The 8th TSME International Conference on Mechanical Engineering
12-15 December 2017
Bangkok, Thailand

DRC0015

Interface for electric wheelchair with tension-athetosis-type cerebral palsy

Motoyu Katsumura[1], Ken'ichi Yano[1,*], Nakao Tomoyuki[2], Atsushi Hamada[2] and Katsuhiko Torii[2]

[1] Department of Mechanical Engineering, Mie University, 1577 Kurimamachiya-cho, Tsu-city, Mie, 514-8507, Japan
[2] Imasen Engineering Corporation, 3-1-8 Techno Plaza Kakamigahara-city, Gifu, 509-0109, Japan

* Corresponding Author: yanolab@robot.mach.mie-u.ac.jp

Abstract. Individuals with cerebral palsy use electric wheelchairs due to their abnormal gait caused by paralysis and other symptoms. However, it is difficult for them to operate the wheelchair joystick because of their suddenly occurring, uncontrollable, involuntary movements and the difficulty they have in maintaining their posture. In this study, we developed a control filter, which suppresses the effects of involuntary movement. This is capable of controlling electric wheelchair as intended by individuals with tension-athetosis-type cerebral palsy. We demonstrate the effectiveness of the proposed method in experiments that compares the stability of operation between normal systems and the proposed method.

1. Introduction

Recently, the use of electric wheelchairs has become widespread as the population age and the number of people with physical disabilities increase. Joystick-type electric wheelchairs are especially commonly used by people with physical disabilities. It is possible to regard people with tension-athetosis-type cerebral palsy as good candidates for electric wheelchair use. The symptoms of cerebral palsy include difficulty controlling their movements and postures, due to dysfunction in the brain. Because patients with cerebral palsy walk abnormally as their muscular strength becomes weaker and weaker, many of them have lower back pain. As a result, they would benefit greatly from using an electric wheelchair on a daily basis. However, there is a big problem in considering tension-athetosis-type cerebral palsy, namely the occurrence of involuntary movement. Here, we consider involuntary movement as unintended trembling of the hands and exertion of force. Because of the influence of involuntary movement, it is difficult for patients to write using a pen and to perform other ordinary actions needed in daily life. When such patients operate a joystick-type electric wheelchair, the operation becomes unstable due to involuntary movements. If a person who exhibits involuntary movement uses an electric wheelchair in daily life, the possibility of having an accident, such as falling into a river or gutter, would be high, and so electric wheelchairs are not safe for such patients to use.

At present, handle-type, chin-control-type and switch-type electric wheelchairs are commercially available. These devices have interfaces that are suitable for their functioning. However, it is difficult for people who exhibit involuntary movement to operate these interfaces because these interfaces can be manipulated in all directions and require maintenance of the posture. Moreover, in recent years, besides joysticks, various interfaces that use physical movements such as seat surface inclination [1] and biomedical signals such as brain waves [2] have been developed. However, because extraction intention of the operator is unstable and the development of these technologies is very expensive, these researches have not yet led to interfaces that can be put into practical use.

On the other hand, a previous study suggested an adaptive involuntary movement attenuation filter [3], which focused on the synthetic velocity of the hand as a parameter with which to identify the presence of involuntary movement. This is a position-correction filter which is able to judge the strength and weakness of involuntary movements based on the synthetic velocity and the attenuation of involuntary movements. This filter makes use of the attenuation weight coefficient. When the synthetic velocity is large, which means that the involuntary movement is strong, the attenuation is large, while when the synthetic velocity is small, which means that the involuntary movement is weak, the attenuation is small. Due to the attenuation weight coefficient, we determined the degree of correction. Using this filter, it is possible for persons with cerebral palsy to draw pictures and write characters by themselves (see figure 1). However, there are time delays in this filter. For the operation of electric wheelchairs, which requires readiness, we need to design a new control system to make the operation more intuitive and comfortable.

