

# Development of Electric Wheelchair with Operational Force Detecting Interface for Persons with Becker's Muscular Dystrophy

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**Abstract.** Even if some adjustment is provided, it is still harder for disabled people to use the joystick to operate the wheelchair although they can move their bodies. There is considerable difference in disabled characteristics among individuals. To deal with this difficulty, clarifying each person's characteristics and understanding one's individual characteristics are important issues for the proposal of their operation systems. This paper aims to propose the new operation interface, which generates no stress in operation, considering the physical characteristics among those who feel difficulty in operating with joystick. The subject for system validation is set to be a man who has Becker's muscular dystrophy as patient.

**Keywords:** Human Interface, Electric Wheelchair, Operation, Severely Disabled, Becker's Muscular Dystrophy.

## 1 Introduction

Nowadays, the number of the severely disabled has been increasing every year in Japan [1]. By providing a mobility device for them, their social activities can be still carried out to improve their QOL. An electric wheelchair is expected to be one of their mobility devices.

A severely disabled person is classified from the human interface for operating an electric wheelchair. Since the severely disabled are difficult to move the body, they need the realization of the input device by utilizing a sound, brain waves, etc [2][3][4][5]. The slight disabled use the joystick by adjusting reaction force, the available amount of operations, an attachment position, etc. to fit each individual's residual function. The disabled can use the joystick by using their upper limb and head to operate an electric wheel chair. However, even if the adjustment is provided, it is still harder for disabled persons to use the joystick to operate the wheelchair although they can move their bodies. Furthermore, there is considerable difference in disabled characteristics among individuals. To deal with this difficulty, clarifying each

person's characteristics and understanding one's individual characteristics are important issues for the proposal of their operation systems.

The plan of this research is based on the following two issues. The first issue is the clarification of the feature of the physical stress which the disabled feel in joystick operation, and the proposal of the input device considering the feature. The other issue, in order to reduce a stress of operation an electric wheelchair, concerns the proposal of a technique to stabilize the behavior of an electric wheelchair with respect to environmental disturbance, such as a slope and a level difference of a sidewalk.

This paper aims to propose the new operation device, which generates no stress in operation, considering the physical characteristics among those who feel difficulty in operating with joystick. The subject for system validation is set to be a man who has Becker's muscular dystrophy as patient. The experiment in this research was conducted under approval of Ethical Review Board of the National Rehabilitation Center for Persons with Disabilities in Japan.

## **2 Examination of Patient**

We conducted the experiment to examine the feature of disabled at the clinic for the wheelchair and seating design currently performed in the National Rehabilitation Center with Disabled.

### **2.1 Condition of Becker's Muscular Dystrophy**

The Becker type muscular dystrophy, as target in this research, is a kind of creeping palsy, muscular power, and muscular power may decline from proximal muscles, and it is categorized as sickness [6]. The patient load is estimated to be about 22000 people in Japan [1]. Since muscular power declines, it is mentioned that rise-and-fall operation on stairs becomes difficult, they cannot run and falls over easily in such condition etc. Therefore, in order to lead their independent life, it is effective to use an electric wheelchair [2]. As abovementioned, in order to develop the operation input device for a muscular dystrophy patient to operate an electric wheelchair, it is important that it can be operated with weak force.

### **2.2 Survey of Subject**

The patient in this research is a university student, who has Becker's muscular dystrophy. Because he cannot run and walk by himself, he usually uses an electric wheel chair in daily lives.

In order to extract the requirement item of an input device, we interviewed the muscular dystrophy person concerning the dissatisfaction and problem about usage of the joy stick for operating an electric wheelchair. The representing replies are shown as follows:

1. He can write with a pen, and move a mouse of a PC.
2. When he continues grasping a pen, moving a mouse and operate the joystick, he cannot operate an electric wheel chair for a long time because his elbow becomes painful.

