Use Cases for Rider Assistant Mobile Application Evaluation Using Travelling Simulator

Naohisa Hashimoto[1,2], Takashi Okuma[1], Seiichi Miyakoshi[1],
Kohji Tomita[1], Osamu Matsumoto[1], Alexander Smirnov[2,3], Alexey Kashevnik[2,3], Igor Lashkov[2,3]
[1]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, JAPAN
[2]ITMO University, St.Petersburg, Russia
[3]SPIIRAS, St.Petersburg, Russia
{naohisa-hashimoto, takashi-okuma, s-miyakoshi, k.tomita, o.matsumoto}@aist.go.jp,
{smir, alexey}@iias.spb.su, igor-lashkov@ya.ru

***Abstract*—Today's personal mobility vehicles have been considered as a solution for solving the last/first mile problem of a rider in big cities. It is important to investigate the rider factors, rider behavior, and rider–machine interface while using personal mobility vehicles in order to propose useful and safe personal mobility systems (including vehicles and software for the rider assistance). These factors can be evaluated using a simulator that attains realistic environments. The paper presents use cases for the rider assistant using a personal mobile application and their evaluation using the developed travelling simulator. The mobile application for the rider assistant is generated recommendations for the rider based on detected dangerous situation during the riding to prevent an accident. Dangerous situations detection is based on images analysis of the rider face taken from the front camera of the rider's mobile device mounted in the personal mobility vehicle.**

I. INTRODUCTION

Many researchers have been seeking ways to solve traffic problems. Increasing urban traffic load leads to increasing of traffic jams, traffic accidents, and air pollution, all of which result in serious damage to quality of life. A potential 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 vehicles, should also be considered to reduce urban traffic volumes.

The rapid increase in the proportion of elderly people in the population has caused several issues in Japan [1]. Elderly people (over 65 years old) in Japan have accounted for more road fatalities than people in any other age group [2]. Automobiles are the optimal means of transportation for the elderly because they permit door-to-door transportation. However, to address the aforementioned traffic problems, we have to shift at least part of transportation burden from individual automobiles to public transportation, some aspects of which are less than ideal for elderly people. To resolve this conflict, useful and eco-friendly transportation have to be provided for the elderly people. Public transportation is useful and eco-friendly, but the last-mile problem remains, especially for elderly people [3]. Personal mobility vehicles are considered an option for solving this problem.

Some techniques for personal mobility systems have already been proposed and implemented. These techniques include personal mobility vehicles and software for the rider assistance for personal mobile device based on images analysis of the rider face taking from the front camera. We proposed an intelligent wheelchair [4-6], and two wheeled self-balancing vehicle, which can be useful for not only elderly users but also young users. For new techniques concerning personal mobility, it is important to investigate rider factors, rider behavior, rider–machine interface, and rider assistant features provided by the personal mobile application mounted in the mobility vehicle. Evaluation of these factors, it is reasonable to conduct with a simulator but on in a road that attains realistic environments. It is necessary to perform experiments under same conditions to evaluate different mobility vehicles. A simulator have to provide the same experimental conditions.

The main objective of this study is to develop use cases for evaluating rider assistant mobile application that tracks the rider behavior using the front camera of personal smartphone. For the evaluation, the application of several types of mobility vehicles travelling simulator has been proposed. A service field simulator for pedestrians has been proposed by Takashi Okuma in [7], [8]. In this study, authors implemented two types of personal mobility vehicles in the service field simulator for evaluating the mobile application for the rider assistant.

The rest of the paper is organized as follows. Section II describes the traveling simulator prototype. Section III presents the mobile application for dangerous situation detection to assist the rider. Section IV describes use cases for rider assistant mobile application evaluation using the travelling simulator. Finally, Conclusion summarize the paper.

II. THE PROTOTYPE OF TRAVELING SIMULATOR

A. System configuration

The system configuration of the proposed traveling simulator is shown in Fig. 1. It consists of a turn table, a personal computer (PC) for the turn table control, two Arduinos for controlling the AC serve motor and counting encoder pulse, a mobility device, a virtual reality system [7], [8], and a PC for the virtual reality system.

