DRIVER'S STATE MONITORING BY FUNCTION OF FACIAL EXPRESSION DETECTION FOR AUTONOMOUS DRIVING

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Abstract— Some driver may be angry when a traffic congestion happens. Anger is thought as crucial risk factor which may result in severe traffic accidents. Driver's psychosomatic state adaptive driving support safety function may play effective role to reduce that kind of traffic accidents. Consequently, detection technology of anger is highly expected. This research firstly clarified root cause of traffic incidents experiences by means of executing Internet survey. From statistical analysis of the traffic incidents experiences, major psychosomatic state just before traffic incidents were identified as haste, distraction, drowsiness and anger. This research focused anger of a driver while driving. By means of using Kohonen neural network, this research created a technology to detect angry state of a driver in high accuracy. Recently autonomous driving of vehicle is said to be introduced into commercial market in the near future. A novel driver's psychosomatic state adaptive driving support safety function is proposed in cooperation with an autonomous driving unit to reduce the number of traffic accidents.

Index Terms—Traffics incidents, anger, Driver, Kohonen Neural Network, driver's state monitoring.

I. INTRODUCTION

Although the number of traffic fatalities in Japan as of 2014 has declined under 4,200 and the number of traffic accidents have declined as shown in Fig. 1, the number of traffic injuries has still exceeded 0.7 million [1]. Reducing the number of traffic accident has become an urgent challenge to create sustainable mobile society. Establishing technologies which may reduce the number of traffic accidents remains one the highest ranked issues. From the reason preventive safety technologies may play more and more important role, one of candidates may be driver's psychosomatic state adaptive driving support function, which has potential ability to enhance safety performance of vehicle safety [2] [3].Accordingly clarifying root cause of traffic accidents may be important issues. The Safety Engineering Committee of the Science Council of Japan (2000) has asserted that analytical survey of traffic accidents as well as traffic incidents is essential to clarify root cause of traffic accidents. Previous research reported that 71% to 90% of traffic accidents were occurred by human factors [4] [5] [6].

This research assumed that root cause of traffic accidents may be same as that of traffic incidents including near-miss accidents. Therefore, Internet survey by using questionnaire was introduced because of its easiness to collect real world experiences. From the analysis, anger is one of major factors of traffic incidents just before traffic incidents. Anger is often seen in a traffic congestion situation [7] [8]. Therefore, this research focused driver's anger which may result in severe traffic accidents.

Human emotion may be expressed by six facial expressions [9], which are "ordinary", "drowsiness," "anger", "sorrow", "delight" and "surprise". From previous research [10], facial expression is expressed by using Kohonen neural network (hereinafter; KNN) [11]. In the previous research of the author [12], we executed recognition of six type of facial expressions by using KNN. Accordingly, this research adopted six types of facial expression as alternative characteristics to identify driver's anger state. By using KNN, this research defined six types of facial expression including anger [9]as a self-organized map. Normalization of orientation and size of face was executed by coordination of eyes and nose. Facial expression was judged by minimization of Mahalanobis' distance[13]. By using this recognition method, this research established to detect anger of a driver in high accuracy [14]. Finally, this research proposeda novel driver's angry state adaptive driving support safety function is proposed in cooperation with an autonomous driving unit [15].

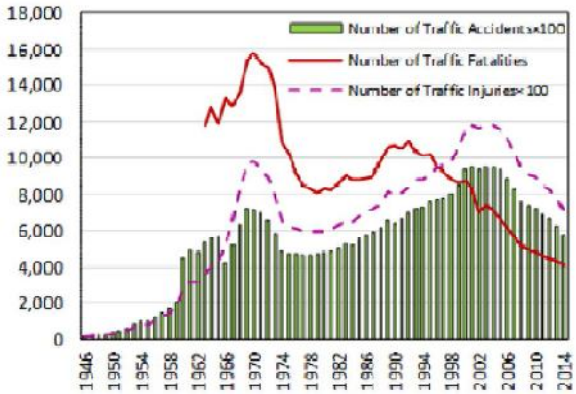


Fig. 1. Road traffic accidents trends in Japan up to 2014

II. METHOD OF INTERNET SURVEY

This research assumedroot cause of traffic accidents may be same as that of traffic incidents including near-miss accidents. Therefore, Internet survey by using questionnaire was introduced because of its easiness to collect real world experiences. Seven traffic incidents model were defined by referring seven traffic accidents model used in the Advanced

Safety Promotion Project Phase III in Japan [16] as shown in Table 1.Survey area of traffic incidents experiences was extended to ordinary driving occasion which has potential accident risk as well as apparent accident risk as shown in Fig. 2. Internet survey was executed according to the sequence shown in Table 2.

