Proposal of Guidance Method in Car Navigation Systems

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***Abstract*—Automotive navigation systems have become increasingly popular. Web-based map applications, such as Google Maps, that are available on smartphones are commonly used in automotive navigation systems. Such systems help drivers navigate through unfamiliar regions. However, drivers may occasionally misjudge or make an incorrect turn in response to voice directions such as "In XX meters, turn right". This possibly happens because of the difference between perceived and actual distance. This study aims to examine the differences in the perceived and actual values of not only distance but also elapsed time. It then proposes a guidance method that instructs drivers to turn on their right or left blinker before approaching a turn. The method reduces the likelihood of drivers missing turns and does not bother drivers with repeated instructions. In addition, the method ensures that the cars behind are aware of the driver's intended actions as the blinkers are turned on prior to making the turn; thus, it is superior in terms of driving safety.**

Keywords-Car navigation; driving safety; guidance method; voice instruction; perceptual distance.

I. INTRODUCTION

Automotive navigation systems have become increasingly popular. Web-based map applications, such as Google Maps [1], that can be accessed on mobile devices (e.g., smartphones) are a commonly used automotive navigation system, helping drivers navigate through unfamiliar regions. However, despite voice instructions such as "in XX meters, turn right", drivers may occasionally miss a turn, go in the wrong direction, or make a last-minute turn, which can be dangerous. This is possibly because drivers miscalculate the indicated distance.

This research examines the difference between the perceived and actual values of not only distance but also elapsed time. The experiments show that most participants could accurately perceive distance within 100 m, although this accuracy rapidly decreased when the distance increased to more than 100 m. Thus, we conclude that re-instructing drivers within 100 m of a turn helps them accurately perceive distance.

We firstly considered that the voice countdown method based on conventional visual count down bar [2] was the most effective in accurately perceiving distance. In this paper, we evaluated the countdown method. However, the method tended to offer repeated instructions that can prove bothersome to a driver. Thus, we proposed an instruction method in which drivers are asked to turn on their right or left blinker as they are nearing a turn. The experimental evaluations reveal that the method prevents drivers from making wrong turns and helps them drive safely, although the accuracy of perceived distance is marginally lower than that observed in the countdown method. The method does not bother a driver with repeated instructions. Moreover, it is superior in terms of driving safety because the cars behind become aware of the driver's intended actions when the latter turns on the blinker.

The remainder of this paper is organized as follows. Section II discusses related works. Section III evaluates the accuracy of perceived distance and time. Section IV analyzes the accuracy of selecting an intersection. Section V presents the novel instruction method. Section VI tests the proposed instruction method by conducting related experiments. Section VII compares the proposed method with existing ones. Section VIII offers concluding remarks and suggestions for future research.

II. RELATED WORKS

Automotive navigation systems have three main tasks: positioning, routing, and navigation (guidance). This study focuses on navigation or guidance methods. Guidance methods generally include the display of instructions on a road map in a navigation system, an information display on a windshield, and/or voice instructions.

However, studies have shown that the continuous need to look at the navigation system's display for information can be distracting and dangerous [3]. Therefore, most navigation systems are a combination of a road map display and voice instructions. Guidance information generally includes distance to the destination and landmarks that can help drivers locate the destination [4]. It is easy to miss a turn in response to distance-based instructions such as "In XX meters, turn right/left." Thus, manufactures of car navigation systems have upgraded guidance methods by, for example, integrating a 3D map that improves identifiability of mapped roads in reality. Figure 1 is an image of Panasonic's car navigation system with a 3D map, Strada CN-F1XVD [5]. Augmented reality (AR) technologies have also contributed to improving identifiability in guidance instructions [6]-[8]. Akaho et.al. [6] analyzed the AR methods and comfirmed ease of understanding, safety, and the characteristics of AR-Navi in comparison with conventional method using 3D maps. However, 3D maps and AR technologies do not

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resolve the problem of drivers having to constantly look at the display for instructions.