(a) Without assist **(b) With assist**

Figure 1. Results of drawing and writing assist systems

In this study, we propose an involuntary movement suppression filter for patients with cerebral palsy so that they can operate an electric wheelchair as intended.

2. Analysis of involuntary movement

First, we analyzed the involuntary movements that occurred during the operation of an electric wheelchair. In this study, we used the electric wheelchair shown in figure 2, Standard Electric Tilt model EMC-250T with electric tilting made by Imasen Engineering Corporation. It is a joystick-type electric wheelchair. Its operation area is a circle with a radius of 21 mm and we can get operation voltage.

This experiment involved operating the wheelchair in the forward, backward, left and right directions, and positions are given in mm. The subject of this experiment was a male in his 30s with tension-athetosis-type cerebral palsy. We explained the content of the experiment to the subject and we obtained his consent. In this experiment, the subject ran a straight course with a width of 800 mm. The subject tried not to leave the course while driving and not to lose his hold on the joystick if possible. Moreover, the running speed of electric wheelchair was maintained at 6.0 km/h during the experiment.

Figure 2. Standard Electric Tilt Model EMC-250

Figure 3 shows the joystick operation wave in running the straight course. The upper figure shows the operation wave for the forward and backward directions, while the lower graph shows the operation wave for the left and right directions. Moreover, in these graphs, forward and leftward motion are both considered positive. During the operation shown in figure 3, because involuntary movements occurred, the subject lost his hold on the joystick in trying to prevent contact with the wall. We confirmed that the operations returned to the position of the neutral axis for each operation in the forward and backward directions. Next, we instructed the subject not to lose his hold on the joystick, and figure 4 shows the joystick operation wave. There were no severe involuntary movement movements, and the waveform was stable in the forward and backward directions. On the other hand, there were constant involuntary movements in the left and right directions. Therefore, the electric wheelchair meandered. From these results, we concluded that the subject could operate the joystick as intended in forward and backward directions but in the left and right directions, the subject could not operate the joystick as intended because the involuntary movements become severe.

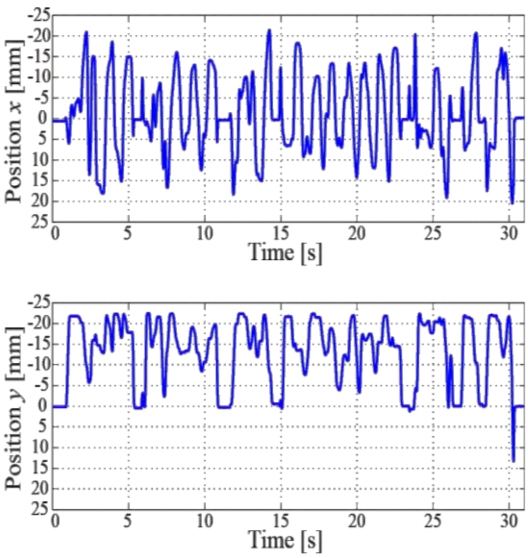


Figure 3. Results for straight course running (first time)

