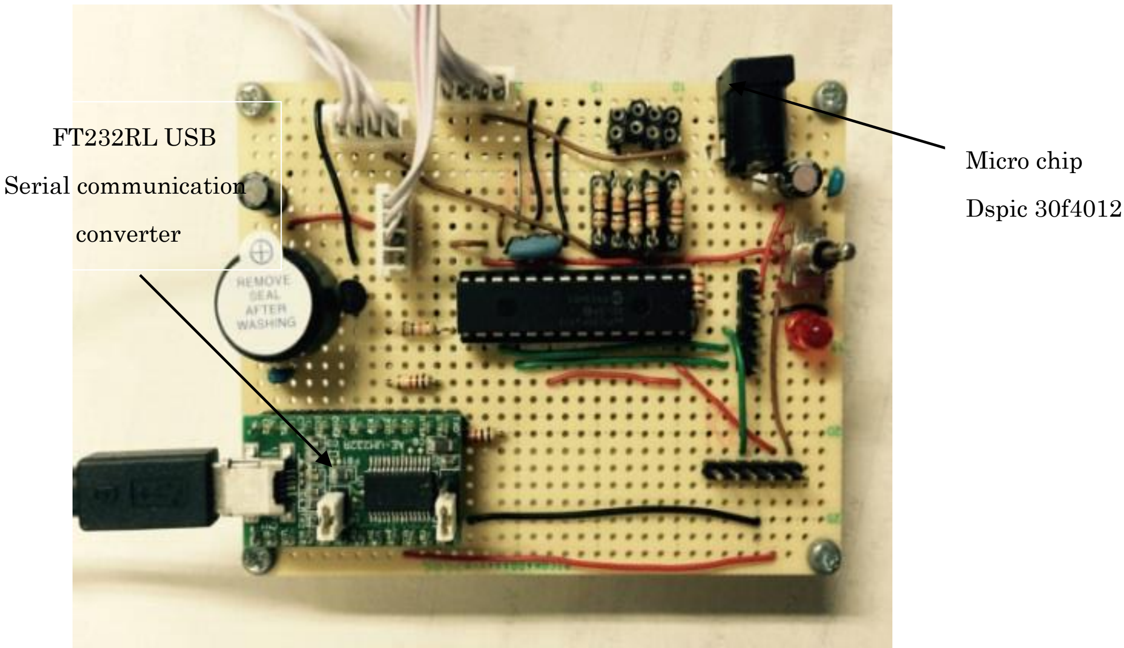


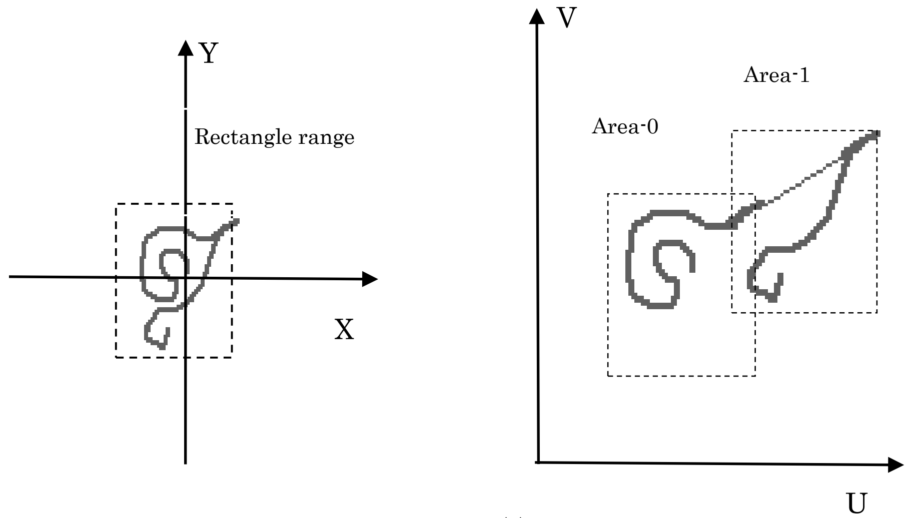
Figure 3- 5 Controlling board of pillow-type computer input device

3.3 Mouse operation algorithm

3.3.1 Switching of Proportional Mode and Joystick Mode

Since the target patient has serious physical disability and under the bed-ridden condition, the input devices should have user-friendliness and good operability based on his or her remaining physical abilities. Here we consider two coordinates, one is the command coordinate system as shown in Figure 3- 6 (a) and the other is the screen coordinate system as shown in Figure 3- 6 (b). On the command coordinate system, x represents the horizontal position of the gravity center of the head which is estimated by the four pressure sensors. y represents the nodding angle estimated by potentiometer. These command data are generated by moving the head.

Suppose the user is able to shake and nod his head intentionally in the specified narrow rectangle range without any physical difficulty. It is desirable that head movement in this rectangle range can specify all the position over the monitor screen. However, reasonable area which corresponds to the rectangle range is limited to some width like Area0 or Area1 et al. The ratio between the rectangle range in the Sensor coordinate system and the corresponding area in the screen coordinate system is determined by the accuracy of the sensor and the operability of the input device.



(a) Command coordinate of pillow user **(b) Screen coordinate of the computer**

Figure 3- 6 Command and Screen Coordinate System

The basic designing algorithm is that if the command data is in the rectangle range which means the user can move his head easily, the cursor moves proportionally to the head movement (Proportional Mode) in the specified area. This mouse movement in Proportional Mode is mostly used as an efficient way. However, the user has limited availabilities; the available area on the screen is also limited.

The algorithm of the input device is proposed as follows. In case that the command signals are in the specified rectangle range, the computer mouse moves proportional to the command data. If the command data is out of the specified rectangle range, the corresponding rectangle area in the screen coordinate moves toward the same direction with the command data. The corresponding rectangle area in the screen coordinate is surrounded by colored square.

Figure 3- 6 shows one example where the command data starts at the origin of the command coordinate and the command data runs over the rectangle in the middle. Until the command data runs out of the rectangle range, the trajectory of the command data is traced in the screen coordinate. If the command data is out of the rectangle range at the right upper point, the area-0 is moved toward right upper direction and arrives at area-1. And if the command data returns into the rectangle range, the mouse moves proportionally to the command data. A feature of this algorithm is that the

mouse can be moved accurately at any point in the monitor.

3.3.2 Measurement method of the head position

- **Calibration of four pressure sensors**

Firstly the pressure sensors were calibrated. Relations of the output data and pressure data was obtained as shown in Figure 3- 7. Based on this calibrated data and linear interpolation external force can be estimated.

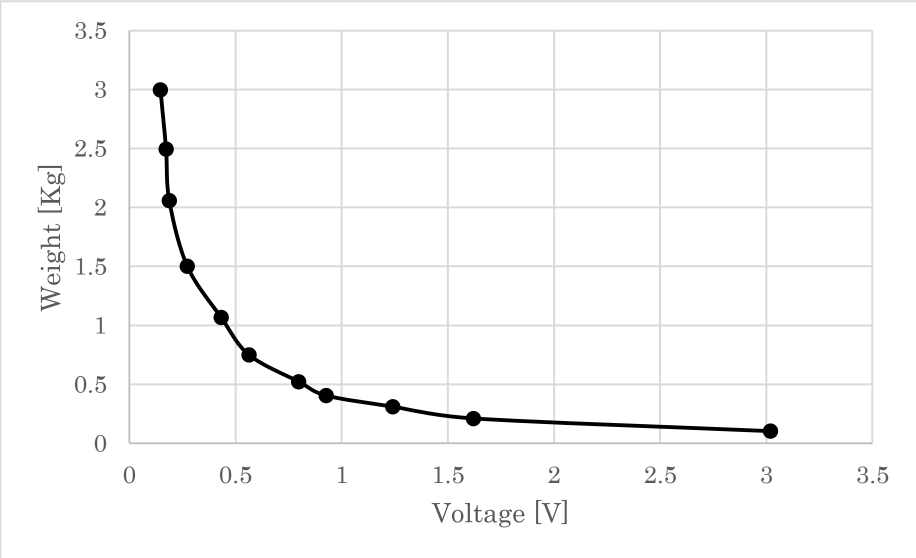


Figure 3- 7 Force applied to the force sensor

In my experimental input device, four pressure sensors were arranged at four corners of the square with side length 10cm. Figure 3- 8K(x shows a pillow-type computer input device, $f1$, $f2$, $f3$,$f4$ represent four pressure forces of the four pressure sensors. $\overrightarrow{r1}$, $\overrightarrow{r2}$, $\overrightarrow{r3}$, $\overrightarrow{r4}$ represent the four displacement vectors of the four pressure forces with respect to the head place, and then according to the physical theory of resultant moment theorem of concurrent forces of plane, supposed that G represents the pressure applied to the pillow generated from the human head. $\vec{r}$ represents the displacement vector the human head with respect to the head place. And then the equation can be obtained as follows:

$$\mathrm{G} \times \vec{r} = f1 \times \overrightarrow{r1} + f2 \times \overrightarrow{r2} + f3 \times \overrightarrow{r3} + f4 \times \overrightarrow{r4} \qquad (1)$$

Supposed that x represents the distance deviating from the center in the direction of X-axis of human head, y represents the distance deviating from the center in the direction of Y-axis of human head, so the algebraic sum of equation(1) can be obtained as follows:

$$(f1 + f3) \times (\frac{Lx}{2} + x) - (f2 + f4) \times (\frac{Lx}{2} - x) = 0 \quad (2)$$

$$(f1 + f2) \times (\frac{Ly}{2} - y) - (f3 + f4) \times (\frac{Ly}{2} + y) = 0 \quad (3)$$