3. He becomes fatigue with operation of electric wheelchair with joystick only in 30 minutes even if he is in good physical condition. Therefore, he has almost no chance to operate it independently. His parents and friends help him to move in his life.
4. He has not been so fatigued while pushing buttons of a mouse. This means that such operations need only terminal muscle.
5. It is desirable to move his muscles in the viewpoint of keeping up his physical function when he is in good condition. The input device is ideal to be changed easily between a normal joystick and a low-fatigue input device.

As abovementioned, in order to reduce a stress for the person to move, it is necessary to develop a new operation input instead of joystick.

### **3 Development of Force Detecting Interface**

#### **3.1 Extraction of Requirement Items for Proposal an Interface**

Based on the mentioned survey as shown in section 2, the requirement items for proposal an interface are shown as follows:

- It can be operated with small force from the viewpoint that the force of operation a joystick is lost when it is used continuously.
- It is possible to operate in small available range from the viewpoint that the vicinity of elbow becomes painful when it is used for a long time.
- From the viewpoint of maintaining a residual function effectively, it is an interface using the physical terminal function (finger) moderately.

#### **3.2 Physical Characteristics for Proposal of an Interface**

We also examined patient's terminal function characteristics. We measured his maximum button-pushing force of fingers when he didn't feel fatigued. The person could exert about 2N, which is 1/7 of the button-pushing force in the case of general person as shown in Figure1. This result indicates that the pushing force of interface should be designed to be less than 2N for the person.

#### **3.3 Proposal an Interface Considering Physical Characteristics**

The electric wheelchair is controlled based on displacement of a joystick, and, generally the maximum displacement of a joystick is about 3 - 6cm in all directions. An input device with small displacement is needed because of people cannot operate a joystick satisfactorily. In order to make operation displacement become zero, we focused on the force detecting interface. Unlike the displacement-input method of joystick, the force detecting method realized an interface which does not input displacement at all ideally. Therefore, the person A of muscular dystrophy can operate it without a physical stress by using a force detecting method.

To realize these points, the device is considered a force-detection interface like button shape without long operating distance. A force-detection interface is able to be operated with small force input when the sensitivity of output with respect to input was higher. However, it is hard to switch the situation of operation quickly when the sensitivity is high. It is easy to operate the switching device in on or off condition quickly. The switching device is not possible to be controlled precisely. Therefore we propose a new interface which is combined their effective functions. The shape is imitated with a mouse of PC, from the questionnaire survey. Because it is hard for the person to hold on the joystick, his palm can put on device like the mouse shape, which is called on the palm-rest as shown in Figure2. This aims to support getting the swing of person's body.

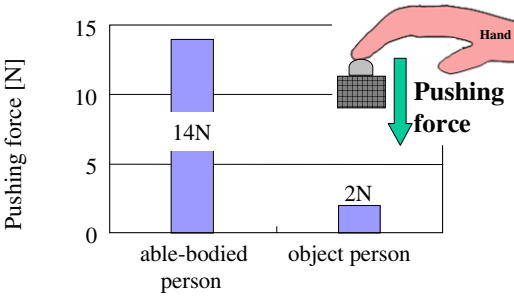


Fig. 1. Forces of able-bodied person and object person

### 3.4 Correspondence Between an Operation Method of Force Detecting Interface and an Electrical Wheelchair Behavior

Figure 2 shows the operation method of force detecting interface. In order to operate an electric wheelchair, the input system for operating eight degree of freedom is need as shown in Figure2(a). The interface is designed to be 3-button interface, which consists of a switching function and a force detecting function, to realize 8 degrees. As a function of the interface, when the button of middle is pushed, an electric wheelchair runs at straightly. When the left (right) button is pushed, an electric wheelchair performs the left (right) rotation on the spot. Moreover, when a center button and the left (right) button are pushed simultaneously, an electric wheelchair turns left (right) and when three buttons are pushed, the wheelchair goes reverse.

