SAFETY IMPROVEMENT FOR MOBILITY SCOOTERS USING AUTOMATIC DECELERATION

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ABSTRACT

The number of mobility scooter accidents is increasing. A mechanism for decelerating the speed of a mobility scooter has been developed using a laser scanner (LS). When the LS notices barriers in the direction of travel, it automatically slows the vehicle. The main purpose of this paper is to examine the improvement of maneuverability of mobility scooters by using automatic deceleration. Automatic deceleration systems have become popular for motorized vehicles because the environment of usage for a scooter is different from the environment of usage for a full-sized motor vehicle. Mobility scooters share space in much closer proximity to pedestrians. This critical difference requires systems to detect more close-range objects and respond quickly.

This experiment was conducted using three types of courses: a right-turn course, a left-turn course, and a straight course with an obstacle. Four women and four men, each over the age of 65, were selected as examinees. None of the participants had ever driven a mobility scooter.

For this study, the effects of automatic deceleration were determined by comparing indicators between the mobility scooters that run with and without automatic deceleration. The decrease in the number of scooter contacts with the walls of a test course was used to indicate improvement in maneuverability. The time required to pass through a test course was the index of improvement for convenience. The other information gained is subjective opinion from interviews and surveys.

The time required for a driver to pass through the course decreased, indicating that automatic deceleration does not lead to a reduction in convenience. From the survey interviews, the drivers reported that the automatic deceleration feature gave them a mental margin that improved their ability to concentrate on steering the scooter, indicating that automatic deceleration improves driving performance.

We conclude that automatic deceleration can improve driving performance without impairing convenience, and it can improve safety when operating a mobility scooter. Finally, automatic deceleration can support unaccustomed drivers as they learn to drive a mobility scooter.

Keywords: Maneuverability, Elderly people, Consciousness survey

1 INTRODUCTION

(1) Problems with wider use of mobility scooters

With the aging of society, it is expected that more people will have difficulty with mobility due to the physical deterioration associated with aging, thus necessitating safe transportation for those with mobility difficulties. One solution to improve the mobility of elderly people is the use of mobility scooters. In fact, the number of mobility scooter users is on the rise, and with it, the number of related accidents has also increased. According to the National Institute of Technology and Evaluation (NITE), Japan, 67 cases of one-car accidents were reported in from 2005 to 2009. Of these accidents, 20 accidents resulted in death and there were 16 serious injuries. In the serious accidents that had clear causes, about 75% were caused by incorrect operation or negligence by the drivers. It is prudent to take action to prevent such accidents and enable the users to operate their scooters safely.

The specifications for mobility scooters were defined in the Japan Industrial Standard (JIS) T 9208, established in 2009. Safety functions and additional design work for risk management were provided in JIS T9208, which is the main standard for the product itself, but it does not address the prevention of accidents caused by errors in operation or judgment by the users.

(2) Goal of this study

This study examines the use of automatic deceleration for mobility scooters when the scooter is in danger of collision, as a way to improve operation. A laser ranger finder (LS) is used to achieve automatic deceleration. Irrespective of the operation ability of the driver, automatic deceleration is activated to prevent accidents or serious damage. Because this system supports the driver in terms of the part of cognitive activity used to notice and avoid obstacles, the driver is free to concentrate on controlling the steering wheel. With a smaller cognitive burden, better operation can be achieved. A disadvantage of this system is that automatic deceleration or the machine's override of the operator's control may deprive drivers of their sense of freedom in driving the scooter and may reduce the time it takes to complete a trip (convenience).

The goals of this study are as follows:

- To verify changes in operation and convenience created by the automatic deceleration system.
- To verify situations where automatic deceleration is effective.

As an objective way to verify the changes in operation, the number of collisions was measured. As an objective guideline to verify changes in convenience, operation time was measured.In addition, interviews and questionnaires were conducted.

To facilitate the study of unskilled drivers operating mobility scooters without accidents, the subjects of this study were all unskilled users. The use of unskilled drivers allowed us to verify whether automatic deceleration could improve their operation safety without reducing convenience. In particular, we studied situations where automatic deceleration was most effective for accident prevention or for better operation in limited spaces.

Automatic deceleration systems have become popular for motorized vehicles. For example, the Subaru EyeSight™ was eleased by Fuji Heavy Industries Ltd. Automatic deceleration systems in regular motor vehicles prevent collisions between vehicles, whereas in mobility scooters, they prevent collisions between mobility scooters and pedestrians or other barriers in the pedestrian pathway. Mobility scooters regularly share space with pedestrians. This greater proximity creates greater opportunity for personal injuries. The distance between mobility scooter and pedestrian is much closer than the distance between motor vehicles, which requires greater sensitivity for detection of close-range objects and faster response rates.