And then the x,y coordinates of the gravity center of the user's head are obtained by the following equations:
equation(2) and equation(3) can be simplified as follows:

$$x = \frac{f2+f4-f1-f3}{f1+f2+f3+f4} \times \frac{Lx}{2}$$

$$y = \frac{f1+f2-f3-f4}{f1+f2+f3+f4} \times \frac{Ly}{2}$$

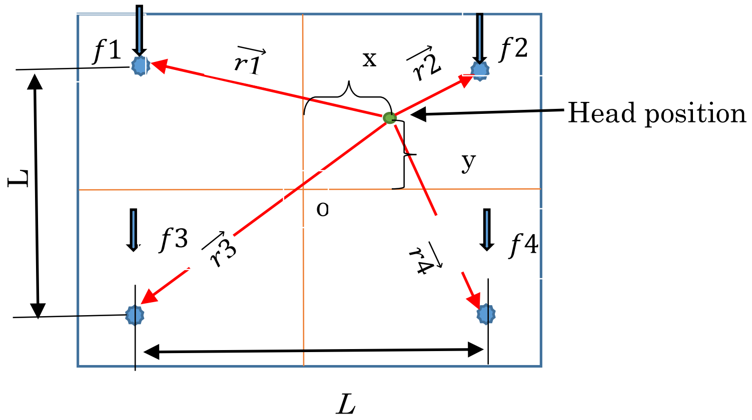


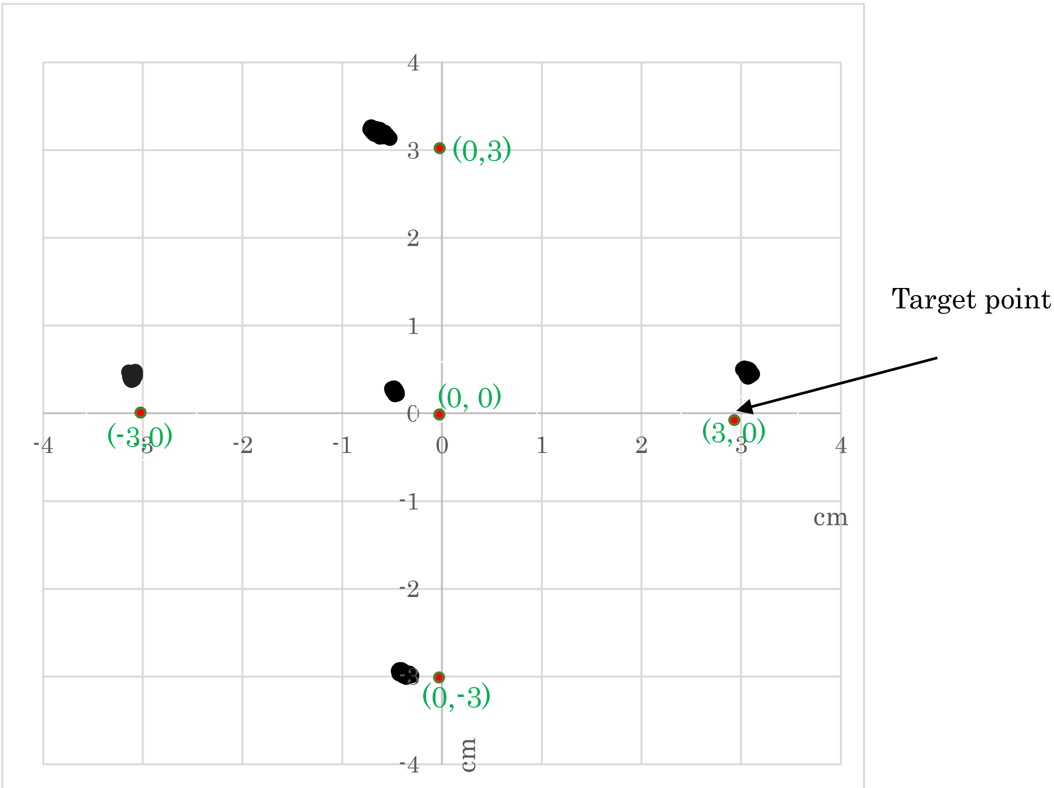
Figure 3- 8 Four pressure sensors on the board

- **Detection of the device accuracy**

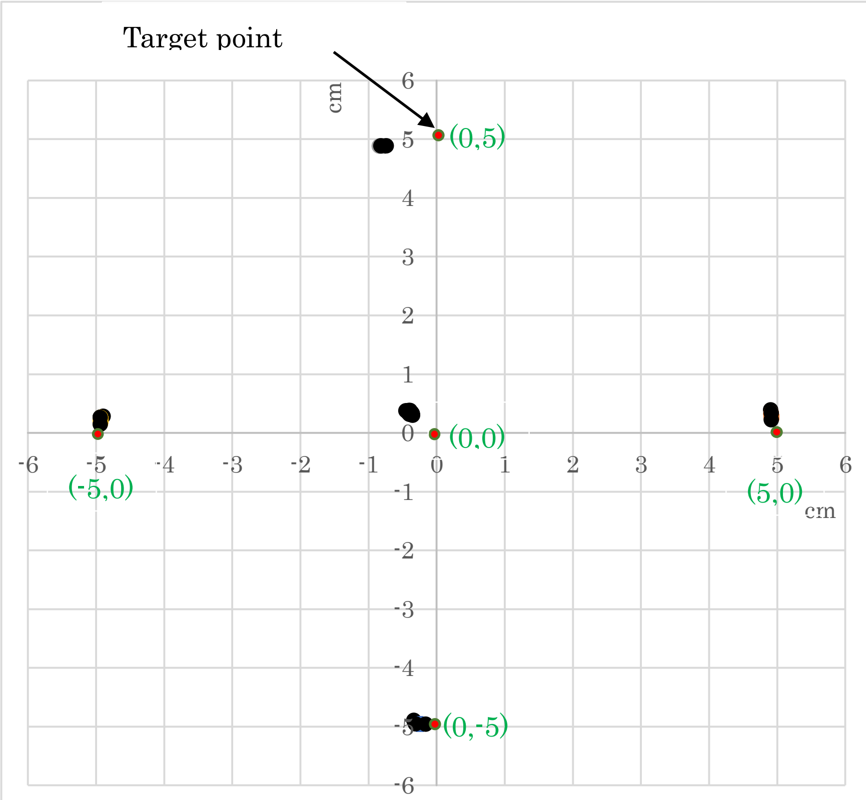
In order to evaluate the estimation of the gravity center of the target weight using the experimental device, 2.5kg weight was put on the top plate at specified coordinates. Based on the calculation method described above, the distance deviating from the central point can be detected through experiment of moving head to the different place of the pillow device.

In this experiment, two groups of data are collected. One group of experiment is to move 2.5kg weight along the circumference of 3 cm on the five places of (0,0),(3,0),(0,3),(-3,0) and (0,-3) successively. There are 250 groups of experiment data on each experiment point. And the experiment numbers are converged shown in Figure 3- 9 (a); The other group of experiment is to move 2.5kg weight along the circumference of 5 cm on the five points of (0,0),(5,0),(0,5),(-5,0) and (0,-5) successively. There are 200 groups of experiment data on each experiment point. These experiment data are converged shown in Figure 3- 9 (b). Estimated positions of the circumference of 3 cm experiment is shown in Table 1, and estimated positions of the circumference of 5 cm experiment is shown in Table2.

From the two graphs we can see that the centralized location of the experiment data deviates the target place slightly because the experiment data deviates the central point slightly when the 2.5kg weight is on the central point of the pillow, the error of the different place is almost same, but not big, so the accuracy of the device is worth to be trusted and can be available to be used.



(a)Circumference of 3 cm



(b) Circumference of 5 cm

Figure 3- 9 Estimated head location result by the experiment

Table 1 Estimation of the gravity center of target point with 3 cm inverval

No	Weight position [cm]	Estimated weight position [cm]
1	x=0.0 , y=0.0	x=-0.5 , y=0.3
2	x=3.0 , y=0.0	x=3.0 , y=0.5
3	x=0.0 , y=3.0	x=-0.6 , y=3.2
4	x=-3.0 , y=0.0	x=-3.1 , y=0.4
5	x=0.0 , y=-3.0	x=-0.4 , y=3.0

Table 2 Estimated of the gravity center of the target point with 5 cm interval

No	Actual position [cm]	Estimated position [cm]
1	x=0.0 , y=0.0	x=-0.4 , y=0.3
2	X=5.0 , y=0.0	x=4.9 , y=0.3
3	x=0.0 , y=5.0	x=-0,8 , y=4.9
4	x=-5.0 , y=0.0	x=-4.9 , y=0.2
5	X=0.0 , y=-5.0	X=-0.2 , y=-5.0

3.3.3 Determination of the rectangle range

The rectangle range for the available command signal should be determined depends on the user's abilities. In the experiment seven examinees were requested to shake their head slightly. The requested shaking angle of the head was from minus 15 degree to plus 15 degree. The horizontal y coordinate of the gravity center of the head varied from minus 0.5cm to plus 0.5cm. The examinees are requested to nod their heads as much as possible from the low angle to high angle. The horizontal z coordinate of the gravity center of the head varied from minus 0.15cm to plus 0.15cm. The nodding action changed the horizontal position of the gravity center negligible small amount. But the nodding action moved the top plate about 4cm. Considering these data the available range in the command coordinate are specified as follows

・Displacement of the gravity center of the head by the shaking action should be in the range from minus 0.4cm to plus 0.4cm.

・Displacement of the top plate of the input device should be in the range from minus 1.0cm to plus 1.0 cm.

And the corresponding area on the monitor screen were 480 pixels horizontally and 480 pixels vertically shown in Figure 3- 10 .

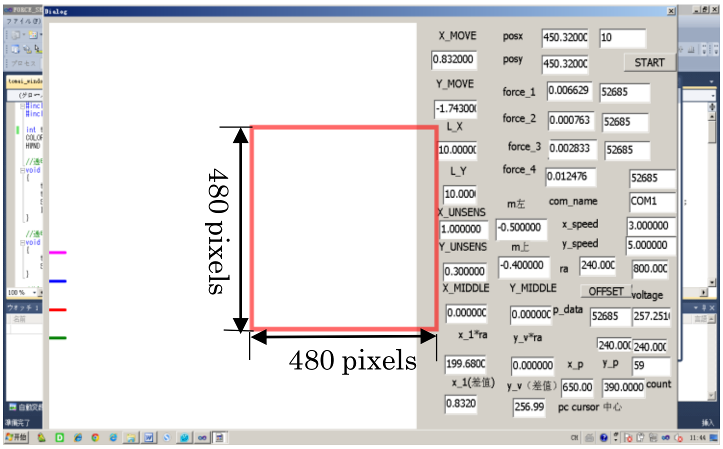


Figure 3- 10　Corresponding area on the monitor screen according to the shaking range of the users

3.4　Experiment

3.4.1　Tracing test

In order to rest the pointing accuracy of the proposed input device, four examinees were requested to conduct tracing test on the bed as shown in Figure 3- 12. The examinees moved his head up, down, right and left to make the cursor go along the boundary of two rectangles marked in red with length 770pixels and height 560pixels shown in Figure 3- 12. The experimental results of the four examinees are shown in Figure 3- 13 (a), Figure 3- 13(b), Figure 3- 13 (c) and Figure 3- 13 (d). The first examinee spent 48 seconds to conduct this tracing task. The required time for each examinee was shown in Table 3. Considering that the users are patients with serious disabilities, the proposed input device has user-friendliness and accuracy.