The second guidance method, that is, an information display on a windshield, was developed to resolve the abovementioned issue. Figure 2 depicts an AR navigation system and windshield projection unit designed by Pioneer Corporation. The AR navigation system is to the lower left of the image. The in-vehicle camera captures a real-time video of the road and vehicles ahead of the car, and guidance information is overlaid using computer-generated imagery on a live feed using AR technology. The information on the AR navigation system is also projected on a see-through windshield display.

Large and Burnett [9] examine the effects of different types of voice navigation described in [6]. However, to the best of our knowledge, no study explores ways to improve the guidance accuracy of voice navigation systems

III. PERCEIVED DISTANCE AND ELAPSED TIME

Existing automotive navigation systems offer driving instructions such as “in XX meters, turn right” or “turn left at the intersection.” However, the difference between perceived and actual distance may cause drivers to misjudge a turn or even steer abruptly, which can be dangerous. This study, therefore, conducts experiments to evaluate differences

Figure 1. Panasonic’s car navigation system, Strada CN-F1XVD [1]

Figure 2. Pioneer Corporation’s Cyber Navi [3]

Figure 3. Test course in the university

between the perceived and actual values for distance and elapsed time.

A. *Experiment for halting vehicles*

A total of 20 students with a driving license were asked to drive a Toyota Noah installed with a navigation system on a circuit road in Iwate Prefectural University (see Figure 3). Each participant is informed of the distance and time (in seconds) within which they must halt the car. The distances used in this experiment are 100, 300, and 500 m. Each participant must drive and stop the car thrice for each distance category. The elapsed times are 10, 20, and 30 s, and the participants must drive and stop the car for each elapsed time.

Prior to estimating the perceived values and conducting the experiment, the participants were asked to drive few laps of the test course to ensure they understand the examiner’s instructions and to confirm the distance and elapsed time.

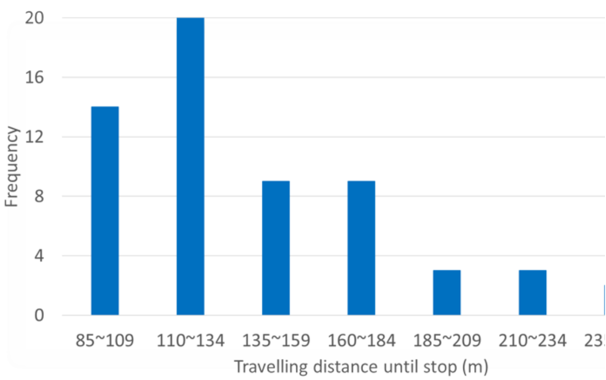
B. *Experiment results for perceived distance*

Table I presents the average distance, average difference between the instructed and perceived distance, and standard deviations. If the instructed distance is longer, the average difference tends to be larger. This difference varies by as much as ten percent among the participants, as indicated by the standard deviations in Table I. In other words, each participant perceives distance differently. This means that additional instructions are needed for distances less than 100 m, and instructions such as “In XX meters, turn right/left” are not effective when the distance is greater than 100 m.

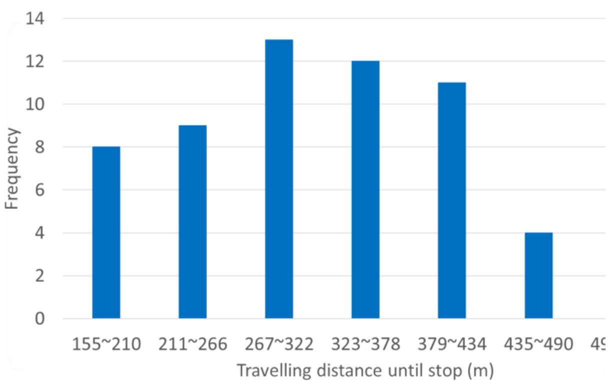
TABLE I. ESTIMATION RESULTS FOR PERCEIVED DISTANCE