A Mobility Scooter is a transportation comparatively new device. Therefore, there are few previous researches.
As previous research of the use actual condition of a Mobility Scooter, MIZOHAT et al. (2003) carried out the questionnaire for the Mobility Scooter user and the seller. As a result, it pointed out that Mobility Scooter user's characteristic, purchase / use motive, the use purpose and distance of movement, changed with city scales. Nakajima et al.(2004) conducted hearing survey to a Mobility Scooter user. From this hearing, it pointed out that the use situation of the Mobility Scooter in the building and the problem. And the improvement plan of these problems was proposed. The Ministry of Land, Infrastructure and Transport of the Japanese government released the traffic barrier-free technical standard surveillance study report in 2003. It reported that the problems using a Mobility Scooter on a public transportation.
These previous researches made it clear the characteristic of the person using a Mobility Scooter, the purpose, and the problem. But there was little research which had mentioned the improvement plan. In addition, these improvement plans paid attention to the use environment and machine side. Therefore, this research is meaningful because it investigate about the improvement plan which paid attention to the passenger's driving skill.

There were many previous research that treat electric wheelchair as a target. Simpson(2005) insisted that researchers have used technologies originally developed for mobile robots to create "smart wheelchairs." Smart wheelchairs have been the subject of research since the early 1980s. Over 40 research have done until 2005. But there is difference in target group between mobility scooter and electric wheelchair. The target group of electric wheelchair is impaired person who have severer impairment in mobility than mobility scooter. Severer impairment make target of development self-sustained operation. In this research target group set on mild impairment people. And it make target of development assist of driver.

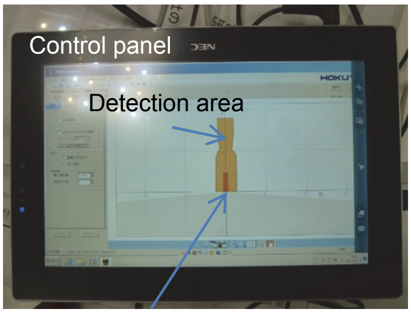
2 MOBILITY SCOOTER USED IN THE EXPERIMENT

(1) Laser scanners (LSs)

To achieve automatic deceleration in mobility scooters, a LS was installed on the vehicle used in this study. Because, the LS had the high capability of pedestrian detection, and was already certificated as safety equipment. (IEC (2005), IEC (2008)) The specifications for the LS (SE1L-H02LP Trial products, IDEC) used in this study are shown in Table 1. The LS was set at a height of 540 mm from the floor along a central line through the front of the mobility scooter (this is the height of the irradiation point of the laser). With the LS, the time required for the laser to be irradiated, hit the object, reflect, and come back was measured to calculate the distance to the obstacle, enabling the LS to detect obstacles in its set detection range. The detection range can be set for 3 levels. The responses can be programed in each level.

Table 1. Specifications for LS

Item	Specification
Type	Se1L-H02LP Trial Product
Protection Area	Max. 3.5 m
Warning Area	Max. 10 n
Detection Angle	190°
Scan Cycle	30 ms
Response Time	Off: 60–510 m, On: 210–510 ms
Outer size	90 mm (L), 90 mm (W), 9.5 mm(H)
Weight	Less than 1.0 kg
Light source wavelength	905 nm



Location of the
Laser range finder

Figure 1. Laser scanner installed on the mobility scooter

(2) Automatic deceleration

The LS installed on the front of the mobility scooter detects obstacles in front of it. Because the LS is installed on the steering wheel, the direction of the steering wheel and LS are always the same. Thus, obstacles ahead of the scooter can always be detected. When the LS detects an obstacle in the set range, the mobility scooter automatically decelerates. When there are no obstacles in its path, the maximum speed of the scooter is 6 km/h, whether the LS is installed or not. However, when obstacles are detected in the LS range, the maximum speed is reduced to 2 km/h. After detecting an obstacle, the speed of the vehicle is slowed down to one-third the normal speed. The mobility scooter used in this study proceeds for another 1 m till completion of deceleration after detecting an obstacle when running at a speed of 6 km/h.

(3) Setting the detection range

Before commencement of these experiments using the LS, it was necessary to set the detection range for the LS. We conducted a “pre-experiment” to study how the range should be set. Therefore, it is found that it is necessary to set the detection range so that deceleration takes place before controlling the steering wheel and detection is only for the front of the scooter. Furthermore, it was necessary to make clear notification of this information about automatic deceleration while conducting the experiment. Specifically, information about the distance required for deceleration to start and complete (detection range) should be provided to new drivers before they actually experience it. We conducted the experiment with these parameters.