Figure 3- 12 Examinee with input device

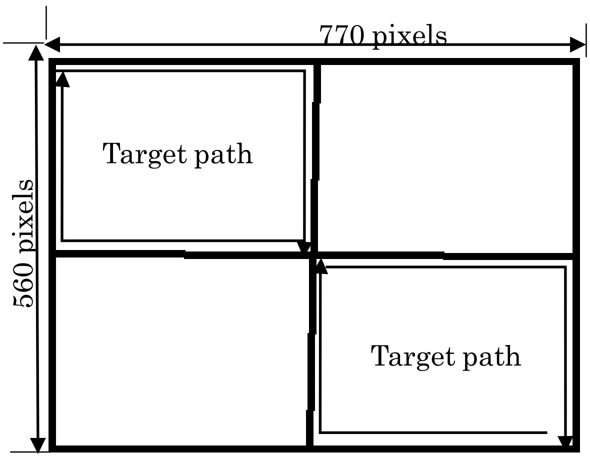
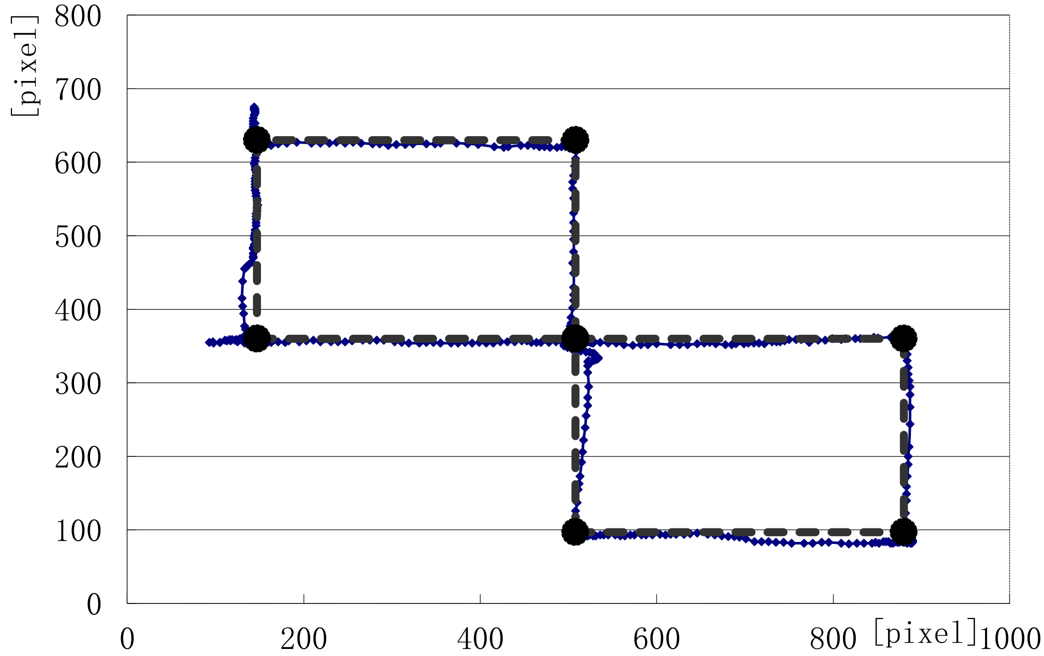
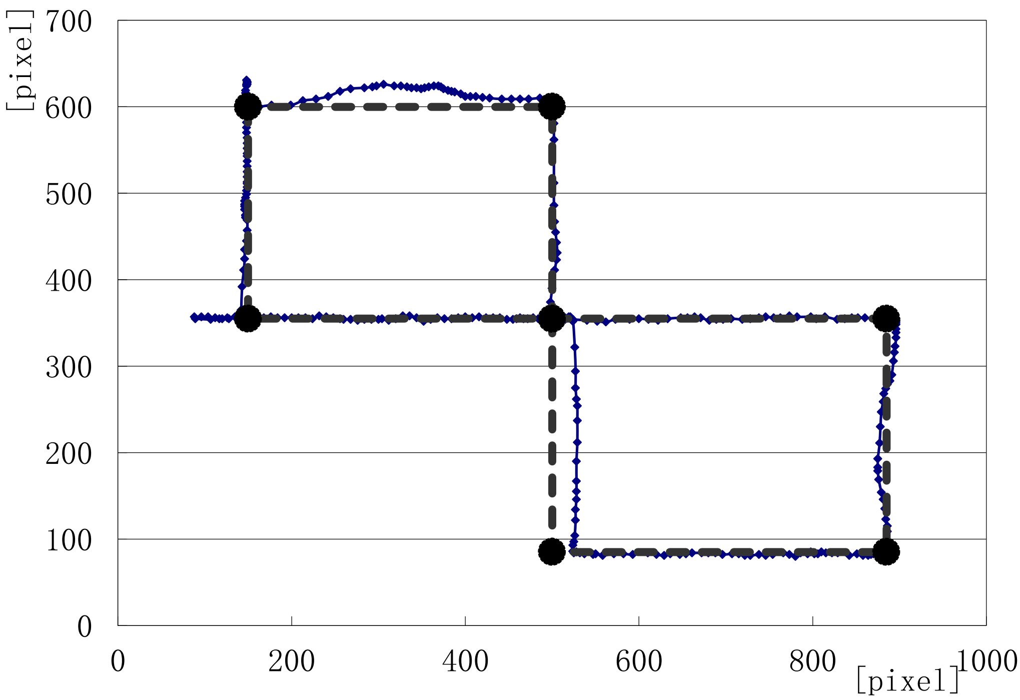


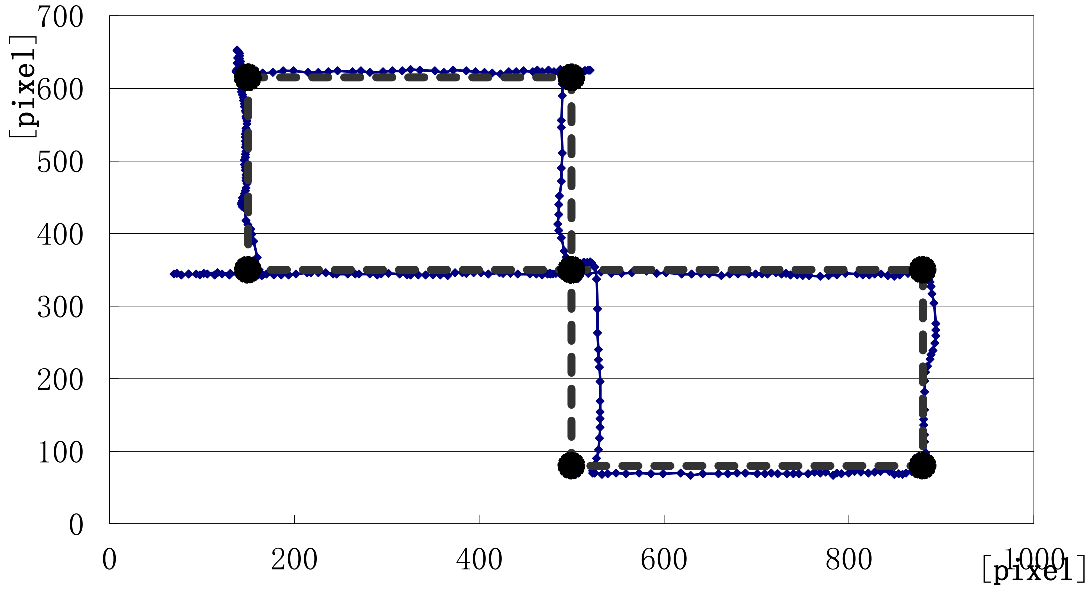
Figure 3- 12 Target trajectory on the monitor of cursor movement in red



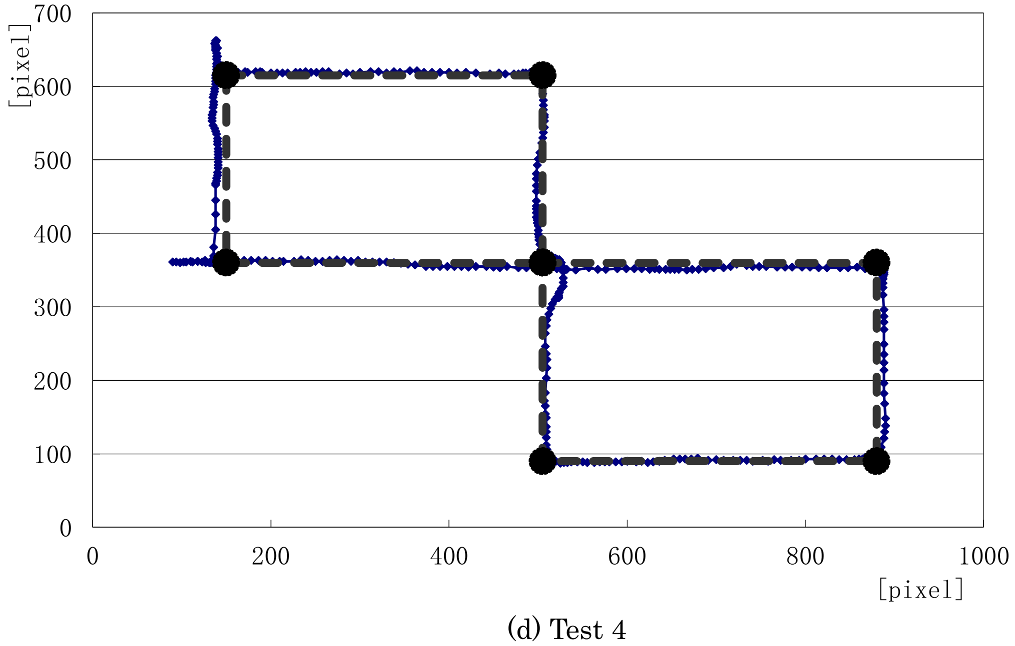
(a)Test 1



(b) Test 2



(c) Test 3



(d) Test 4

Figure 3- 13 Experimental results of tracing test by four examinees

Table 3 Required time to trace target rectangle

Examinee	Time required [sec]
1	48
2	48
3	47
4	49

3.4.2 Typing test

Typing test using the proposed input device was conducted. Three examinees were requested to select the character from the screen keyboard and write the letter " good morning ".Typing task to use screen keyboard usually requires to locate the cursor onto the target character and to push the click button. In place of the pushing the click button, the proposd input device employed a method that the target character is selected by placing the cursor on the target character for more than 0.6 second. Experimental results are shown in Table 4. The results show that typing tasks by using the proposed device spent almost 61 average seconds without errors. But in case that the examinees made miss-typing, he required 0.6 seconds more for re-typing one character. When authors had same typing tests to use vision [34], the average time of typing was 53 seconds. When authors had same tests to use three pressure sensors, the average time of typing was 107 seconds [35]. Conventional type of computer input device to use touch switch spent 135 seconds in an average [32]. Comparing these input devices, the vision device was fastest since the click action could be achieved by opening his mouth. The difference of the required time was caused by accumulating the cursor locating time that becomes totally 7.2(= 0.6seconds×12 characters) seconds. It means that the speed of locating the cursor onto the target position was almost equal between the vision device and proposed pillow-type device.