	100 m	300 m	500 m
Average (m)	138	327	527
Avg. difference (m)	41	82	120
Std. dev. (m)	38.7	91.3	121.6

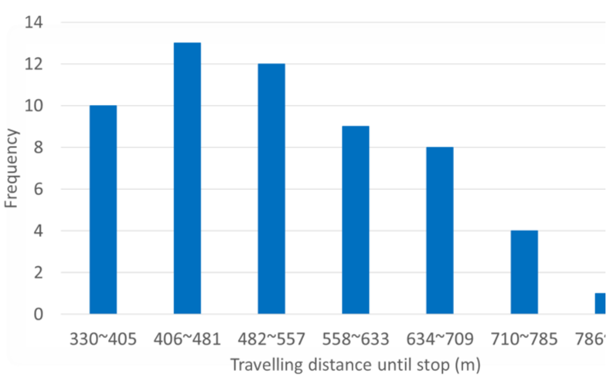
Figure 4 shows the frequency distribution for each instructed distance. The vertical axis denotes the frequencies employed in the experiments and the horizontal axis indicates the difference between the instructed and travelled distances. The frequency distribution is estimated for iterations for each instructed distance. The results suggest that the data are widely distributed, and the curve does not take the form of a normal distribution. Some participants travelled considerably further than the instructed distance, although no participant travelled significantly less than the instructed distance. These



(a) Instruction distance = 100 m



(b) Instruction distance = 300 m



(c) Instruction distance = 300 m

Figure 4. Frequency distribution for an instructed distance

results suggest that re-instructing drivers when they are within 100 m of a turn or destination decreases the likelihood of them going in the wrong direction.

C. Experimental result for perceived elapsed time

Table II presents average distance, average difference between instructed and travelled time, and standard deviations in the context of elapsed time. Figure 5 presents the frequency distribution for each instructed elapsed time. The vertical axis indicates the frequencies applied in the experiments and the horizontal axis denotes the ranges of time elapsed between the instructed time and the vehicle halting. The frequency distribution is estimated from 60 iterations for each elapsed time.

The results reveal significantly small deviations from an instructed time (<15%). When the instructed time is 10 s, the error distance is roughly 20 m at 60 km/hour.

A method that notifies drivers of the elapsed time would be more effective that one with distance instructions. However, it is difficult to estimate elapsed time on urban roads or streets since drivers seldom maintain a consistent speed. Nevertheless, the method can be useful on regional roads such as highways, where drivers are generally expected to travel at a constant pace.

The next section proposes a guidance method that can prove more effective than the distance instruction method.

IV. NOVEL GUIDANCE METHOD

The results in the previous section indicate that re-instructing drivers within 100 m of a turn or destination decreases the likelihood of them driving in the wrong direction.

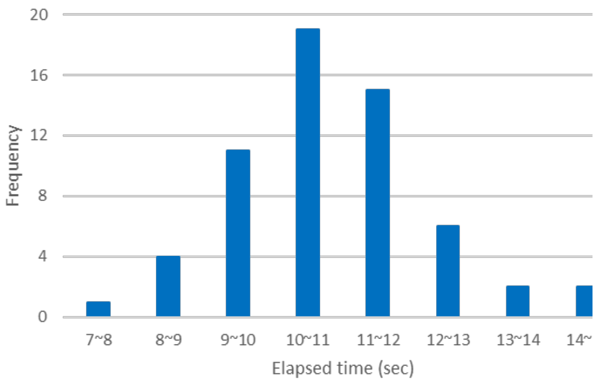
We propose the following alternative guidance methods:

1) A countdown method that provides drivers with voice instructions at various distance intervals (50, 40, 30, 20, 10, and 0 m).
2) A blinker method that instructs drivers to turn on their blinker at, for example, 30 m before the target intersection. In Japan, drivers must turn on their blinkers at least 30 m from thae target intersection (Article 21 of the Order for Enforcement of the Road Traffic Act).