Fig. 2 shows the interface of the PC for the turntable. The status of communication between the mobility, Arduino, PC for the turntable, and PC for the virtual reality can be confirmed via this interface. Further, the control parameters of the turntable can be adjusted in order to make the feelings of the turntable movement more realistic by utilizing this interface. The mobility has an RS-232 connection wireless communication tool and sends the input data of the joystick or leaning angle of the mobility to the PC for the turning table. The mobility is completely fixed on the turntable with strong tape during the experiments. The PC for the turntable sends the current angle of the turntable and velocity of the mobility. The PC for the virtual reality shows the surrounding according to the position of the mobility.

Fig. 3 shows the turntable. An AC servomotor in the turntable rotates it according to the output of PC for the turntable, transmitted through RS-232 connection. The turntable has an encoder to measure the rotation angle of the turntable, and the Arduino counts the encoder and sends the angle to the PC for the turntable.

B. Virtual reality system

The turntable connects to the virtual reality system, which was presented by Okuma [7], [8]. The virtual reality system functions as a service field simulator for pedestrians. In this study, we employed the turntable in order to evaluate personal mobility vehicles. The design policy is as follows.

- Virtual environment is displayed through a 360° omnidirectional screen.
- Virtual viewpoint is controlled by walking-in-place motion.
- Photo-realistic avatars can be displayed in the virtual environment for communication with other people.

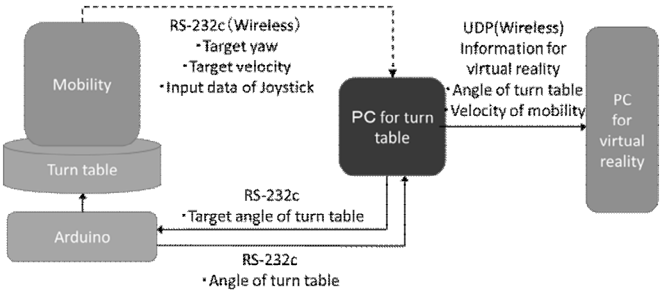

Fig. 1. System Configuration

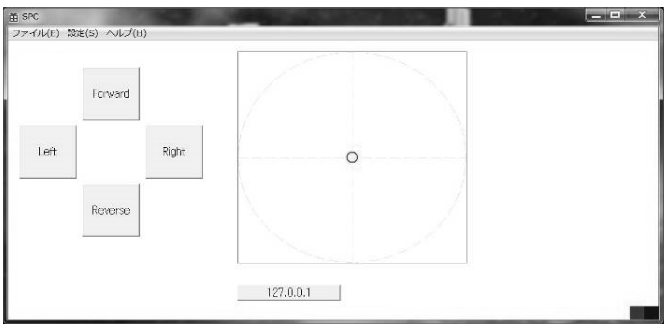

Fig. 2. Interface of PC software for the turn table (circle means a position of joystick)

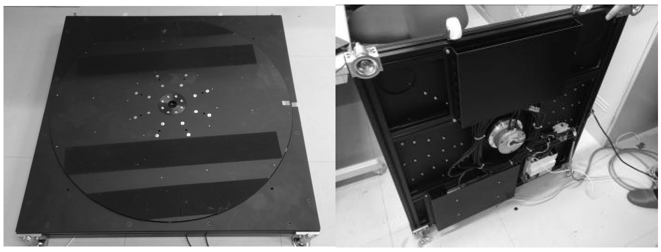

Fig. 3. Turn table (Left upper surface of the turntable, right: under part of the turntable)

Fig. 4. Virtual reality system (front door is open)

Instead of walking-in-place motion, we employed joystick input. The pedestrian can change the direction freely by him/herself without moving; however, it is difficult for the personal mobility vehicles to rotate without any movement. Thus, we employed the turntable. Fig. 4 shows the service field simulator.

