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Research paper

Research and development of control system for semi-automatic infirm wheelchair mobility using head motion

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Abstract

The objective of this research is to improve and develop the control system for semi-automatic infirm wheelchair mobility using a head motion for the disabled person wheelchair to fulfill the need of the person with the disability of arms and legs as the result of accident or illness as the result of an underlying disease. The disabled person can control this disabled person wheelchair by the use of head via semi-automatic infirm wheelchair mobility control unit using a head motion for wheelchair mobility. The wheelchair comprises of 2 sets of DC motor (24 V 450 W) and 2 sets of battery (12 V 45 Amp), which are connected for manipulation in driving forward and moving to the left or right side. Brake system is applied to the safety of the disabled person and can be controlled the wheelchair mobility by use of the head to press a switch. The finding of the testing result indicated maximum average velocity of forwarding mobility in horizontal mobility (going forward) at 3.97 kilometers/hour, maximum slope ascending mobility of 15 degrees at average ascending mobility velocity of 2.41 kilometers/hour, minimum left turning circle at 1.54 meters, minimum right turning circle at 1.60 meters, minimum braking distance at 0.49 meters, and 7-hour usability of battery duration per one charging (charging duration took around 3 hours/time). The finding from the tests conducted with the disabled persons indicated that it could be well used by disabled people without dependence and more convenient for daily life.

Keywords: *Wheelchair; Rehabilitation; Ethnographic Research; Mobility Device; Control system.*

1. Introduction

In current situation, there has been increased in patients as the result of cerebrovascular disease-causing problem of hyposthenia of upper arms and legs which are the organs that can be slowly treated and reconditioned if they are affected from Cerebrovascular symptom, and increase in patients who fail to use their arms and legs or inflexibly use as the result of illness, caducity and accident. Therefore, the need for wheelchair use by patients for facilitation has increased, resulting in the continuous development of patient wheelchair-related innovation for facilitation and easy use to the patients and patient caretakers whether in the matters of mobility control, figure, attractiveness, modernity, use of more lightweight materials, and various and equipped usability forms. New innovations have been launched into marketplaces due to the goal of patients and caretaker facilitation, causing price differentiation for patient wheelchairs from the addition of technology application in patient wheelchairs [1-3]. In Thailand, wheelchairs have been continuously developed under equal competitions with various nations. The continuous production and development of newly invented patient wheelchairs have been extensively evinced whether being the use of electric power as commander in forward and backward mobility [4] , turning direction control or making seat able to message back and neck, etc. The technology which is contained in a patient wheelchair will offer the proper alternatives for the needs of the users or buyers [5-6]. However, in fact, most of the designs for the patient wheelchair products launched in various forms or new forms have been specific for the person with disability of legs, resulting in limitation and inconvenience of extensive usability according to needs. The patients with disabilities of arms and legs, therefore, are unable to help themselves as needed and must wait for bits of help from other people or their caretakers.
According to the aforesaid, the purpose of this invention aims at designing and developing control system for semi-automatic infirm wheelchair mobility using head motion for the disabled person wheelchair so that the patients or disabled persons can use their heads in commanding the wheelchair mobility, and can command wheelchair via the system and mechanism which are designed to make the disabled person wheelchair movable, the disabled person enable to help themselves and be convenient for daily life. In addition, the technology has been developed to be proper for application in Thailand and reduce the dependency of foreign technologies.

2. Material and method

2.1. Design of mobility control system

The design and development of control system for semi-automatic infirm wheelchair mobility using head motion is the design of patient wheelchair mechanism to facilitate the patients to be able use their head section in commanding wheelchair mobility. The devices are designed and installed with the wheelchair of the patient or the infirm at limbs section. Those devices comprise of Mobility Control Unit for use in commanding mobility of wheelchair [7-8], whereas 2 sets of motors are installed at Mobility Command Unit (MCU) at hook of both wheels for use in driving forward and use in moving to left or right side. The overall components are shown in Figure 1 and overall size is show in Figure 2.