Table 1. Traffic incident model

No.	Incident scene
1	Pedestrian to vehicle collision
2	Crossing path collision
3	Right turn collision
4	Left turn collision
5	Right turn collision
6	Head-on collision
7	Rear end collision

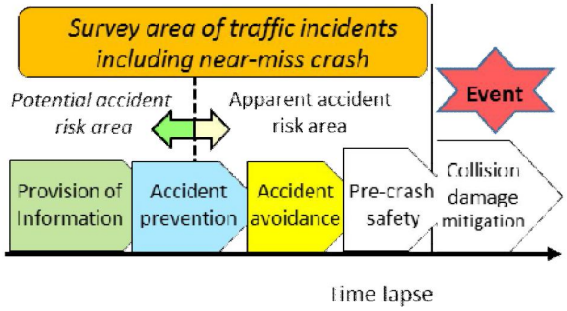


Fig. 2. Survey area of traffic incidents

Table 2. Survey sequence of Internet

Survey method	Deliver questionnaire including free comments and collect answer by Internet
Control of respondents	Random sampling with avoiding bias of age, gender, driving experiences and residential area
Screening	After some question at the beginning, main question is gained. Allocate certain number of respondents to each slot (i.e. age × gender) at first stage to to gain proper respondents
Pick up of effective answer	Give obligation to respond to each question in order to avoid missing value
PC operating environment	OS; after Windows2000 and Mac OS X Browser; after Microsoft Explorer band Firefox2.x

III. IDENTIFICATION OF ROOT CAUSE OF TRAFFIC INCIDENTS

In Internet survey, the number of respondents was 2,000 (1,117 males and 883 females), the average age was 41.1 years, the average driving experience was 19.9 years and the average number of traffic incidents was 2.34. Statistical sampling error of the Internet surrey was calculated by 2.2%. Analytical result of the survey was shown in Fig. 3. Top five psychosomatic states just before traffic incidents were “Hasty” (26.6%), “Distraction” (26.5%), “Normal” (18.0%) and “Drowsiness” (4.6%) as well as“anger” (3.1%). From the results detecting driver’s psychosomatic state just before traffic incident is indispensable for establishing countermeasures to reduce the number of the traffic accident. This study focused a state of anger as driver’s psychosomatic state to reduce severe traffic accidents.

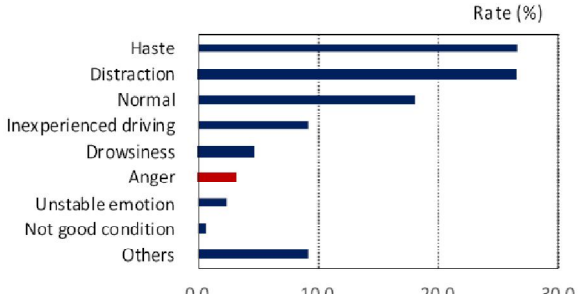


Fig. 3. Analytical results of psychosomatic states

IV. CREATION OF FACIAL EXPRESSION MAP

A. Recognition by Kohonen neural network

Kohonen neural network is known as competitive learning neural network which only winning neuron can learn input data set in learning stage. This learning may have feature to create self-organized map which expresses correlation among input data of facial expressions. KNN may generate complementary picture among each facial expressions. This research has introduced a method, which KNN recognizes a candidate picture by using centroid vector. A centroid vector was identified by learning the highest similarity between created facial expression map and candidate picture.

B. Acquisition of facial expression picture

Previous research reported that facial expression of humankind which shows emotion were six types[9]. They were “ordinary”, “drowsiness”, “anger”, “sorrow”, “delight”, “surprise”. Accordingly, this research used the above six facial expressions. Six picture were taken for each six facial expressions. One out of six of one facial expression was selected for a learning data of KNN according to previous research [11] [12] as shown in Fig. 4.

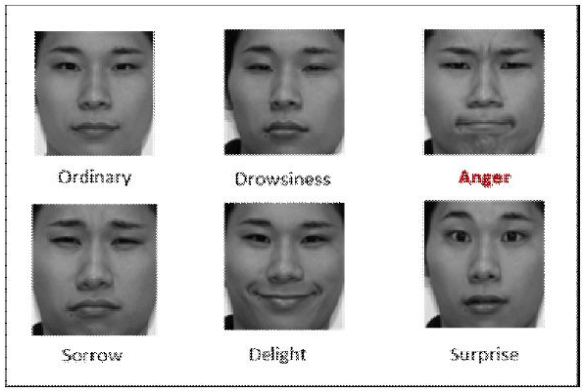


Fig. 4. Six type of facial expressions

C. Generation facial expression map

Original face expression was in 512× 512 pixel of 24 bit which was gray-scaled. Then both orientation and dimension of face were corrected by coordination eyes. A picture in 256 × 256 pixel of facial expression was extracted by referring central point of nose. Then this picture was compressed in 64 × 64 pixel. Accordingly, self-organized map was created as input vector of KNN neural network. Output picture of KNN unit was in 32 × 32 pixel as shown in Fig.5.