3 METHODOLOGY

(1) Configuration of the experiment

Dates: December 9th in 2011 (15:00–17:30), 13th (9:30–12:00 and 15:00–17:30), and 16th (15:00–17:30)
Venue: Osaka University, Photonics Center IDEC laboratory (Indoor)
The number of subjects: 8 (Male 4, Female 4)
The participants were novice in driving mobility scooters and were all above the age of 65.

Two types of courses were set for the experiment with certain control of the steering wheel assumed. Referring to earlier research, the difficulty of the courses was set at a level that required a certain level of driving skill. (Ishibashi et al. (2010)) These conditions recreate a situation where improved operation is required to use a mobility scooter in daily life. For the guidelines to evaluate operation and convenience, operation time and the number of collisions were counted as objective guidelines, whereas questionnaires and interviews were used as subjective guidelines. Through the study and analysis of the changes in response to these guidelines when driving with or without automatic deceleration, the goals of this study were achieved.

For the sake of this discussion, the activities conducted with automatic deceleration in use are described as “with automatic deceleration” and the ones without as “with an existing situation.” The following are diagrams of the experiment courses.

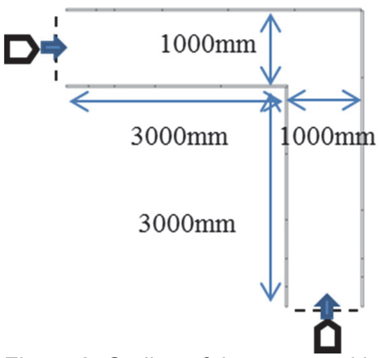


Figure 2. Outline of the course with a right-angle corner

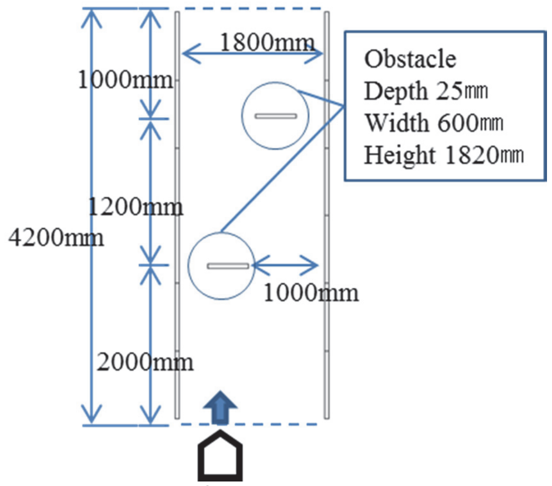


Figure 3. Diagram of the course with obstacles

(2) Procedure

Before the experiment, to assure that the subjects got used to operating the mobility scooter, the subjects were required to drive for about 10–20 min after listening to the instructions on how to operate the vehicle.

The procedure for the experiment was as follows.

1. The subject waits at the start point to confirm the conditions for driving.
2. The course and driving condition (with or without automatic deceleration) vary each time.
3. With a signal, the subject starts the mobility scooter and drives it to the goal.
4. A staff member runs after the subject to record the operation time and number of collisions. Another staff member shoots a crane shot video of the operation.
5. After reaching the goal, the subjects answer the questionnaires by category.

The procedure from 1 to 5 was conducted for both cases of “with automatic deceleration” and “with an existing situation.” After completing one set of procedures, the questionnaire for comparison was given. After completing three sets, questionnaires with open-ended questions to elicit comments were administered. Two subjects participated in each set of experiments.

(3) Verification method

To verify the effects of automatic deceleration, various guidelines were measured to compare the effects between operating with or without the automatic deceleration feature. The changes in the number of collisions were related to operation and the changes in the operation time were related to convenience. The questionnaires and interviews upon completion of driving provide subjective responses from the drivers for verification. It is expected that automatic deceleration influences judgment and operation by the driver; thus, the questionnaire included items about these points.

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(4) Questionnaire

Questionnaires was given upon completion of each course and after driving both “with an existing situation” and “with automatic deceleration.”
Survey was about the various difficulties the driver(s) experienced during the operation of the scooter and the other was about the comparison between the conditions of driving with or without automatic deceleration.
The following questions were asked in questionnaires with a seventh grade reading and comprehension level of difficulty.

