Experimental Study on Riding Skill for Using Standing Type Vehicles

Differences between Unskilled and Skilled Subjects to Complete Task

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***Abstract*—Many researchers have attempted to solve existing traffic problems. One potential solution to these problems is to reduce traffic volumes in urban areas. In order for this to happen, a modal shift from conventional passenger vehicles to public transportation and eco-vehicles, including personal vehicles, should be considered. There are several types of personal vehicles; in this study, we focus on standing type personal vehicles for solving last mile/first mile problem. As opposed to bicycles, few people have experience in using standing type vehicles; the skill of riding these vehicles depends on the individual. By understanding the differences between skilled riders and unskilled riders, we would like to study for educational programs or assistant system for riding standing type vehicles. The objective of this study was to analyze the differences between skilled and unskilled subjects riding standing type vehicles. The experiment was performed to gather riding data for comparing the difference. We employed two standing type vehicles for the experiments. One is small, and the other is large. In the experiments, two types of subjects traveled the same course, and yaw, pitch, and roll data, and x-, y-, and z-acceleration data of each subject was gathered as riding data. In addition, time duration to finish the goal was evaluated. From the gathered results, the time duration was considered in this paper. In particular, by using the t-value, it was found that there was a significant difference in the time duration between skilled subjects and unskilled subjects when using a large type standing type vehicle. Thus, if we analyze the skill level for using standing type vehicles, we should consider the time duration to complete a slalom course.**

Keywords - Personal mobility vehicles; Experimental analysis; Standing type vehicles.

I. INTRODUCTION

Increasing urban traffic leads an increase in traffic jams, traffic accidents, and air pollution, all of which have a negative impact on the quality of life [1]-[8]. One possible solution to these problems is to reduce traffic volumes in urban areas. Modal shifts from conventional vehicles to public transportation and eco-vehicles, including personal mobility vehicles, should be considered to reduce urban traffic volumes [9]-[15]. In this study, we focused on personal mobility vehicles to reduce traffic volumes.

Automobiles are the traditional optimal means of transportation as they permit door-to-door transportation. However, in order to address the traffic problems mentioned above, we have to shift at least some movement of people from individual automobiles to public transportation. To resolve this problem, useful and eco-friendly alternative transportation must be provided. Considering the use of public transportation, the first and last mile problem remains, especially for elderly people [9]-[12].

With respect to the key solution of the first and last mile problem, not only personal mobility but also automated vehicles and electric commuter vehicles were proposed by several researchers and projects [11]. It is difficult to solve the problem by only one transportation method as every place has different conditions, laws, users and environment, and user's preferences are different.

In this paper, personal mobility vehicles (vehicles for individual use), are investigated as one of the most effective options for solving the first and last mile problem [12][13][15]. Several other types of individual vehicles are also expected to be used as personal mobility vehicles, such as electric scooters, new one-seater vehicles, and wheelchair-type mobility devices. Standing type personal mobility is the target of this study. In Japan, the use of standing type vehicles on public road is prohibited. As to the acceptance, Pham studied the occupied spaces for standing type personal mobility [16]. As for safety, Lavallee reported an analysis of existing safety regulations for Segways, the legal framework for using these vehicles, and traffic rules [17]. The Australian Capital Territory reported experimental results of acceptance, safety, and effect on the community and the pros and cons of using Segways in community areas [18]. In addition, research on an assistance system for standing type vehicles has been conducted by several researchers [19]-[26], but the statistical data on riding new types of self-balancing vehicles with real subjects and on public roads is insufficient.

As opposed to bicycles, few people have experience in using standing type vehicles; thus, the skill of riding these vehicles depends on the individual. By understanding the

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differences between skilled riders and unskilled riders, we would like to study for educational programs or assistant system for riding standing type vehicles.

The objective of this study is to analyze the differences between skilled and unskilled subjects riding a standing type vehicle in a preliminary experiment. Before this study, we performed preliminary experiments with only a few subjects under simple conditions [27]. Hence, it was difficult to analyze that data in order to evaluating standing type vehicles. In this study, more experiments were performed to obtain riding data. In the experiment, both skilled and unskilled subjects traveled on the same course, and the yaw, pitch, and roll data, and x-, y-, and z-acceleration data of each subject were obtained as riding data. By comparing the data from two kinds of subjects, the statistical differences were found. These differences are useful for evaluation of the skill of riding standing type vehicles.

The rest of the paper is structured as follows. In Section 2, we present test vehicles. In Section 3, the performed experiments are described. Finally, we conclude the work in Section 4.

II. TEST VEHICLES

Two types of personal mobility vehicles were used in the evaluation, and they are discussed in detail in this section.