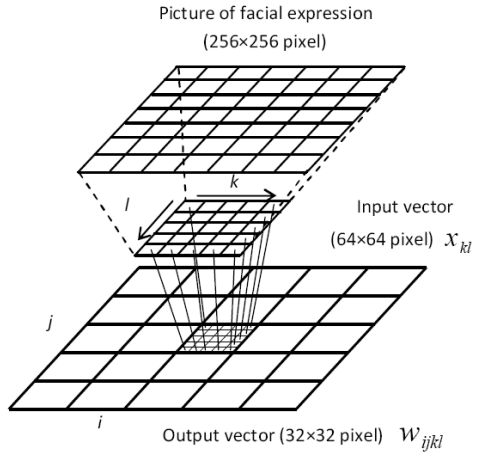


Fig. 5. Structure of KNN

D. Learning process by KNN

Learning by KNN was executed by giving four type of random number in initial stage. Then KNN learned each six facial expression maps as shown in Fig.6. In the process uklwas defined as similarity factor, where xkl is input picture, wijklcombined load of KNN.

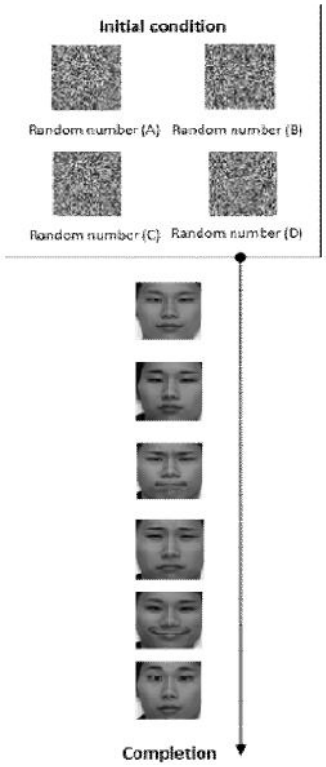


Fig. 6. Learning process of facial expressions

Similarity factor was defined following equation (1).

$$u_{kl} = \frac{\Sigma x_{kl} w_{ijkl}}{\sqrt{\Sigma x_{kl}^2 \ \Sigma w_{ijkl}^2}} \quad (1)$$

Maximum of similarity factor uklwas defined as maximum unit of similarity.

V. RECOGNITION OF FACIAL EXPRESSION

A. Recognition by maximum similarity unit This research tried to estimate accuracy of detecting anger of 8 voluntarily participants, who consented to join in this experiment. Distribution degree of similarity was acquired from generated map. Learning of facial expression map was 100 times. Similarity between generated facial expression and unknown input facial expression was calculated by equation (1). Location of maximum similarity was determined as recognized facial expression.

B. Recognition by Mahalanobis' distance

By using Mahalanobis' distance as a recognition algorithm, this research tried to estimate accuracy of detecting anger. Strongly reacted portion to a maximum similarity data was extracted by a certain amount of Mahalanobis' distance. Then recognition was executed whether the portion was included following equation (2).

$$P_i = \sum_{k}^{N_i} (x_{kl} - x_{\min}) \quad (2)$$

In equation (2), 1idenotes class of facial expression, Pidenotes similarity of class of facial expression in the same distribution, xkl denotessimilarity of data k in i class of facial expression, xmin denotes minimum similarity on similarity map. Consequently, accuracy of facial expression was defined by maximum value of facial expression class derived from equation (2). Recognition was executed according to the sequence as shown in Fig. 7.

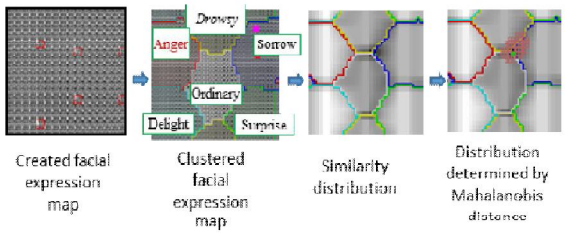


Fig. 7. Recognition by Mahalanobis distance

VI. RECOGNITION RESULTS

This research obtained cooperation of 8 participants who consented to join the experiment. This research took 6 pictures for 6 facial expressions per one participant. 240 out of 288 picture of facial expression was selected. 40 facial expressions were allocated for each facial expression. Then recognition experiment by means of using KNN was executed. At

the same time subjective evaluation for six facialexpressions was executed by the same participant. Recognition results using by maximum similarity unit is shown in Table 3. Recognition accuracy of anger showed not high value among 6 facial expressions, which was 55.0 % in seventh top common. However, amount of subject evaluation of drowsiness was in third top common. As discrepancy of the two category was large. Therefore, improvement was needed to adopt this method.