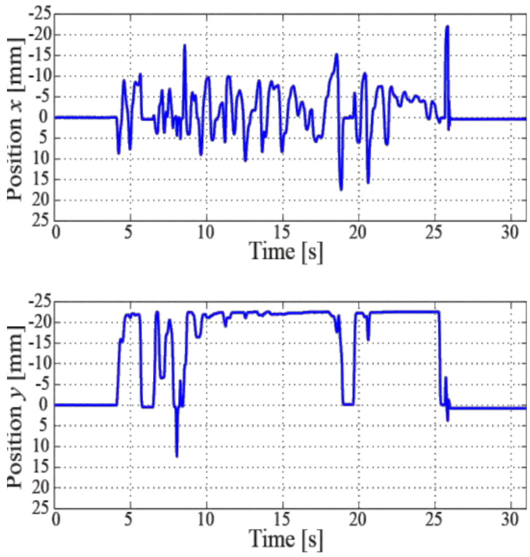
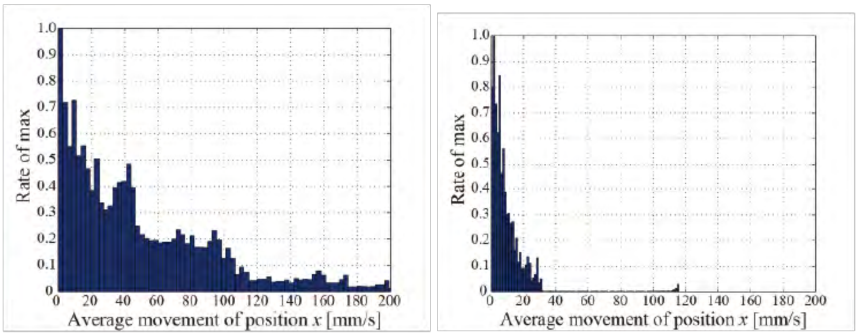


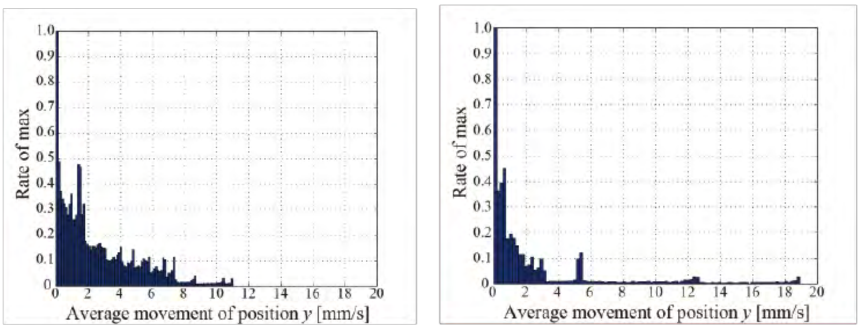
Figure 4. Results for straight course running (second time)

We extracted two points from the operation wave and analyzed the characteristics of the wheelchair operation. One point had a large amplitude due to involuntary movements and the other corresponded to a time when the wheelchair was operating as intended according to the subject's voluntary movements. We produced a histogram of the average movement at these points and compared them. Figure 5 shows the comparison for forward and backward directions and figure 6 shows the comparison for left and right directions. In the left and right directions, the average movement is mainly more than 20 mm/s when involuntary movements occurred, while it was less than 20 mm/s during voluntary movements. Therefore, 20 mm/s was the threshold value between voluntary movements and involuntary movements. In the same way, a threshold value of 2.0 mm/s exists in the forward and backward directions, but 2.0 mm/s is extremely small. Therefore, it is considered that there was no difference between voluntary movements and involuntary movements so far in the forward and backward directions. Based on these analysis results, we designed an involuntary movement suppression filter.



(a) Involuntarily **(b) Voluntarily**

Figure 5. Histogram of left and right directions



(a) Involuntarily **(b) Voluntarily**

Figure 6. Histogram of forward and backward directions

3. Design of control systems

Based on the analysis given in the previous section, we designed a filter that suppresses the effect of involuntary movement on the operation wave. This filter distinguishes voluntary movements from involuntary movements by the use of the threshold value for average movement that we set in the previous section. A block diagram of the designed filter is shown in figure 7.