The button consists of a switching sensor, which judges whether the button was pushed or not, and a force detecting sensor to measure the pushing force. In addition, the velocity of wheelchair can be controlled with respect to the button-pushing force. From this function, when the left button and the right button were pushed simultaneously, it is set to run reverse, while bending to the direction of large force by compared with left and right force.

As abovementioned, it becomes feasible to operate an electric wheel chair with the proposed input device which consists of three force sensors and button switches. Figure 3 shows the prototype of electric wheelchair with force detecting interface.

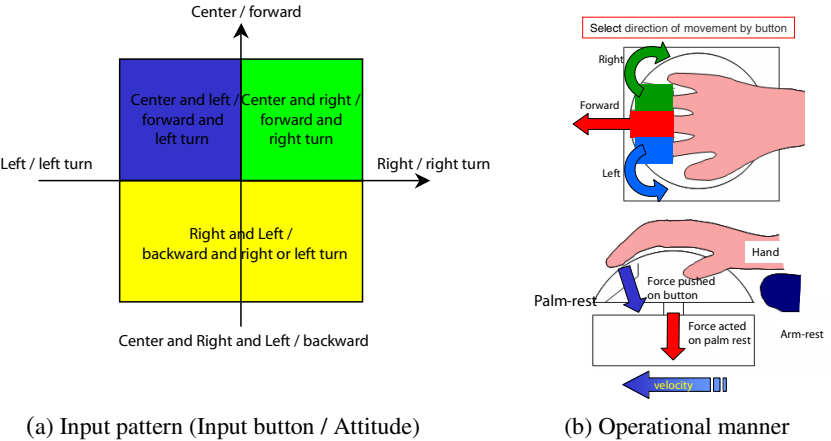


Fig. 2. Operational manner of Operational Force Detecting Interface



Fig. 3. Description of electric wheelchair with force detecting interface

3.5 Problem of a Force Detecting Interface

Force input method generally tends to be directly influenced with respect to disturbance. The force detecting interface proposed in this paper may cause an operation mistake to the influence of vertical vibration while running on sidewalk too. Therefore, in order to operate an electric wheelchair stably, vertical vibration needs to judge the influence which it has on an operation input, and needs to propose the method of removing its influence on running stability.

## 4 Disturbance Rejection Method for Extracting an Operation Intention

### 4.1 Extraction of Disturbance for Stable Operating

The force detecting interface is sensitive to unintended input to electric wheelchair under the influence of the running environment such as bump and slope and the caster behavior etc. The level difference is considered to influence both operation and behavior of an electric wheelchair and a level difference is directly considered as "disturbance given to an operator."

A caster is a front wheel of an electric wheelchair and the direction of movement of an electric wheelchair is determined by the caster angle as the feature of an electric wheelchair. When an intention of an operator and a caster's angle do not agree each other, the behavior of an electric wheelchair is considered to be disturbance to an intention of operator. Therefore, a caster's behavior is indirectly considered as "disturbance given to an operator" through the behavior of an electric wheelchair.

A slope changes the balance of force which works at the center of gravity of an electric wheelchair. It is considered as disturbance for an electric wheelchair to move. Therefore, a slope is indirectly considered as "disturbance given to an operator" through the behavior of an electric wheelchair.

### 4.2 Proposal of Disturbance Rejection Method While Operating

To examine an influence of operator's intention against disturbance, we conducted the experiment using an electric wheelchair running on the road including shock or vibration.

We propose an intention extraction system using experimental results. Based on the measured palm-rest force as shown in Figure2, the system judges whether there is operator's intention input or not. The method is simple as applying the low pass filter with respect to the detected force of button. The cutoff frequency is proportionally varied with respect to force deviation from palm weight. In order to propose this method, it is necessary to determine the following information.

1. Distinguishing between an operation intention of an operator and the influence of disturbance.
2. Determining the cutoff frequency with respect to the information input into the operation device.

Without influence of disturbance, the force measured on a palm rest is considered as a constant value in which an operator holds on an interface. Then, definite-period-of-time measurement of the power concerning a palm rest was carried out, and the average value was set as a threshold value.