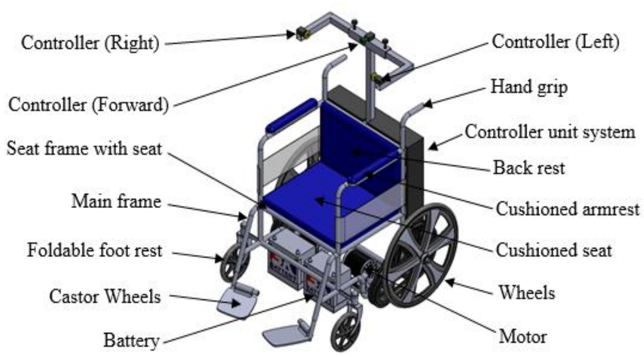

Fig. 1: Components of Disabled Person Wheelchair

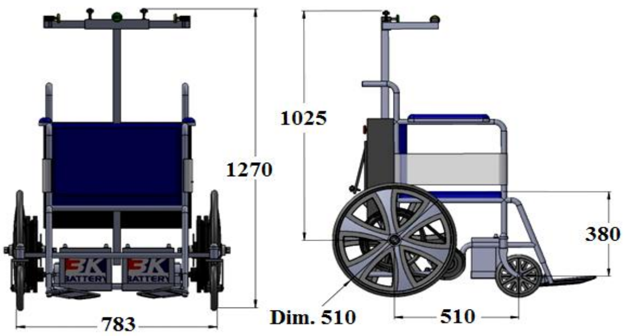

Fig. 2: Overall Size of Disabled Person Wheelchair (Unit: mm)

2.2. Function of mobility control unit

Semi-Automatic infirm wheelchair mobility control system using head motion uses the steel structure which is welded and formed as shown in Figure 3, comprising of forming steel structure for use as controlling mechanism of the wheelchair mobility. The said structure is installed at the back of the wheelchair backrest so that the patient or disabled person can use his/her head to command the wheelchair mobility. Mobility Control Unit of the wheelchair comprises of the steel structure which is formed and extruded from both left and right ends in L shape for use in installing Switches which are pressed for function. Switches consist of Switch that is function of forward mobility control (S1), Switch that is function of right turning mobility control (S2), and Switch that is function of left turning mobility control (S3) to control driving of DC electric motor. Leveller is connected with steel shaft for fastening beam and function of levelling to be appropriate for the patient's body. When the patient uses his/her head to press "Forward Button", the wheelchair will move forward. When the patient uses his/her head to press "Left Turning Button" and "Right Turning Button", the wheelchair will turn left and turn right respectively. The wheelchair mobility is derived from function of DC electric motor which is fixed with the structure of the wheelchair at the lower part of the wheelchair, and connected with Driving Pinion Unit that transmits power for driving rear wheels. Front wheels support the mobility. Upon emergency, all electric circuits can be broken off by Emergency Switch (S4) which is installed at the backrest area at the back of the wheelchair. In part of electrical energy, it is derived from Battery which is installed beneath seat, taking charging duration of Batter for around 3 hours/time. Footboard for the patient is installed in front of the wheelchair. This wheelchair is controllable by the patient who is the controller via Mobility Control Unit by head and also controllable by the porter or caretaker via hand grip as shown in Figure 4.

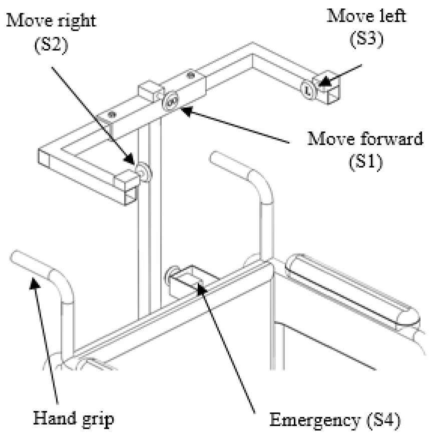

Fig. 3: Mobility Control Unit of Disabled Person Wheelchair.

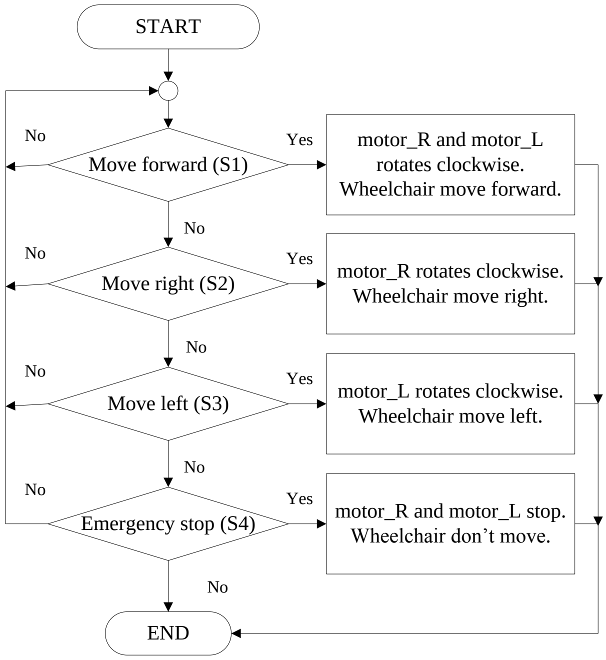

Fig. 4: Diagram of Function of Disabled Person Wheelchair.