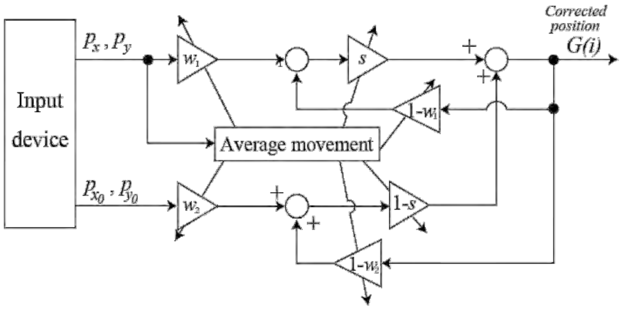


Figure 7. Block diagram of proposed systems

In this figure, $P(i) = (Px(i), Py(i))$ represents the input coordinates of the joystick operation, $P_0 = (Px_0, Py_0)$ gives the coordinates of the neutral axis, $G(i) = (Gx(i), Gy(i))$ gives the corrected coordinates, and ω is a weighing factor as shown in equation (1):

$$\begin{cases} \omega_1(i) = 0.01 \cdot 0.001^{\frac{|v(i)|}{V_j}} \\ \omega_2(i) = 0.\ 1 \cdot 0.001^{\frac{V_j}{|v(i)|}} \end{cases} \tag{1}$$

Here, $v(i)$ is the average movement calculated from the input coordinates and V_j is the threshold value of the average movement. From a comparison of $|\ v(i)|$ and V_j, $G(i)$ is determined by equation (2):

$$G(i) = \begin{cases} \omega_1(i)P(i) + (1 - \omega_1)G(i-1) \\ \quad [if\ \ (|\ \ v(i)| < V_j\ \ ] \\ \omega_2(i)P_0 + \left(1 - \omega_2(i)\right)G(i-1) \\ \quad [if\ \ (|\ \ v(i)| > V_j\ \ ] \end{cases} \tag{2}$$

Moreover, parameter s is determined using equation (3):

$$s = \begin{cases} 1 & (|\ \ v(i)| < V_j) \\ 0 & (|\ \ v(i)| > V_j) \end{cases} \tag{3}$$

With this filter, when a movement is identified as an involuntary movement, $G(i)$ is corrected to the coordinates based on the neutral axis, and trembling operation waves caused by involuntary movements are suppressed. Thus, using this filter, it is possible to suppress large tremors which lead to meandering. In the next section, we show the effectiveness of this proposed control system.

4. Verification experiment

We conducted experiments to show the effectiveness of this filter. In this experiment, we tested the stability of the wheelchair's straight motion in the course shown in figure 8. The subject ran on a board with width of 800 mm, length of 5,400 mm and thickness of 28 mm. The subject in this experiment was the same as the previous subject. It is known that involuntary movements are made more severe by the tension. We explained the contents of the experiment to the subject and we obtained his consent. The subject focused on not leaving the course while driving, not losing his hold on the joystick, and running along the centerline. Moreover, the running speed of the electric wheelchair was kept at 6.0km/h during the experiment.

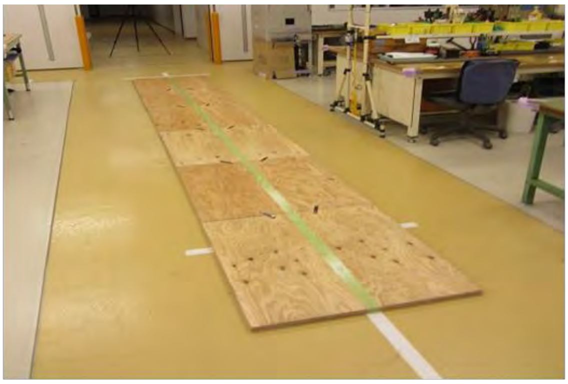


Figure 8. Experiment course

When the filter was not introduced, involuntary movements caused diversion from the centerline and wheelchair fell off the platform. On the other hand, when the filter was introduced, the operation of joystick did not change, but it was possible for the subject to go straight without meandering. The operation conditions are shown in figure 9. Moreover, the operation wave for each direction is shown in figure 10. From these graphs, it was concluded that it is possible to prevent meandering by correcting the waveform for motion in forward direction from the actual operation, in which frequent turning toward the left and right occur due to involuntary movements. In addition, it was concluded that in the waveform for motion in the left and right directions, the filter suppresses unintended operations due to involuntary movements and resulting in the improved wave for straight running stability. From these results, we confirmed that these control systems extract involuntary movements which cause meandering and suppress their influence. Thus, these results show the effectiveness of this control system.

