Driver's Distraction Detection Function in Cooperation with Artificial Intelligence

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***Abstract*—**Reduction of traffic accidents may be one of urgent challenges to create sustainable mobility society. Currently preventive safety technologies of vehicles are expected to play important role to reduce the number of traffic accidents. This research proposes a concept of artificial intelligence based driver's states monitoring function. From analysis of Internet survey, driver's distraction state is one of dominant psychosomatic state which drivers often fall in inattentive driving. By means of using pattern recognition, this research established a method to detect driver's cognitive distraction. Four types of classification feature were examined as alternative characteristics of distraction states, which are gaze direction of eyes, head orientation, pupil diameter and heart rate from electrocardiogram (ECG) waveform. Loss-based Error-Correcting Output Coding (LD-ECOC) was adopted as a classification algorithm. Driver's states monitoring function was comprised of driver's distraction detection function, which was part of an artificial intelligence unit in cooperation with autonomous driving function for reduction of the number of traffic accidents.

***Keywords*—**Artificial Intelligence; Driver's Psychosomatic States Detection; ECOC; Pattern Recognition; Traffic Accidents.

***Abbreviations*—**Artificial Intelligence (AI); Electrocardiograph (ECG); Heart Rate R-wave to R-wave Interval (HR-RRI); Loss-based Error-Correcting Output Coding (LD-ECOC); Pupil Diameter (PD); Standard Deviation (SD); Visual Information (VI).

I. INTRODUCTION

ALTHOUGH the number of traffic fatalities in Japan as of 2015 has stayed reduced under 4,200 and the number of traffic accidents have reduced as well, the number of traffic injury has still stayed some 0.6 million as shown in figure 1 [1].

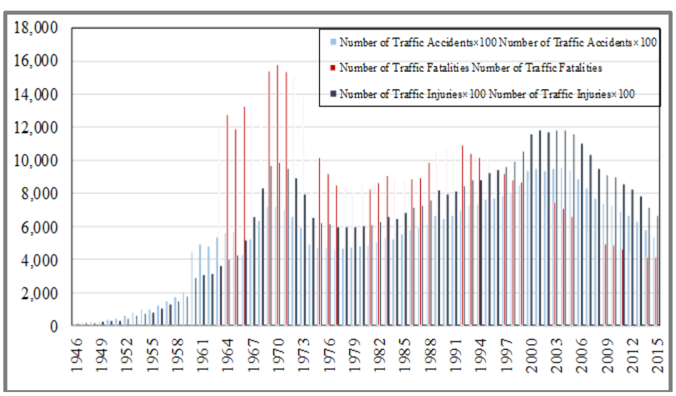

Figure 1: Transition of Road Traffic Accidents in Japan up to 2015

Reduction of the number of traffic accidents has become an urgent challenge to create sustainable mobile society. Preventive safety systems may be one of effective solutions to reduce the number of traffic accidents. From analysis of traffic accidents in real world, it is said that electronic stability control system has reduction effect of traffic accidents [2] in certain degree as well as pre-crash system [Hattori et al., 3]. Recently automatic emergency braking has been proven to reduce the number of traffic accidents, especially in the event of rear-end collision [Krafft et al., 4]. Autonomous driving may reduce the number of traffic accidents, which is expected to be introduced into production vehicle in late 2010's [5]. Artificial intelligence is expected to further enhance performance of autonomous driving in the traffic safety area as well as driving comfort area. Driver's states adoptive safety function should be incorporated as one of contents of artificial intelligence in cooperation with autonomous driving to further reduce the number of traffic accidents. Human error is said to be dominant cause of traffic accidents [Treat et al., 6; 7; Klauer et al., 8]. This research assumed that traffic incident experiences including near-miss accident has the same root cause as traffic accidents. Then this research introduced an Internet survey to clarify root cause of traffic incidents. The Internet survey set four types of questionnaires. From the analysis of traffic incident experiences, dominant psychosomatic state was identified as haste, distraction and drowsiness. This research focused driver's distraction, which are often occurred in ordinary driving. By means of using a driving simulator, this research replicated driver's cognitive distraction, of which cognitive tasks were conversation and/or arithmetic. This research selected four types of physiological information as alternative characteristics of driver's cognitive distraction, which were heart rate R-wave to R-wave Interval (HR-RRI) from waveform of electrocardiogram (ECG), movements of both eye and head, and diameter of pupil. After pre-processing the related signal, this research executed pattern recognition, which classification algorithm was Loss -based Error-Correcting Output Coding (ECOC) [Allwein et al., 9] to detect driver's cognitive distraction. This research established a method to detect driver's cognitive distraction, which comprises driver's states monitoring function.