Table 4 The result of typing test

Examinee	1st test [sec]	2nd test [sec]	3rd test [sec]
1	58	59	63
2	65	77 (2 characters miss-type)	71 (1 characters miss-type)
3	71 (1 character miss-type)	77 (2 characters miss-type)	65
4	59	60	64
5	64	60	58

3.5 Conclusion

An original pillow-type computer input device is developed. A remarkable feature is that the environment around the bed can be arranged smartly without disturbing wires and obstacles. Another feature is that the nodding action of the head can be measured accurately by the introduction of the slider mechanism. The slider mechanism enabled the patient to nod with slight head movement, which is preferable for the patients with serious physical disability.

A mouse control algorithm is also proposed. The algorithm enabled the patient with limited physical abilities to move the cursor with accuracy and speed.

Experimental results revealed the applicability of our input device.

Chapter 4 Face mount computer input device

4.1 Introduction

It is expected that even serious patients can be live self-independently by the support of the various care-givers and assist devices [36].Advanced robotic and also sensing technologies are successfully introduced in many cases. However, there are still some problems. For example, the device developed in chapter 2 is used in a large range of patients with disabilities, but there are some serious patients of small range who cannot use the pillow type computer input device smoothly. So it is necessary to develop a special device individually according to the patient's requirements to help him live self-independently. A spinal cord injury patient [37]is shown in Figure 4- 1 Figure 4- 1.

Figure 4- 1 Patient with spinal cord injury

He is injured by a falling accident in the factory and damaged around his neck. Because of the damage, his limbs are paralyzed and all his intentional physical abilities are limited above his neck. He needs artificial aspirator and has communication difficulty since uttering voice is not possible [38].

It is also important to notice that his direction of the body is changed every two hours to prevent a bedsore. In order to assist daily life of such persons, computer input devices to enable the communication are already developed. For the patient under bed-ridden condition, his or her input device should have function to cope with their body changes on the bed by the care giver. Their bodies were turned to leftward and right word every two hours. Wearable input device may be available. But the stand type input device needs to adjusted its position, this adjusting task is unfavorable typically for night medical staffs [39] [40].

4.2 Proposed face mount computer input device

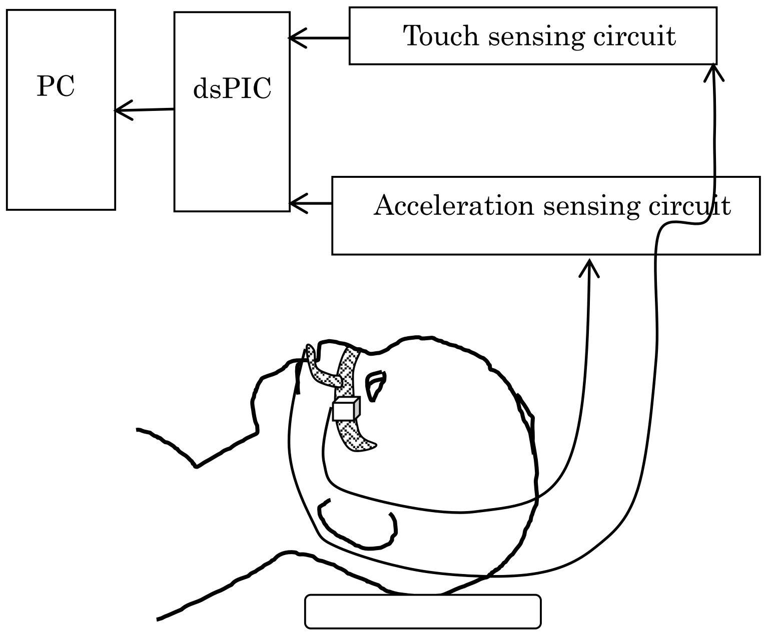
In this study a face mount type input device is proposed. A feature of the device is that the even under the body change for the prevention of bedsore the sensor need not to be re-adjusted. Of course, the body change includes the direction of his or her head and hands. One idea proposed here is to use compact face mount input device.

The device is stuck to the face and robust to the unfavorable movements. The proposed device is a mask-type input device which employs acceleration sensor for the cursor positioning and the touch senor for the switching motion. By the fine machine work, the mask sticks to the face and nose surface.
The second one is a compact nose-clip type touch sensor which is mounted at the tip of the nasal cavity. The function of this sensor is limited only to clicking function.

Functions required for the input devices are mostly on/off switching and computer cursor positioning. On/off switching functions activate and inactivate the output signal by using the touch sensor, distant sensor and optical sensors. The output signal of these switching devices is used to select the word and items on the computer monitor. Computer cursor positioning functions uses information about two-dimensional movement of the user's body. In Figure 4- 1 the user wears a head wand on which a three-dimensional acceleration sensor and chewing action sensor are mounted. Using this three-dimensional acceleration sensor, angle of the head shaking motion and the head nodding motion can be obtained. Using these angle data, the computer cursor is located to the desired position on the monitor. The chewing action sensor detects the swelling of the chewing muscles on the temples by the conductive sensor. Using this interface, the user can move the computer cursor to the desired position and select the desired word and item on monitor with accuracy.

In order to enable two-dimensional computer cursor positioning, there exist some interface devices to use image processing and vital signal from the brain are already developed. It should be noticed that the care and assist devices used around the bed need to be free from the blockade of the medical and care tasks.

The configuration of mask-type input device is shown in Figure 4- 2. The mask is made of UV resin and the shape is fabricated with good coherency with the face. By this fine machine work, the mask is stuck the face. On the mask body acceleration sensor and touch sensor are mounted. On the lower part of the mask a touch sensor is mounted. The touch between the tip of the user’s lips and the touch sensor electrode can be detected is by the capacitance.



Function: Obtain the signal of mouth chewing motion for clicking

Function: Obtain the signal of the head shaking motion and head nodding motion for the cursor positioning

Figure 4- 2 System Setup

In this study, the controlling system of proposed face mount computer input device consists employed a micro-chip cpu called Dspic 33Fj32MC302 [41] which receives the signals of acceleration sensor and touch sensor, and then convert the analog signals into digital signals, and then send the digitals to a computer through the FT232RL USB serial conversion module developed by Strawberry Linux Co.Ltd [33]. The controller of the whole system is shown in Figure 4- 3.

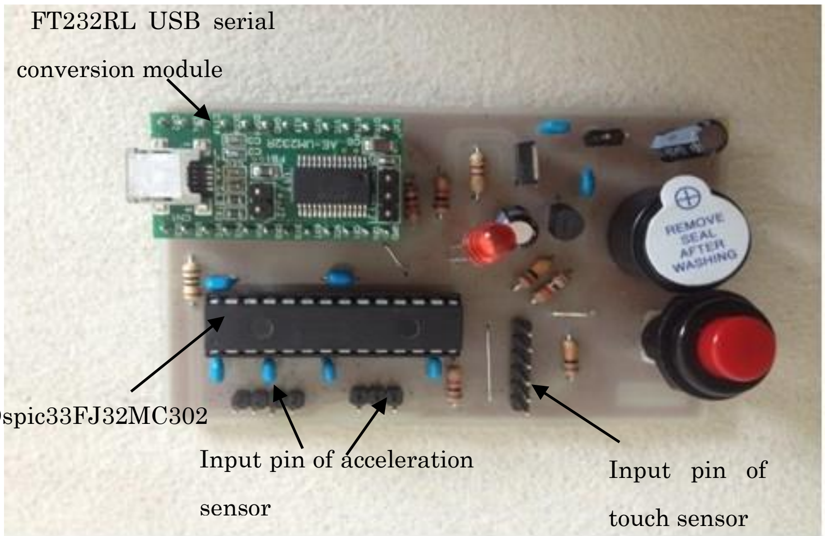


Figure 4- 3 Controller of face mount computer input device

4.3 Mouse operation algorithm

4.3.1 Switching of proportional mode and joystick mode

Since the target patient has serious physical disability and under the bed-ridden condition, the input devices should have user-friendliness and good operability based on his or her remaining physical abilities. Here we consider two coordinates, one is the command coordinate system and the other is the screen coordinate system as shown in Figure 4- 4 .

On the command coordinate system, x represents the horizontal position of the gravity center of the head which is estimated by the output signal of X-axis and Z-axis of the three- dimensional acceleration sensor. y represents the nodding angle estimated by the output signal of Y-axis and Z-axis of the three-dimensional acceleration sensor. These command data are generated by the moving the head.