C. Two types of personal mobility vehicles

Originally, the virtual reality system was developed for pedestrians. In this study, two types of personal mobility vehicles have been employed. This section explains each of them. Fig. 5 shows the wheelchair. The employed wheelchair was modified from an electric wheelchair, which is manufactured by Aisinseiki Corporation [9]. It is manually controlled using a joystick and has a maximum speed of 6 km/h. In this study, the input of the joystick is transmitted to the PC for the turntable through wireless communication.

Fig. 5. Wheelchair

Two Wheeled Self-Balancing Vehicles are not widely used yet, and the researches for introduction are necessary. In addition, there are several models of self-balancing vehicles at this moment. Thus, three models of self-balancing vehicles are developed for this simulator in order to adapt every models. The three models are explained the following sections.

The Segway is widely used globally. A model—“Segway® PT i2”—produced by Segway Japan Corporation, was employed in this experiment [10], [11]. Segways are used for tours in national parks, for assistance while playing golf, for information service staff, and patrol staff in Japan. Patrol staff use the Segway in Tsukuba Designated Zone in order to improve the efficiency of patrols [4]. The Segway is attracting attention as a new type of transportation or personal mobility. Fig. 6 shows a scene demonstrating the use of the Segway. In this study, it was difficult to set the Segway on the turntable; thus, we developed a handle bar similar to the Segway and set a potential meter to estimate the leaning angle of the handle bar. The leaning angle of the handle bar is transmitted to the PC for the turntable as the input of the joystick.

In AIST institute there are two original models of standing type vehicles have been developed. The first one (AIST-V1) is a human-riding wheeled inverted pendulum vehicle [4], [12]. The features of this vehicle are as follows.

- Smaller and lighter than a Segway.
- Includes a suspension system.
- Easy to lift.
- The occupied space is approximately equal to the space that a person occupies while walking.
- Maximum velocity is low and the distance per charge is short, but the increased total efficiency makes this a competitive option for one-person transport.

AIST-V1 vehicle has two individual controllable wheels in the body, and stick-shaped handles are attached vertically at both sides of the body. Two motors and a computer are installed in the body, and the upper surface of the vehicle is the platform on which the rider stands. The angles of both wheels are measured by counting the number of encoder pulses and the angle of both wheels and the angular velocity of the pitch direction of the vehicle is measured using gyro-sensors and an accelerometer. A force sensor attached to the platform of the vehicle detects whether the rider is on or off. Fig. 7 shows AIST-V1, and Table 1 shows the specification of AIST-PM. In this study, it is impossible to use self-balancing function without moving on the turn table; thus, AIST-V1 is fixed on the turn table. Further, a small joystick was set on the top of the right handle bar. The input of the joystick is transmitted to the PC for the turn table through Bluetooth.

Fig. 8 shows the original standing type vehicle (AIST-V2) [13]. This vehicle is largely identical to AIST-V1. The main difference is that it uses omni-wheels. Therefore, it is an omnidirectional vehicle. Instead of using a joystick, the rider controls this vehicle by only shifting of the weight of his/her body.

In this study, it is impossible to use the self-balancing function on the turn table, thus, the standing type vehicle is fixed on the turn table. However, instead of using a joystick, force sensors in the vehicle are used as input devices. The input of the joystick is transmitted to a PC for the turn table through Bluetooth.

Fig. 6. Segway

TABLE I. SPECIFICATION OF STANDING TYPE VEHICLE1

Characteristic	Value
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	13
Design do not match our template	Lithium-polymer

Fig. 7. Standing type vehicle1(AIST-V1)

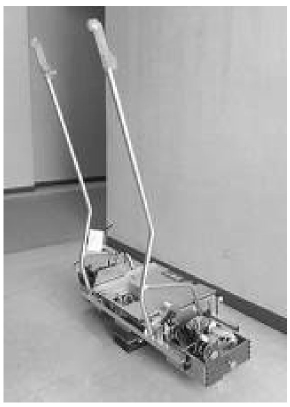

Fig. 8. Standing type vehicle 2(AIST-V2)

We developed the turn table and implemented it along with the virtual reality system. Fig. 9, Fig. 10, and Fig. 11, show the scenes of preliminary experiments with three types of mobility. It was confirmed that the components of the system can communicate with each other and that this system might be useful for a simulator by employing four subjects.

