Difference of Steering Maneuver on Right and Left Turn Depends on Driver*

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Abstract
In this paper, we discuss the difference of driver’s characteristics. Nowadays, driver assist systems are developed. It is very important to develop an effective driver assist system. We focus our attention on steering maneuver. We performed the experiment using the actual car. In the experiment, we measured not only a vehicle state but also the force acting on steering wheel and the motion of driver’s arm. The six-degree-force transducer on steering wheel is newly developed. The motion capture system using supersonic wave is adapted. We found three kinds of characteristic maneuvers. First, it is the difference of steer angle. A beginner driver steers with high frequency. On the other hand, an expert driver steers without high frequency. Next, we investigated the location of grabs on steering wheel of each subjects. The beginner grabs particular place of steering wheel. They don’t cross their arms during cornering. Finally, we found the difference of characteristic about pushing and pulling force on steering wheel.

Key words: Automobile, Driver Behavior, Steering Gain, Steering Assist System

1. Introduction
Recently, “Driver assist systems” has increased (1)(2)(3). For example, there are an adaptive cruise control system that follows proceeding vehicle, a lane departure warning system and a following system. In the near future, “Steer by wire system” will appear. These highly automated systems have various problems such as automation surprise, modeconflict , trusty and share burden of decision (4). These systems need to work in cooperation with the human driver (5)(6). Figure 1 shows a notional model of cooperative system. Both the human and the system need to know each other’s functions and characteristics. The human driver needs to know what the control system senses and decides, and then what the control system will operate. On the other hand, the control system needs to know what the human driver is aware of and recognizes in each situation, and then what the human driver will operate. A control-system-designer of the driver assist system can easily know maneuver of the assist system. However, it is extremely difficult for the assist system to know the maneuver of the driver. Accordingly, a driver model which the control system can understand is needed (7)(8). The driver model should represent the human desire and the driver’s characteristic. There are various patterns of driver characteristics. These patterns are classified into two broad categories. One is difference of person’s attribute such as the driving skill, the experience of driving, sex and age. The other is difference of situations that always changes such as weather, a driving scene and driver’s feelings. First of all, we focus on the difference of the driver’s skill in this research. In the
most evaluations of the automotive development are done by experienced test drivers, especially at the department of the stability of steering maneuver and vehicle performance. However, for instance a target user of the parking support system is a beginner driver rather than an expert driver. Moreover, beginner's driver not only a younger driver but also a senior driver and a female driver will increase in near future. Then it is important to know the driver’s characteristics whose skill is low or became weak. As the fundamental examination, we examined the driver’s characteristics. The drivers are selected from beginners to experts. In this paper, the purpose is to obtain quantitative experimental results of the differences of steering maneuver as preliminary step for the statistical investigation.

2. Experiment

2.1. Experimental Vehicle and Subject

The experimental vehicle is shown in Fig.2. The experimental vehicle is a 4WD wagon type vehicle (2500cc). The overall gear ratio and the steering force can be set freely using a variable gear ratio and a power steering system. Figure 3 shows steering column shaft adapted the variable gear ratio system and the electric power steering system. Gear ratio can be set in the range between 6 and 22. The power assist force can be set in the range between 0[Nm] and 30[Nm] by using Oil pressure type and Electric type together. The experimental course is a test course which imitates an urban area. A combination of intersections such as a general crank shape course and a general slalom area is used. Three male and two female drivers are selected for the experiment. Table 1 shows characteristics of subjects. Subject A is test driver working at automobile company. Subject B is common driver with 10 years driving experience. Subject C, D and E are beginner drivers who rarely drive. In the experiments, it was instructed that subjects must drive within safe velocity.
2.2. Measurement item

In this experiment, we measured general vehicle states such as a velocity, a yaw rate, a lateral acceleration, a steering wheel angle and a steering torque. Furthermore, 3-axis forces and 3-axis torques acting on the steering wheel and also a motion of driver’s arm were measured in this research. Special attention was given to the pull/push force acting on the steering. Figure 4 shows the new six-degree-of-force transducer that we developed. This system can be used under three rotations from rock to rock (from left end to right end of the rotation) and is designed on the condition that the steering wheel center is set like usual steering wheel. Using this six-degree-of-force transducer is much more similar to the actual car than using the pass one degree of freedom transducer. In addition, it is very important to measure the driver posture and the accuracy of the motion when physical load of driving added to the driver and the characteristic of impedance concerning with steering maneuver is imposed on the driver. These measurements were not able to be measured with a steering wheel angle sensor alone. The holding positions could be measured by video analysis. However, it is difficult to get high-quality data in analysis using the video. It takes long to analyze the data. For these reasons, we used a motion capture to measure the holding positions and a possession substituting operation. An optical motion capture system is adapted to many researches. However, an optical motion capture system is unstable for the measurement in the actual car cockpit because of the influence of brightness and the limitation of place. Moreover, a magnetic motion capture is unstable because of limitations of the number of markers and noise. Then a motion capture system of the supersonic wave type is used in this research. Therefore the position of steering wheel which a driver holds and the operation movements can be measured. Figure 5 shows the motion capture

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Age</th>
<th>Sex</th>
<th>Driver Career</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>48</td>
<td>male</td>
<td>30y’</td>
<td>expert</td>
</tr>
<tr>
<td>B</td>
<td>32</td>
<td>male</td>
<td>10y’</td>
<td>common</td>
</tr>
<tr>
<td>C</td>
<td>30</td>
<td>male</td>
<td>very few</td>
<td>beginner</td>
</tr>
<tr>
<td>D</td>
<td>34</td>
<td>female</td>
<td>few</td>
<td>beginner</td>
</tr>
<tr>
<td>E</td>
<td>22</td>
<td>female</td>
<td>very few</td>
<td>beginner</td>
</tr>
</tbody>
</table>

Fig. 3. Variable Steering Column

Table 1. Subjects

Fig. 4. Six degree Force Transducer system on Steering Wheel
system for which supersonic wave is used. In this system, it became possible for the substitutive possession of the hands on the steering wheel to be measured in the vehicle during running. There are seven measurement points attached to wrists, lower arms, upper arms and head.

