

Research on Interactive Motion Control of an Electric Wheelchair

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Abstract

Interactive motion control gives the functionality to make the conventional motor control technology detect body intelligence. We evaluated about the assistant system of the electric wheelchair using this control. The experiment measured the torque and feedback frequency of the motor under various conditions. As a result, the assistant system was understood that it is effective to use interactive motion control.

Keywords

interactive motion control, assistant system, electric wheelchair

1. INTRODUCTION

This research aims at realization of the driving control in an electric wheelchair by assistant system. This is a wheelchair that has both sides of the portability of a wheelchair, and the simple operation of an electric wheelchair [Fujii et al., 2002]. In recent years, we have to take notice of rehabilitation and a care support with arrival of an aging society with fewer children. A wheelchair is typical welfare equipment for a movement used when a walk becomes difficult. The writer etc. has called the amalgamation technology of a human being and a technology the human technology design [Zhao et al., 2000; Zhao et al., 2001; Fujii et al., 2001]. Interactive motion control [Fujii et al., 2004; Ikemoto et al., 2004] is developed from this concept. In welfare or a care supporting aircraft machine, interactive motion control is that the user aiming at a functional restoration can involve a motor and a control unit directly or indirectly. The motor of this status has a human functionality partially, and it will be expected that it provides real-time reaction to human action. The optimal control can be performed from the correlation materialized between the electric intelligence from a controlled system, and a physical functional intelligence. The optimal motor capacity for the application to an electric wheelchair is designed first. And a three-phase induction motor of 12V was developed with the small controller [Fujii, 2002]. The programming language of motor control [Ikemoto et al., 2002] is using QMCL (quick motion control language). QMCL is instituted as a programming language for interactive motion control, and finally the effectiveness of interactive motion control is veri-

fied through an experiment using an assistant type electric wheelchair. The experiment analyzed by measuring the torque and feedback frequency of a motor.

2. DESIGN OF ELECTRIC WHEELCHAIR

2.1 Optimum design of motor

A development of a small motor is important for the design of an electric wheelchair. The fundamental design of a three-phase induction motor becomes like the following formula. Figure 1 expresses the example of a design of the motor.

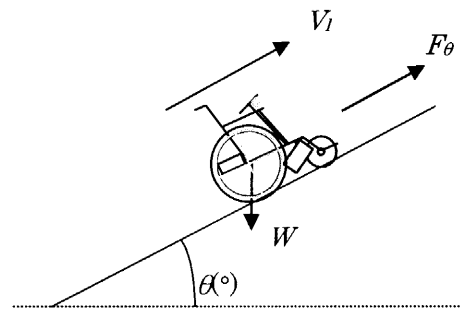


Fig. 1 Example of design of a motor

$$\text{Running power (kW): } P_0 = \frac{F_\theta \cdot V_l}{6120 \cdot \eta} \quad (1)$$

$$\text{Traction force (kg): } F_\theta = W \mu \cos \theta + W \sin \theta \quad (2)$$

$$\text{Acceleration power (kW): } P_a = \frac{GD_1^2 \cdot N_1^2}{365 \cdot 10^3 \cdot t_a} \quad (3)$$

$$GD_1^2 = W \cdot \left(\frac{D_p}{1000} \right)^2 \quad (4)$$

$$N_1 = \frac{V_l}{\pi \cdot D_p} \quad (5)$$

$$\text{Motor revolutions per minute (rpm): } n = N_1 \cdot k \quad (6)$$

Motor capacity (kW): $P = P_0 + P_a$ (7)

W : gross weight (kg), D_p : tire outer diameter (mm),
 μ : running resistance coefficient, V_r : running speed (m/
M), k : gear deceleration ratio, η : mechanical efficiency,
 τ_a : acceleration time (s)