It is important to eliminate the differences between actual movement and movement in the simulator in order to develop the effective and useful simulator. With respect to the wheelchair, we measured the actual movement from the input of joystick. Fig. 12 and Fig. 13 shows the result on actual movement and movement in the simulator. In Fig. 13, it was impossible to measure accurate velocity of Segway, thus experimental velocity data of other two wheeled self-balancing vehicle was employed [11]. The tendency of change of its velocity was similar by constructing and adjusting the function, and it was achieved that rider's feeling was acceptable by performing several preliminary experiments.

From these figures, it is realized that actual movement and movement in the simulator are quite similar by constructing the original function for the personal mobility vehicles.

Fig. 9. Scenes of preliminary experiments (Mobility: AIST-V1)

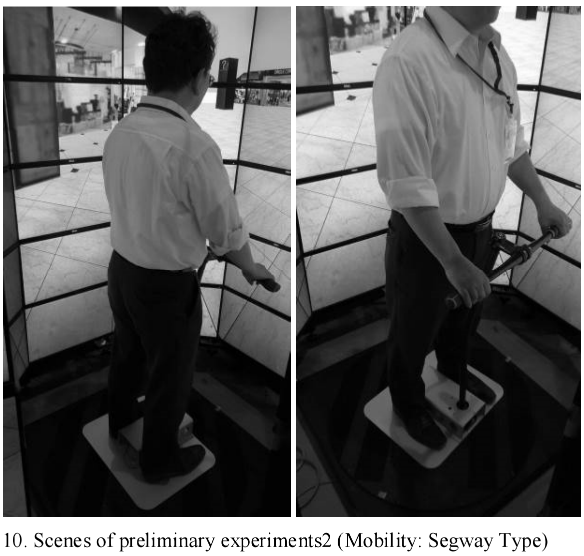

Fig. 10. Scenes of preliminary experiments2 (Mobility: Segway Type)

Fig. 11. Scenes of preliminary experiments3 (Mobility: Wheelchair)

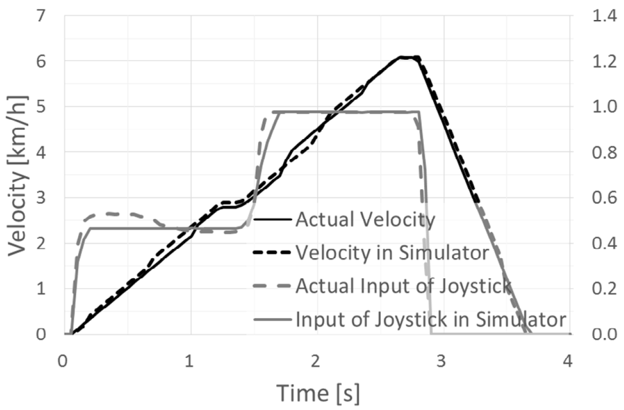

Fig. 12. The experimental results between actual and output movements in wheelchair