-The difficulty of the course
Feeling the course was
3. Extremely easy 2.Easy 1. Rather easy
0. Neither
-1. Rather difficult -2.Difficult -3. Extremely easy

-Timing to control the steering wheel in turning the corner
Aware the timing to control steeling was
3. Extremely easy 2.Easy 1. Rather easy
0. Neither
-1. Rather difficult -2.Difficult -3. Extremely easy

-Control of the steering wheel
Control steeling wheel was
3. Extremely easy 2.Easy 1. Rather easy
0. Neither
-1. Rather difficult -2.Difficult -3. Extremely easy

-Drive as you expected
Expected and consequent was
3. Absolutely same 2.same 1. Rather same
0. Neither
-1. Rather different -2.Different -3. Absolutely different

4 RESULTS

(1) Results of operation time measurement

The average operation time in both “with an existing situation” and “with automatic deceleration” for each course and the results of measurement are shown in Table 2.
There was no significant change observed in operation time with automatic deceleration, which indicates automatic deceleration worked as well as the speed control by the driver. Thus, no degradation of convenience was observed in terms of operation time in this experiment. It can be inferred that automatic deceleration has a small possibility of causing inconvenience for the drivers.

Table 2. Average operation time for each course and the results of measurement

Course	Average operation time(s)		Significant probability (central figure)	Significant difference (5% standard)
	Existing situation	Automatic deceleration		
With the right angle corner (left turn)	13.43	12.38	0.026	Yes
With the right angle corner (right turn)	16.67	14.43	0.161	None
With obstacles	14.36	14.67	0.449	None

Wilcoxon signed-rank test is applied.

(2) Results of measuring the number of collisions

The average number of collisions in both “with an existing situation” and “with automatic deceleration” and the results of measurement are shown in Table 3.

Table 3. Average number of collisions and the results of measurement

Course	Average operation time(s)		Significant probability (central figure)	Significant difference (5% standard)
	Existing situation	Automatic deceleration		
With the right angle corner (left turn)	0.13	0.08	0655	None
With the right angle corner (right turn)	0.13	0.13	1.00	None
With obstacles	0.38	0.08	0.068	None

Wilcoxon signed-rank test is applied.

No decrease in the number of collisions was observed “with automatic deceleration.” This was because the number of collisions in the “existing situation” and the number of samples were small, which made it difficult to differentiate. However, a decrease was observed in the average number of collisions with automatic deceleration in operation. Therefore, it is expected that with a larger number of samples, a clearer effect of automatic deceleration can be observed.

(3) Results of questionnaires

Table 4 shows the results of this questionnaire. The higher the grade, the more positive the answers; this indicates that it was easy or comfortable to operate. The lower the grade, the more negative the answers; this indicates that it was difficult or hard to operate.
From these questionnaires, the drivers reported that automatic deceleration made it easier for them to judge the timing to take a turn, control the steering wheel, and drive without getting nervous. In the interviews, the drivers mentioned the benefits of automatic deceleration even with a delay in cognition. They reported a feeling of safety for being able to avoid serious damage even in collisions due to limited speed near obstacles, and they expressed that they had better concentration for judging the timing to take a turn or control the steering wheel because of the easier speed control with automatic deceleration.

Table 4. Results of the questionnaires about various difficulties

Course	Item	Existing situation	Automatic deceleration	Significant Probability
With the right angle corner (left turn)	The difficulty of the course	1.25	1.75	0.003**
	Timing to control the steering wheel in turning the corner	1.08	2.13	0.000**
	Control of the steering wheel	1.00	1.46	0.040*
	Drive as you expected	1.21	2.00	0.003**
With the right angle corner (right turn)	The difficulty of the course	1.08	1.74	0.002**
	Timing to control the steering wheel in turning the corner	1.21	1.93	0.001**
	Control of the steering wheel	1.04	1.48	0.007**
	Drive as you expected	1.30	1.51	0.185
With obstacles	The difficulty of the course	0.67	1.42	0.016*
	Timing to control the steering wheel in turning the corner	0.71	1.92	0.002**
	Control of the steering wheel	0.42	1.38	0.001**
	Drive as you expected	0.79	1.67	0.002**

** Wilcoxon signed-rank test is applied at 1% significance
* Wilcoxon signed-rank test is applied at 5% significance

5 DISCUSSION

(1) Verification of when automatic deceleration is effective

The previous section demonstrated that automatic deceleration made it easier for the drivers to operate the mobility scooter. To discover when automatic deceleration is most effective, differences under differing conditions were studied.