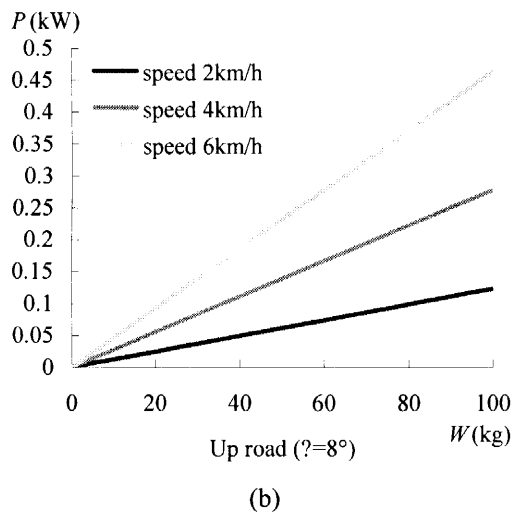
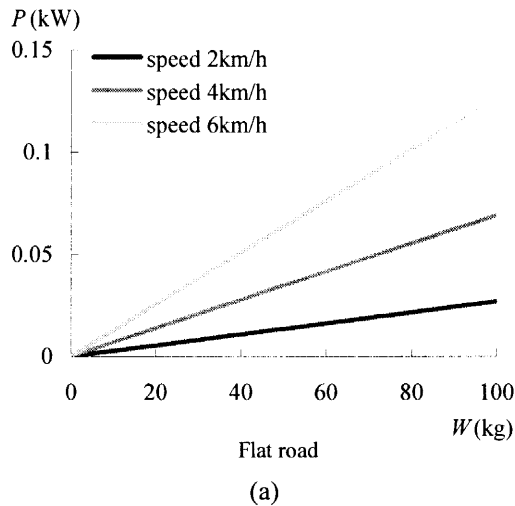


Fig. 2 Relation of gross weight and motor capacity

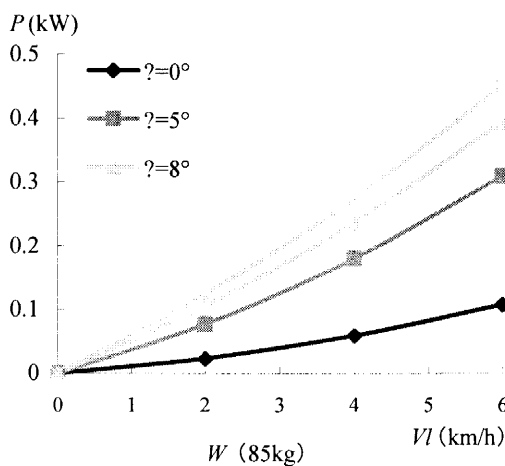


Fig.3 Relation of running speed and motor capacity

Figure 2 shows the relation between the gross weight of an electric wheelchair, and a motor capacity. Figure 2 (a) shows the graph of a flat road. Figure 2 (b) shows the graph of a slope. Graph shows the speed of the electric wheelchair. Figure 3 shows the relation between running speed and a motor capacity. The gross weight of an electric wheelchair is 85kg. The θ expresses the angle of the slope. The motor design was performed from the above thing. The standards of this motor are 12V, 120W, and 4 poles. Figure 4 shows appearance of the small motor.

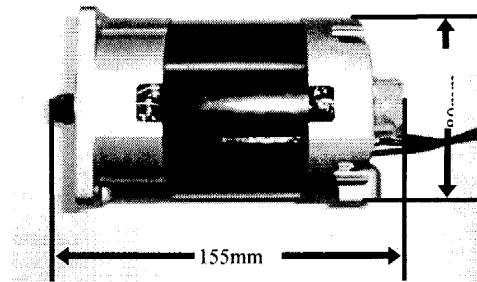


Fig. 4 Small type three-phase induction motor

2.2 Appearance of electric wheelchair

An electric wheelchair is a wheelchair that installed a small portable drive unit in the common wheelchair. Figure 5 shows the appearance of an electric wheelchair and a unit. A drive unit is in front of a wheelchair, and it has equipped with the battery and the control unit rearward.

2.3 Basic performance of electric wheelchair

The basic performance is as follows.

Table 1 Basic performance

Running speed	6 [km]
Level difference	6 [cm]
Up road	10 [°]
Running time	1.5 [h]
Recharge time	4 [h]

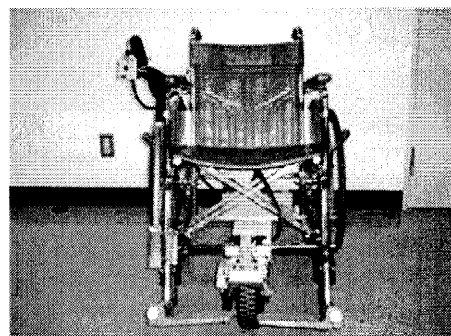


Fig. 5 Appearance of electric wheelchair

2.4 Composition of electric wheelchair

Figure 6 shows the composition of the electric wheelchair. Figure 7 shows a drive unit part. The motor is compact by the miniaturization of a car body.