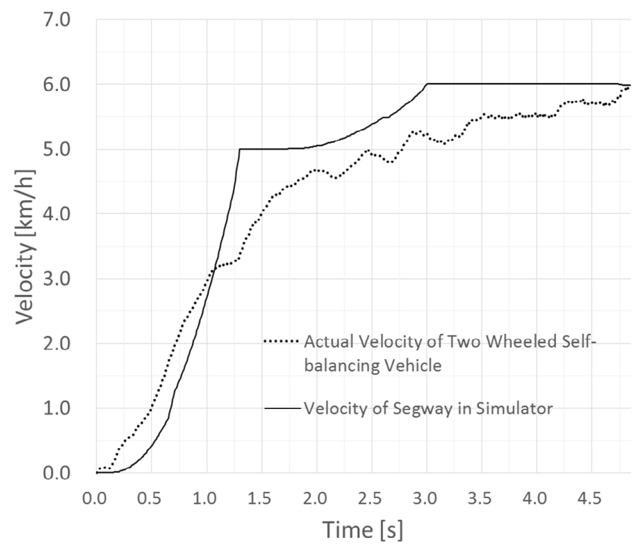

Fig. 13. The experimental results between actual and output movements in Segway model

III. DANGEROUS SITUATION DETECTION FOR RIDER ASSISTANT

Dangerous situation detection and accident prevention is a popular research direction in recent years [12], [13], [14]. While riding two wheeled self-balancing vehicles a person can fix a personal smartphone which will monitor his/her face using the front camera and detection of one of two dangerous situations: drowsiness and distraction. Based on the detected dangerous situation recommendations for the driver are generated in order to assist preventing an accident. A state-of-the-art analysis of existing research work for dangerous events detection is presented by authors in [15].

For analysis of the rider head and face the reference model has been proposed (see Fig. 14). Every time when the mobile application gets image from the front camera this image is recognized and situation is estimated (is it dangerous or not). Then the process is repeated until the rider closes the application or stops dangerous situation estimation function.

Presented reference model includes three main components: rider, smartphone, and cloud. Smartphone analyses the rider head and face and generate recommendations in case of dangerous situation is detected. Information for analyzing the rider head and face is collected by the mobile application component from the front camera using the image recognition module. The application analyzes head movements (head rotation and nods), percentage of closure of eyelid (PERCLOS), eye blink rate and gaze, and yawning using the analysis module that is responsible for extraction of the visual features from the images taken by front camera. Rider interface is used to show to the rider determined dangerous state and recommendations. Recommendation module is responsible for generation of context-aware recommendations for the rider based on the detected dangerous situation and current situation in the road. Local database is responsible for storing a data collected by the smartphone. If the Internet connection is available, the smartphone uses the cloud to exchange useful information with other system users and to store generic information about the driver's behavior.

Such information as smartphone characteristics, application usage statistics, and dangerous events occurred during trip is stored for a deep analysis and using in the future. Smartphone characteristics are GPU, sensors (GPS, Accelerometer, Gyroscope, Magnetometer), front camera, memory & battery capacity, and version of operation system. The cloud is also used for keeping behavior patterns to analyze and create new dangerous situation. Operations that are carried out in the cloud storage are:

- correcting the dangerous events recognition;
- behavior patterns matching;
- analysis and classification of driver behavior for generating recommendations for safe driving;

The system is focused on the behavioral and physiological signals acquired from the rider to assess his/her mental state in real-time [16]. In the presented approach, the rider is considered as a set of mental states. Each of these states has its own particular control behavior and interstate transition probabilities. The canonical example of this type of model would be a bank of standard linear controllers (e.g., Kalman Filters plus a simple control law). Each controller has different dynamics and measurements, sequenced together with a Markov network of probabilistic transitions. The states of the model can be hierarchically organized to describe the short and long-term behaviors by using the driver ontology that includes visual cues and visual behaviors and determines relationships between them.

Algorithms for determination of dangerous states and recommendation generation are based on information from smartphone camera described in details in [17]. The smartphone's front camera monitors the head movements, facial expressions, and the prolonged and frequent eye blinks to identify drowsiness or distraction dangerous state.

The implementation of the proposed rider assistant system for dangerous situation detection has been developed for Android-based mobile device. The mobile application has been developed using C and C++. For the image recognition the open source computer vision (OpenCV) library has been used.

The face recognition process includes following key steps:

- The creation of the face detector.
- Face detection and face tracking.
- Facial landmarks detection like as "left eye", "right eye".
- Facial characteristics classification like as "eyes open", "eyes close".