2.3. Experimental setup

The daily life usage of the wheelchair of the infirm by the person with disability of arms and legs is related to the frequent mobility. The most importance for usability of this semi-automatic infirm wheelchair of the infirm is to contribute to the ability of the disabled person in self-help and living similar to normal person by means of wheelchair mobility. The important mobility is the mobility alignment of the wheelchair body where most of its mobility includes either straight line or curve. The tests of semi-automatic infirm wheelchair of the infirm are classified into 6 tests including horizontal mobility test (going forward), slope mobility, turn determination test, braking distance test, usability duration test and actual usability test of the person with disability of arms and legs.

2.4. Average velocity

Velocity of the wheelchair is determined whereas average velocity is total distance divided by considered period of time. [9] If velocity and position of particle is required for knowing, it can be calculated from Equation (1).

$$v = \frac{s}{t} \tag{1}$$

When
v = Average velocity (m/s)
s = Distant (m)

t = Time (s)

3. Results and discussion

3.1. Horizontal mobility test (going forward)

Horizontal mobility is the mobility of object to the direction which is parallel to the earth's surface. It is the change in the object's former position to new position. The test under this topic is conducted by testing horizontal mobility (going forward) of the infirm wheelchair whereas mobility is compared with time as shown in Figure 5.

Fig. 5: Horizontal Mobility Test.

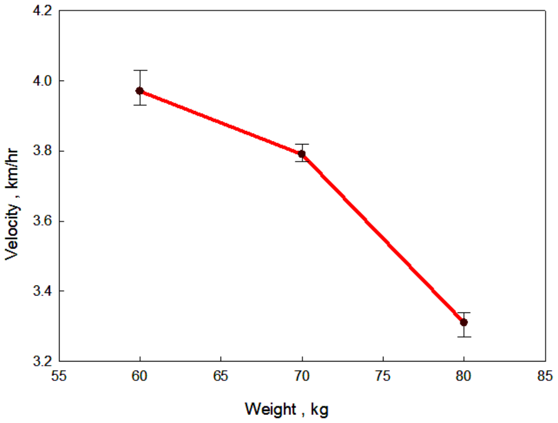

Fig. 6: Graph of Relationship between Velocity and Load.

From Figure 6, the finding indicated the satisfactory horizontal mobility without shaking upon start of the wheelchair, and with stop by inertia force that caused the insignificant slide of the wheelchair. When the wheelchair was loaded, maximum average velocity in horizontal mobility was at 3.97 kilometers/hour at load of 60 kilogram.

3.2. Slope mobility test

Slope mobility is the mobility of object in the direction which is not parallel to the earth's surface and the angle of mobility direction degree and gravity are related. Test is conducted by using 60 kilogram weighed tester in testing and then adjusting more slopes until the wheelchair is unable to move up as shown in Figure 7.

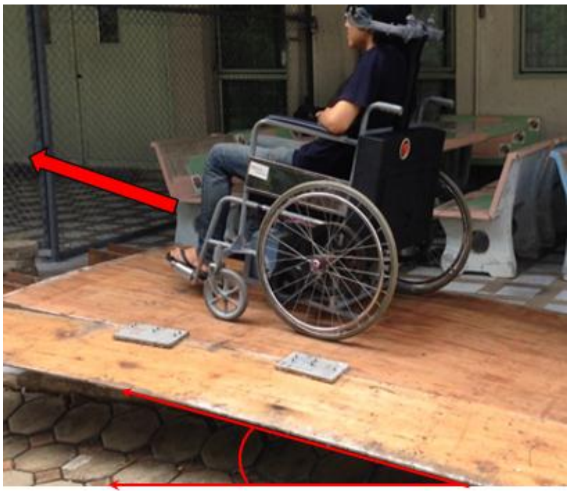

Fig. 7: Slope Mobility Test.

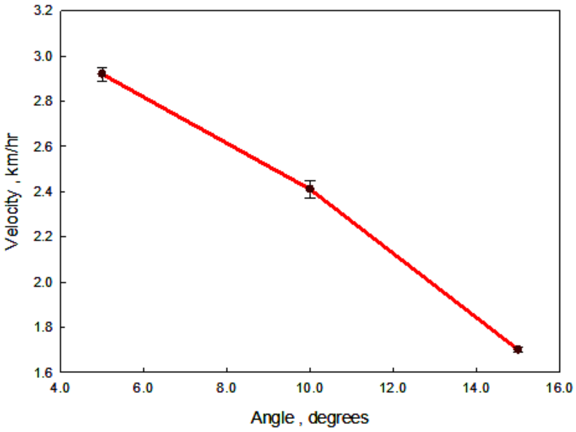

Fig. 8: Graph of Relationship between Velocity and Slope.

