



DEVELOPMENT OF A METHOD FOR IDENTIFYING THE NUMBER OF TIMES TO TURN AROUND DURING A DRIVING FOR PARKING

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Abstract

In Japan, a super-aging society, fatal and injury accidents caused by elderly drivers have become a serious social problem. Traffic accidents caused by elderly drivers are caused partly by driving errors (e.g., misjudging the brake and accelerator pedals, reversing, missing a traffic signal, etc.) resulting from cognitive decline. As many researchers have stated, it is necessary for elderly drivers to avoid driving or return their driving licenses through appropriate evaluation of their own driving ability to continue a safe traffic society. Driving ability has been evaluated subjectively by using questionnaires or objectively by observing driving behavior. The authors have analyzed driving behavior at intersections, where driving operations are most complex. Meanwhile, it is said that declining cognitive function can lead to the appearance of unsteady driving, lowered parking skills, and wandering driving. Therefore, in this study, we focused on parking behavior and attempted to construct a method to measure the number of vehicle turns related to parking skill. In this study, the driving data of 95 elderly people living in Hakui, Ishikawa Prefecture, who participated in the observation survey were used for analysis. Data items included time, location (latitude and longitude), 3-axis acceleration, and speed. In analyzing parking behavior, the part of driving intended for parking was extracted from the driving data. Next, since it was difficult to determine whether the vehicle was moving forward or backward only from the acceleration information in the direction of moving, we calculated direction vectors from changes in the vehicle's position, and identified the turnaround operation by calculating the narrow angle between these direction vectors in a time-series sequence. A threshold value must be set for the narrow angle, and in this study, trial and error was done by applying a peak detection method for time-series data. As a result, it was confirmed that it is possible to generally identify the turnaround by setting the narrow angle to about 140 degrees.

Keywords: elderly drivers, parking behavior, turnarounds

1 Introduction

In Japan, a super-aging society, the frequent fatal and injury accidents caused by elderly drivers who misplaced the pedals have become a serious social problem. Since the number of driver's license holders over 75 years old is increasing and exceed 9 million by 2022, it is necessary to take prompt countermeasures. Ministry of Economy, Trade and Industry has defined vehicles with functions such as collision damage reduction brakes (for pedestrians) and acceleration control system for pedal missteps as "Safety Support Cars S" and is promoting the use of such vehicles in cooperation with the public and private sectors. However, it is said that even vehicles equipped with advanced functions such as ADAS cannot completely prevent accidents caused by incorrect driving.

Moreover, it is also said that driving errors such as pedal missteps and ignoring traffic signals are caused by a decline in cognitive functions. Therefore, in order to maintain a safe traffic society, it is necessary to encourage elderly drivers to reduce their driving and return their driver's licenses by reviewing their own cognitive abilities, judgment, and operation skills. In addition, it has been reported that drivers with impaired cognitive abilities develop wobbly driving, wandering driving, and poor parking skills.

The authors have been analyzing the driving behavior of vehicles at intersections, where driving operations are the most complex. Utilizing the knowledge obtained in the previous studies, this study focuses on the parking operation of elderly drivers and attempts to develop a method to measure the "number of vehicle turnarounds," which is closely related to parking skills.

2 Previous studies

It is a common issue worldwide how to manage the driving of elderly people. So far, many research results have been accumulated on the evaluation of driving ability (subjective evaluation based on questionnaire surveys, etc., and objective evaluation based on driving performance), driving avoidance situations, and verification of the effectiveness of interventions such as advice and driving training.

Molnar, et al. [1] examined how strongly subjectively reported driving avoidance behaviors (commonly referred to as self-regulation) and exposure were related to their objectively measured counterparts and whether it depended on the specific behavior.

They used data from the Longitudinal Research on Aging Drivers (LongROAD) study, a multisite, prospective cohort study designed to generate empirical data for understanding the role of medical, behavioral, environmental, and technological factors in driving safety during the process of aging and objective driving measures were derived from GPS/datalogger data from 2131 LongROAD participants' vehicles. Moreover, the corresponding subjective measures were made from answer to questionnaire regarding their driving exposure, patterns, and other aspects of driving. They estimated linear and logistic models to examine the relationship between the subjective and objective driving measures of interest, and conducted multivariable analysis to examine the potential role of selected factors in the relationship between objective and subjective driving avoidance behaviors.