A. Segway

The Segway [15], developed by the Segway Corporation, was employed as a personal mobility vehicle (as shown in Fig. 1). The “Segway® PT i2” model, produced by the Segway Japan Corporation, was employed in this experiment. Segways are currently used in Japan in national parks for conducting tours, on golf courses for player assistance, and zoos, stations, airports, to name but a few of the places, by information service staff and security staff. The security staff at the Tsukuba Designated Zone use Segways in order to improve the efficiency of their patrolling. In addition, some cities and universities in Japan have introduced pilot programs using Segways for multiple purposes. Thus, the Segway is attracting attention as a new type of transportation, enabling personal mobility.

Figure 1. Segway.

B. AIST -Personal Mobility (AIST-PM)

The AIST-PM, which was developed by AIST, is a human-riding wheeled inverted pendulum vehicle [24][27], as shown in Fig. 2.

The features of the AIST-PM are as follows:

1. Smaller and lighter than a Segway
2. Has a suspension system
3. Easily lifted
4. The occupied space is almost equal to the space that one person occupies while walking
5. Maximum velocity is low, and kilometers-per-charge is low, but the total efficiency is good as one-person transportation.

The AIST-PM has two individual controllable wheels in the body, and the stick-shaped handles are attached vertically on each side of the body. Two motors and a computer are installed in the body, and the upper face of the vehicle is the platform on which the subject stands.

The left and right wheels are each driven by direct-current motors (DC-motors), which are controlled by an on-board computer installed in the vehicle. The angles of the wheels are measured by counting the number of encoder pulses, and the angle and angular velocity of the pitch direction of the vehicle are measured using gyro-sensors and an accelerometer. A force sensor attached to the platform of the vehicle detects whether the subject is on or off. Table 1 shows the specification of AIST-PM.

TABLE I. SPECIFICATION OF AIST-PM[24]

Length, Width	0.43[m], 0.55[m]
Tire diameter	0.13 [m]
Weight	12.6 [kg]
Payload (including a passenger)	80 [kg]
Distance (mile per charge)	About 10 [km]
Height of rider’s platform	0.19 [m]
Length of sticks	1.25 [m]
Battery	Lithium-polymer

Figure 2. AIST-PM

III. EXPERIMENTS

This section discusses the mobile-sensor system used in the experiments, experimental conditions, routes and the results obtained.

A. *Mobile Sensor System for Obtaining Riding Data*

It was difficult to obtain data from a Segway, so it was therefore easier to use an add-on system which could be used on all of the standing type vehicles tested. An add-on mobile-sensor system was thus manufactured. This system consisted of a laptop computer, a gyro-sensor, a G-sensor, a Global Positioning System (GPS) receiver, and a lithium-ion battery. The configuration of the mobile system is shown in Fig. 3. Figure 4 shows the coordinate system used. By using this system, the following riding data was gathered:

1. Velocity
2. Trajectory
3. Roll, Yaw and Pitch rates
4. x-, y- and z-accelerations
5. Time duration to complete the course, which is estimated by using X, Y, Z and Roll, Yaw, and Pitch rate.

All data were saved at 10 Hz on the laptop computer.

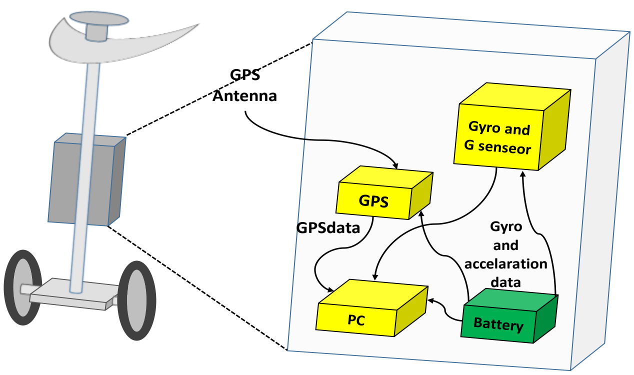

Figure 3. System Configuration

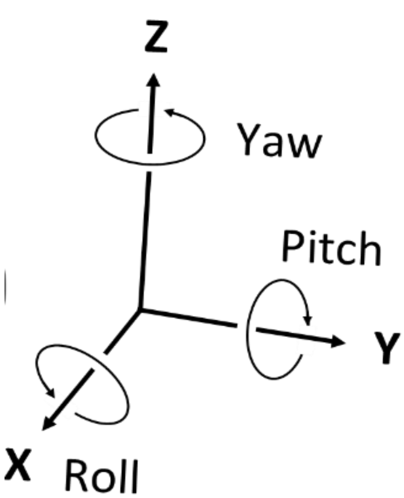

Figure 4. Coordinate system of the sensor

B. *Experimental Conditions*

We used two kinds of subjects for this experiment, one skilled and the other unskilled. A skilled person is defined in this study as a person who has ridden a standing type vehicle more than 50 times. 28 subjects (15 men and 13 women) were employed for the experiments. The average age of subjects was 41.3. We employed between- subjects approach.