This research aimed at proposing a concept of driver's states monitoring function, which should be a part of an artificial intelligence unit in cooperation with autonomous driving for reduction of the number of traffic accidents.

II. Analysis of Traffic Incidents Experiences

In the previous research of author, traffic incidents in the real world was collected by Internet survey [Miyaji et al., 10]. This research refined those results to clarify root cause of traffic incident experiences. The Internet survey set four types of questionnaires (basic attribute, traffic incident case, driver's behaviour and psychosomatic state). The number of respondents applied to the Internet survey were 2,000, which were 1,117 males and 883 females. The average age was 41.1 years, and the average driving experience was 19.9 years. From the analysis of collected traffic incidents experiences, top five psychosomatic states just before the traffic incidents were "hasty" (26.6%), "distraction" (26.5%), and "Normal" (18.0%) as well as "drowsiness" (4.6%) as shown in figure 2.

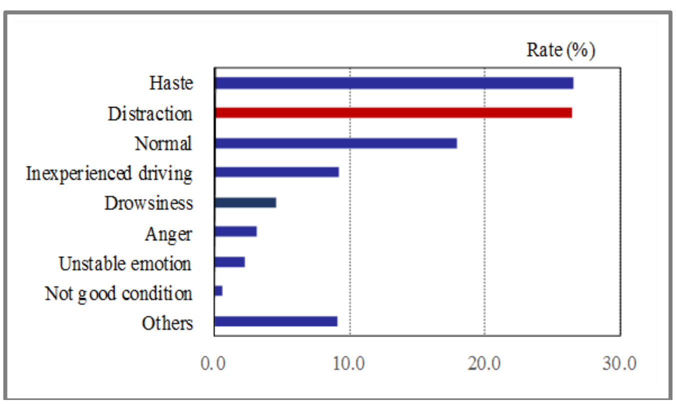

Figure 2: Psychosomatic States just before Traffic Incidents

III. Physiological Information

3.1. *Replication of Physiological States*

This research adopted a mock-up type driving simulator. The head count of subjects was eight (7 males and 3 females) who ordinarily drove as part of commuting and consented to join the experiment. They were asked to operate on a drive course projected to frontal screen. Driving course was a rural scene without road traffic signals. When they were given tasks as mental loads, the replication of cognitive distraction occurred. The task was two types of cognitive loads, conversation, and/ or, arithmetic which were verbally subtracting prime number, for example 7 or 11 from 1,000 successively, or, explaining their commuting route.

3.2. *Influence of Autonomic Nerve*

When a driver falls in a distraction state imposed by mental loads of thinking and/or conversation, autonomic nerve should be vitalized to accelerate sympathetic nerve. The phenomenon appears increase of heart beats [Kahneman et al., 11; Sternberg, 12], which results in decreasing of heart rate R-wave to R-wave intervals (RRI) in electrocardiograph (ECG) waveform (hereinafter: HR-RRI). The phenomenon also arises dilation of pupil of eyes. From the previous research, influence of driver's cognitive distraction affects in movement of eyes and head, which showed that mental task concentrates focal points ahead, and gaze angle concentrates in some area [Yamada, 13; Victor, 14; Kutila, 15]. This activity also influences head rotation angle. From the above review, this research selected heart rate RRI (HR-RRI), pupil diameter, and gaze angle and head rotation angle (visual information) as candidate alternative characteristics of driver's cognitive distraction.

3.3. *Physiological Information of Heart Rate RRI (HR-RRI)*

This research processed heart rate and heart rate RRI by measuring RRI from an ECG waveform, which the monitor lead method with 3 chest electrodes was used. Sampling rate was 1000 Hz for processing of ECG waveform. The waveform of ECG was measured every five seconds, and sampling rate of data set was 60Hz. The structure of your manuscript is expected to follow in this manner for review / survey / tutorial paper.

3.4. *Physiological Information of Visual Information*

Visual information may be effective as alternative characteristics of cognitive distraction when a driver is engaged in conversation and/or thinking. This research introduced tracking unit (The seeing-machine's faceLAB, Australia) to obtain visual information. The unit measures physiological information related pictures of movement of eyes and head. The unit was composed of stereo cameras with signal processor. Measurement items was eye gaze angle and pupil diameter as well as head rotation angle with sampling rate 60 Hz. The coordination of gaze angle and head rotation angle are both output as a vertical rotation which was pitch angle component and a lateral rotation which was yaw angle component. According to the previous research, this research decided standard deviation of combined gaze angle ad that of head rotation angle as a classification feature. Because movement of head acts in synchronization with the movement of eyes, change of gaze angle may result in changes in head rotation angle. This research selected SD of gaze angle, SD of head rotation angle and pupil diameter as classification features for pattern recognition. Avoid special symbols and formulas in title and abstract.