From Figure 8, the finding indicated satisfactory operation of the wheelchair mobility at slope of 5 degrees. Until slope was increased to 15-degree angle, the wheelchair started very slow until it was almost unable to move up. It was therefore deemed to be the maximum slope angel where the wheelchair was movable.

3.3. Turn determination test

Turn determination test is conducted by moving with centripetal force of circle, using 60 kilogram weighed tester and determining minimum turn both of left turn and right turn which can be performed by the wheelchair. Three tests are repeatedly conducted to find average as shown in Figure 9.

Fig. 9: Turn Determination Test.

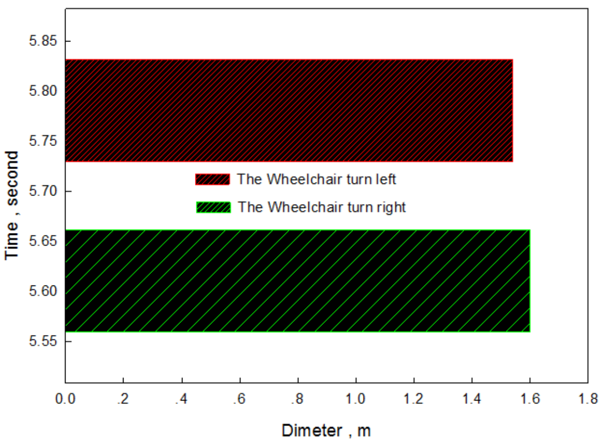

Fig. 10: Graph of Relationship between Time and Turn Distance.

From Figure 10, the finding indicated satisfactory operation of both left and right turning of the wheelchair. According to the test, minimum left turn of 1.54 meter and minimum right turn of 1.60 meter were found.

3.4. Braking distance test

Braking distance test is the determination of maximum braking distance from the wheelchair mobility. The test is conducted by the way that the 60-kilogram weighed tester sits on the wheelchair which is moved at maximum velocity and then braked to determine braking distance which can be performed by the wheelchair. Three tests are repeatedly conducted to determine average as shown in Figure 11.

Fig. 11: Braking Distance Test.

The finding from the test indicated that brake system could well respond to the operation. When braking, deceleration condition of the wheelchair slowly occurred until stopping. The measured distance from the braking beginning of the wheelchair until the wheelchair was motionless was at 0.49 meter for braking duration of 1.03 second.

3.5. Usability duration test

The usability duration test is conducted to test the useful life capacity for Battery of the wheelchair per full charging of Battery. The series of 2 sets of Battery 12 V 45 Amp are connected. The usability of the wheelchair is tested to continuously and horizontally move until Battery is over. Three tests are repeatedly conducted to find average as shown in Figure 12.

Fig. 12: Battery Used in Test.

The finding from the tests indicated that upon continuous usability of the wheelchair in operating function, average usability duration was 7 hours/1 charging. Full charging duration of around 3 hours/time was taken. However, usability duration depends on the nature of the user's usability.

3.6. Actual usability test for disabled person

Actual usability test for disabled person is conducted by trial use of the wheelchair by the infirm or the person with disability of arms and legs to command forward mobility, left turning mobility, right turning mobility and stop of the wheelchair. Data was collected from the disabled persons whether how more or less they are satisfied as shown in Figure 13.

Fig. 13: Actual Usability Test.

The finding from the test indicated that in usability of operating functions, it could be used well by the disabled persons. In part of usability flexibility, weight shall be improved to be lighter than before and usability control system shall be improved to be more convenient. Generally, the infirm or the person with disability of arms and legs could help themselves and it was convenient for their daily life.

4. Conclusion

The objective of this research aims at improving and developing the control system for semi-automatic infirm wheelchair mobility using head motion for the wheelchair of the person with disability of arms and legs to fulfil the need of the person with disability of arms and legs as the result of accident or illness. The disabled person can control this disable person wheelchair by use of his/her head to command via semi-automatic infirm wheelchair mobility control unit by head for self-help and convenience for daily life. In addition, the technology has been developed to be proper for application in Thailand and reduce dependency of foreign technologies. Tests are classified into horizontal mobility test (going forward), slope ascending mobility, maximum turn test, brake test, actual useful life test, and actual usability test of the disabled persons. The testing results described maximum average velocity of forward mobility in horizontal mobility (going forward) at 3.97 kilometers/hour, maximum slope ascending mobility of 15 degree at average ascending mobility velocity of 2.41 kilometers/hour, minimum left turn at 1.54 meter, minimum right turn at 1.60 meter, minimum braking distance at 0.49 meters, 7-hour usability of battery duration per one charging (charging duration took around 3 hours/time). The finding from the tests conducted with the disabled persons indicated it could be satisfactorily used by the disabled persons without dependence and it was convenient for their daily life.

Acknowledgement

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