To provide the functionality of face detection in consecutive video frames the Face API is used with a classification API that determines whether a certain characteristic is present i.e. a face can be classified with regards to whether its eyes are open or closed. Both of these classifications rely upon landmark detection. A landmark is a point of interest within a face. The left eye, right eye, and nose base are all examples of landmarks.

Classification is expressed as a certainty value, indicating the confidence that the facial characteristic is present. In our case, a value of 0.3 or less for the eye state classification indicates that it is likely that person's eyes are in a closed state. The overall speed and efficiency of the application has been improved by applying several optimization techniques. To improve the frame processing performance, the width and the height of the camera frames to 640 x 480 pixels have been set. Also, the requested frame rate to 30 frames per second has been adjusted.

The Fig. 15 and Fig. 16 illustrate the user interface of mobile application. When a face is detected, it is marked by a rectangle around the head in the camera image. The face detector marks landmarks by circles. The Euler Y and Euler Z angles characterize a face's orientation. The "Left eye OP" and "Right eye OP" parameters show the probabilities whether the left or right eye, respectively, is open. The higher value of these measurements is on the image, the higher probability that the eyes are open.

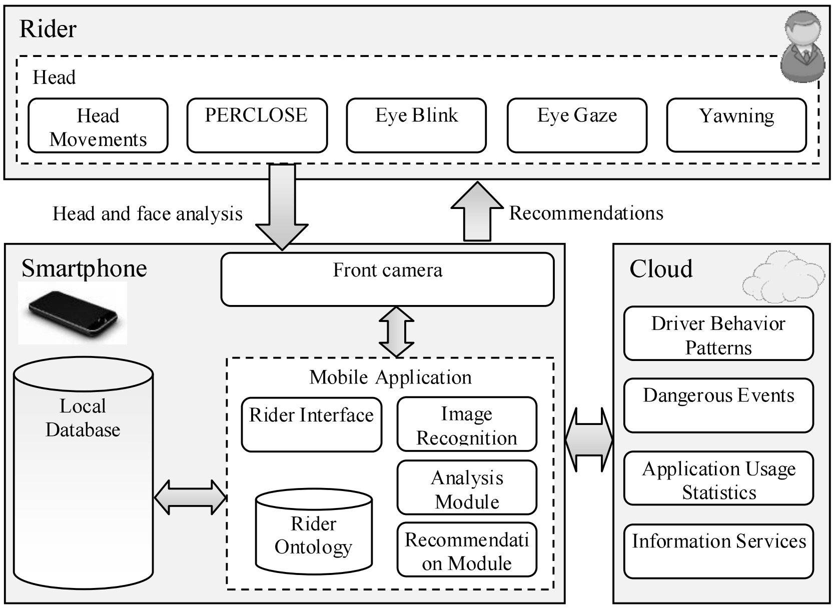

Fig. 14. The reference model of the rider assistant system for dangerous situation detection

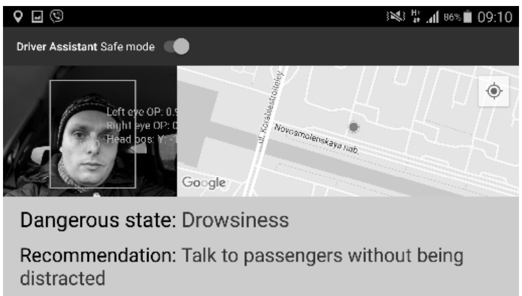

Fig. 15. Prototype example: drowsiness dangerous state identification

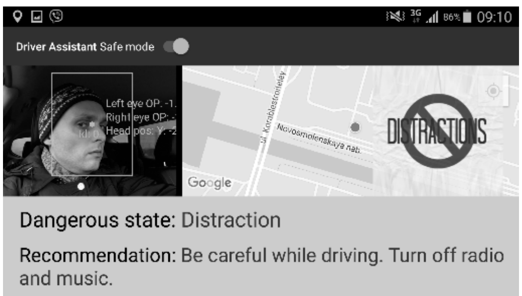

Fig. 16. Prototype example: distraction dangerous state identification

IV. USE CASES FOR RIDER ASSISTANT MOBILE APPLICATION EVALUATION

There are two use cases for the rider assistant mobile application are explained in this chapter.