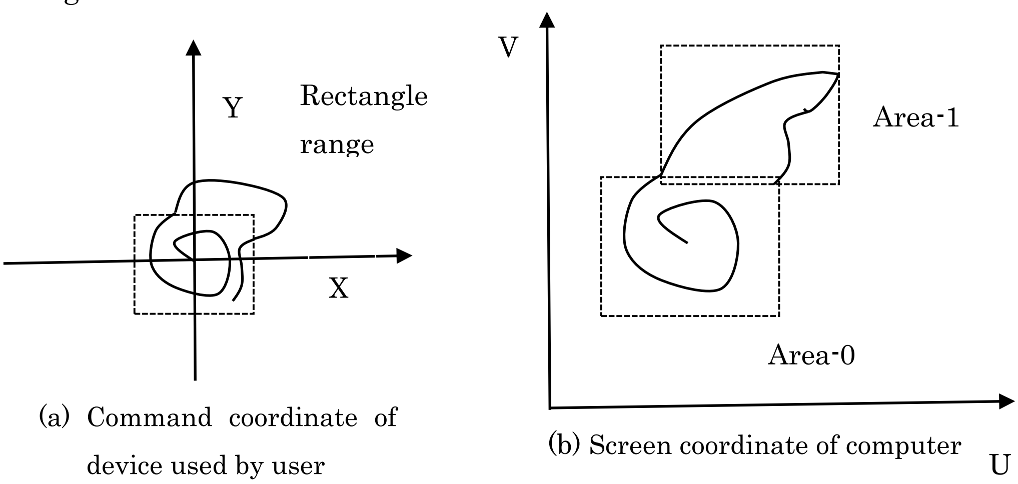


Figure 4- 4 Command and Screen Coordinate System

Suppose the user is able to shake and nod his head intentionally in the specified narrow rectangle range without any physical difficulty. It is desirable that head movement in this rectangle range can specify all the position over the monitor screen. However, reasonable area which corresponds to the rectangle range is limited to some width like Area0 or Area1 et al. The ratio between the rectangle range in the Sensor coordinate system and the corresponding area in the screen coordinate system is determined by the accuracy of the sensor and the operability of the input device.

The basic designing algorithm is that if the command data is in the rectangle range which means the user can move his head easily, the cursor moves proportionally to the head movement (Proportional Mode) in the specified area. This mouse movement in Proportional Mode is mostly used as an efficient way. However, the user has limited availabilities; the available area on the screen is also limited.

The algorithm of input device is proposed as follows:

In case that the command signals are in the specified rectangle range, the computer mouse moves proportional to the command data. If the command data is out of the specified rectangle range, the corresponding rectangle area in the screen coordinate moves toward the same direction with the command data. The corresponding rectangle area in the screen coordinate is surrounded by colored square.

Figure 4- 4 shows one example where the command data starts at the origin of the command coordinate and the command data runs over the rectangle in the middle. Until the command data runs out of the rectangle range, the trajectory of the command data is traced in the screen coordinate. If the command data is out of the rectangle range at the right upper point, the area-0 is moved toward right upper direction and arrives at area-1. And if the command data returns into the rectangle range, the mouse moves proportionally to the command data. A feature of this algorithm is that the mouse can be moved accurately at any point in the monitor.

4.3.2 Detection method of head motion

- **The principle of the acceleration sensor**

The working principle of three-axis acceleration sensor (KXM52-1050) [42] is that the gravitational acceleration changes the acceleration of gravity component in three axes depending on the location of the acceleration sensor in the space and When the three-axis acceleration sensor works, it will output a voltage corresponding to the three axes space acceleration signal, rotating of three-axis accelerometer itself can change the size of the acceleration of gravity acting on each axis. So the three-axis accelerometer can be used to detect position change.

The three-axis acceleration sensor is fixed on the user's face, so the head rotation can drives three-axis accelerometer to rotate to alter the gravitational acceleration on the space coordinate system. In order to detect the head movement signal, three-axis acceleration sensor is employed. Because the working voltage of single chip microcomputer adopted in the experiment is under the state of 3.3 v, so the parameter corresponding to 3.3v of three-axis accelerometer adopts working voltage of 3.3v, sensitivity of 660 mv, offset voltage of 1.65 v.

Due to the user in a flat state, in order to adjust the position and angle of sensor easily and considering the comfort for the user to operate the device, the face mount type device is employed. The three-axis acceleration sensor in fixed on the mask body shown in Figure 4- 5 .

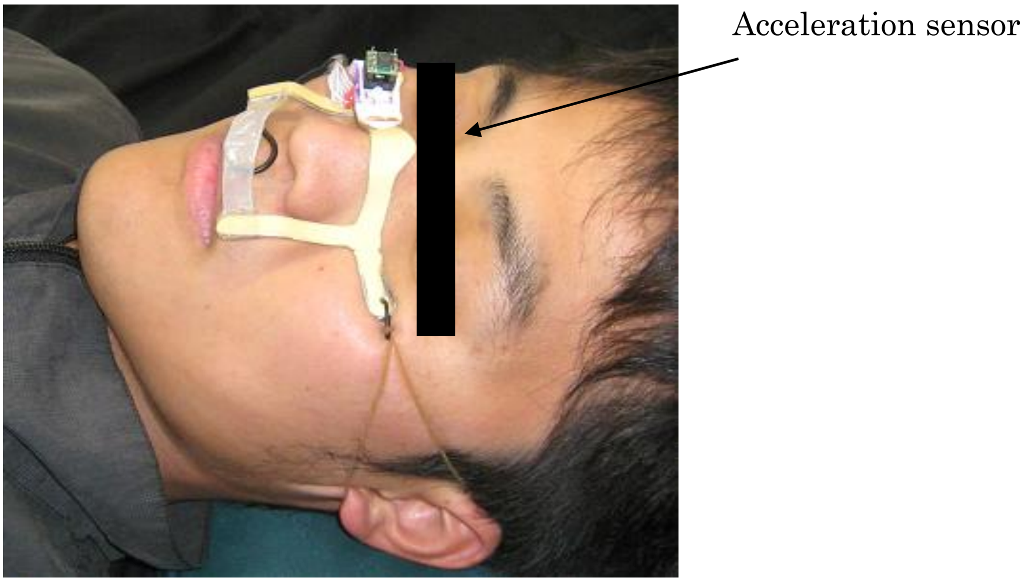


Figure 4- 5 Mask-type input device

The physical signal of three-axis acceleration sensor is converted into electrical signals by the method of ten bit analog to digital mode. Ten bit of the analog to digital conversion mode of the output digital signal ranges from 0 to 1023. The coordinate of the three-axis acceleration sensor is shown in Figure 4- 6, the simulation of the space coordinate system of the three-axis acceleration sensor is shown in Figure 4- 7.

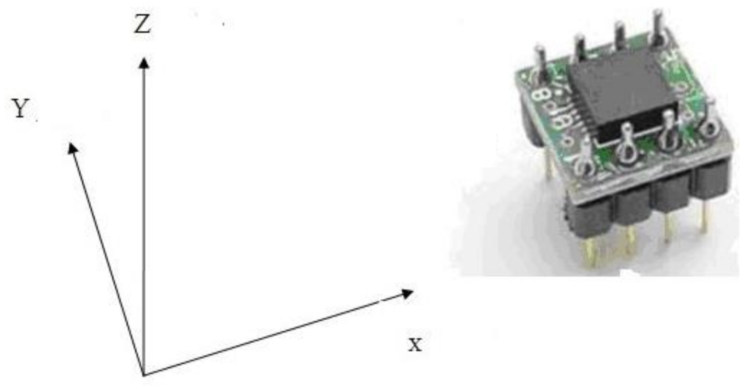


Figure 4- 6 Physical direction of schematic three-axis acceleration sensor [42]

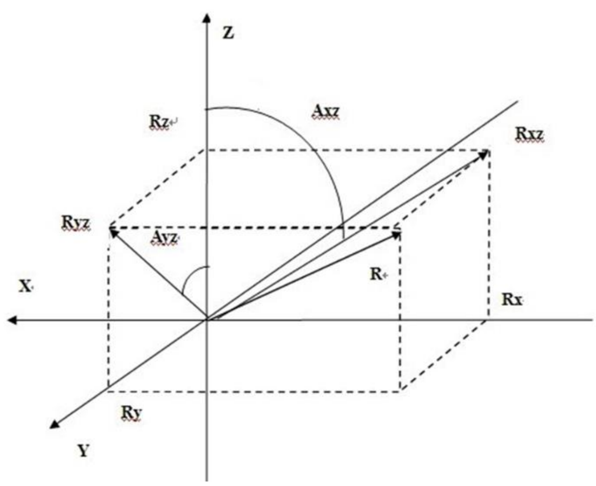


Figure 4- 7 Schematic diagram of space coordinate system

In the space coordinate system, RX,RY,RZ is the actual output linear correlation value of the three axis acceleration sensor, that is to say, RX,RY,RZ represent projection on the acceleration of gravity in three axes of the three-axis acceleration sensor when rotating. Here a relative formula can be obtained shown in equation (4.1). So Supposed that *AdcRx*、*AdcRy* 、*AdcRz* are the x, y, z axis transformation patterns of ten bits analog to digital conversion mode, their reference voltage of the analog to digital conversion mode is 3.3v, in order to convert the analog-to-digital value into the voltage value, the following formula is employed as shown in equation(4.2)~(4.4).

$$R^2 = RX^2 + RY^2 + RZ^2 \tag{4.1}$$

$$V\_RX = AdcRx \times VREF \div 1023 \tag{4.2}$$

$$V\_RY = AdcRy \times VREF \div 1023 \tag{4.3}$$

$$V\_RZ = AdcRz \times VREF \div 1023 \tag{4.4}$$

In formulas above, $VREF = 3.3V$

In addition, there is a zero acceleration voltage value corresponding to the acceleration. And the zero voltage corresponding to the acceleration is 0 g(g is the acceleration of gravity), here a voltage of symbol relative to the offset voltage of 0g voltage can be obtained. In this study, the offset voltage of the three-axis acceleration sensor used in the experiment is 1.65v which is the voltage of 0g. And then the offset voltage relative to the voltage of 0g can be calculated as follows shown in equation(4.5~4.7) when the three-axis acceleration sensor is rotating in the space

$$OffsetRx = V\_RX - VREF \tag{4.5}$$

$$OffsetRy = V\_RY - VREF \tag{4.6}$$

$$OffsetRz = V\_RZ - VREF \tag{4.7}$$

In the equation above, $OffsetRx, OffsetRy, OffsetRz$ separately represent the offset voltage of x-axis, y-axis, and z-axis relative to the offset voltage of 0g.

In this study, the sensitivity of the three-axis acceleration sensor is 660mv/g, that is 0.66v/g, in order to obtain the acceleration in units of g, the formulas are introduced as shown in equation(4.8~4.10).

$$S\_RX = \frac{OffsetRx}{Sensitivity} \tag{4.8}$$

$$S\_RY = \frac{OffsetRy}{Sensitivity} \tag{4.9}$$

$$S\_RZ = \frac{OffsetRz}{Sensitivity} \tag{4.10}$$

In this study, the experiment is performed according to the methods above, and in accordance with the conditions of the experiment, the experiment process is divided into two parts, one part is to make the three-axis acceleration sensor rotate around the y axis of the three-axis acceleration sensor, and the signal curve is shown in Figure 4- 8 . From the graph we can see that when the three-axis acceleration sensor s rotating around y axis, the amplitude of x-axis is biggest in the amplitudes of the three axis. This shows that the sensitivity of the x axis is highest in this condition.

