Driver behavior analysis by measuring perspiration and other bio-signals

This research is subsidized by the New Energy and Industrial Technology Development Organization (NEDO)

Background
For the better safety of automobile traffic systems, ITS technology is paid attention. To construct the advanced system for the driving assist, condition monitoring of vehicle systems including drivers are necessary. This research aims at the estimation of driver’s sense of danger, or stress, by measuring bio-signals, such as perspiration. Also, relations of vehicles state and driver’s behavior are analyzed. Experiments are conducted with the universal driving simulator.

Perspiration
Estimation of a driver’s sense of danger by measuring perspiration change is conducted. Also correlation between car motion and perspiration change to evaluate the comfort driving is examined.

Evading & Platooning Experiments
Two situations are simulated with the universal driving simulator. The first situation is that preceding car suddenly stops in highway and following car’s driver evade. The other situation is platooning and driver sat in the following track. Perspiration change of each driver is measured to estimate the driver’s stress.

The right graph below shows the car’s motion variables and driver’s bio-signals.

Evaluation Indices for Risk Perception of Rear-End Collision

TTC: Time to Collision
TTC is an indicator that predicts the time to hit in the case where present relative velocity is maintained. The formula is shown below.

\[ TTC = \frac{L}{V_r - V_f} \]

iTTC: inverse Time to Collision
It is differential rate of increase of the angle of vision. The equation of iTTC is written below.

\[ iTTC = \frac{1}{dt} \left( \frac{d\theta}{\theta} \right) \]

Discussion
Perspiration change is related to the indicator of iTTC. This result suggests that the DS experiment can evoke the driver’s sense of danger and the information of risk is mainly obtained by the vision.
Behaviors analysis for emergency avoidance of automatic platooning

Background

For automatic platooning in mixed traffic environment, it’s absolutely necessary to avoid end-rear collision of a following truck to a preceding truck, only by driver’s manual operations for an emergent stop. When braking power of following truck is higher than the preceding truck, driver behaviors for safely emergent avoidance are discussed.

Emergent deceleration scenario

Automatic platooning by 2 trucks for 10 gap distance is simulated by a driving simulator. While the preceding truck suddenly stops without advance notice, driver in following truck manually operates for an emergent avoidance.

Behaviors analysis

Driver reaction time, brake response time, mean maximum deceleration time, and stopping gap distance are defined as shown in the figure.

In the conditions of maximum deceleration of the preceding truck is 0.6G (5.88 m/s²) and maximum decelerations of the preceding trucks are 0.6G, 0.65G (6.37 m/s²), 0.7G (6.86m/s²), gap distances and velocities are recorded in the following figures during the experiments for emergent braking.

Experimental results

In the conditions of the maximum decelerations of the following truck are 0.6G, 0.65G, and 0.7, experiments for emergent avoidance were executed for 10 subjects, and each for two times. The results of stopping gap distances are shown in the table, where the negative distances, shown in the red, indicate the following truck collide with the preceding truck.

<table>
<thead>
<tr>
<th>Objects</th>
<th>Stopping gap distances (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. deceleration 0.6G</td>
</tr>
<tr>
<td>1</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>0.45</td>
</tr>
<tr>
<td>3</td>
<td>0.35</td>
</tr>
<tr>
<td>4</td>
<td>-4.45</td>
</tr>
<tr>
<td>5</td>
<td>-0.23</td>
</tr>
<tr>
<td>6</td>
<td>-2.51</td>
</tr>
<tr>
<td>7</td>
<td>-4.21</td>
</tr>
<tr>
<td>8</td>
<td>-1.29</td>
</tr>
<tr>
<td>9</td>
<td>-3.37</td>
</tr>
<tr>
<td>10</td>
<td>-2.89</td>
</tr>
</tbody>
</table>

Conclusions

There is a high possibility of rear-end collision, when maximum decelerations of preceding truck and following truck are same as 0.6G. However, when maximum decelerations of following truck are adjusted to 0.65G and 0.7G, it becomes easy to avoid end-rear collision only dependent on brake mechanics.
Evaluation of driving sensation in simulating automatic platooning

Fund by New Energy and Industrial Technology Development Organization

Background

Simulating technologies by driving simulator (DS) are developing to validate securities and reliabilities of automatic platooning of trucks. In the case, several DS are considered to be used for realizing the automatic platooning environment. Therefore, it is important to make clear of driver sensation to fixed-based DS and moving-based DS.

Objective

The study aims on assessing driver sensations to the fixed-based DS and the moving-based DS. Two psychophysiological indices of electromyography of masseter and palmar perspiration are used to evaluate driver sensations by simulating automatic platooning.

Scenario

Gap distance between preceding and following trucks is 4 meters, and driving velocities of both trucks are 80km/h. As a reaction to emergent deceleration from 80km/h to 30km/h for 2.5s of the preceding truck, the following truck decelerates in same driving parameters in automatic mode. Then, driver sensation is discussed by physiological responses to the scenario.

Experiments

Subject just seats in the following truck, and don’t operates. In the experiments, the bio-signals of the subject are measured.

Sensation indices

The raw signals (a) of EMG are dealt with to absolute values for rectifying processing (b), and the absolute values are smoothed by five point mean method (c), and then normalizing processing is completed by multiplying self mean value. Finally, evaluation values of sensation index are calculated by fourth root of mean value of fourth power of normalizing data. The measured signals of palmar perspiration are processed in same above method.

Results

The results of sensation indices are presented in the figures. Lateral axis shows DS types, and vertical axis is evaluation value of sensation indices. The evaluation values of sensation indices are significantly different between the fixed-based DS and moving-based DS (T-test).

Conclusions

By the two psychophysiological signals, EMG of masseter and palmar perspiration, driver sensation to a fixed-based and a moving-based driving simulator are quantitatively estimated. Relative to the fixed-based DS, driver sensation index resulted from the moving-based DS is significant high. It indicates that moving-based DS could give subjects high driving sensation.
EEG analysis of a driver manipulating a driving simulator using PARAFAC

Driving simulator (DS)

To carry out the study, we utilized a driving simulator developed by Suda laboratory, which is composed of a six-degree-of-freedom motion platform with a turntable and an image generation system using 9 projectors to produce realistic all-round view. This simulator can provide a subject manipulating it with realistic feeling to drive a car. EEG is recorded when the subject drives the simulator and it is analyzed with PARAFAC.

Experiments

EEG Recorder: Polymate AP1132+AP-U040, Teac.
Arrangement of electrodes: 10-20 system; additional four electrodes are placed around eyes to indentify eye blinks.

Results of PARAFAC

<table>
<thead>
<tr>
<th>Spectral profile</th>
<th>Temporal profile</th>
</tr>
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<tbody>
<tr>
<td><img src="image1" alt="Spectral Profile" /></td>
<td><img src="image2" alt="Temporal Profile" /></td>
</tr>
<tr>
<td>Spatial profile</td>
<td><img src="image3" alt="Spatial Profile" /></td>
</tr>
</tbody>
</table>

Results of five experiments, where only the third atom is included.

Results when driving around Tanimachi junction, which requires heavy task for the driver.

Discussion

1. When the driver runs on the oval course, alpha waves sometimes appear on EEG, while no alpha waves are observed when driving at Tanimachi junction.
2. EEG indicates the driver drowsed when driving on the oval course.