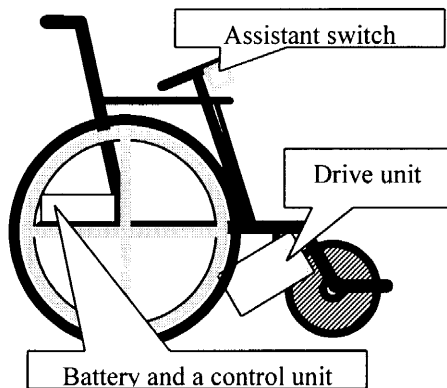


Fig. 6 Composition of electric wheelchair

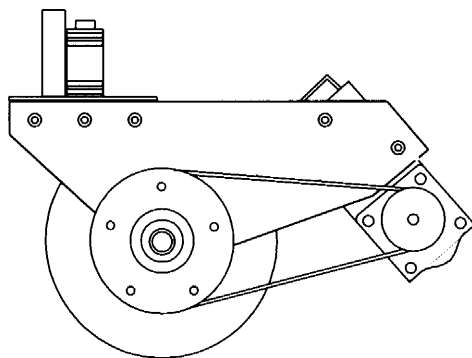


Fig. 7 Drive unit part

- (1) Drive unit
Motor: Induction geared motor, AC12V, 120W, 4poles, reduction ratio 1/6
- (2) A battery and a control unit
Controller: MITY SERVO
Model: DC24V, CPU platform V3W080, OS C3W270
- (3) Function
Manual operative method
Assistant operation
A manual operative method is an operation at a constant speed by a switch. An assistant operation is an operation of the wheelchair by assist.

2.5 Special feature of electric wheelchair

The special feature can be shown as follows.

- (1) The small drive unit can desorbed a wheelchair of a senior or a physically handicapped person.
- (2) A handle can also be desorbed easily.
- (3) It is not necessary to process a wheelchair.
- (4) The operating method of a wheelchair can be changed with a switch.

- (5) On a long downward slope, a battery carries out a reduction charge using run energy.
- (6) Operation is both a user and a care worker.
- (7) Operation noise is quiet.

3. ASSISTANT SYSTEM

3.1 Explanation of interactive motion control

In the equipment of control apparatus, motion control technology has various systems for the use purpose. Since the direct relation between the generating torque of a motor and a human being is needed in the case of interactive motion control technology, it cannot respond with the conventional motion control technology. Therefore, it is necessary to add the following motion control to the conventional control technology.

- (a) A direct drive is desirable.
Because, it is in order not to give an impact to load.
- (b) When linking the gear aiming at a slowdown directly, in consideration of the sensitivity of controllability, about 8:1 are a limit.
This is related to the amount of information of the energy consumed by a gear box, and load torque.
- (c) They have a desirable direction without a sensor.
The motor of this research is premised on generating torque and reacting also to the torque of a load side in an instant. Furthermore, a controller also carries out transfer of a controlled variable, and the duty of measurement. It aims at measuring on real time, such as torque of a load side, and speed.
- (d) It is necessary to change a control constant freely during operation.
It is because each demand changes with users in interactive motion control.

- (e) Synchronized operation is required.
This uses the pulse generator from the outside connected to the signal terminal of a controller. It is for carrying out positioning control.
- (f) In addition, it is in the stage of research and development about the interactive motion control technology which human demands.

Figure 8 shows the driver system of interactive motion control.

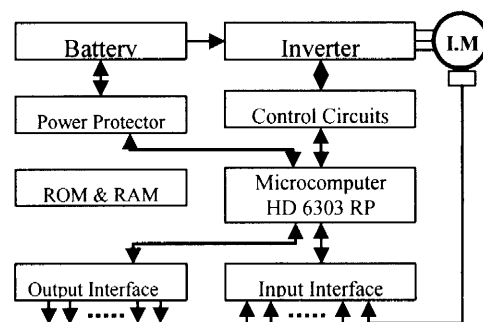


Fig. 8 Drive system for interactive motion control

Manufacturing plants commonly use motion control on production lines for controlling speed, torque, or positioning. Dynamic interactive motion control allows reacting or responding to motions of human requests. Figure 9 shows the example of a motion of interactive motion control. Motion signals are indirect electrical information such as strength. τ_i is direct torque applied to the motor shaft. Interactive motion control detects a user load continuously, and judges an operation.