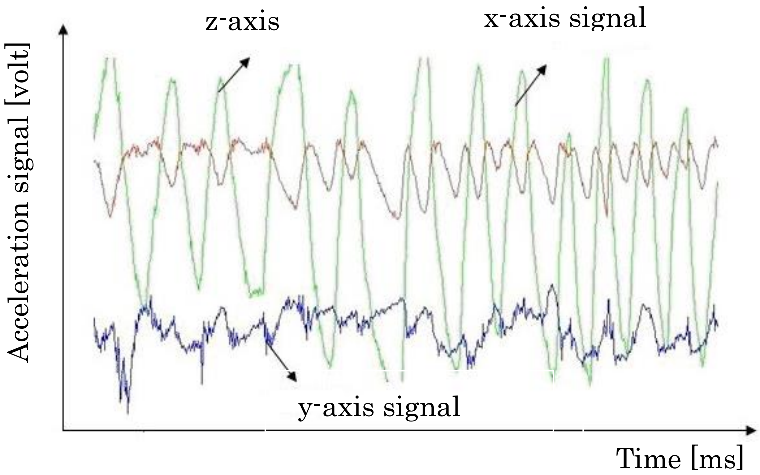


Figure 4- 8 Shaft signal curve of three-axis acceleration sensor rotating around Y axis

The other part is to make the three-axis acceleration sensor rotate around the x axis, and the signal curve is shown in Figure 3-12. From the graph we can see that when the three-axis acceleration sensor s rotating around x axis, the amplitude of x-axis is biggest in the amplitudes of the three axis. This shows that the sensitivity of the y axis is highest in this condition.

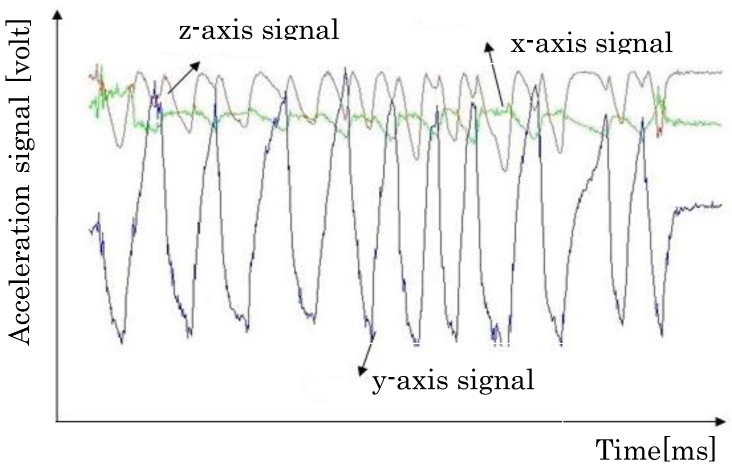


Figure 4- 9 Signal curve of each axis of three-axis acceleration sensor rotating around X axis

In order to further determine the sensitivity range of each coordinate axis, the data of each coordinate axis is collected respectively, and the specific graph is shown as follows: when the three-axis acceleration sensor is firstly rotating in clockwise around x axis and then rotating in counterclockwise around x axis the graph of which is shown in Figure 4- 8 ; When the three-axis acceleration sensor is firstly rotating in clockwise around y axis and then rotating in counterclockwise around y axis Figure 4- 9.

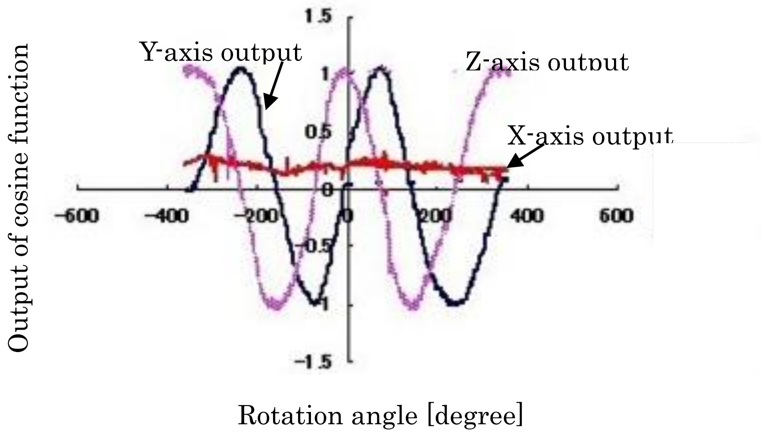


Figure 4- 10 Output of cosine function rotating around x axis

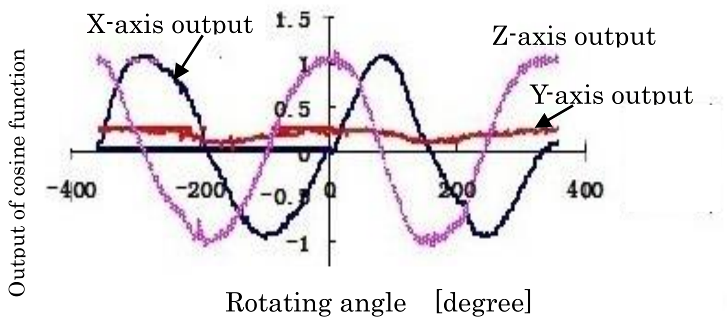


Figure 4- 11 Output of cosine function rotating around the y axis

The conclusion can be obtained from Figure 4- 10 and Figure 4- 11 , when the three-axis acceleration sensor is rotating around x axis, There is almost no change in the curve of the x axis, while the curve of y axis changes in sine law, and the curve of z axis changes in cosine law. When the three-axis acceleration sensor is rotating around y axis, there is almost no change in the curve of y axis, while the curve of y axis changes in sine law, and the curve of z axis changes in cosine law. Whether the three-axis acceleration sensor is rotating around x axis or y axis, the curve of z axis changes in sine law, while the curve of x axis and y axis changes in cosine law.

4.3.3 Command of the mouse cursor movement

According to the working principle of the three-axis acceleration sensor, the parameter of RX/RZ and RY/RZ is employed in the program which is designed to control the mouse cursor movement. When the user moves his head up and down, the parameter of RX/RZ works; when the user moves his head left and right, the parameter of RY/RZ works. The flowchart of the mouse cursor movement is designed as follows in Figure 4-12.

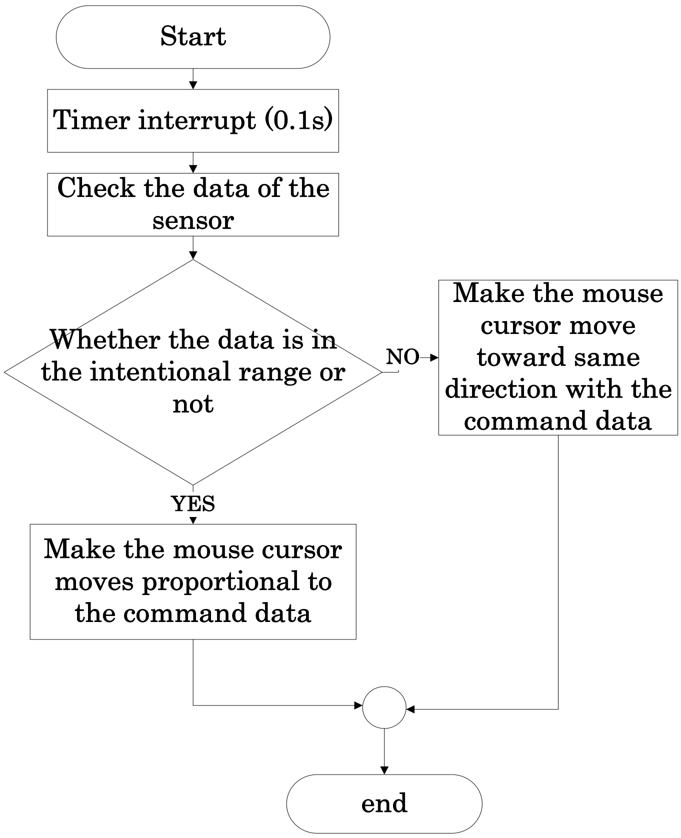


Figure 4- 12 Flow chart of mouse cursor positioning

4.4 Detection of the mouth movement

The mask-type input device developed in this study employs a three-axis acceleration sensor for cursor positioning such as choosing characters and the touch sensor for mouse cursor clicking function. The touch sensor is mounted on the low part of the mask body, it is mainly used to detect the mouth movement, when the user swell and chew his mouth muscles, the touch senor fixed over the mouse in advance can detect mouth movement. The principle of touch sensor is described as follows: the electrode of a touch sensor represents one plate of such a capacitor. The corresponding 2nd plate is represented by the environment of the sensor electrode. This capacitor, i.e. the sensor electrode, is connected to a measurement circuit. The capacitance of the sensor pad is measured periodically. If a conductive approaches or touches the electrode, the measured capacitance will increase. So the electric current also increase, which leads to bigger output voltage of touch sensor. This change is detected by the measurement circuit and converted into a trigger signal [43]. The connecting method between the touch sensor and microchip computer is shown in Figure 4- 13 , when touching the touch sensor, the voltage of I/O pin connecting to the touch sensor in the microchip computer increases up to 3.3v, while leave the touch sensor, the voltage of the I/O pin decreases . The output signal of the touch sensor is shown in Figure 4- 14.