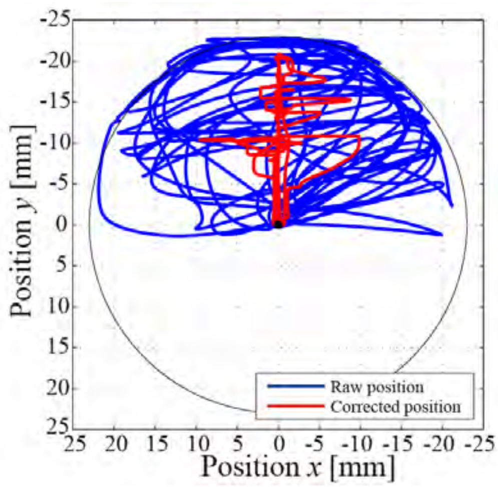


Figure 9. Operation condition

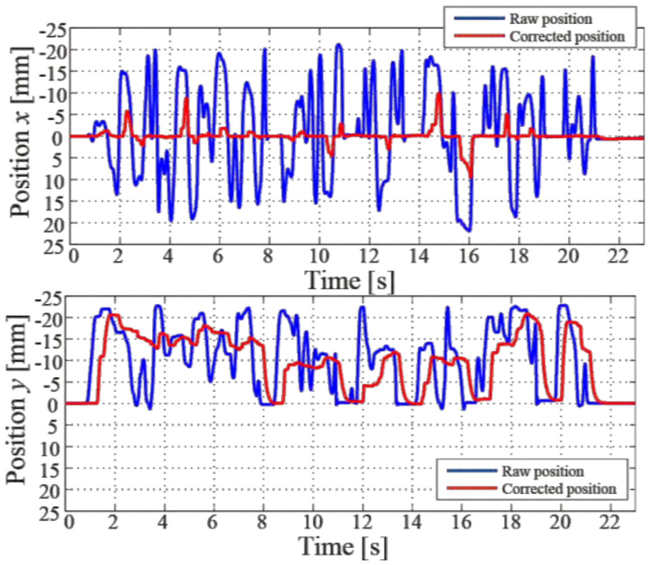


Figure 10. Results of verification experiment

5. Conclusion

It is difficult for an individual with tension-athetosis-type cerebral palsy to operate an electric wheelchair as intended because of the occurrence of involuntary movement. On the other hand, the abnormal gait of such patients due to paralysis leads to lower back pain, and the use of an electric wheelchair would be a great benefit. However, when such patients operate joystick-type electric wheelchairs, meandering occurs due to involuntary movements. The purpose of this study was to improve the running stability of electric wheelchair for a person with cerebral palsy. We analyzed the characteristics of the operation of such wheelchairs and designed an involuntary movement suppression filter focused on average movements. With the use of this filter, it was possible to go straight without meandering even if involuntary movement occurs. In the future, we will show the effectiveness of the proposed control systems in daily life, and it is expected that these results will lead to an independent life for individuals with tension-athetosis-type cerebral palsy.

References

[1] Han Q, Osawa S and Ozaki K 2014 *Trans.s of Japan Society of Kansei Engineering* **13**(1) pp 55-62

[2] Rebsamen B, Burdet E, Teo C L, Zeng Q, Guan C, Ang M, and Laugier C 2006 *Proc. of 1st IEEE/RAS-EMBS Int. Conf. Biomedical Robotics and Biomechatronics* (Italy)

[3] Nakao T, Matsui H, Yano K, Kubota N, Miyagawa N and Horihata S 2011 *J. of Biomechanical Science and Engineering* **6**(5) pp 362-377