Kosuge et al. [2] utilize a workbook to provide feedback on the accuracy of self-perceptions of driving performance, and conduct a follow-up study two months later to verify the effectiveness of the intervention. In that study, evaluations of on-road driving on public roads were also conducted, with electronic devices installed in a car and the driver being accompanied by a driving evaluator. The results suggest that the intervention led to an improvement of driving ability through an increase in the accuracy of the self-assessment of driving performance.

Huang, et al. [3] mentioned that it is important for older drivers to understand their own driving abilities, given the decline in perceptual, cognitive, and physical functioning associated with aging. In this study, 25 articles were selected from 10 major academic article databases and systematic reviews were conducted to synthesize the literature on the self-perception of driving ability among the elderly. Then, it was shown that the methods used to assess elderly people' self-perception of their driving ability vary considerably, and that older drivers tend to overestimate their own driving ability. Moreover, it describes the necessity of developing subjective evaluation methods that provide drivers with a more accurate estimate of their true driving ability, and the need for comparisons between subjective and objective driving evaluations.

Fausto, et al. [4] conducted systematic review and meta-analysis in order to summarize and quantify the effects of different driving interventions among elderly people on outcomes of crashes, on-road driving performance, self-reported outcomes of errors and crashes, and driving simulator performance. They focused on randomized controlled trials examining the effects of a driving intervention among elderly people ≥ 50 years of age. As the results, thirty-one studies were identified using a systematic literature review, and 26 were included in meta-analyses. Identified driving interventions are as follows: physical retraining/exercise, visual-perceptual training, cognitive training, education, context-specific training (i.e., on-road training in car, driving simulator training) and combined intervention approaches. They calculated effect sizes for each driving intervention type relative to control groups using random-effects. They summarized that skill-specific interventions (physical retraining/exercise, visual-perceptual training, cognitive training) and combined intervention approaches improved on-road driving performance and reduced at-fault crashes.

3 Data acquisition

In this study, the data obtained by the observation survey of driving behavior was used, which was conducted based on an agreement among Kanazawa University, the city of Hakui in Ishikawa Prefecture, and a private-sectors. 95 elderly drivers living in Hakui city cooperated in the survey, and observation equipment sensors were installed in their vehicles. Observation items are date and time, driving location, tri-axis acceleration (km/s^2), driving speed (km/s), and roll-, pitch-, yaw- rates. The observation frequency was 15 Hz. The observation period was one month in February 2022.

4 Procedure to measure the “number of vehicle turnarounds,”

Noting that the direction of travel changes significantly when turning around when parking, a method for calculating the number of times to turn around was constructed. The calculation flow of the number of turnarounds is shown in Figure 1. The details are described below.

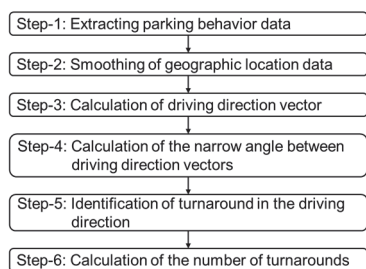


Figure 1 Calculation flow of the number of turnarounds

4.1 Step-1: Extracting parking behavior data

The part of parking behavior is extracted from the observed driving data. In this study, parking behavior is defined as driving from 20 seconds before the engine completely stops (i.e., acceleration and speed are zero) until the engine stops. The recordings were conducted with 15 Hz, so 300 data points were recorded during the 20 seconds.

4.2 Step-2: Smoothing of geographic location data

When the trajectory of the vehicle was displayed in GIS, the trajectory was not smooth even when the vehicle was moving straight. It is thought that this was caused by an observation error in the positioning information. Therefore, smoothing of the trajectory was conducted. A moving average was calculated using the positioning information of 15 points before and after (i.e., 1 second before and after) an observation point, and the moving average was used as the location of the vehicle.