For the action confirmation of the fundamental IMC, the experimental equipment shown in Figure 10 was used. The belt installed on the motor shaft is for confirming the IMC by the external torque. Interactive motion control has the following functions.

- Instant stop motion by the sudden torque of the motor shaft.
- Positive rotational motion by the torque of the motor shaft and decision motion of the inversion operation mode.
- Maximum torque discrimination motion.
- Synchronous tracking motion from external signal.
- Real-time information retrieval motion.
- Inputs terminal to electric signals and such as grasping power and voice.

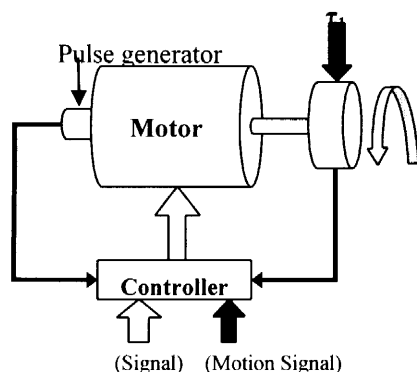


Fig. 9 Example of interactive motion control

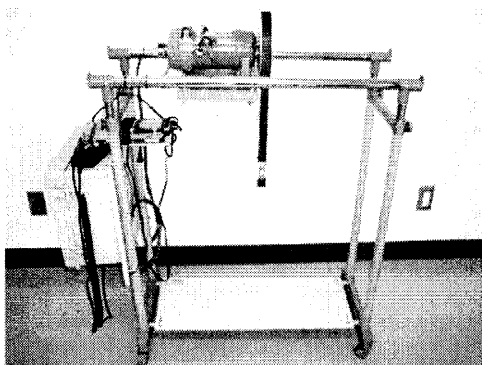


Fig. 10 Experimental equipment for interactive motion control

3.2 Control performance of QMCL

The change of motor parameter and operation mode of on stream is possible by all digitization for this control method. The positioning unit is united with the speed control amplifier, and the encoder output signal is directly taken in. In addition, the feedback signal from current detector is added, and the torque control is possible by the order of the torque limit.

Table 2 Control performance

Number of pulse	2500*4=10000
Maximum of torque	500%
Lowest speed	0.3rpm (Stable)

3.3 Experiment of assistant drive control

Until now, the development of the electric wheelchair of this laboratory was a handle type wheelchair. We developed the electric wheelchair for movement of handle rim. Therefore, when an electric wheelchair was used by a handle rim, the assistant drive program was developed. The view of an assistant drive is shown in Figure 11. The solid-line part of Figure 11 expresses wave (U_r) when a user operates a wheelchair without an assistant drive. The dotted line part expresses wave (A_d) when a user does an assistant drive. In an assistant drive, assistant starting speed (S_a), assistant power (A_p), and assistant time (A_t) can be set up. An assistant drive operates a wheelchair manually first. When the speed of a wheelchair reaches S_a , it is the way of starting an assist. The speed raise of the assistant drive is carried out to A_p . And an assistant drive assists only A_t .

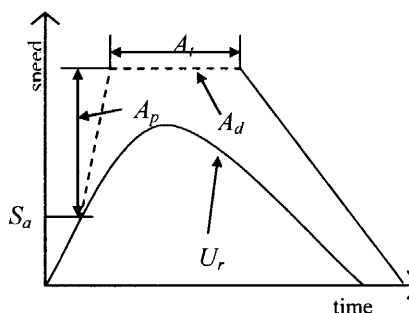


Fig. 11 Method of assistant system

4. EXPERIMENTS OF ELECTRIC WHEELCHAIR

4.1 Measuring method

A measuring of an experimental data is experiment composition like Figure 12. The data has measured the operation for about 10 seconds. Figure 13 is a window of wave measuring software. The early setups are as follows.