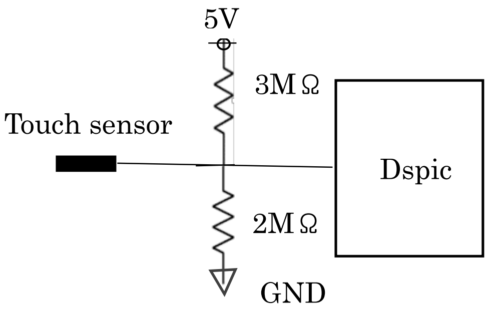


Figure 4- 13 Connection between touch sensor and Dspic

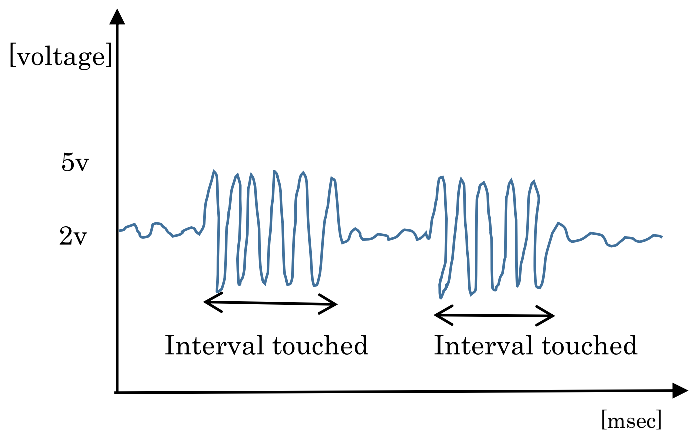


Figure 4- 14 Output voltage of touch sensor

4.5 Experiment

4.5.1 Tracing test

In order to test the applicability of the proposed input device, four examinees were requested to conduct tracing test on the bed as shown in Figure 4- 15 . The examinees moved his head up, down , right and left to make the cursor go along the two rectangles with length 770 pixels and height 560pixels. The tracing test results of examinees are shown in Figure 4- 16. The first examinee spent 52 seconds to conduct this tracing task. The required time for each examinee was shown in. Considering that the users are patients with serious spinal cord injury, the proposed input device has user-friendliness and accuracy.

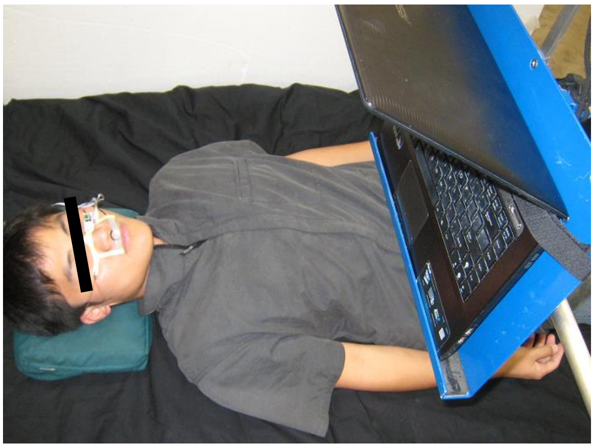
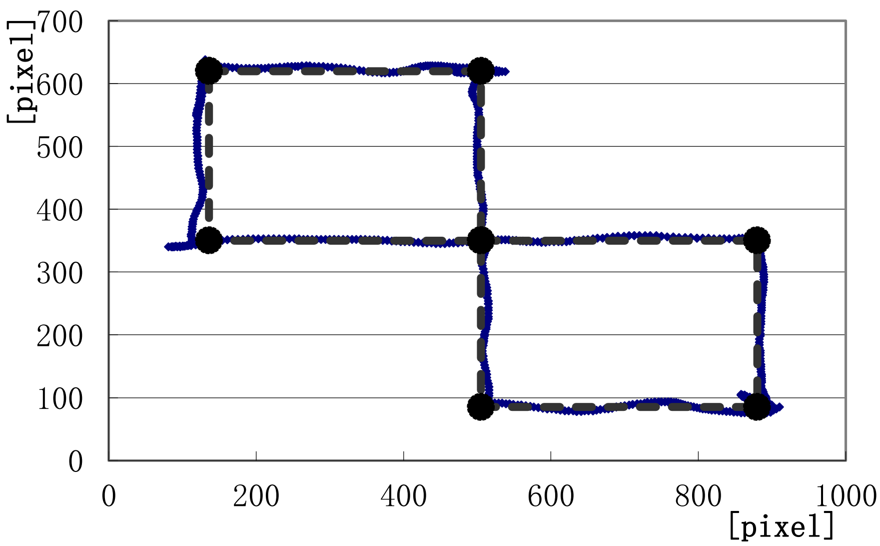
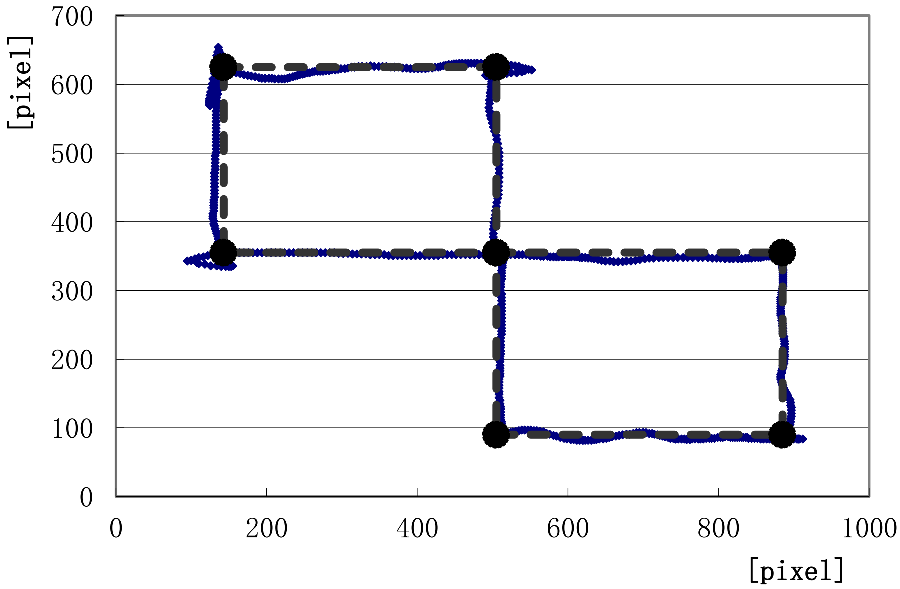


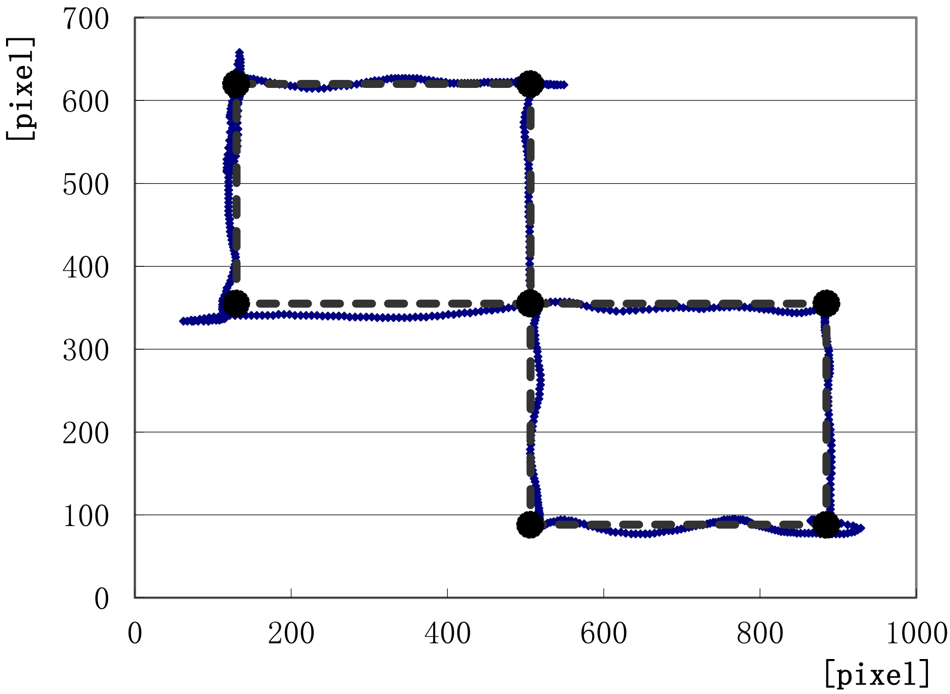
Figure 4- 15 Examinee with input device



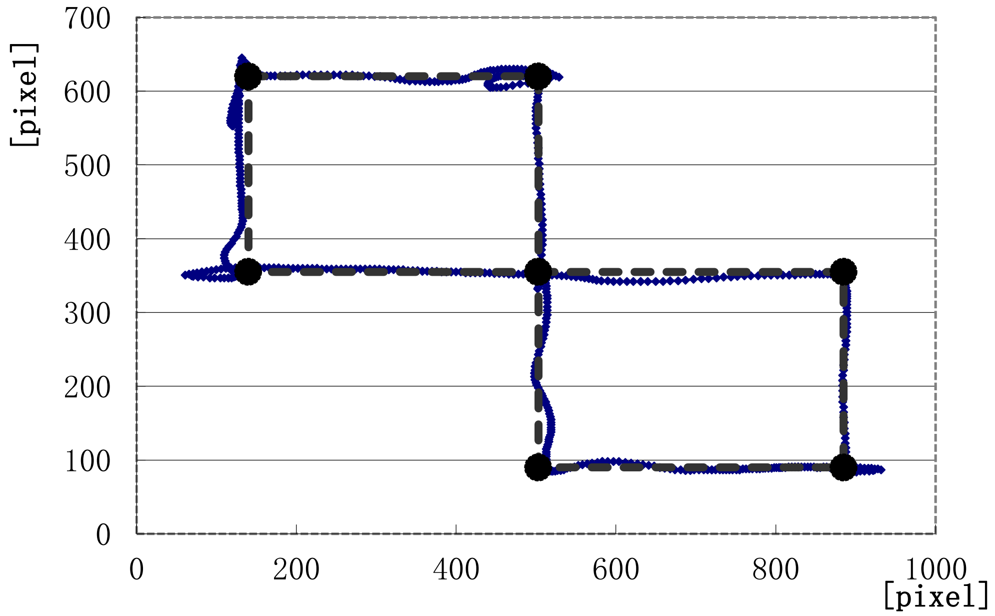
(a) Test 1



(b) Test 2



(c) Test 3



(d) Test 4

Figure 4- 16 Experimental result of tracing test

Table 5 Required time of trace target rectangle

Examinee	Time required [sec]
1	52
2	49
3	53
4	51

4.5.2 Typing test

Typing test using the proposed mask-type input device was conducted. Three examinees were requested to select the character from the screen keyboard shown in Figure 4- 17 and write the letter " Good morning, ladies and gentlemen! ". Typing task to use screen keyboard usually requires to locate the cursor onto the target character and to push the click button. In place of the pushing the click button, our input device employed a method that the target character is selected by contacting the touch sensor and the lips. All examinees finished to write the text almost in 120 seconds. Experimental results are shown in Table 1 1. The speed was compared with that of conventional communication system to use a touch sensor which spent

140 seconds [35]. Therefore, the face mount computer input device developed in this study enables user to operate communication software easily.