For safety reasons, test subjects wore helmets. The routes were clear of people, and the experiments were conducted only in no rain conditions. In addition, two staff members accompanied the subjects in case of accidents.

C. *Experimental Routes*

Experimental routes, prepared for this study by AIST, are shown in Fig. 5 and Fig. 6. These routes were designed by AIST by referring the standard course for wheelchair. These routes were planned for only this study and were not associate with any company. The reason why we used two different routes was to consider the size of each vehicle. The subjects were tasked to traverse the experimental routes. The experimental routes included the following tasks:

1). Slalom
2). Going up and down a slope
3). Traveling on a step

The numbers in Fig. 5 and Fig. 6 identify each of the above tasks.

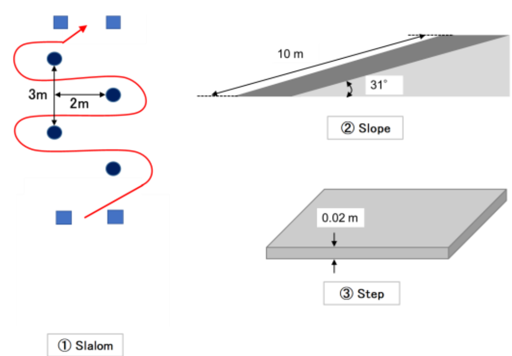

Figure 5. Experimental routes for Segway

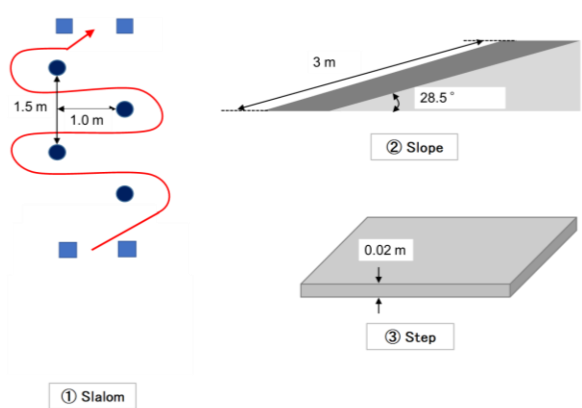

Figure 6. Experimental routes for AIST-PM

D. *Experimental Result*

The experiments were performed. Figure 7 shows the scenes of experiments by using Segway for each task. Figure 8 shows the scenes of experiments by using AIST-PM for each task. By using X, Y, Z accelerations and Yaw, Pitch and Roll rate information, the time was estimated with high accuracy.

Figure 7. Experimental scens by using Segway (From the top: the subject is traveling on slalom, on Slope and on Step)

Table 2 shows the average time duration to complete slalom course by using Segway and AIST-PM. The number of skilled subjects was 3 and of unskilled subjects 25 was respectively. The statistical differences between data sets were evaluated by employing Welch's t-test [28]-[30]. It was found that there was a 5 % statistical difference between the skilled subjects and the unskilled subjects by using Segway on Slalom, shown in Table 3. It is presumed that the skilled subjects could control Segway smoothly and correctly. In addition, they could avoid wasting time by using the ideal trajectory. Hence, skilled subjects followed the unideal trajectory by doing overturning and short turning. By analyzing the trajectory from GPS, the unskilled subjects did not choose the short distance course, but the longer course. Table 4 shows the average time duration to complete slope course by using Segway and AIST-PM. This result has same tendency as the slalom.

On the other hand, it was not found that there was a 5 % statistical difference between the skilled subjects and the unskilled subjects by using AIST-PM on Slalom, shown in Table 3. And it was not found that there was a 5 % statistical difference between the skilled subjects and the unskilled subjects by using AIST-PM on Slope, shown in Table 5. It means that there was less statistical difference between by using the experimental results.