Measurement data : A motor frequency and motor torque.
Measuring time: 9900ms

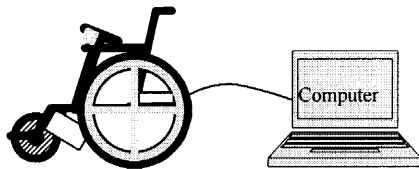


Fig. 12 Experiment composition

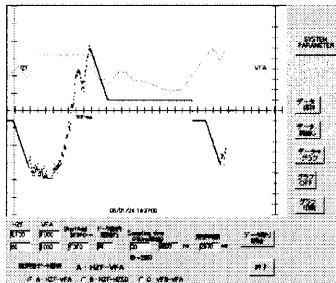


Fig. 13 Screen of wave measuring software

4.2 Description of experiment

Figure 14 shows the operation of an electric wheelchair. This graph shows a motor frequency and time.

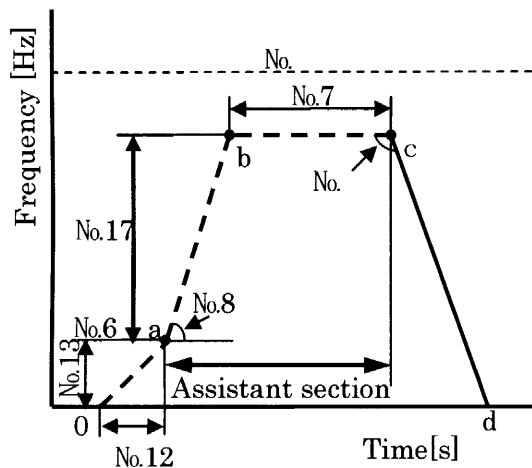


Fig. 14 Relation between time and frequency

0-a is operating the wheelchair. a-c is an assistant operation. c-d is a deceleration frequency.

The aim of an experiment is easing a wheelchair user move load. The experiment subject is as follows.

<Experiment 1>

The wave of a wheelchair without an assist is measured.

<Experiment 2>

User parameter No.6 is changed in order of 700, 1000, 1500, and 2000. No.13 is changed in order of 600, 900, 1400, and 1900. It will perform, if an assist detects the feedback speed variation more than the data of No.6. It does not assist on the frequency below the data of No.13.

<Experiment 3>

It experiments by changing user parameter No.8 and

No.9 in order of 2000, 4000, 8000, and 9500. The gradient of a speed variation of a acceleration and a deceleration is specified. If the numeric number of this parameter becomes large, a speed variation will become early.

<Experiment 4>

It experiments by changing user parameter No.17 in order of 1000, 2000, 3000, and 4000. This determines assistant starting speed. It is a command frequency adding an acceleration of this parameter. Only No.8 is assisted.

<Experiment 5>

The numeric number of a user parameter is determined from an experimental result.

Table 3 User parameters

No.	Function	Measuring rang
6	Assistant frequency	~2000
13	Stop level	~1500
8	Acceleration	~9500
9	Decelerate	~9500
17	Acceleration step	~4000

5. EXPERIMENTAL RESULT

5.1 Experiment 1

Figure 15 is a wave without an assist. This wave moves a wheelchair for 10 seconds. The user is using the hand rim about 6 times.

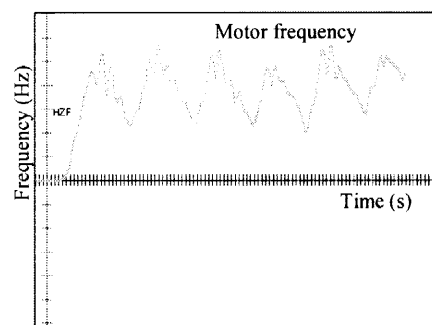


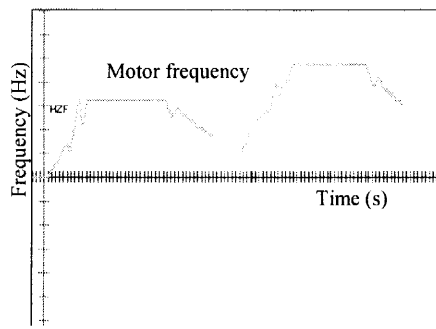
Fig. 15 Wave without assist drive

5.2 Experiment 2

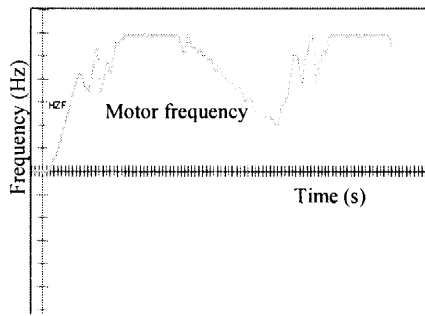
Figure 16 is a wave when changing the number of No.6 and No.13. From an experimental result, this number can change the timing that begins an assistant operation of a wheelchair.