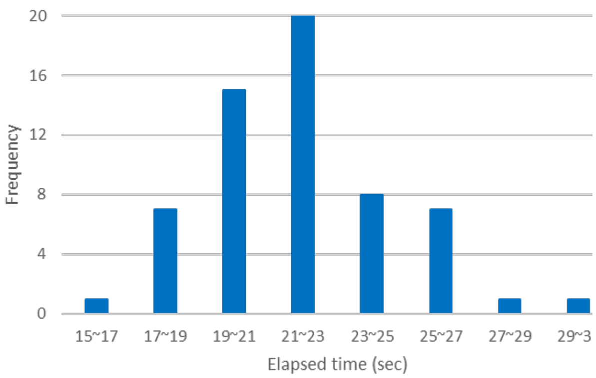
We compare the two methods on a test course, a circuit road in Iwate Prefectural University with intersections made using traffic cones (Figure 6). We first examine an existing navigation system that provides drivers with instructions such as “In 100 m, turn left.” A preliminary exploration of a road

TABLE II. ESTIMATION RESULTS FOR PRECEIVED ELAPSED TIME

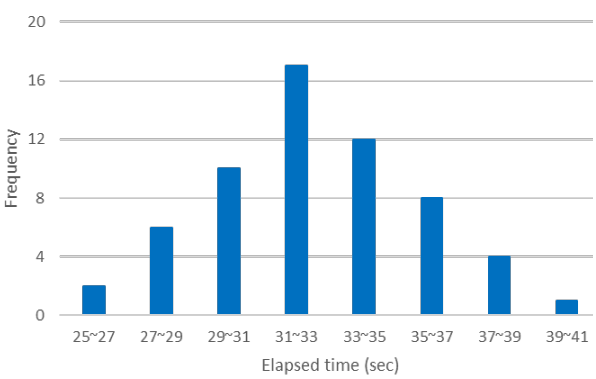
	10 s	20 s	30 s
Average (m)	10.8	21.9	32.5
Avg. difference (m)	1.25	2.6	3.29
Std. dev. (m)	1.44	2.56	3.17



(a) Instruction time = 10 s



(b) Instruction time = 20 s



(c) Instruction time = 30 s

Figure 5. Frequency distribution for elapsed time

map suggests that most distances between intersections are less than 20 m and thus, all traffic cones are placed at 20 m intervals. Figure 7 shows an image of the test car (Nissan Micra) and that of the emergency brake installed on the examiner's side for safety purposes. A total of other 12 university students with a driving license participated in the comparative study. We instructed that the participants halted

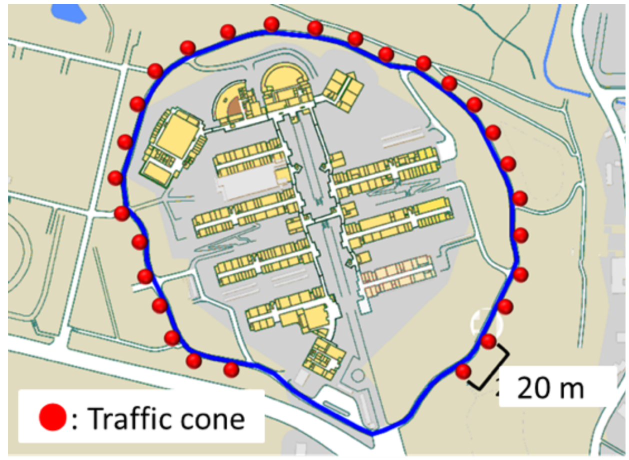


Figure 6. Test course of instruction methods in the university

(1) NISSAN MICRA (2) Emergency brake

Figure 7. Test car

instead of turning when they were notified of an intersection. The test was repeated thrice for each method.

Figure 8 reports the rate of participants who turned (or stopped) correctly in response to each instruction method. The vertical axis denotes the rate of correct turns and the horizontal axis represents each instruction method. The countdown method reports the highest rate of correct turns (91.7%). However, some participants perceived the repeated instructions to be distracting. The rate of correct turns is marginally lower for the blinker method (86.3 %). The participants stated that this method's instructions are simpler than those of the countdown method. As previously mentioned, the blinker method ensures that those in subsequent cars are aware of the driver's intended actions and thus, is superior in term of driving safety.

