Smartphone-controlled methods of unmanned vehicular parking

Takeki Ogitsu, Hiroshi Mizoguchi

Department of Mechanical Engineering, Tokyo University of Science, Noda-shi, Chiba, JAPAN

Major vehicle manufacturers across the globe have recently been competing to research and develop unmanned parking systems. Many of these systems are designed to allow drivers to provide directions to their vehicles through their smartphones. The use of smartphones has become widespread in recent years. If unmanned parking can be developed as a smartphone application, initial costs can be reduced. This would then encourage the widespread use of the application. However, if smartphone applications for unmanned parking vary from one company to another, the design of these applications will not be uniform. Therefore, in this study, we focus on unmanned systems that assign the responsibility of operating the vehicle to the driver, and examine a few methods of operation of such systems.

Practitioner Summary: Takeki Ogitsu received his Ph.D. degree in Media and Governance from Keio University in 2013. He has been a part of the technical staff of the National Institute of Advanced Industrial Science and Technology, Japan, since 2006. He has also been an assistant professor at the Keio University, Japan, since 2010. He is also an assistant professor at the Tokyo University of Science. His research topics are sophistication and development of intelligent systems with a central focus on vehicles. He is a member of the IEEE and JSAE.

Keywords: Unmanned Parking, Smartphone Control, Human–Machine Interface, Ergonomics

1. Introduction

Parking is one of the aspects of driving vehicles that requires the highest skill. When a vehicle has to be backed into a parking space, the driver uses skills that are different from those involved during typical driving. In addition, when a vehicle has to be backed into a parking space, the driver needs to perceive the space available and check for safety in places with blind spots. Vehicle parking spaces are getting narrower every year, making parking increasingly difficult. A recent article (Massey, 2013) reported on the background of parking spaces in the UK and the simultaneous increase in vehicle sizes. According to the article, although the standard width of a parking space in the UK has not changed since 1994, the width of vehicles has increased by approximately 16% in the same period.

Considering this increasing issue in parking spaces, major vehicle manufacturers around the world have begun competing to research and develop unmanned parking systems (Aamouth, 2014; Associated Press 2014; Bosch, 2014). These systems automate vehicle parking, while the driver overlooks the safety of the vehicle with respect to its surroundings from outside the vehicle. The physical and mental task of parking will be circumvented if these systems are accomplished. Moreover, the extra space for the driver to get in and out of the vehicle will not be required if these systems are accomplished.

Many such systems have been designed to allow drivers to provide directions to their vehicles through their smartphones. The use of smartphones has become widespread in recent years, and many people in the world own at least one. If unmanned parking can be developed as a smartphone application, initial costs will be reduced, which would hence encourage its widespread use. However, if smartphone applications for unmanned parking vary from one company to another, the design of these applications will not be uniform, and this will hinder its widespread use.

When designing an unmanned parking system, it should be clear at the outset where the responsibility of controlling the unmanned parking system should be located. An unmanned system would become “just a dream” once the location of responsibility is identified, even if it is technologically accomplishable. Needless to say, unmanned parking should also be designed considering location of responsibility.
Therefore, in this study, we focus on unmanned systems that assign the driver the responsibility of operating the vehicle, and examine a few methods of operation of such systems. Then, an unmanned simulator is developed, and two methods appropriate for operation are evaluated in a subjective experiment.

In the following section, smartphone-control methods for unmanned parking are explained. In the next section, the simulator used in the subjective experiment and the experimental conditions are explained, and the experimental results are reported.

2. Smartphone-control methods

Smartphone-control methods for unmanned parking require at least enable/disable signals of control. Drivers ensure the safety of the vehicle and its surroundings from outside the vehicle, using the ON/OFF control of the unmanned parking system via their smartphones. If a signal to disable control is triggered and the vehicle stops at the maximum deceleration immediately, the safety of the vehicle and its surroundings are maintained. Therefore, this study focuses on the design of an interface that allows drivers to send the enable/disable signals of control via their smartphones. Fig.1 shows the three interfaces examined in this study.

First, the unmanned parking system described above is examined. The system conducts parking with just a click of the smartphone. Fig.1 (a) shows the characteristics of the system. This interface is the same as a Click-ON/Click-OFF switch. The Click-ON/Click-OFF switch is able to detect the driver’s intent just at the moment when the switch is clicked. Therefore, this switch must not be used unless the system (such as a demonstration or cloud parking system) allocates responsibilities mainly to the operator. This is because in this interface, control is continued even if the driver states that he is not able to take responsibility because of a sudden illness, for instance.

Next, an interface for a smartphone that has a two-position switch function is examined.

Fig.1 (b) shows the characteristics of the interface. This interface is the same as a Push-ON/Release-OFF switch. While the driver’s fingers are in contact with the smartphone, the interface deals Push-ON, and when the fingers are released, the interface deals Release-OFF. The design method of the interface is the same as that of a device called the dead man’s switch used in railways. If the operation environment of the unmanned operation system is simple and the operators are trained, the interface can efficiently ensure safety. However, in case the operator panics, and forgets to Release-OFF, there is a possibility of incorrect controls being triggered, leading to accidents.

Finally, an interface with a three-position switch function in smartphones is examined. Fig.1 (c) shows the characteristics of this interface. The interface is the same as a Hard-Push-OFF/Push-ON/Release-OFF switch. As long as the driver moves his fingers on the smartphone display, the interface deals Push-ON. The interface deals Hard-Push-OFF when this movement stops. When the fingers are not in touch with the smartphone display, the interface deals Release-OFF. This interface makes use of a person’s tendency to push an already pushed switch more strongly and release it when under panic.