(2) Verification of differences by conditions

The differences in the effect of automatic deceleration by conditions were studied using a Chi-square test based on the results of the questionnaires conducted after driving. No differences were found in the effect of automatic deceleration by courses or the number of driving. However, differences in the effects of automatic deceleration were observed according to the different difficulty level of driving experienced "with an existing situation." Table 5 shows the summary of the difficulty the drivers experienced when they drove "with an existing situation." The more difficulty the drivers experienced in driving "with an existing situation," the greater the improvement in their overall operation "with automatic deceleration."

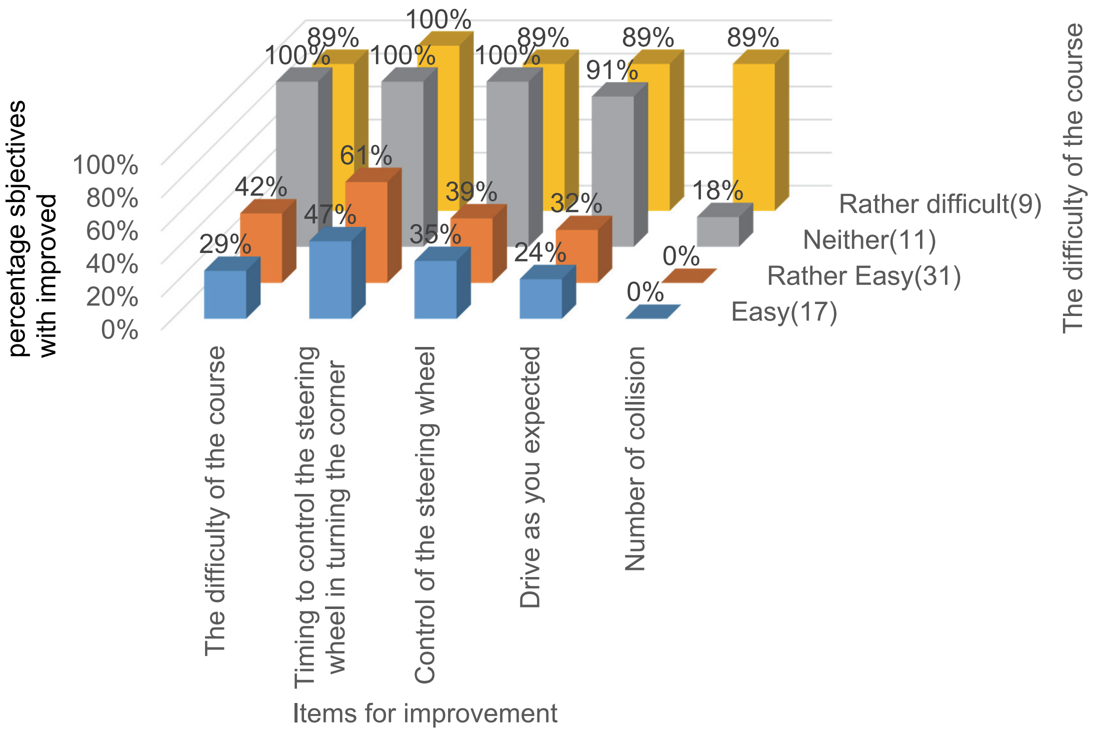

Figure 4. Rate of improvements by driving difficulty "with an existing situation"

(3) Summary of analysis

The differences in the effects of automatic deceleration were generated by the difference in the levels of difficulty in driving. Because the drivers experienced a sense of greater difficulty in driving "with an existing situation," they tended to report more difficulty judging the timing to make a turn or to control the steering wheel than the other drivers; these drivers can expect positive effects from automatic deceleration on these activities. Furthermore, as a result of improved judgment of timing or control of the steering wheel, it became possible for them to drive more easily or more as they imagined. Thus, the group that found driving “with an existing situation” more difficult perceived greater improvement in overall operational ability.

The difficulty experienced by the drivers differed among each individual. In this study, all drivers operated the mobility scooter for the first time with the same practice time. Thus, it is likely that this difference in difficulty can be attributed to the skill level of the drivers. Therefore, it can be said that less-skilled drivers experience greater effects.

6 CONCLUSION

It was found that automatic deceleration can improve operation without reducing convenience from a subjective view point. In this study, improvements could not be observed from the objective guidelines. However, better results can be expected with larger sample size.

The specific effects reported in the questionnaires and interviews were easier control of speed and driving without fear, which allowed better judgment of timing to take a turn or better operation of the steering wheel.

The study of when automatic deceleration is effective found that the effects differed according to how difficult the driver perceived the course to be. The more difficult the drivers found the course, the greater improvement they found with the overall operation. This is because these drivers also felt that judging the timing to take a turn or to control the steering wheel was very difficult. Drivers with these difficulties experienced a greater sense of improvement.

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