IV. Appropriateness of Related Physiological Information

4.1. Heart Rate RRI

When cognitive tasks were applied to the subjects, heart rate increased around 6 beats per minute in average, which coincided the previous research [Kahneman et al., 11; Sternberg, 12]. However, HR-RRI decreased 10.6 % in average compared with ordinary driving as shown in Table 1. From the result, this research decided to adopt average value of HR-RRI for classification feature of a state of cognitive distraction.

4.2. Visual Information

Average value of standard deviation (SD) of gaze angle in arithmetic loads decreased 8.4% compared with ordinary driving. However, average value of SD of head rotation angle with cognition loads decreases 44 % as shown in Table 1. From the result, this research decided to adopt average value of SD of gaze angle and head rotation angel for classification feature of a state of cognitive distraction.

4.3. Pupil Diameter

When cognitive loads applied to the subject, dilation of pupil generated by acceleration of sympathetic nerve and distribution of focus point was scattered. This action should increase pupil diameter. The average value of pupil diameter by 15 % as shown in Table 1. From the above results, this research decided to adopt average value of visual information (SD of gaze angle, SD of head rotation angle), average value of pupil diameter and heart rate RRI as classification features to use in pattern recognition execution to detect a state of cognitive distraction.

Table 1: Trends of Physiological Information by Cognitive Tasks

Physiological Information	Trends
Heart rate	Heart rate increased by 10.6 %
Heart rate RRI	Heart rate RRI decreased by 10.6%
SD of visual information	SD of gaze angle decreased by 8.4% SD of head rotation angle increased by 44%
Pupil diameter	Pupil diameter increased by 15%

V. Classification of Driver's States by using Pattern Recognition

5.1. Classification Algorithm

Lots of multi-class identification methods have been proposed to classify more than 3 labels. These methods can be categorized into two main approaches. One uses a loss function which should treat at least three labels at the same time, which optimize it directly by some methods. Examples are Neural network and k-nearest neighbor algorithm. Although, theoretical approach may be easier to execute their procedure, computational calculation may have difficulties because of a large number of samples. Other is based on combining the binary classifiers. The advantages of it is low computational calculation time and ease of execution as well as generalization capability. In the sense, error-correcting output codes (ECOC) is one of solutions that expands binary classifiers to multi-class identification. It divides multi-class classification problem into some binary classification problems by an encoding rule and decodes binary classification results to multiple classes by a decoding rule. According to the previous research, this research introduced Loss-based ECOC (LD-ECOC) method in combination with AdaBoost [Freund & Schapire, 16; Kudo, 17] as binary classifier to enhance identification performance of detecting driver's cognitive distraction. LD-ECOC is the method of using loss value l_i and adopted code table *W*.

which is defined as $W \in \{1,-1,0\}^{p \times G}$.

This research treated ternary class problem, accordingly G is set 3, then the number of binary classifiers (this case; AdaBoost) should be 6 (p = 6). W is defined by equation (1). Loss value is defined by equation (2), where is defined as Hamming distance. Using exponential function, when product of the code table W and the hypothesis *h* is positive, l_i becomes negative. Similarly, when product of *W* and *h* is negative, li becomes positive. Additionally, when product is 0, l_i becomes 0 and it is not used to classify. If the calculated loss value is small, it is possible to classify proper class. Hamming distance, *r* is class label which minimizes loss value obtained from equation (2).

$$W = \begin{pmatrix} 1 & -1 & -1 \\ -1 & 1 & -1 \\ -1 & -1 & 1 \\ 1 & -1 & 0 \\ 1 & 0 & -1 \\ 0 & 1 & -1 \end{pmatrix} \quad (1)$$

$$l_i\left(W(r), H(\hat{X})\right) = \sum_{j=1}^{p} \begin{cases} \exp\left(\left|h_j(\hat{x}_i)\right|\right) & \text{if } W(r,j)h_j(\hat{x}_i) < 0 \\ -\exp\left(\left|h_j(\hat{x}_i)\right|\right) & \text{if } W(r,j)h_j(\hat{x}_i) > 0 \\ 0 & \text{if } W(r,j)h_j(\hat{x}_i) = 0 \end{cases}$$
$$= \sum_{j=1}^{p} -\,\mathrm{sign}\left(W(r,j)h_j(\hat{x}_i)\right)\exp\left(\left|h_j(\hat{x}_i)\right|\right) \quad (2)$$

5.2. Detection Performance of Cognitive Distractions

Classification performance by means of using LD-ECOC are shown in Table 2. Top common result in average accuracy was 96.8 percent in conversation task, of which features were combination of all three features of visual information (VI), pupil diameter (PD) and HR-RRI. Second top common in average accuracy was 95.5 percent in arithmetic task. From the results, combination of all three features in conversation tasks showed the highest classification performance.