A. Use case of two wheeled self-balancing vehicle

With respect to two wheeled self-balancing vehicle, if a rider uses it under his/her distracted status, he/she will be in the dangerous situation. Two wheeled self-balancing vehicle cannot hold stability if one tire is off the road or in control off-mode because of its feature. It is therefore necessary to evaluate the distracted situation in riding two wheeled self-balancing vehicle. For the evaluation, the experiments must be performed under the identical situations and environments. In the real world, it is impossible perform experiments under the same conditions and situations. Thus, we constructed the proposed traveling simulator, which can provide same situation and conditions. In addition, we employed the rider assistance system, which has been explained in the Section III in order to evaluate distraction status of riders in the simulator. The rider assistance system is installed in a personal mobile device. The personal mobile device is mounted on the handle bar and track the rider's face and estimate his/her state. It is expected that riders installed a navigation application and use their personal mobile devices as a navigation system while riding the self-balancing vehicle. Fig. 17 shows the smart phone, which is set on the handle bar. We will try to perform some experiments with this system under same conditions. The experimental condition is that riders are asked to travel straight in a simulator with city area. The following points will be evaluated in the experiments.

- Duration with distracted condition.
- Relationship between distracted condition and traveling deviation.
- Rider factors among age, gender, riding experiences.

Fig. 17. Personal mobile device on the handle bar of a self-balancing vehicle

B. *Use case of wheelchair*

With respect to the wheelchair, the main users are elderly people. A wheelchair is stable itself and safer than other standing vehicles. Hence, normally, the reaction time of elderly people is larger than it of non-elderly people [14], thus, it is important to evaluate distracted status, which causes accidents in a wheelchair. Also, it is expected that wheelchair users would use a personal mobile device for navigation system. For these reasons, it is necessary especially for elderly riders to perform experiments on using wheelchairs. The personal mobile device, with the rider assistance application is installed, is set on the front place of the arm rest of the wheelchair. This place is the appropriate for detecting face and estimating distracted status for the smart phone. Fig. 18 shows the smart phone, which is set on the wheelchair. The experiments will also be performed with same scenarios as self-balancing vehicle.

V. CONCLUSION

In this paper, we introduced use cases for rider assistant mobile application evaluation using the travelling simulator. Mobile application determines two dangerous states (drowsiness and distraction) of a rider using the front camera of mobile device and image recognition technique. The traveling simulator has been proposed and briefly explained the concept, system configuration, employed mobility, and preliminary experiments. In the future authors plant to conduct experiments with the developed mobile application and travelling simulator in according the developed scenarios.

ACKNOWLEDGMENT

The presented results are part of the research carried out within the project funded by grants ## 16-07-00462, 16-29-04349, and 14-07-00363 of the Russian Foundation for Basic Research, programs # I.31 of the Russian Academy of Sciences. The work has been partially financially supported by Government of Russian Federation, Grant 074-U01.

Fig. 18. The smart phone set on the arm of the wheelchair

REFERENCES

[1] Cabinet Office, “White Paper on Traffic Safety in Japan 2006”, 2006, 11 p.

[2] National Police Agency in Japan, “Statictics Repot 2012”, 2012 (in Japanese).

[3] B. Balcik, B. Beamon, K.Smilowitz, “Last Mile Distribution in Humanitarian Relief”, *Journal of Intelligent Transportation Systems*, vol. 12, no. 2, 2008, pp. 51–63.

[4] A. Boyali, N. Hashimoto, O. Matsumoto, “Hand posture control of a robotic wheelchair using a leap motion sensor and block sparse representation based classification”, *The Third International Conference on Smart Systems, Devices and Technologies*, 2014, pp. 20–25.