Moreover, the force concerning the palm rest with respect to an operation input is a constant value without fluctuation. From such a relation, an intention of operator is considered as a value near the threshold value, and a component influenced by disturbance is a fluctuation from the threshold value.

In order to determine the cutoff frequency, we conducted the experiments which the device is influenced by the vertical vibration such as a bump, a step and a step. As

an experimental condition, an operator made an electric wheelchair go straight by pushing a button by fixed power on various roads. Based on the obtained running data, the optimal cutoff frequency was drawn to reject the influence of disturbance. However, because of the cutoff frequency depends on two parameters, which are near the threshold and the fluctuation from a threshold, as shown in Figure4. Therefore, between their parameters, it becomes discontinuous situation. As a result, a switching situation of cutoff frequency occurs and it worsens maneuverability. Therefore, the cutoff frequency is considered as the linear function with respect to the force acting on the palm rest. If the force acting on a palm rest is below the threshold value, the proposed system can recognize the intention of an operator as shown in Figure4. Therefore, the cutoff frequency is changed in proportion to the fluctuation from the threshold, and when the fluctuation from a threshold is large, it is judged that it was influenced by disturbance.

The effectiveness of the proposed system is investigated in the case of actual road such as bump, slope and studded paving block. Figure5 shows the effectiveness of the proposed disturbance rejection system at bump situation at 2km/h. Although the forced pushing button is influenced by disturbance at 7sec., the force can be satisfactorily removed the influence from disturbance with the proposed system.

Moreover, the intention of an operator is confirmed as operation input removes disturbance from 3 sec. to 6 sec.

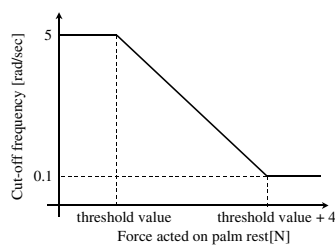


Fig. 4. Cutoff frequency

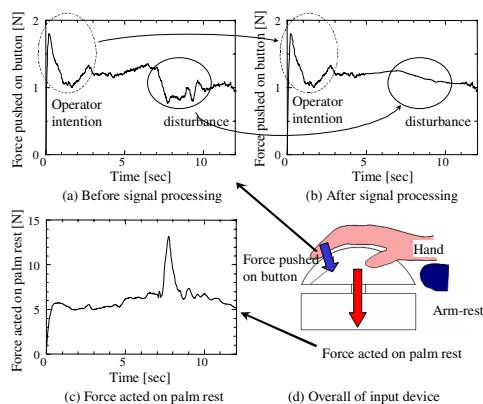


Fig. 5. Effectiveness of the proposed disturbance rejection system at bump situation at 2km/h

As mentioned above, the validity of the disturbance rejection method for extracting the proposed operation intention has been confirmed in the case of actual road such as bump, slope and studded paving block.

## 5 Evaluation of Force Detecting Interface

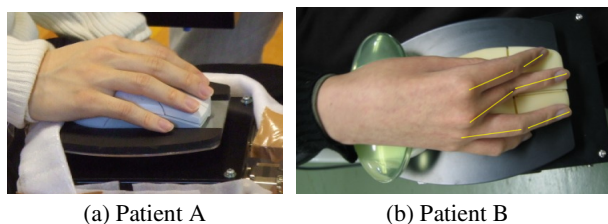
Two muscular dystrophy persons are employed to examine the validity of the proposed force detecting interface. Concretely, when the persons operated an electric

wheelchair using proposed force detecting interface, by comparing with the conventional joy stick, we examined the validity of a force detecting interface and grasp the problem in the present condition. For securing experimental safety, the persons operated freely within the enclosure of the National Rehabilitation Center for Persons with Disabilities. We made an interview to each person in the end of experiment.