In contrast to a three-position switch, the two-position switch is unable to detect the action of a continuously pushed switch. However, in a three-position switch, the operator needs to apply subtle pressure to keep the switch ON, because if the pressure applied is too strong or too weak, the switch turns OFF. Therefore, the operator’s load clearly gains.

The Click-ON/Click-OFF switch function is not appropriate for an unmanned parking interface. To decide whether the Push-ON/Release-OFF switch or Hard-Push-OFF/Push-On/Release-OFF switch is more suitable for accomplishing unmanned parking, an evaluation of the reaction time and the driver’s load in subjective experiments is required.
3. Experimental evaluation

In this section, subjective experiments using a simulator that evaluates the response time and the driver's load of smartphone-control methods for unmanned parking are explained.

3.1 Experimental conditions

The experiment simulates a situation where vehicles are backed into a parking space. The form of the parking are on the simulator display is shown in Fig. 2. As shown in the figure, the aisle width of the parking is 7 m, the parking space width is 2.48 m, and parking space length is 5 m. The vehicle width is 1.745 m, length is 4.48 m, and the wheel base is 2.7 m. The other parking spaces are assumed to be occupied, and are fixed to be unable to enter. The simulator randomly prepares several possible trajectories that avoid collision with obstacles, without actually turning the wheel. The simulator then randomly selects one of the trajectories before the start of the experiment, and places the vehicle on the farthest place from the parking space in the trajectory.

The unmanned parking control is designed to drive just along the prepared trajectory. Therefore, the vehicle never touches obstacles. When the control is enabled, the vehicle accelerates 5.0 m/s² and maintains a speed of 5.0 km/h. In addition, when the vehicle approaches the target parking position in the parking space, the vehicle decelerates 5.0 m/s² and stops. Control enable/disable signals from the smartphone are received with a 200 ms delay. Once the control is disabled, the vehicle decelerates immediately at 0.5 G and stops.

The discussed smartphone-control methods here are as follows: Push-ON/Release-OFF switch function and Hard-Push-OFF/Push-ON/Release-OFF switch function. The Push-ON/Release-OFF switch function for the unmanned parking control is enabled as long as the driver's fingers touch the smartphone display, and disabled when the contact is released. Hard-Push-OFF/Push-ON/Release-OFF switch function for the unmanned parking control is enabled while the driver's fingers move on the smartphone display and disabled when the contact is released.

In the experiment, 12 subjects and 6 subjects per switch function conducted unmanned parking repeatedly for 10 times. When the vehicle arrives in the target parking space, the parking is regarded to be accomplished. The simulator is then initialized to select another prepared trajectory and the experiment is restarted. In the tenth experiment, when the vehicle enters the parking space from a distance of about 1m, a pedestrian suddenly rushes out from the neighbor parked vehicle. Because the time-to-collision between the pedestrian and the vehicle is 0.5 s, an accident is inevitable.

The response time and the driver's load have been evaluated. The response time is defined by when the pedestrian becomes visible to when the driver disables control. The driver's load is evaluated by the period during which the driver is able to continue moving his fingers and overlook the vehicle's safety. After the experiment, the subjects answered the following two questions:
I. Which switch function had a heavier driver's load?

II. Were you able to continue operating the Hard-push-OFF/Push-ON/Release-OFF functions while ensuring safety in unmanned parking?

The subjects were told as a guide that the parking would take 30 s on average.

Figure 2. Parking area.

3.2 Experimental results

Fig. 4 shows each drivers’ response time while using the Push-ON/Release-OFF switch function and the Hard-Push-OFF/Push-ON/Release-OFF switch function. The results show that the Hard-Push-OFF/Push-ON/Release-OFF switch function has a significantly shorter response time than the Push-ON/Release-OFF switch function ($p<0.1$). It means that the Hard-Push-OFF/Push-ON/Release-OFF switch function is more likely to avoid accidents than the Push-ON/Release-OFF switch function, because the brake reaction distance of the Hard-Push-OFF/Push-ON/Release-OFF switch function is shorter than that of the other switch function. Fig. 5 and Fig. 6 show results of the questionnaire for the subjects. The result shows the operation load of the Push-ON/Release-OFF switch function is significantly lighter than that of the other ($p<0.1$). However, the subjects answered that the operation load of the Hard-Push-OFF/Push-ON/Release-OFF switch function is small enough to operate safely ($p<0.01$).

The above results show that in smartphone-control methods for unmanned parking, the Hard-Push-OFF/Push-ON/Release-OFF switch function is strongly recommended.

Figure 3. Reaction times.
4. Conclusion

This study was conducted to propose a design of operation methods using smartphones for implementing unmanned parking systems. Unmanned parking systems that assign operation responsibility to drivers were focused in this study, and several operation methods were discussed. A simulator for unmanned parking was then developed, and two most appropriate methods for the operation were evaluated by a subjective experiment. The evaluation indicates that using the Hard-Push-OFF/Push-ON/Release-OFF switch function to enable/disable the operation is the best method with respect to the driver’s operation responsibility, reaction time, and the operation load. In the future, we will validate these results by developing and evaluating the actual system. We will also discuss and evaluate other functions of smartphones for unmanned parking.

References