5.3 Experiment 3

Figure 17 is the wave that changed the number of No.8 and No.9. If No.8 and No.9 have a number reduced, an electric wheelchair will be in a brake status. It is better to set this number as a high value from an experimental result.

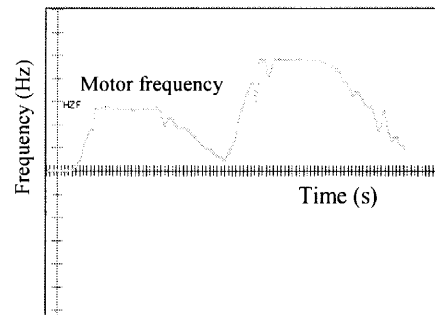


(a) No.6=700, No.13=600

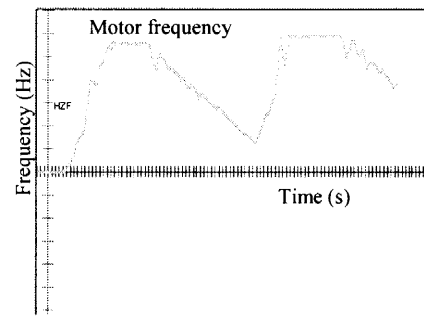


(b) No.6=2000, No.13=1900

Fig. 16 Wave of assistant drive



(a) No.17=1000

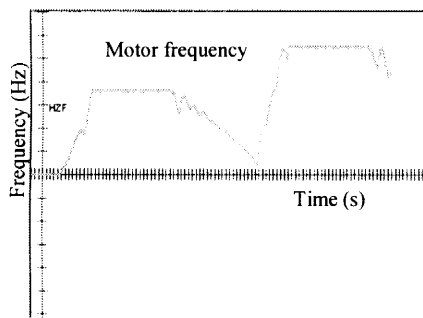


(b) No.17=4000

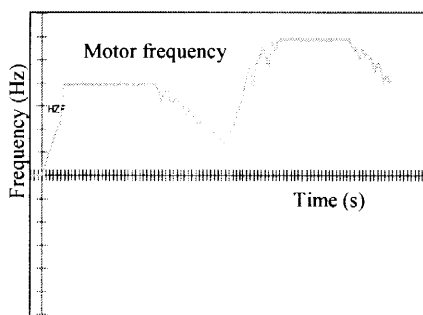
Fig. 18 Wave of assistant drive

5.5 Experiment 5

Figure 19 is the wave which was the most comfortable to ride in this experiment. The wheelchair should just grasp a hand rim twice.



(a) No.8=2000, No.9=2000



(b) No.8=9500, No.9=9500

Fig. 17 Wave of assistant drive

5.4 Experiment 4

Figure 18 is the wave that changed the number of No.17. The number of No.17 can set up assistant power from an experimental result.

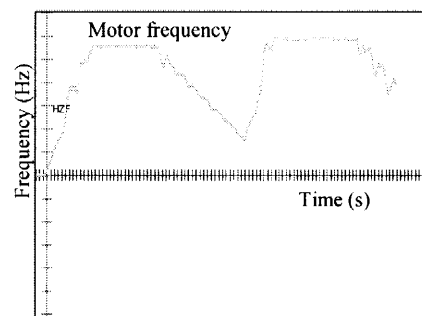


Fig. 19 Wave of the optimal assistant drive

6. CONCLUSION

It can say that the interactive motion control technology is suitable for the motor control of a low-speed region by the small capacity. This region is applicable to the equipment of a welfare support etc. Interactive motion control can help a care worker's load and independence of a user. The following can say from an experimental result.

- (1) The enhancement of the assistant function in the flat ground was completed.
- (2) An assistant drive can improve by a program.
- (3) The user has eased the load in the wheelchair.

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