4.3 Step-3: Calculation of driving direction vector

Two locations are extracted from the driving location calculated in step 2, and the vector of the driving direction is calculated. The direction vector varies depending on the time interval between the two points. In case the time interval is set to be short, a large change in the driving direction that occurs during a turnaround is observed as a series of small changes in the driving direction. In addition, in case the time interval is too long, the number of driving direction vectors calculated will become small. Therefore, in this study, the driving direction vectors were calculated using the location information at a certain point and five points ahead (i.e., one third seconds later). Figure 2 shows the direction vectors connecting certain point and point one-third seconds later.

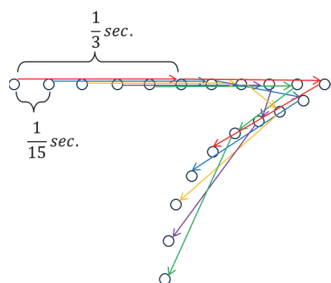


Figure 2 Direction vectors connecting certain point and point one-third seconds later

4.4 Step-4: Calculation of the narrow angle between driving direction vectors

The narrow angle between two vectors is derived using the driving direction vectors calculated in Step-3. In this process, the time interval between the two direction vectors needs to be adjusted. Figure 3 shows the different narrow angles derived depending on set time intervals. The left-hand figure shows the narrow angles of the direction vectors at a certain point and one point ahead (i.e., 1/15 of a second later). The dashed lines are vectors that are displayed by shifting the direction vectors at 1 points ahead by a parallel shift. The figure on the right similarly shows the narrow angle between the direction vectors at a certain point and 15 points ahead (i.e., 1 second later). The dashed lines are vectors that are displayed by shifting the direction vectors at 15 points ahead by a parallel shift. Comparing the left and right figures, it can be seen that longer time interval results in a larger narrow angle between the two vectors.

Figure 4 shows the change in the narrow angle for a parking operation where the number of turnarounds was two times. The left figure shows the transition of narrow angle with the vector at 1 point ahead, and the right figure shows the transition of narrow angle with the vector at 15 points ahead. It can be seen from these figures that when the time interval is set longer, larger narrow angles can be obtained. Therefore, in this study, the direction vectors at a certain point and at a point one second later were used to calculate the narrow angle.

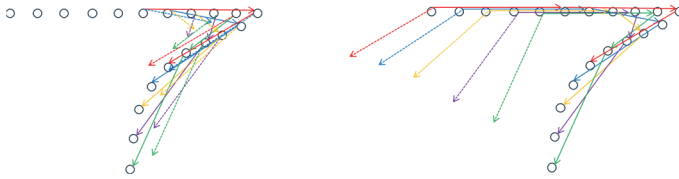


Figure 3 Narrow angles derived depending on set different time intervals

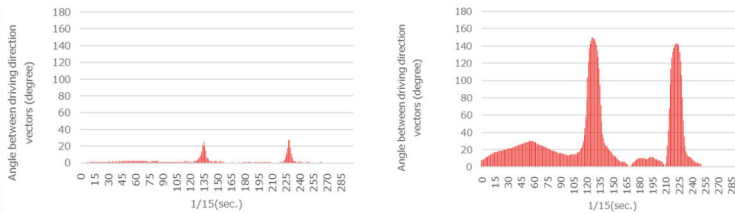


Figure 4 Transition of the narrow angle where two times turnarounds

4.5 Step-5: Identification of turnaround in the driving direction

As seen in Figure 4, the narrow angle increases once and then decreases when there is a turnaround. In this study, the peak detection method is applied to identify the turnaround by detecting the point at which the narrow angle turns from increasing to decreasing. However, when the narrow angle is small, the increase and decrease of the narrow angle occur, and these are detected as peaks. Therefore, it is necessary to set a threshold for the narrow angle to determine a turnaround. Here, a graph of narrow angles for parking behaviors with different numbers of turnarounds is drawn to obtain knowledge that contributes to the setting of an appropriate threshold. Figure 5 shows the driving trajectories of parking behavior when the number of turnarounds is 2 and 4. Figure 6 shows the transition of the narrow angle during 20 seconds in the driving trajectory shown in Figure 5. The left figure clearly shows that there are two peaks. On the other hand, there are five peaks in the right figure, however, referring to the driving trajectory, there is a large amount of time between the first and second peaks. Therefore, the number of turnarounds is assumed to be four. Based on the above, the threshold for determining the number of turnarounds was set at 140° .