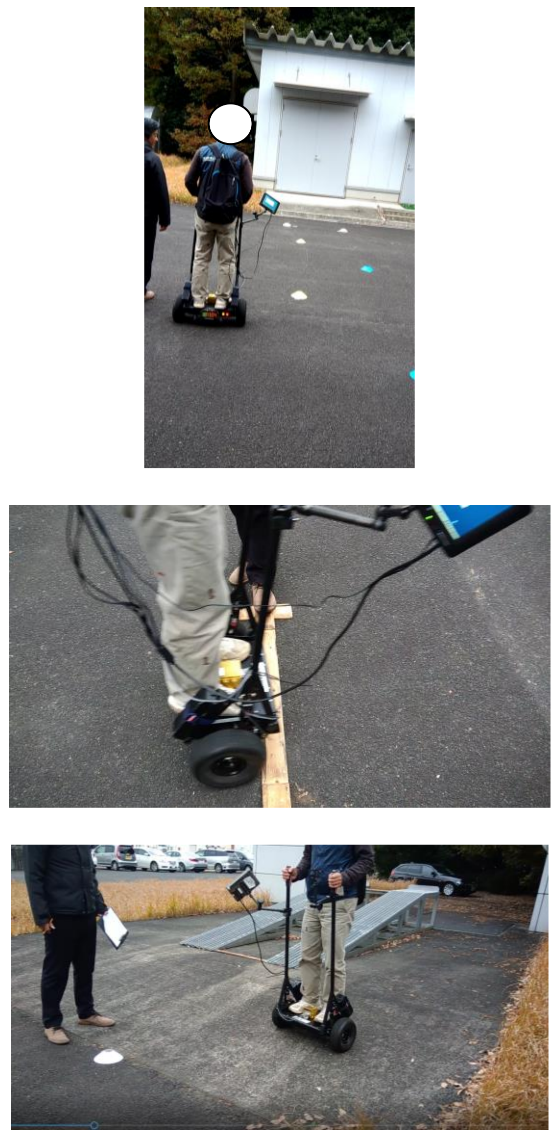

Figure 8. Experimental scens by using AIST-PM (From the top: the subject is traveling on Slalom, on Slope and on Step)

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It is presumed that to use AIST-PM is easier than Segway and subjects could get accustomed to the AIST-PM during the lecture period. In addition, the averages between skilled subjects and unskilled subjects are different, but the variance by using AIST-PM is large. Thus, calculated t-value is not enough, and we cannot conclude its difference only from the results. We need to do the experiments more.

As to the step, it was not found that statistical differences between skilled subjects and unskilled subjects about the time to complete.

TABLE II. EXPERIMENTAL RESULTS FOR TIME DURATION ON SLALOM COURSE ON EACH VEHICLE TYPE

	Skilled Subjects	Unskilled Subjects
Segway	13.0 [s]	29.9 [s]
AIST-PM	24.0 [s]	35.5 [s]

TABLE III. EXPERIMENTAL RESULTS FOR T-VALUE OF TIME DURATION ON SLALOM COURSE ON EACH VEHICLE TYPE

	t-value	Degree of Freedom
Between Skilled Subjects and Unskilled Subjects on Using AIST-PM	1.6	25
Between Skilled Subjects and Unskilled Subjects on Using Segway	1.39	26

TABLE IV. EXPERIMENTAL RESULTS FOR TIME DURATION ON SLOPE COURSE ON EACH VEHICLE TYPE

	Skilled Subjects	Unskilled Subjects
Segway	35.2 [s]	49.6 [s]
AIST-PM	21.2 [s]	33.5 [s]

TABLE V. EXPERIMENTAL RESULTS FOR T-VALUE OF TIME DURATION ON SLOPE COURSE ON EACH VEHICLE TYPE

	t-value	Degrees of Freedom
Between Skilled Subjects and Unskilled Subjects on Using AIST-PM	2.067	24
Between Skilled Subjects and Unskilled Subjects on Using Segway	1.39	25

IV. CONCLUSIONS

In this paper, the differences in riding between skilled and unskilled subjects were analyzed for standing type personal vehicles. The standing type vehicles used, and the experiments including the experimental conditions, routes, mobile sensor system, and results were explained in detail. The experiments were performed to gather riding data from skilled and unskilled subjects. In the experiments, both skilled and unskilled subjects traveled the same routes, and the yaw, pitch and roll data, and X-, Y- and Z-acceleration data of each subject was gathered.

By comparing the data from the two kinds of subjects, the time duration was considered in this paper. In particular, by using the t-value, it was found that there was a significant difference in the time duration between skilled subjects and unskilled subjects when using a large type standing type vehicle. Thus, if we analyze the skill level for using standing type vehicles, we should consider the time duration to complete a slalom course. In addition, the importance of the design for standing type vehicles is to consider the friendly or functional interface for traveling on slalom course easily.

We have a plan to analyze the experimental results in different views, including features of subjects and do the experiments with more subjects.

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