[5] A. Boyali, N. Hashimoto, “Block-sparse representation classification based gesture recognition approach for a robotic wheelchair”, *IEEE Intelligent Vehicles Symposium*, 2014, pp. 1133–1138.

[6] N. Hashimoto, Y. Takinami O. Matsumoto, “An Experimental Study on Vehicle Behavior to Wheel Chairs and Standing-type Vehicles at Intersection”, *Proceedings of IEEE ITST*, 2012, pp. 350–355.

[7] T. Okuma, T. Kurata, "Service Field Simulator: Virtual environment display system for analyzing human behavior in service fields", *Proceedings of ICServ2014*, 2014, pp. 55-60.

[8] J. Hyun, Y. Habuchi, A. Park, T. Ishikawa, M. Kourogi, T. Kurata, "Service-Field Simulator using MR Techniques: Behavior Comparison in Real and Virtual Environments”, P*roceedings on ICAT2010*, 2010, pp. 14–21.

[9] AISIN SEIKI Website, http://www.aisin.com/product/welfare/

[10] Mineta Transportation Institute, “Using Bicycles for the First and Last Mile of a Commute,” *Report No. S-09-02*, 2009.

[11] N. Hashimoto, K. Tomita, A. Kamimura, O. Matsumoto, “Technology evaluations of personal mobility vehicles in Tsukuba-city mobility robot designated zone—An experimental approach for personal mobility for sharing”, *Proceedings of International Conference on Connected Vehicles and Expo*, 2014, pp. 773-774.

[12] G. Underwooda, A. Ngaia, J. Underwood, Driving experience and situation awareness in hazard detection, *Safety Science*, vol. 56, 2013, pp. 29–35.

[13] M. Aurichta, R. Stark, “How to Consider Emotional Reactions of the Driver within the Development of Advanced Driver Assistance Systems?”, *Proc. CIRP*, vol. 21, 2014, pp. 70–74.

[14] F. Biassoni, D. Ruscio, R. Ciceri, “Limitations and automation. The role of information about device-specific features in ADAS acceptability”, *Safety Science*, vol. 85, 2016, pp. 179–186.

[15] A. Smirnov, I. Lashkov, “State-of-the-Art Analysis of Available Advanced Driver Assistance Systems”, *Proceedings of the 17th Conference of the Open Innovations Association FRUCT*, Yaroslavl, Russia, 2015, pp. 345–349.

[16] G. Rigas, Y. Goletsis, P. Bougia, D. Fotiadis, “Towards Driver's State Recognition on Real Driving Conditions”, *International Journal of Vehicular Technology*, vol. 2011, 2011, 14 p.

[17] A. Smirnov, A. Kashevnik, I. Lashkov, O. Baraniuc, V. Parfenov, “Smartphone-Based Identification of Dangerous Driving Situations: Algorithms and Implementation”, *Proceedings of the 18th Conference of Open Innovations Association FRUCT*, 2016, pp. 306–313.

[18] “Segway Review Report”, *A Review of Segway Use in the Australian Capital Territory*.

[19] M. Sasaki, N. Yanagihara, O. Matsumoto, K. Komoriya, ”Forward and Backward Motion Control of Personal Riding-Type Wheeled Mobile Platform”, *Proceedings of IEEE International Conference on Robotics and Automation*, 2004, pp.3331–3336.

[20] S. Miyakoshi, “Omni-directional parallel two wheel type inverted pendulum mobile platform using mecanum wheels and omni-wheels”, *Proceedings of JSME Conference on Robotics and Mechatronics*, Yokohama, 2A1-07a4, 2016. (in Japanese).

[21] N. Hashimoto, S. Kato, S. Tsugawa, “A cooperative assistance system between vehicles for elderly drivers”, *IATTS Research*, vol.33, no.1, 2009, pp. 35–41.