4.6 Step-6: Calculation of the number of turnarounds

Peaks are detected by applying the `find_peaks` function in Python's SciPy library to the transition data of narrow angles obtained in Step-5. The number of turnaround is determined by counting the number of peaks detected.

5 Measurement results

The number of turnarounds was determined for all parking behaviors of the 95 participants. As a result, the maximum number of turnarounds was six times. The transition of the narrow angle for this case is shown in Figure 7. It can be seen that there were six peaks where the narrow angle exceeded 140° . Moreover, Figure 8 shows the driving trajectory at this time. It can be seen from the driving trajectory that the driving direction changed six times.



Figure 5 Driving trajectories during parking in case turnarounds is 2 and 4 times

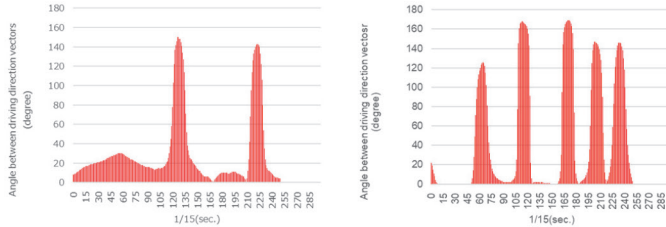


Figure 6 Transition of the narrow angle in case turnarounds is 2 and 4 times

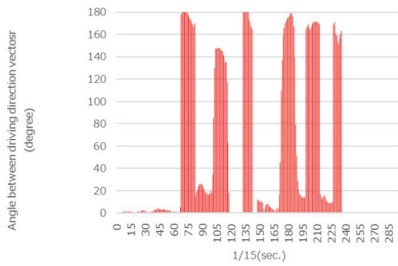


Figure 7 Transition of the narrow angle in case turnarounds is 6 times

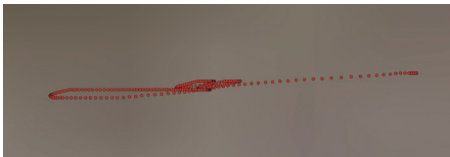


Figure 8 Driving trajectory in case turnarounds is 6 times

However, the trajectory shows that the vehicle changes its driving direction from forward to backward rather than turnaround. This means that the method developed in this study may include such forward/backward movement of the vehicle in the number of turnarounds. By evaluating the vehicle's direction, lateral acceleration, and yaw angle simultaneously, it may be possible to determine the number of turnarounds more precisely.

6 Conclusion

In this study, the authors focused on the decline in parking skill, which is associated with the decline in cognitive function. To evaluate parking skill, the number of turnarounds during parking behavior were examined. This research attempted to develop a method to determine the number of turnarounds during parking behavior based on acceleration and location information, both of which are commonly measured by driving recorders. The narrow angle between the driving direction vectors was calculated in a time series, and a peak detection method was applied to identify the number of turnarounds. By setting the threshold as 140 degrees, it was confirmed that the turnaround could be generally identified.

In this study, the number of turnarounds was counted for 20 seconds before the vehicle completely stopped. However, it is thought that drivers with impaired cognitive functions may take a longer time to park the vehicle. Therefore, it is necessary in the future to improve the method to calculate the number of turnarounds without limiting specified time duration. In the future, we will examine the occurrence of specific driving behaviors such as sudden acceleration and sudden braking during parking. Furthermore, the relationship between cognitive functions and driving behaviors will be verified by integrating the driving behaviors during parking and driving behaviors at intersections that have been evaluated by the authors.

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