The blinker method provides the most effective voice instructions, particularly when the distance between intersections is less than 100 m. Figure 9 is an example of a test course for the blinker method. The evaluated distance between the intersections is less than 20 m. A total of 10 participants with a driving license were asked to drive a Nissan Micra.

For the blinker method, the examiner selected three out of six intersections shown in Figure 9. All participants made an equal number of correct right and left turns (i.e., 15 each).

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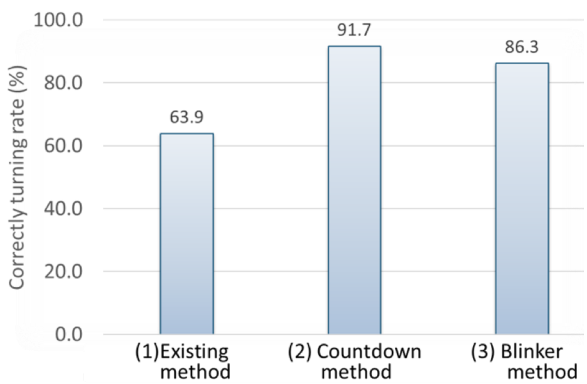

Figure 8. Correctly turning rate

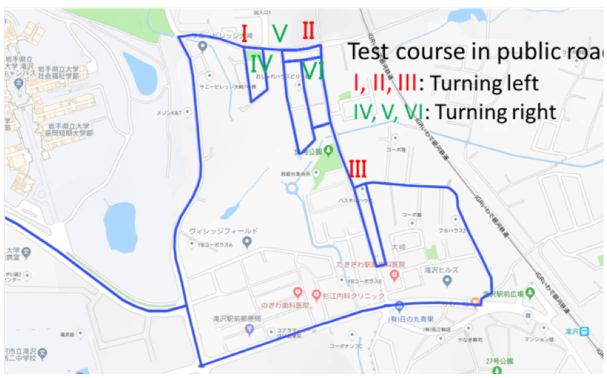

Figure 9. Test course for the blinker method in public roads

Figure 10. Detail map around the intersection V

However, one participant selected a wrong intersection. This is possibly because the distance between intersections VI and V was only 10 m (see Figure 10), making the intersection difficult to identify given the significantly short distance.

Next, we compare the blinker method with Google Maps on a public road (Figure 9). The test format is similar to that employed for the blinker method. The same 10 drivers were asked to participate in the evaluation of the blinker method. Table III presents the examination results and shows that the proposed blinker method is superior to Google Maps on roads where the distance between intersections is less than 20 m.

TABLE III. ACCURACY OF TURNING INTERSECTIONS

Intersection #	Turn L/R	Blinker method (%)	Google Map (%)
I	L	100	100
II	L	100	20
III	L	100	40
IV	R	100	80
V	R	80	40
VI	R	100	100

V. CONCLUSIONS

Automotive navigation systems have become increasingly popular and accessible through applications on mobile devices such as smartphones. While they help drivers navigate through unfamiliar regions, drivers may occasionally misjudge or make incorrect turns, particularly in response to voice instructions such as “In XX meters, turn right/left.” This miscalculation can be attributed to the difference in perceived and actual distance. Thus, this study experimentally evaluates the difference between perceived and actual values for distance and elapsed time. The data indicate that re-instructing drivers regarding distance is effective on urban roads and when the distance is less than 100 m, and instructions related to elapsed time are useful on regional road such as highways.

We propose a guidance method in which drivers are instructed to turn on their right or left blinker upon approaching a turn. This method not only decreases the likelihood of incorrect turns but also is superior in terms of safety driving because it informs the cars behind of the driver’s intended actions.

We employed vibrotactile actuators for notifications and will continue to do so for further analyses. Future research could explore guidance methods without sound and visual notifications.

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