![Driver’s Motion Capture System](image)

Fig. 5. Driver’s Motion Capture System

3. Experimental result

3.1 Comparison of steering wheel angle

The steering wheel angles during running on the crank course and the slalom course were investigated. Figure 6 shows time history of the steering wheel angle of each subject on both courses. In this figure, the result of subject A (expert) is smooth wave pattern. On the other hand, the results of subject B (common) and subject C (beginner) are jagged wave pattern in detail. We found that these subjects choppy operate the steering wheel. Such a beginner’s steering maneuver may raise the weaving of a vehicle because of the staggering steering. Therefore it is possible that his/her vehicle contacts to another cars or persons in a narrowness road and an urban area. Then we investigate the approximate function for this curve. Matlab System Identification Toolbox is used for the approximation. Figure 7 shows the approximated result and the square error of the approximation. The result of the expert driver can be approximated by a cubic function, but a five dimensional function is needed for the common driver. Moreover, for the beginner driver, even a five dimensional function is inadequacy. These results show that a higher dimensional function is needed in order to make proper approximation for the beginner driver. It is possible that the driver’s characteristic for skill can be found by this analysis.

![Time history of steering wheel angle](image)

Fig. 6. Time history of steering wheel angle
3.2 Grab Location on steering wheel

We investigated the grabbing position on the steering wheel measured with the motion capture system. Even if the steer angle is similarly operated, there is some ways of holding the steering wheel. This difference changes the quantity of force to hold the steering wheel and a maximum angular velocity. Therefore the accuracy of steering maneuver is changed. Four setup patterns were performed (the steering gear ratio; 16, 8, the steering torque; 5[Nm], 2[Nm]). Figure 8 shows the orbit of the wrist position of beginner and expert drivers for each of the setups while driving on the slalom course. In this figure, lines of blue type show orbits of right hand in each setup. Lines of red type show orbit of left hand in each setup. Yellow line shows steering wheel. The expert driver moves his wrist within the steering wheel.
It is estimated that the expert driver changes the holding position of the steering wheel smoothly. On the other hand, the beginner driver hardly moves his wrist within the steering wheel. This result shows that the beginner driver changes the holding position with short quick step. Thus there is the difference of the driver’s characteristic concerning with the grabbing location according to the driver’s skill.

3.3 Push and pull forth on steering wheel

We investigated the push/pull force along the axis of the steering wheel. In general, a driver rotates the steering wheel in order to drive the car. In addition, a driver uses the steering wheel for supporting his body in some situations. For example, at rapid braking, the driver’s arms are stretched to support his body that is moving ahead, and a driver strongly grips the steering wheel. It is apparent that the steering wheel is used to stabilize driver’s posture. This reason can be illustrated by the phenomenon that it is difficult to maintain steady sitting posture in Passenger's seat by the only lower half of the body. And the change of force acting on steering wheel is caused by the driver’s feeling due to a driving situation. From the above-mentioned, it can be possible to guess a driver’s attribute, a feeling and a skill by measuring six direction forces acting on steering wheel. Figure 9 shows time history of the force and torque acting on the steering wheel in direction of the vertically axis to steering wheel on slalom course. In this experiment, there is the marked difference of pushing and pulling force in direction of only vertically axis to steering wheel because the high acceleration is not excited. In Fig. 9, the subject D tends to pull the steering wheel always while driving. On the other hand, the subject B tends to drive pushing steering wheel. Other drivers have similar tendency. There is possibility which this pull action of the driver causes high frequency component. When the driver pulls the steering wheel, the entire body of the driver decreases its maintenance ability because the back of the driver leaves to seat back as shown Fig.10 (a). Therefore the stiffness of body decreases. On the other hand, when the driver pushes the steering wheel, the driver accurately operates the steering wheel because the stiffness of the whole body is increased. The reason of this phenomenon is that the driver’s back is pushed to the seat back pushing steering wheel. Then the whole stiffness of the system is increased due to the increase of driver’s stiffness as shown Fig.10 (b). We will consider in-depth investigation of this possibility in the future.

![Fig. 9. Time history of Push/Pull force and steering torque](image-url)
4. Conclusion

In this paper, we discuss the difference of driver’s characteristics. We focus on steering maneuver. Experimental results of the differences of steering maneuver were quantitatively obtained as preliminary step for the statistical investigation. The experiment using the actual car is performed. We measured steering wheel angle, wheel grab position and pushing/pulling force acting on the steering wheel. We found three kinds of characteristic maneuvers. First, it is the difference of steer angle. A beginner driver steers with high frequency. On the other hand, an expert driver steers without high frequency. It is understood that the distinction by the functional approximation is possible. Next, we investigated the grabbing location on steering wheel of each subjects. The beginners grab particular place of steering wheel. They don’t cross their arms during cornering. Finally, we found the difference of characteristic about pushing and pulling force on steering wheel. The action of pulling the steering wheel always while driving is quantitatively measured. It is understood that this characteristic influences the steering maneuver. We would like to put this result to very good account in order to construct the driver model in the future.

References