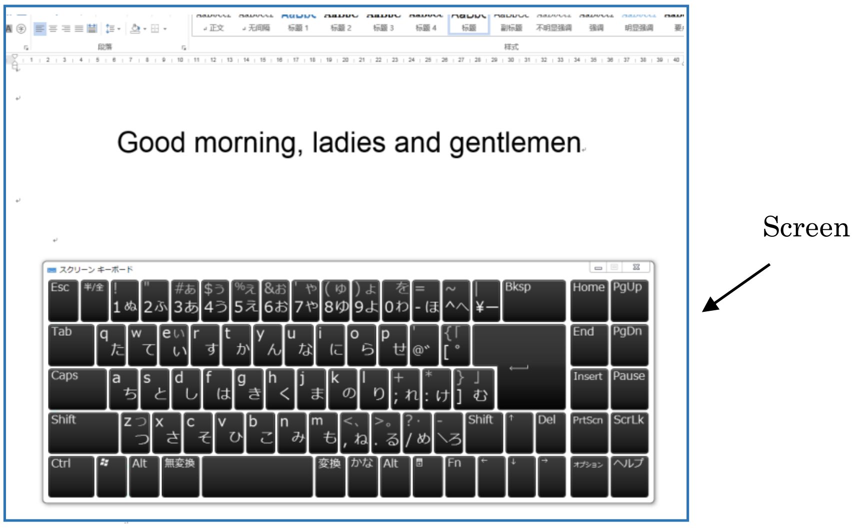


Figure 4- 17 Typing experiment

Table 1 1 Results of typing test

Examine	1st test [sec]	2nd test [sec]	3rd test [sec]
1	121	114	121
2	109	108	129(1 error)
3	128(1 error)	120	123

4.6 Conclusion

An original face mount-type computer input devices is developed. A remarkable feature is that input device is attached to the user's face with compact body and are robust to the change of the direction of the body for the prevention of the bedsore.

In this study a nose click type input device is also proposed. The prototype of nose-clip type input device is shown in Figure 4- 19 . Conductive tape is wrapped on the right lever. The Contact between the conductive tape and the tip of the user's lips can be detected by the capacitance sensor. One examinee using the device is shown in Figure 4- 18. A main function of this input device is to activate the emergency call in the night. Even under the change of body direction, the sensor is available.

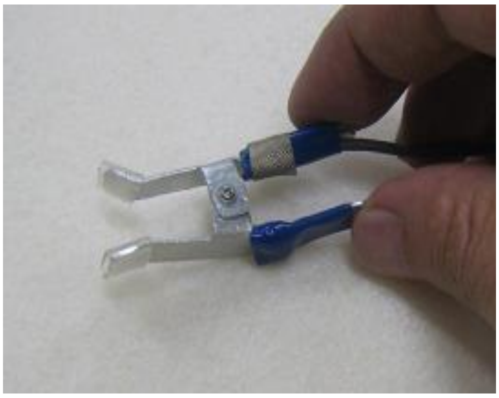


Figure 4- 19 nose-clip type input device

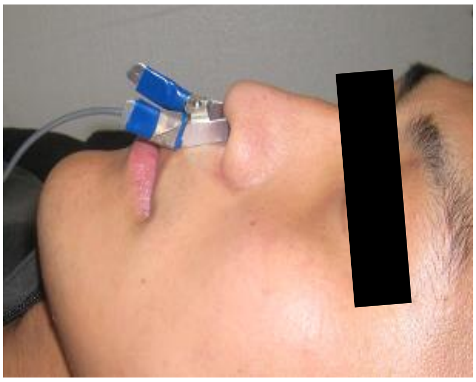


Figure 4- 18 Nose clip sensor and the user

A mouse control algorithm is also proposed. The algorithm enabled the patient with limited physical abilities to move the cursor with accuracy and speed.

Experimental results revealed the applicability of our input device.

Chapter 5 Conclusions and Future

In this chapter, the major contributions of this research are summarized and recommendations for future work are proposed.

5.1 Conclusions

In this research, two kinds of computer input devices are developed as effective input devices of a communication system.

- **Proposal of pillow-type computer input device**

The interface device is achieved in a compact pillow type body. It is designed to move computer cursor as the user expect by using his or her head movement. Using this interface device the computer cursor on the computer monitor can be located to the desired position two-dimensionally by the slight movement of the user's head. In order to improve the user-friendliness of the interface, the pillow is mounted on the sliding mechanism. One feature of the device is the introduction of the four pressure sensors and two sliders. The head movement of the user is estimated by the four pressure sensors under the pillow. Due to these pressure sensors, rotating head movement around the neck and nodding movement of the head can be measured quantitatively. Four pressure sensors enable to measure the degree of the shaking action of the head. Sliders enable to measure the degree of the nodding action of the head. In addition, the slider made the nodding action easier by reducing the friction force between the head and the pillow.

In addition, considering the patients with serious disabilities can move their heads in a small range, in order to help these patients operate the device easily, an original algorithm was developed to enhance the operability of the input device. A feature of the algorithm is that the movement of the cursor in the near range is conducted in proportion to the slight head movement and the positioning in the wide area is specified by the stronger head movement as well. The algorithm of our input device is proposed as follows. In case that the command signals are in the specified rectangle range, the computer mouse moves proportional to the command data. If the command data is out of the specified rectangle range, the corresponding rectangle area in the screen coordinate moves toward the same direction with the command data.

A supporting and care devices around the bed often becomes barriers for the care and assist task for the patient. The proposed pillow type interface is designed not to disturb the care and assist tasks. The pillow-type computer input device can be used in a large range of the people with various disabilities. No matter how the symptoms of the severe disease is progressive, the device is available for use as long as that the patient has a little head movement.

- **Proposal of face mount computer input device**

In this study, the second device called face mount-type computer input device is developed. The device is a mask-type input device which employs acceleration sensor for the cursor positioning and the touch senor for the switching motion. By the fine machine work, the mask sticks to the face and nose surface. By using the three-dimensional acceleration sensor, the user can move his head in a small range to realize the computer cursor positioning functions without difficulty. The touch sensor is mounted on the low part of the mask body just over the mouse, so the user can easily swell his mouse chewing muscles to touch the touch sensor to realize the mouse click function. The device was available under various body motion. The mouse control algorithm enabled the patient with limited physical abilities to move the computer cursor to the desired position and select the desired word and item on monitor with accuracy and speed. Experimental results also revealed the applicability of the face mount computer input device. The patients successfully could communicate with their families and operate electric devices by using the communication device.

Input devices for patients under bed-ridden condition need special consideration. Directions of the patient are changed every two hours for the prevention of the bedsore. Therefore, input device should be designed to cope with this situation. Readjustment of the sensor is unfavorable. A feature of the device developed in this study is that the even under the body change for the prevention of bedsore the sensor need not to be re-adjusted.

5.2 Future

In this research, the development of pillow-type computer input device and face mount computer input device aims to improve the life quality of people with serious disabilities. Compared with the conventional input devices, the devices developed in this study have greater speed and accuracy in inputting the text and they are more convenient for the patients with serious disabilities to communicate with others. Because the conditions of the patients are various and the symptoms of some intractable diseases are constantly progressive year by year, so it is necessary to continue to research the equipment of rehabilitation in the welfare field.

Although some people are suffering the serious diseases or disabilities, they have clear consciousness as the healthy people, and they have the right to take part in the social activities. In order to help these people to better adapt to the life and realize their life value, the future task of the computer input device not only focus on the word processing, but also support intellectual, creative activities and social participation as the goal.

At the same time, whatever and whenever the patients do by the computer the computer input device can provide the function that whatever and whenever the patients use the computer, they can succeed to call the nurses or the caregivers when they are in emergent situations.

Acknowledgments

In the year of 2012, I came to Nagasaki University as an exchange student. And studied the knowledge of designing the devices of rehabilitation in the laboratory of Ishimatsu professor for one year. Although the stay was short, I learned much from Ishimatsu professor not only in the studying field, but also much more about the life spirits of human. So I feel deeply that it is necessary to continue the research and returned the laboratory for learning the doctoral course after I got my master's degree in China in the same year. From all that my professor have done and conscientious attitude towards the work as well as culture guidelines for us, I deeply realized that how bright he is and what a broad minded he has. My professor often takes us to visit the serious patients who are in bed-ridden situations and who cannot live by themselves just relying on artificial respirator. Ishimatsu professor has a tender sympathy for these patients and wants to help these patients with a mercy heart. The patients make great efforts to struggle with their body disabilities. The strong will expressed on the patients' face stimulates Ishimatsu professor's enthusiasm of creation. In order to support the patients' life, Ishimatsu professor usually considered all kinds of programs day and night and often forgot to have meals. He guided us to do lots of experiments using many sensors just to realize the goal of be convenient for the patients to use. Though the experiment is a little difficult for me, Ishimatsu professor never gave up, and taught me patiently where I cannot understand. We also feel the joy from the heart when the patients use our device to lead a comfortable life expertly. Ishimatsu professor always taught us to be with a loving life with a grateful heart and instruct us to treat the disabled properly not to look down on them because everyone has self-esteem when they were born. With the admiration and gratitude to Ishimatsu professor and support for my teacher's life career, I applied for my doctoral course to continue the research in Ishimatsu professor's laboratory.

How time flies, and the doctoral learning career is coming to its close, during these times, what I learned from Ishimatsu professor is not only the professional knowledge, but also how to do ourselves. Ishimatsu professor's behavior taught me how to live, how to establish a correct outlook on life, how to face life's challenges and how to get to a strong in face of all kinds of hardships of life. Much appreciation for Ishimatsu professor because he taught the most precious things of life before I enter the society. When researching, devote all the energy; when teaching the students, keep patience and enthusiasm; when facing hardships, be always positive and optimistic; when communicating with others, always maintain modesty and generous attitude.

At same time, I also want to express much gratitude to Dr Muromugi, he as the assistant of Ishiamtsu professor, was always keen to help me when I was at a loss in the research, but no one to ask, he gave me much advice and help me to solve the problem and check the experimental results when Ishimatsu professor was on business. I am very thankful to Dr Muromugi. However, he has taken up other school as an associate professor, the kindness will firmly remained in my heart forever.

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Because so many people are enthusiastic to help me in my life and study, I feel nothing only warmth without sadness in the foreign country. Here I express my sincere gratitude to them once again. Thanks for them to bring e much joy. I wish them healthy and happy forever.

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