Table 2: Performance of Cognitive Distraction Detection by LD-ECOC (Units: %)

Classification Features		Average Accuracy
Visual Information (VI)	Ordinary Driving	70.4
	Conversation	64.5
	Arithmetic	56.7
VI + heart rate RRI (HR-RRI)	Ordinary Driving	80.4
	Conversation	76.9
	Arithmetic	75.5
VI + pupil diameter (PD)	Ordinary Driving	87.9
	Conversation	84.0
	Arithmetic	80.2
VI + PD + HR-RRI	Ordinary Driving	95.0
	Conversation	96.8
	Arithmetic	95.5

From the above results of classification performance, it is said that LD-ECOC are available method to detect driver’s distraction on the driving simulator basis. This research adopted amount of average value of ordinary driving, conversation and arithmetic as detection performance of cognitive distraction detection by LD-ECOC, which was 95.8%.

VI. Artificial Intelligence based Driver's Distraction Monitoring Function

This research proposed an artificial intelligence (AI) unit in cooperation with autonomous driving which function is to detect driver’s cognitive state and give information or alert to a driver by detecting both driver’s states and road conditions as well as weather ahead. The contents of information should be imminent danger ahead. The composition of the AI unit is shown in figure 3, where driver’s state monitoring function is a part of it. Driver’s distraction is detected by means of using pattern recognition function which algorithm is LD-ECOC. The AI unit should activate an automatic emergency braking unit which is a part of an autonomous driving system. The operation of the AI based driver's distraction monitoring function would act as follows;

The function always monitors driver’s psychosomatic states such as “distraction” as well as surrounding road condition in cooperation with help of the AI, which always watches vehicle condition, road conditions ahead of a vehicle and weather ahead by means of using mobile communication unit between road infrastructure. Driver should usually look frontal road conditions as well as peripheral of vehicle to execute safely driving. When driver’s cognitive distraction detection function judges that driver may be fallen in a detection state, or be provided imminent danger from the AI unit, driving distraction monitoring function would provide information or alert to the driver as well as providing the imminent danger to traffic monitoring sensor of road infrastructure. When imminent danger may be unavoidable, the AI unit could intervene to activate an automatic emergency braking of the autonomous driving unit to avoid a traffic accident instead of the driver. The functional operation may reduce the risk of being involved in the traffic accident.

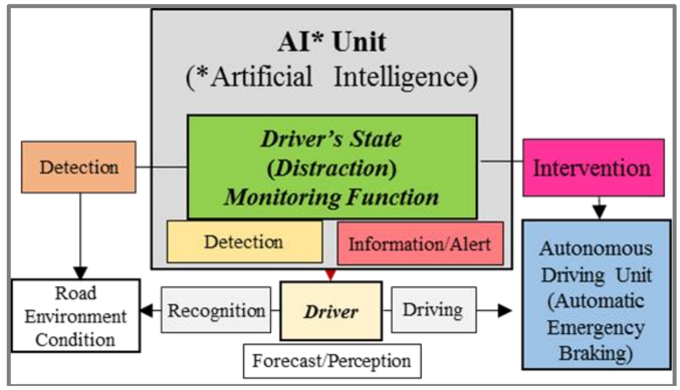

Figure 3: Proposed Artificial Intelligence based Driver's States Monitoring Function

VII. Conclusion

This research indicated a possibility of reducing the number of traffic accidents by introducing artificial intelligence based driver's distraction monitoring function which is comprised of driver’s cognitive distraction function. By means of using Internet survey, dominant root cause of traffic incidents as well as traffic accidents were identified. Then physiological information as alternative of driver’s states were acquired by means of using tracking unit and biomedical technologies. Detection of driver’s state was executed by means of using a pattern recognition method which algorithm is LD-ECOC. The conclusion is as follows;

a) Internet survey may be one of effective methods to collect real world experiences which would be used in a big data collection and analysis.
b) Driver’s distraction is one of dominant psychosomatic states which is likely to be involved in traffic incidents as well as traffic accidents.
c) LD-ECOC is effective classification method to evaluate an accuracy of a state of distraction detection.
d) Furthermore, heart rate RRI, pupil diameter, and standard deviation of visual information (eye gaze angle and head rotation angle) are available as features as alternative characteristics for classification of driver’s cognitive distraction.

e) Artificial intelligence based driver's distraction monitoring function may have potential to reduce the number of traffic accidents.

Future issue includes further enhancing performance of detecting the driver's distraction. Moreover, statistical investigation including Internet survey in the real world for reduction effect of the number of the traffic accident as to preventive safety devices would be widely executed to promote introduction of vehicle safety devices. Development of artificial intelligence based driver's distraction monitoring function would be fostered to reduce the number of the traffic accident.

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