Table 3. Recognition accuracy by Maximum similarity

Type of facial expression	Recognition accuracy (%)	Subjective evaluation (%)
Ordinary	80.0	97.9
Drowsiness	85.0	81.3
Anger	**55.0**	**91.7**
Sorrow	50.0	39.6
Delight	87.5	89.6
Surprise	62.5	93.8
Average	70.0	82.3

As one of improved method this research tried to introduce recognition by Mahalanobis' distance, which results is shown in Table 4. Recognition accuracy of anger showed maximum value among 6 facial expressions, which was 93.8 % in top common. However, amount of subject evaluation of drowsiness was in third top common. Average value of recognition accuracy of these 6 facial expression was almost the same amount as subjective evaluation done by 8 participants. Consequently, this method by means of using Mahalanobis' distance was said as enhanced method to estimate a state of anger. Then this research selected the method which average accuracy was 86.5% for detection of anger state between facial expression and subjective evaluation.

Table 4. Recognition accuracy by Mahalanobis' distance

Type of facial expression	Recognition accuracy (%)	Subjective evaluation (%)
Ordinary	75.0	97.9
Drowsiness	93.8	81.3
Anger	**81.3**	**91.7**
Sorrow	60.4	39.6
Delight	91.7	89.6
Surprise	87.5	93.8
Average	84.2	82.3

This method of detecting driver's anger state may be applicable to driver's psychosomatic monitoring safety unit.

VII. PSYCHOSOMATIC STATE ADAPTIVE DRIVING SUPPORT SAFETY FUNCTION IN COOPERATION WITH AUTONOMOUS DRIVING

This research proposed a potential driver's state adaptive driving support safety function in cooperation with an autonomous driving unitas shown in Fig. 8. The function always monitors driver's psychosomatic states such as "anger"as well as surrounding road condition in cooperation with an artificial intelligence (hereinafter; AI) unit. AI unit always may monitor driver's condition, vehicle condition and road conditions ahead of a vehicle by means of using mobile communication between road infrastructure. Driver usually looks frontal road conditions as well as peripheral of vehicle to safely drive. When driver's anger detection function estimate that driver may be fallen in ananger state, or be provided imminent danger from the AI unit, driving monitor safety unit could provide information or alert to the driver as well as providing the imminent risky state to traffic monitoring sensor of road infrastructure. If driver monitoring safety unit estimate imminent danger is unavoidable, the AI unit could intervene the driver by activating an autonomous driving unit to avoid a traffic accident by using automatic braking system or other safety devices. The function may reduce the risk of being involved in the traffic accident. Those units compose "a driver state adaptive driving support safety function".

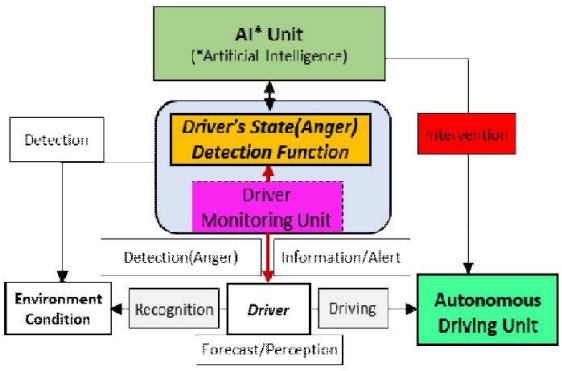


Fig. 8. Proposed safety functionin combination with AI

CONCLUSION

This research proposed a concept of a psychosomatic state adaptive driving support safety function in cooperation with an artificial intelligence which may control some of autonomous driving unit. By introducing Internet survey, this research identified root cause of traffic incidents which may be same as traffic accidents. Then this research introduced KNN

as recognition algorithm which detects anger state od a driver.

A) Driver's anger is one of important psychosomatic states which is likely to be involved in severer traffic accidents.

B) Kohonen neural network may be effective means to estimate an accuracy of anger state.

C) Driver's state adaptive driving support safetyfunction in cooperation with an artificial intelligence may have potential to reduce the number of trafficaccidents. Consequently, installation of anger detection function in cooperation with artificial intelligence should incorporated into vehicle.

Future issue includes research to identify reduction effect of traffic accidents by means of using detection function of anger state. Furthermore, statistical survey to identify reduction rate of the number of the traffic accident in real world be expected. It should widely be executed to promote introduction of such vehicle safety devices to reduce the number of the traffic accidents.

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