## 5.1 Evaluation Results

Patient A: Fundamental operation of going straight, a right and left turn, etc. was possible. An affirmative opinion is obtained as follows: he can operate with weak force, easy use without operational stress. Moreover, he was able to input the force of 0.5N as same as the time of an operation start after 30 minutes. This means that a degradation of the force accompanying the passing time cannot be noticed. This is an epoch-making effect. As a negative opinion, operation size is too large and it is hard to input force for him.

Patient B: Fundamental operation of going straight, a right and left turn, etc. was possible. Comparison with joystick, he evaluated the system that it is not easy to use as expected, from the viewpoint of maneuverability and stress. When the person inputs force to the interface, his modifications of between second and third finger become larger than patient A as shown in Figure6. As a factor, the forms of the person's hand and fingers do not suit the shape of interface and the position of button. Moreover, as an operation function, when the third finger was used, the system is evaluated that it becomes hard to use.



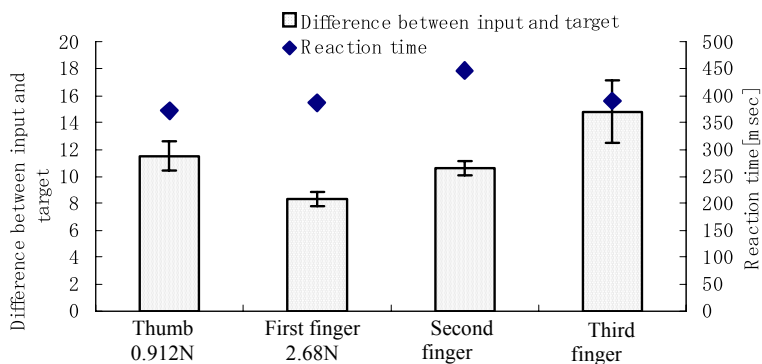
**Fig. 6.** Difference of hand modifications between patient A and patient B

## 5.2 Evaluation of Patient B's Finger Function, and a New Input Device

In order to evaluate the performance of the finger, which used for force detecting interface, based on a quantitative index, we conducted the experiment as a subject of patient B. We measured three evaluation indices such as the maximum force, reaction time and target following capability against each finger. However, the little finger is not measured.

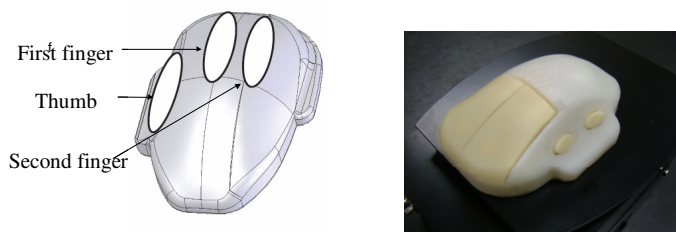
Figure7 summarizes the evaluation results using the index in the case of each finger. As this result, the thumb is a good performance in the target follow capability although the maximum force of thumb is smaller as compared with the third finger. Moreover, most differences among each finger cannot be noticed in the case of reaction time.





**Fig. 7.** Result of finger performance measurement t

From the above consideration, the new force detecting interface which operated a button by the thumb, the first, and the second finger is proposed not using the third finger as shown in Figure 8. Moreover, as substitution of the function to push three buttons at the time of reverse, the second joint of thumb was proposed to use with weak force. At the time of forward running, the operator pushed the button by the first joint of the thumb with weak force.



**Fig. 8.** Sketch of newly proposed interface

## 6 Conclusions

This paper proposed an operation interface for a muscular dystrophy patient as severely disabled based on the analysis of the physical characteristics from the observation of actual operation of an electrical wheelchair.

1. The new idea of button type force detecting interface for a muscular dystrophy person was proposed: the interface is realized for operating an electrical wheelchair with weak force.
2. The disturbance rejection system was proposed to recognize the operation intention while operating automatically without physical stress.
3. The effect on enhancing the maneuverability of muscular dystrophy patient while operating, in order to relief the physical stress was proved by experiments using the electric wheelchair with the proposed interface.

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